PACIFIC ENSO UPDATE

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

1st Quarter, 2019 Vol. 25, No. 1 **ISSUED: March 20, 2019**

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

http://www.weather.gov/peac

CURRENT CONDITIONS

From Hawaii, to American Samoa, and across much of Micronesia, the weather and climate of 2018 will be remembered for the widespread influence and impacts of tropical cyclones. During February 2018, Cyclone Gita caused heavy damage on American Samoa. Nearly all of the islands of Micronesia experienced at least some moderate impacts from tropical cyclones in 2018 (e.g., heavy rainfall, high surf, marine gales, etc.); while some of the islands (particularly the main islands of the CNMI) experienced catastrophic damage from very intense tropical cyclones. The typhoon season in Micronesia was off to an early start in March when a tropical disturbance that would later become Typhoon Jelawat, passed slowly through Pohnpei State, yielding over 20 inches of rainfall in two days on parts of Pohnpei Island. The rains from Jelewat plus additional high rainfall during March would send the Pohnpei WSO rainfall total to its all-time record monthly high value of 57.92 inches. During early July, Tropical Storm Maria passed over Guam while possessing an unusual embedded mesovortex with a radar signature similar to that of a tornado-producing mesocyclone. This mesovortex brought a short period of typhoon-force winds to a small strip of Guam's northern coast at a time that its parent storm (Maria) had just become a tropical storm. This would be only the beginning of a very busy typhoon season for Guam and the CNMI that would end in late October with the passage of Super Typhoon Yutu directly over Tinian and the southern portion of Saipan. Hawaii was also impacted by tropical cyclones, with hurricanes Hector and Lane passing near the island chain at an unusually high intensity while so close to any of the Hawaiian islands. One of the main effects from these two hurricanes and other passing tropical cyclones to the state of Hawaii in 2018 was very high rainfall.

Several new records were set for extreme rainfall across the US-API during 2018, with some locations logging record or near-record high daily, monthly and annual totals. Very high rainfall during the first half of 2018 and continuing through August 2018 pushed multi-month rainfall totals at Majuro and Kwajalein to ever higher record magnitudes, exceeding prior high marks by wide margins. Despite near-average rainfall later in the year the annual totals at these atolls was also near or at record high values. The rains from Jelewat plus additional high rainfall during March 2018 would send the Pohnpei WSO March rainfall total to the all-time record value for March (or for any other month!) of 57.92 inches. The annual rainfall sum of 247.99 inches at WSO Pohnpei also set a new historical record. During the passage of Hurricane Lane, rainfall totals of 2-4 feet were reported across the windward side of the Big Island with a few locations recording even higher amounts. Mountain View received a total of 52.02 inches, which ranks as the highest rainfall total from a tropical cyclone in Hawaii's recorded history.

Dry conditions were not a widespread problem during 2018. Dry conditions on Saipan in early 2018 contributed to some extensive wildfires. Dryness during September and October on Kosrae had impacts of lower stream flow and reduced rain catchment.

Please see the Local Variability Summaries for more details.

Temperature

The temperatures across Micronesia through 2018 were mostly above average, but dropped slightly over the rainy season months, especially in areas where tropical cyclones and monsoonal activity dominated (Fig. CC-1). Very warm temperatures are typically experienced in the US-API when skies are clear and winds are light. Cooler temperatures occur when conditions are unusually cloudy, wet and windy. Note a persistent increase of temperature at Guam from a pronounced coolness during 2015 (wet and windy) to warmer conditions during 2016 and 2017 (abundant sunshine and light winds). Cooler conditions in Kwajalein in 2018 accompanied very wet weather there.

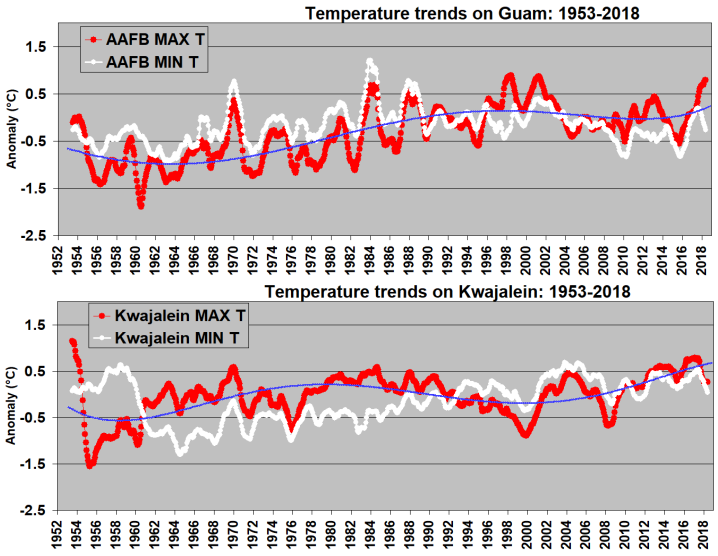

Figure CC-1. A post-WWII time series of maximum and minimum temperatures at Andersen Air Force Base (AAFB) on Guam (top panel) and at the Reagan Test Site on Kwajalein Atoll (bottom panel). Values plotted are a 12-month moving average of the monthly anomalies of temperature. Note a general warming trend, with some obvious non-linear inter-annual and inter-decadal variability. The inter-decadal variability is highlighted by the smooth non-linear trend lines. Very warm MAX and MIN temperatures at Kwajalein during the 1950s are probably an artifact of station location and exposure.

CURRENT CONDITIONS

Sea Level

During the 1st Quarter of 2018, the trade winds began to weaken. The sea level across most of Micronesia was above average during the 1st Quarter of 2018, but underwent a sudden fall during April 2018, with Palau dropping all the way from a stand at +6 inches above average to 0. The sea level at Palau is now below average. At other locations across the US-API, the sea level has remained near average. Above average sea level was noted along the equator (e.g., at Kapingamarangi), in the Hawaiian Islands and at American Samoa. Note the strong coherence of sea level across the stations of Micronesia, and also the close relationship of the sea level with the trade winds (see Figure CC-2). Also note the abrupt lowering of sea level that typically accompanies El Niño (see the sea level section for more details).

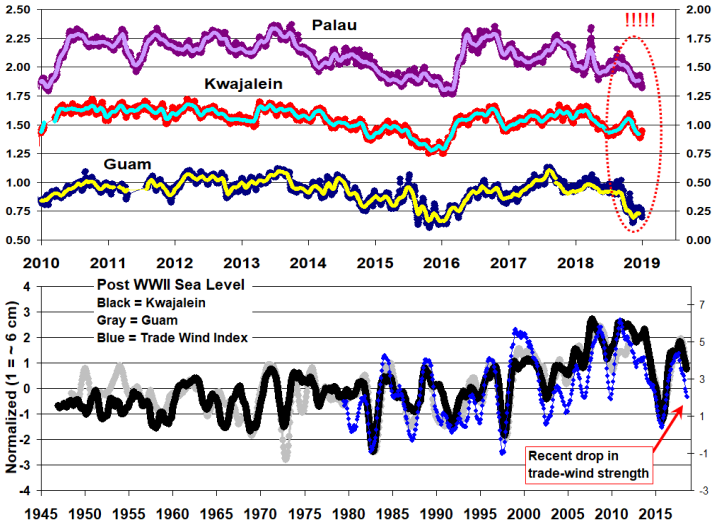

Figure CC-2. (Top) Sea level recorded at Palau, Guam and Kwajalein (as indicated). Daily data is overlain with a 30-day moving average. Over the past decade, only the stand of the sea at the end of the 2009 El Niño and at the end of the 2015 El Niño is lower than the current stand of the sea. (Bottom) The sea level at Guam and Kwajalein plotted with NOAA's Trade Wind Index (5N-5S ; 135E-180) (blue). Recent weakening of the trade winds corresponds with a net fall of sea level of about 6 inches from early 2018 (see the sea level discussion for more details).

ENSO Evolution

The evolution of ENSO during 2018 was hard to interpret. In many ways, the weather and climate across the US-API during 2018 evolved in a way typical of El Niño. The calendar year 2018 began with La Niña-like weather patterns which had persisted through the 4th Quarter of 2017 into the 1st Quarter of 2018. During early 2018, the climate system remained within the SST bounds of La Niña (see Fig. CC-3). During March and April, the Oceanic Niño Index (ONI) warmed and crossed into the cold side of the zone of ENSO-neutral. By June 2018, the ONI became weakly positive, and the CPC's ENSO diagnostic discussion elevated its alert status to an El Niño Watch. By the fall of 2018, the SST warmed to the El Niño threshold, but the CPC's ENSO diagnostic discussion continued an El Niño Watch, waiting for the warmth to be sustained.

Some weather features typical of El Niño or impending El Niño occurred during 2018; these include:
(1) a very wet eastern Micronesia in the first half of the year;
(2) dryness in Palau for several months;
(3) several early season tropical disturbances in eastern Micronesia;

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(4) the continual formation of typhoon pre-cursor disturbances in central and eastern Micronesia;
(5) the endless battering of the Mariana island chain by typhoons;
(6) some unusual westerly winds in eastern Micronesia; and,
(7) a lowering of the sea level at many islands of Micronesia (and particularly a very sharp drop of sea level in the spring, and then in the final two months of the year).

Note: The CPC's Oceanic Niño Index did not reach El Niño thresholds until October. Rather, the highest positive SST anomalies for much of the year were found north of the equator between 5° and 10°N.

Some weather features of *early* 2018 were not typical of of El Niño or impending El Niño; these include:
(1) at the onset of the rainy season, the monsoon and most of the basin's tropical cyclones were well to the north and west of average;
(2) there were not very many episodes of strong westerly winds along the equator;
(3) the typhoon distribution did not penetrate deeply into the "El Niño" Box (see the TC Section); and,
(4) the sea level was high along the equator (albeit lower, and/or falling, to the north of the equator along about 10°N).

During the 2nd half of 2018, the behavior of the weather and climate elements (e.g., the pattern of rainfall, the typhoon distribution, and the sea level) became more typical of El Niño.

Breaking News

After a long climb during 2018 from the cool side to the warm side of ENSO-Neutral, the state of the Pacific climate system finally entered El Niño as per the February 2019 CPC ENSO statement (see CPC ENSO discussion below). In several ways, the climatic elements (typhoon distribution, sea level and the pattern of rainfall) were (and still are) what one might expect at the maturity of a weak El Niño in late 2018/early 2019. Whether El Niño has recently begun, recently matured, or is undergoing an unusually prolonged period of El Niño-like conditions (e.g., 1986-87 and 2014-15), the forecast for rainfall throughout the US-API through the spring of 2019 leans toward dryness at most locations, with the notable exception of American Samoa, which is forecast to be wet. Computer model forecasts now indicate Micronesia-wide below average rainfall through at least April. The uncertainty in the recent and near-term evolution of ENSO precludes a confident forecast of rainfall or typhoon distribution in Micronesia. Any strengthening of El Niño in the next few months would typically be associated with average to above average rainfall and an increase in the chances for an early-season typhoon. If El Niño fades over the next few months, a dry forecast is prudent, along with an associated reduction and delay of typhoon activity through the first half of 2019.

El Niño Diagnostic Discussion[1]
CLIMATE PREDICTION CENTER/NCEP/NWS
and the International Research Institute for Climate and Society

14 February 2019
***ENSO Alert System Status**: El Niño Advisory*

Synopsis: Weak El Niño conditions are present and are expected to continue through the Northern Hemisphere spring 2019 (~55% chance).

"El Niño conditions formed during January 2019, based on the presence of above-average sea surface temperatures (SSTs) across most of the equatorial Pacific Ocean and corresponding

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changes in the overlying atmospheric circulation. The weekly Niño indices remained above average during the month, although decreasing in the Niño-3 and Niño-3.4 regions. However, the Niño-4 region remained elevated, with a value of +0.8°C in early February. Positive subsurface temperature anomalies (averaged across 180°-100°W) increased in the last couple weeks, in association with a downwelling Kelvin wave that contributed to above-average temperatures in the central Pacific. Compared to last month, the region of enhanced equatorial convection expanded near the Date Line, while anomalies remained weak over Indonesia. Low-level wind anomalies became westerly across the western Pacific Ocean, while upper-level wind anomalies were mostly westerly over the eastern Pacific. The equatorial Southern Oscillation index was negative (-0.6 standard deviations). Overall, these features are consistent with borderline, weak El Niño conditions."

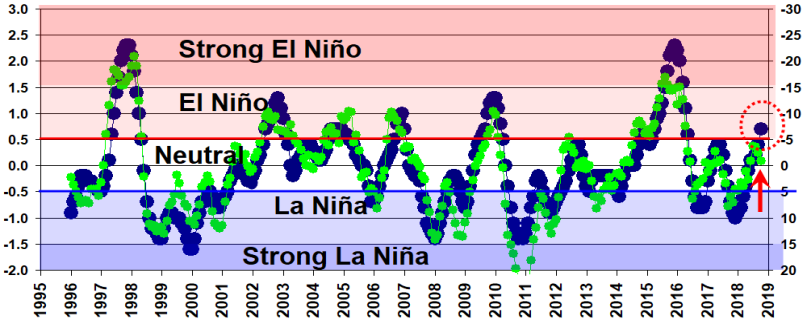


Figure CC-3. A plot of the CPC's Oceanic Niño Index (ONI) for the past two decades. Note that it made a run toward El Niño early in 2017, but then reversed and entered the La Niña category at mid-2017. During the first half of 2018, the ONI began a move through ENSO-neutral and toward El Niño. Continued warming late in 2018 moved the ONI across the El Niño threshold, but it is uncertain if this warming will continue sufficiently into early 2019 and place the climate system into a status of declared El Niño. The CPC issued its final La Niña advisory on 10 May 2018, and established an El Niño Watch in June that continues. **Breaking News**: the state of the Pacific climate system finally entered El Niño as per the February 2019 CPC ENSO statement (see CPC ENSO discussion above).

"The majority of models in the IRI/CPC plume predict a Niño 3.4 index of +0.5°C or greater through at least the Northern Hemisphere spring 2019. Given the recent downwelling Kelvin wave and the forecast of westerly wind anomalies, most forecasters expect SST anomalies in the east-central Pacific to increase slightly in the upcoming month or so. Because forecasts through the spring tend to be more uncertain and/or less accurate, the predicted chance that El Niño will persist beyond the spring is 50% or less. In summary, weak El Niño conditions are present and are expected to continue through the Northern Hemisphere spring 2019 (~55% chance)."

"Due to the expected weak strength, widespread or significant global impacts are not anticipated. However, the impacts often associated with El Niño may occur in some locations during the next few months (the 3-month seasonal outlook will be updated on Thursday February 21st. 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, and Wellington, and RSMC-Nadi (Fiji). 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.

Western North Pacific

The statistics (e.g., storm count, number of typhoons, etc) of Western North Pacific tropical cyclone activity during 2018 reflect a mixture of near-average to above average characteristics. The JTWC numbered 36 tropical cyclones during the calendar year 2018. Of these, the JMA named 29, with the caveat that JTWC's TC 36W (numbered by the JTWC on December 31) was named "Pabuk" by the JMA on January 1st, 2019. Of the 36 TCs numbered by the JTWC during 2018, a large number (8) were tropical depressions (the average is 3); 15 reached only tropical storm intensity (the average is about 10); 13 reached typhoon intensity (the average is about 18); and of the 13 typhoons, 7 reached super typhoon intensity (the average number of super typhoons is 4). See Table CC-1 for a summary of Northern Hemisphere TC activity during 2018, by basin and for the Northern Hemisphere. Although the JTWC number of TCs in the western North Pacific basin was well above average, many of the storms were weaker systems that formed in subtropical latitudes and interacted with a strong and persistent monsoon system displaced to the north and west of the usual location of the monsoon trough. Thus, while the count of numbered systems was high, the count of WNP typhoons was below average. The number of super typhoons, however, was above average, with the most intense super typhoon of the year, Yutu, making a direct strike on Tinian and Saipan while it was near peak intensity (see the Guam and CNMI LVS for more details).

The distribution of TC tracks of the western North Pacific also was mixed with respect to the distribution of TC tracks typically seen in an El Niño year. During the 1st half of the year, many of the TC tracks were well to the north and west of average, and the South China Sea was quite active. However, there was indeed a notable eastward shift of the TC formation region between 2017 and 2018 (Fig. CC-4) yielding an abundance of TC formation and movement of TCs within the "El Niño Box" during 2018 (particularly into its western portion) on Figure CC-4. Because of this shift, Guam and the islands of the Northern Marianas were affected by several TCs. Among these were direct strikes on several islands by typhoons. One of these typhoons – Super Typhoon Yutu – caused catastrophic damage on Tinian and Saipan and another typhoon, Mangkhut, heavily damaged the island of Rota (see the LVS for Guam and the CNMI for more details.)

TROPICAL CYCLONE ACTIVITY

Abundant TC formation in all basins pushed the Northern Hemisphere total to well above average (Table CC-1 and Fig. CC-5). The eastern North Pacific (EPac) is the real stand-out basin in 2018, with a high number of named TCs and a high number of intense TCs. The very abundant EPac hurricane season included several high-impact storm events in the Hawaiian Islands (see the EPac TC summary below).

Northern Hemisphere TC activity statistics (2018 Annual)

Basin	Named Storms	Named Storm Days	Hurricanes/ Typhoons	Hurricane Days	Major Hurricanes	Major Hurricane Days	ACE
NAtl	15 (12)	87.25 (58.1)	8 (6.3)	26.75 (23.0)	2 (2.5)	5.0 (5.4)	128.9 (100.6)
ENP	**23 (16.7)**	**126.25 (75.0)**	**13 (9.4)**	**67.5 (30.6)**	**10 (4.6)**	**35.0 (8.9)**	**316.3 (134.3)**
WNP	**28 (26.0)**	**138.5 (135.3)**	**16 (16.1)**	**65.25 (64.3)**	**9 (8.6)**	**29.0 (22.1)**	**338.0 (289.9)**
NIO	8 (4.8)	26.0 (14.4)	4 (1.6)	6.25 (3.4)	1 (0.6)	0.50 (0.9)	31.1 (19.4)
N Hemi	74 (59.6)	378.0 (282.7)	41 (33.3)	165.75 (121.2)	22 (16.3)	69.5 (37.3)	814.3 (544.1)

Table CC-1. Global tropical cyclone activity by hemisphere and basin. Northern Hemisphere totals are for 2018 and Southern Hemisphere totals are for 01 July 2018 through 01 February 2019 (see basin archives, http://tropical.atmos.colostate.edu/Realtime/). Numbers in parentheses are long-term averages.

[3] A major hurricane/typhoon has an intensity of CAT 3, or higher, on the Saffir-Simpson Hurricane Damage Potential Scale (i.e., maximum sustained winds greater than 110 mph).

Southern Hemisphere TC activity statistics (01 July 2018 through 01 February 2019)

Basin	Named Storms	Named Storm Days	Hurricanes/ Typhoons	Hurricane Days	Major Hurricanes	Major Hurricane Days	ACE
S. IO < 135E	7 (8.3)	31.50 (37.5)	4 (3.8)	13.25 (11.6)	3 (1.6)	4.75 (3.4)	58.6 (57.3)
S. Pac >135 E	4 (4.2)	19.00 (16.9)	1 (2.3)	1.75 (6.3)	0 (0.9)	0.00 (1.6)	15.7 (28.7)
S. Hem	11 (12.5)	50.50 (54.4)	5 (6.1)	15.00 (17.9)	3 (2.5)	4.75 (5.0)	74.3 (86.0)

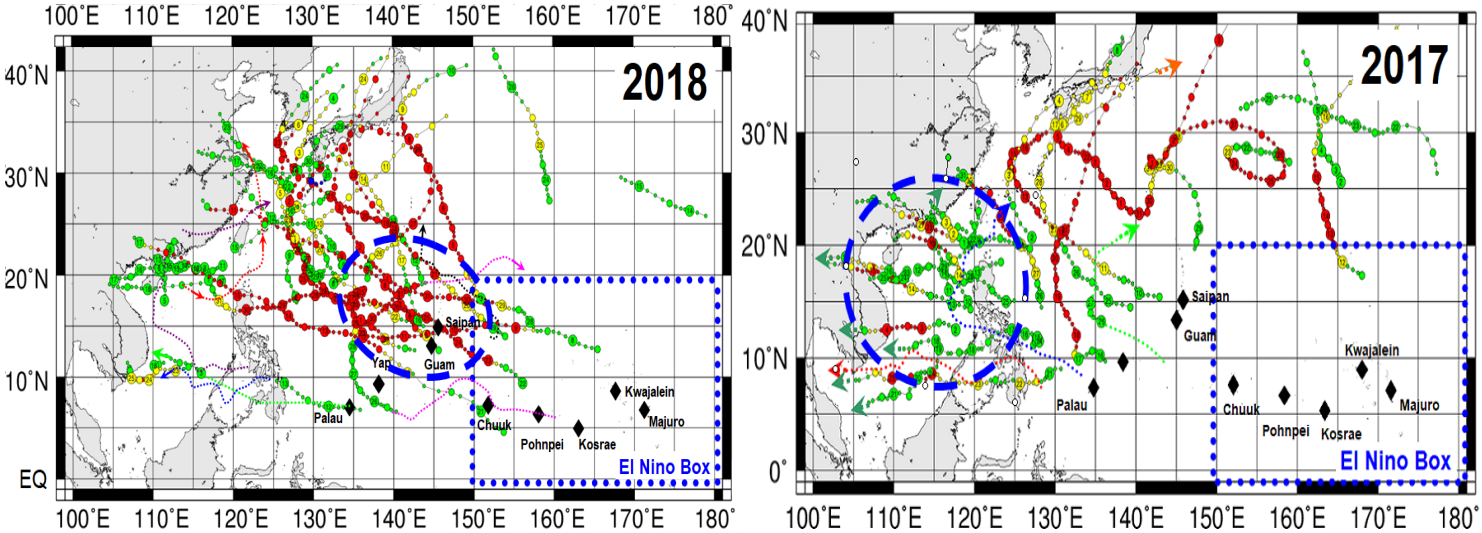


Figure CC-4. Tropical cyclone tracks during the calendar year 2018 (top) and the calendar year 2017 (bottom). Small-dot TC track lines show disturbance stages tracked by the JTWC in the pre- and post-storm stages and some TCs that were numbered by the JTWC but not named by the JMA. Large-dot box encloses the region where TCs form or traverse almost exclusively during El Niño. Large-dash circles illustrate the eastward shift of abundant TC formation during 2018 with respect to 2017. Charts are adapted from the "digital typhoon" web site: http://agora.ex.nii.ac.jp/digital-typhoon/year/wnp/

Southern Hemisphere

The 2017-18 Southern Hemisphere (SH) TC season ended on 30 June 2018. With the expected onset of El Niño conditions, the upcoming 2018-19 SH TC season, the genesis region of South Pacific TCs will likely see activity displaced farther to the east, resulting in above average numbers of TCs in the South Pacific to the east of 180°.\

TROPICAL CYCLONE ACTIVITY

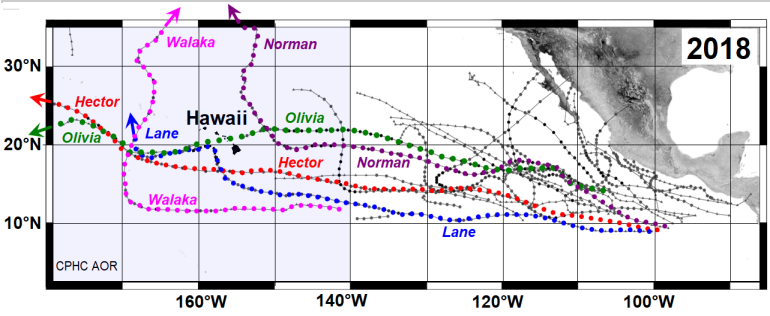


Fig. CC-5. Tracks of eastern North Pacific tropical cyclones during 2018. Selected hurricanes that affected Hawaii are highlighted by the large-dot color-coded tracks (as indicated).

PEAC tropical cyclone assessment

Western North Pacific and American Samoa

Two organizations routinely provide forecasts of western North Pacific typhoon activity: (1) The Guy Carpenter Asia-Pacific Climate Impact Centre (GCACIC) at the School of Energy and Environment, City University of Hong Kong; and, (2) Tropical Storm Risk (TSR), Dr Adam Lea and Professor Mark Saunders, Department of Space and Climate Physics, UCL (University College London). On 11 May 2018, the TSR issued its outlook for the western North Pacific typhoon season; it then issued an update to its outlook on 7 August 2018.

In retrospect, the forecast of the GCACIC forecast for below-normal TC landfalls in all regions of East Asia was likely too low. The TSR forecast for slightly above average basin-wide TC activity was more in-line with the observed abundant activity.

PEAC (Micronesia)

It is still too early to provide an outlook for the 2019 western North Pacific typhoon season.

American Samoa

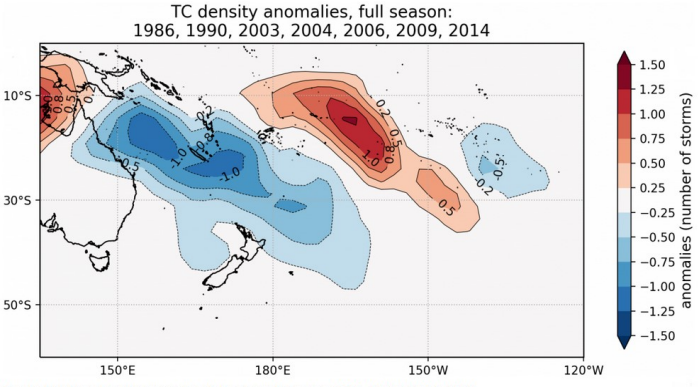
There are indications that the upcoming 2018/2019 TC season in American Samoa could be busy. Two agencies, the Australian Bureau of Meteorology and the National Institute for Water and Atmospheric Research (NIWA) of New Zealand, have issued TC outlooks relevant to American Samoa. The Australian BoM, while not directly providing a forecast for American Samoa, predicts below average activity across all Australian TC regions including in the Coral Sea west of 160° E. The implication of this is that the South Pacific TC activity will be shifted to the east, providing a higher risk to islands near and eastward of the International Date Line.

New Zealand's National Institute for Water and Atmospheric Research (NIWA) has also provided an outlook for the TC activity in the Southwest Pacific for the 2018-19 cyclone season. They anticipate that tropical cyclone activity will be lower than normal around the northern and eastern Coral Sea margin and elevated east of the International Date Line.

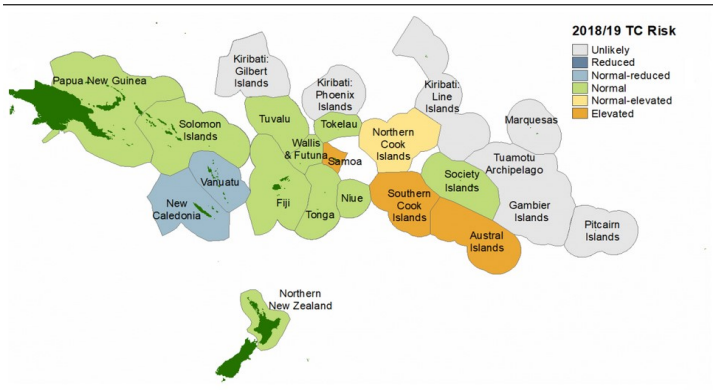
Islands on the fringe of the northern and eastern Coral Sea, including the Solomon Islands, Vanuatu, and New Caledonia, may experience slightly decreased tropical cyclone activity. Increased TC activity is expected in some islands east of the International Date Line, especially those east of 160°W longitude, including Samoa, Tonga, Niue, Fiji, the Cook Islands, and the Austral Islands (see Figure CC-6.) The PEAC concurs with this assessment.

Region	Average count	Chances for > avg
Australian	11	37%
Western	7	44%
Northwestern sub-region	5	41%
Eastern	4	40%
Northern	3	46%

Table CC-2. Australian BoM 2018-19 regional TC outlooks. For example, the Eastern region (i.e., from Australia's east coast out to 160°E) outlook shows a below-average season is most likely, with a 40% chance of more tropical cyclones than average and a 60% chance of fewer.



Tropical cyclone density anomalies, full season for years 1986, 1990, 2003, 2004, 2006, 2009, 2014 [Map: NIWA]



Map of tropical cyclone risk based on the 2018-19 Island Climate Update tropical cyclone guidance. [Map: NIWA]

Figure CC-6. Projections of tropical cyclone activity in the South Pacific during the upcoming 2018-19 cyclone season. Figures are from NIWA: https://www.niwa.co.nz/climate/southwest-pacific-tropical-cyclone-outlook/southwest-pacific-tropical-cyclone-outlook-october-2018.

SEASONAL SEA LEVEL OUTLOOK FOR THE US-AFFILIATED PACFIC ISLANDS

Executive Summary: *In the Cold Tongue (CT) El Niño composite, the seesaw pattern in sea level is clear; namely the thermocline is deepening (shoaling) over the eastern (western) Pacific (note that changes in sea level can be considered as changes in the thermocline depth within first-order approximation). The deepening thermocline induces a strong warm vertical advection by mean upwelling in the eastern Pacific. Thus, the warm SST anomaly is dominant in the eastern Pacific and we see a positive sea level anomaly in the eastern Pacific and negative sea level anomaly in the western Pacific. On the contrary, in the case of the Warm Pool (WP) El Niño, the positive sea level anomaly is located over the central Pacific, and its maximum near 150^{0}W coincides with a nodal point of zonal wind anomaly. The western Pacific stays near-normal (See Kug and Jin, 2009; available at https://journals.ametsoc.org/doi/full/10.1175/2008JCLI2624.1). In Kug and Jin (2009), a slight negative anomaly across 130^{0}E-150^{0}E and a slight positive anomaly across 160^{0}E-180 have also been observed. We therefore see Guam, Koror, Yap, and Chuuk (130^{0}E-150^{0}E) is showing slight negative anomaly while Pohnpei, Majuro, and Kwajalein (160^{0}E-180) is showing slight positive anomaly.*

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 December-January-February (DJF) of 2018-19 to March-April-May (MAM) of 2019, (ii) DJF-return values at 20 and 100-yr period, (iii) the observed monthly mean and maximum sea-level anomalies for the previous season August to October (ASO) of 2018, 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.*

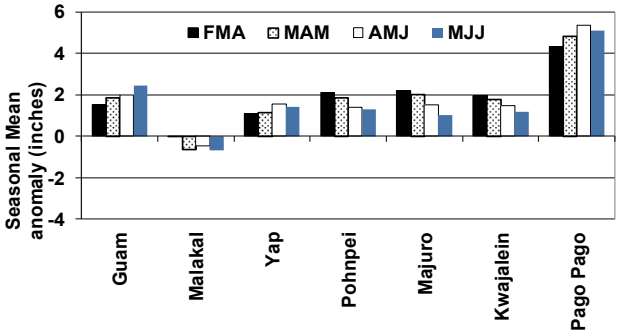
Seasonal Sea Level Forecast (anomalies with respect to climatology) for FMA, MAM, AMJ, and MJJ 2019

Forecasts of the sea-level anomalies in the USAPI are presented using CCA statistical model (see Chowdhury M. R., Chu P-S, and Guard C. (2014): *An Improved Sea Level Forecasting Scheme for Hazards Management in the U.S.-Affiliated Pacific Islands.* ***Int. Journal of Climatology*** *6, 2320-2329*.). Based on the independent SST and zonal wind (U) (SST-U) values in NDJ of 2018-19, the resulting CCA model has been used to forecast the sea level of four consecutive seasons: FMA, MAM, AMJ, and MJJ (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 3-months lead time) provided skillful forecasts for these three consecutive seasons.

Table SL-1: Forecasts of sea level anomalies in inches (FMA, MAM, AMJ, and MJJ)

	Seasonal Mean Deviations [1]					Seasonal Max Deviations [2]			
Tide Gauge Station	**FMA**	**MAM**	**AMJ**	**MJJ**	**Seasonal Outlook[3]**	**FMA**	**MAM**	**AMJ**	**MJJ**
Lead Time [5]	**1M**	**2M**	**3M**	**4M**	**Seasonal Outlook[3]**	**1M**	**2M**	**3M**	**4M**
Marianas, Guam	-2	-2	0	+2	Near-Normal	+18	+19	+19	+19
Malakal, Palau	-3	-3	-2	-2	Below	+38	+37	+36	+36
Yap, FSM	-3	-3	-2	-2	Below	+32	+32	+31	+30
Chuuk, FSM**	-2	-2	-1	0	Near-Normal	+29	+29	+29	+29
Pohnpei, FSM	+2	+2	+2	+1	Normal	+32	+31	+31	+32
Majuro, RMI	+3	+3	+2	+2	Near-Normal	+43	+43	+41	+40
Kwajalein, RMI	+2	+2	+2	+1	Normal	+41	+41	+40	+40
Pago Pago, Am. Samoa***	+4 (+9)	+4 (+9)	+5 (+10)	+5 (+10)	Above	+30 (+35)	+30 (+35)	+30 (+35)	+30 (+35)
Honolulu, Hawaii	+2	+2	+2	+2	Normal	+20	+21	+20	+21
Hilo, Hawaii	+2	+2	+2	+2	Normal	+24	+24	+24	+25

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 5 inches) in American Samoa at the time of September 2009 earthquake. So, -5 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 (Table SL-1; Fig. SL-1) indicate that most of north Pacific stations will stay near normal (lies between -/+ 2 inches) and the islands in FSM and RMI will stay slightly elevated in the forthcoming FMA-MJJ seasons. The lone south Pacific station (i.e., Pago Pago) will be elevated during the same time periods. This happens as Pago Pago maintains a 4-6 months' time-lag with respect to north Pacific stations (i.e., Guam and the Marshalls).

In Hawaii, both Honolulu and Hilo are likely to be slightly elevated, but still close to normal.

Figure SL-1. Seasonal mean sea level (MSL) forecasts for FMA, MAM, AMJ, and MJJ of 2019

SEASONAL SEA LEVEL OUTLOOK FOR THE US-AFFILIATED PACFIC ISLANDS

Observed Monthly Mean Sea Level Anomalies (with respect to climatology) for Jul-Oct (JASO) of 2018

Current Conditions: Current Conditions: Consistent to Warm Pool El Niño (WPE), all of the north Pacific stations displayed marginal fall in October. Some of the stations (e.g., Pohnpei, Majuro, and Kwajalein) recorded rise too. Hawaii sea levels are also elevated—Hilo recorded slight fall in October. Note that the south Pacific station (i.e., Pago Pago) is elevated (+6). This station maintains 4-6 months' time-lag w.r.t north Pacific stations (i.e., Guam and the Marshalls).

Impacts: While the MSL is normal or falling (e.g. significant fall in Guam), tides have been high with high waves in some of the islands. However, there is no noticeable inundation in low-lying atolls and there is no report for damage, so far.

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

Tide Gauge Station	Monthly Mean Deviations[1]					Monthly Max Deviations[2]				
	Oct	Nov	Dec	Jan	Standard Deviations	Oct	Nov	Dec	Jan	Sea level Trend
Marianas, Guam	-2	-2	-1	-3	3.5	+15	+15	+13	+12	Below
Malakal, Palau	-4	-6	-4	-5	4.3	+31	+30	+35	+33	Below
Yap, FSM	-3	-3	-3	-5	4.7	+24	+24	+25	+23	Below
Chuuk, FSM*	-1	-1	+1	-1	3.5					Normal
Pohnpei, FSM	+3	+2	+2	+2	3.8	+31	+30	+30	+31	Above
Majuro, RMI	+5	+3	+4	+7	2.8	+43	+43	+45	+50	Above
Kwajalein, RMI	+3	+1	+1	+3	3.2	+38	+37	+39	+44	Above
Pago Pago, American Samoa***	+5 [+12]	+5 [+10]	+7 [+12]	+9 [+14]	3.2	+28	+27	+37	+41	Above
Honolulu, Hawaii	+3	+1	+1	+2	1.8	+19	+20	+23	+23	Near Normal
Hilo, Hawaii	+5	+2	+1	+0	1.8	+25	+22	+27	+23	Normal

Table SL-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. Red: Falling trend, Black: Stable SL, and Blue: Rising trend. * In Pago Pago, there was a level shift (approximately 2-4 inches) at the time of September 2009 earthquake. *Data Source: University of Hawaii Sea Level Center (UHSLC). ftp://ilikai.soest.hawaii.edu/islp/slpp.anomalies.*

Synopsis of 2-years Sea Level Variability and Forecasts

Starting from JFM of 2017, a comparative perspective of two years of seasonal sea level variations is given below (Fig. SL-2). The sea level in the western Pacific stayed elevated until FMA of 2018. It started to fall from FMA of 2018 and recorded a significant fall until MJJ of 2018. The falling trend lasted until ASO of 2018 and then stayed near-normal. Consistent to WP El Niño, *Guam, Koror, Yap, and Chuuk (130^0E-150^0E) displays marginal negative anomaly while Pohnpei, Majuro, and Kwajalein (160^0E-180) is showing marginal positive anomaly.*

See page 15 for sea level observations from Jason-2 satellite picture (Fig. SL-3).

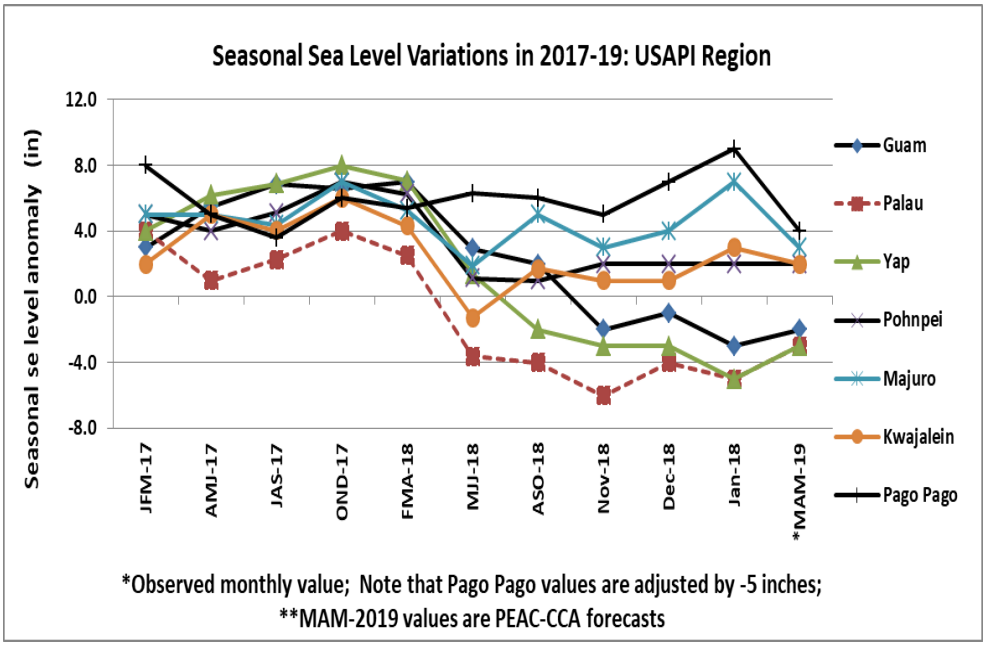


Figure SL-2. A comparative perspective of Island-wise seasonal sea level variations (OND 2016 to DJF 2018-19) (*Note that Pago Pago data needs correction because of level shift after 2009 earthquake. ,There was a level shift (approximately 2-4 inches) at that time which has not been adjusted).

LOCAL SUMMARY AND FORECAST

American Samoa:

WSO Pago Pago 2018 annual rainfall total of 159.82 inches (131%) was the 4th highest annual total in that station's 53-year climate record. Rainfall during 2017 and continuing through 2018 was characterized by overall wet conditions with high month-to-month variability (Figure AS-1 and Figure AS-2). February 2018 was notable for extreme rainfall and damaging wind accompanying Cyclone Gita (see the Cyclone Gita Sidebar report in the 2018 2nd Quarter ENSO Newsletter).

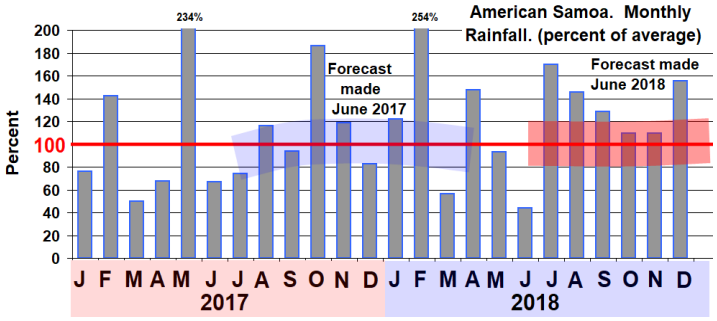


Figure AS-1. A time series of the monthly rainfall at Pago Pago during 2017 and 2018. Note the high month-to-month variability. Because of some very wet months, most sums over 6-months or greater yield above average rainfall. An earlier long-range rainfall forecast made by the PEAC in June 2017 is shown in light blue, and another such forecast made in June 2018 is shown in light red. Note that the earlier forecast did not capture the high variability, but did fall within the range of the difference between above and below average monthly totals. The 2nd half of 2018 was wetter than anticipated.

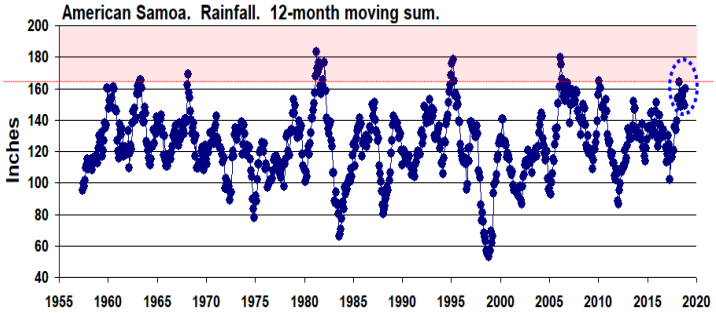


Figure AS-2. A 12-month moving sum of the monthly rainfall at Pago Pago. Note that the plotted values for most of the months of 2018 (inside the dotted blue circle) indicate a relatively high values. The light red shading indicates 12-month rainfall sums that are at-or-above the accumulated 12-month sum ending in April 2018.

Some wet weather statistics include:

(1) The 2018 annual total of 159.82 inches was the 4th wettest calendar year in the 53-year Pago Pago post-WWII historical climate record;
(2) The 163.89 inch 12-month sum of rainfall ending April 2018 was the 4th highest 12-month total;
(3) The 75.36 inches during the 2nd half of 2018 was the 7th highest such total;
(4) The February 2018 total of 32.47 inches was the 2nd wettest February, and 2nd wettest of any month;
(5) The April 2018 total of 17.76 inches was the 10th wettest April;
(6) The 4-month period January to April 2018 was 2nd wettest such period; and
(7) The July 2018 total of 10.68 inches was the 5th wettest July rainfall total.

LOCAL SUMMARY AND FORECAST

Apart from damage from the extreme rains and high winds of Cyclone Gita, there were no other major weather-related problems at American Samoa during the 1st half of 2018. During early July 2018, there were two reported events of flooding, resulting in nuisance damage and with no reported injuries.

American Samoa Rainfall Summary: 4th QTR and 2018 Annual

Station		Oct	Nov	Dec	4th QTR	2018
Pago Pago WSO	Rain (in)	11.83	11.90	22.59	46.32	159.82
	% Avg.	110%	110%	155%	128%	131%
Siufaga Ridge*	Rain (in)	12.45	13.65	17.92	44.02	151.33
	% Avg.	48%	61%	93%	77%	84%

Pago Pago Sea Level

The sea level across Micronesia has fallen over the past few months and is now below its long term average at many locations, particularly to the west of Pohnpei. However, the sea level at Pago Pago remains elevated above its long-term average, even after accounting for the approximately 10-cm shift of the datum during the 2009 earthquake/tsunami event (Figure AS-3).

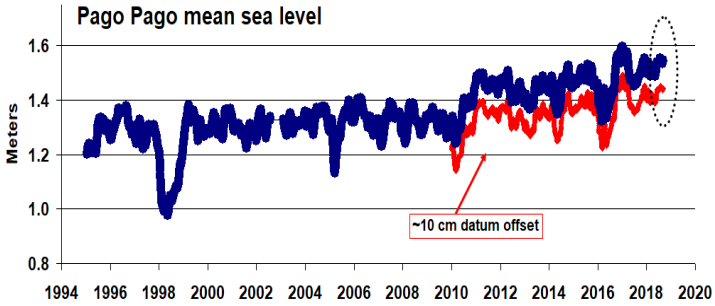
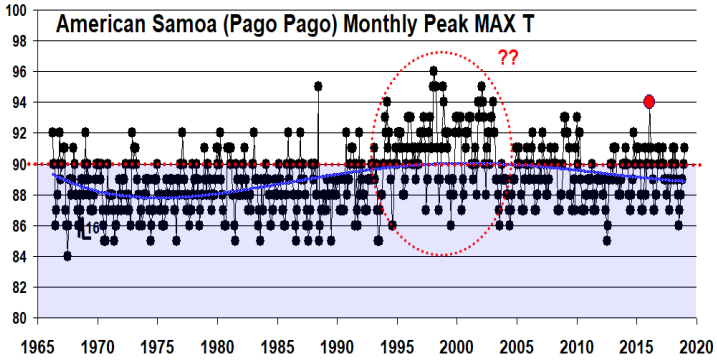


Figure AS-3. A 12-month moving average of the mean sea level at Pago Pago (dark blue time series). A sudden jump in the raw data in 2009 was the result of a datum change (a land subsidence) that occurred during the large earthquake/tsunami event of 29 September 2009. The red line shows the time series with the 10-cm land movement removed. With correction (red line), the lowered sea level during both the 2009 and 2015 El Niño events is more clearly depicted.

WSO Pago Pago temperature time series

The temperature at WSO Pago Pago has a complex history that is not well explained as a simple trend of steady warming. After a period of stable temperatures from 1966 through 1993, there was a decade of excessive warmth from 1994 through 2003, followed by cooler temperatures thereafter (Figure AS-4).



LOCAL SUMMARY AND FORECAST

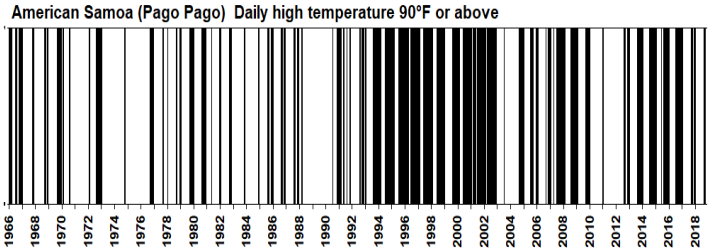


Figure AS-4. WSO Pago Pago temperature time series: (a) a line graph showing monthly peak temperature (°F), and (b) a "bar chart" showing only those temperatures at-or-above 90°F. Unusual warmth from 1994 through 2003 is well defined. Larger red dot for February 2015 happened during a notable hot spell during that month.

Climate Outlook:

After a long climb during 2018 from the cool side to the warm side of ENSO-Neutral, the state of the Pacific climate system finally entered El Niño as per the February 2019 CPC ENSO statement (see the Current Conditions Section). Important climatic elements such as rainfall, cyclone distribution and sea level are not as well correlated at American Samoa as they are in other ENSO core locations (e.g., Micronesia, Australia and even French Polynesia). Considering only rainfall, American Samoa lies along the zero-line separating strong effects of ENSO to the west, and strong (but opposite sign) ENSO effects to the east. Only during strong El Niño events are there useful correlations of ENSO with climatic rainfall conditions at American Samoa.

Whether El Niño has recently begun, recently matured, or is undergoing an unusually prolonged period of El Niño-like conditions (e.g., 1986-87 and 2014-15), it is (so far) undeniable weak, and the outlook for rainfall and cyclone distribution for American Samoa is somewhat uncertain. That being said, computer models indicate average to above-average rainfall over the period FMA 2019, and the PEAC concurs with these projections.

A link providing an outlook for the 2018-19 tropical cyclone season in American Samoa appears on the WSO Pago Pago web site. Portions of the text of that outlook are shown below:

"NOAA, National Weather Service, WSO – Pago Pago, American Samoa. November 1, 2018

NWS -WSO Pago Pago Office predicts a normal-to-above tropical cyclone season for 2018-19. The International Research Institute National Weather Service (NWS) Climate Prediction Center predicts a weak El Nino [that will] *continue through the tropical cyclone season. With this scenario, the South Pacific Convergence Zone (SPCZ) typically develops near to or just northeast of the Samoan Islands before drifting southwest late in the season. Tropical Cyclones will have a higher chance of developing within 300 nautical miles of the Samoan Islands from December through most of this season. This outlook is a general guide to the overall Tropical Cyclone season activity near the American Samoa basin (extends to 300 nautical miles from Tutuila) and does not predict whether, or how many, of these systems will directly affect American Samoa. The tropical cyclone season begins November 1 and runs until April 30. American Samoa will likely see above normal activity, with a 40% chance of above tropical cyclone climatology (elevated risk). This is fairly consistent with El Niño conditions. The outlook calls for 2 to 3 tropical cyclones affecting the Samoan Islands this season, given El Nino conditions by austral summer (Dec-Jan-Feb). … Follow us on Facebook @NWSPagoPago and visit our website: http://weather.gov/ppgfor updated weather information for American Samoa. Please listen to our NOAA Weather Radio, or give us a call at 699-9130. …"*

LOCAL SUMMARY AND FORECAST

Predicted rainfall for American Samoa from January through December 2019:

Inclusive Period	% of long-term average / Forecast rainfall (inches) [1]
Jan - Mar 2019 (Heart of Next Rainy Season)	120%
Apr - Jun 2019 (Onset of Next Dry Season)	110%
Jul - Sep 2019 (Heart of Next Dry Season)	100%
Oct - Dec 2019 (Onset of Rainy Season)	100%

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

Guam/CNMI:

The calendar year 2018 will be remembered in the Mariana Islands as a year of abundant tropical cyclone activity. Tropical cyclones dominated the weather of Guam and the CNMI during the months of July through October. Similar to the wild weather of 1992, when Guam was affected by 5 typhoons (three eye passages and two others within 60 n mi), the Mariana island chain during 2018 was once again a nexus for the tracks of several of the basin's TCs — please see the track map in the TC Section above. It may be well worth to repeat (from the last newsletter) the individual summaries of eight TCs affecting the region during 2018:

Figure G1. A spectacular picture taken by a NOAA polar orbiting satellite using moonlight! The nearly full moon was almost overhead at midnight when Yutu passed over Tinian. Low-light cameras on the satellite were able to capture the image using the dim light of the moon. Dr. Mark Lander's location on Saipan is indicated on the image. At this time, Tinian was almost directly in the middle of the eye, experiencing light winds for about an hour. Dr. Lander meanwhile was in the peak winds of the typhoon, with his patio-deck sliding glass doors being blasted inward by the wind.

(1) Jelewat. (late March). Typhoon Jelawat rapidly intensified while drifting slowly northward when it was located to the north of Yap Island. Heavy rainfall was experienced on Yap Island, and hazardous surf on Guam arriving from Jelawat likely contributed to a drowning.

(2) Maria. (early July). Possessing a transient, but potent, em-

LOCAL SUMMARY AND FORECAST

bedded meso-vortex circulation, Maria, while still a tropical storm, swept across Guam with storm force (48 – 63 kt) sustained winds across much of the island. However, a narrow swath of typhoon force winds directly associated with the meso-vortex were observed across the very top-end of the island. This unusual phenomenon is still under investigation. The strong winds crushed portions of the limestone forest at the Wildlife Preserve at extreme northwest Guam.

(3) Cimaron: (mid-August). Typhoon Cimaron began as a disturbance some 400 miles north of Pohnpei on 17 August and was designated a Tropical Storm a day later around 535 miles east of Saipan. Cimaron intensified slowly on a general west-northwest track, and finally reached minimal typhoon intensity on 20 August about 200 miles east of the Northern Islands of the Commonwealth of the Northern Mariana Islands (CNMI). The Guam Weather Forecast Office (WFO) placed the Northern Islands under a Typhoon Warning, and the typhoon passed 45 miles northeast of Agrihan Island on the 21st. The small settlements on Agrihan, Pagan and Alamagan were safe with damages mostly to agriculture.

(4) Jebi. (Late August) Typhoon Jebi raked the islands of Pagan, Alamagan, and Agrihan in the Northern Mariana Islands with wind gusts over 100 mph, according to the National Weather Service in Guam. Northern Islands Mayor Vicente B. Santos confirmed that people on the Northern Islands of Alamagan, Pagan, and Agrihan were safe, soon after Super Typhoon Jebi threaded its way through the region on its way to Japan. "The people in the Northern Islands are safe and all infrastructure is intact despite of the reported intensity of Typhoon Jebi," said Santos. This comes just two weeks after Typhoon Cimaron thrashed the Northern Islands.

(5) Manghkut. (early September). During the late afternoon of September 10, 2018, Typhoon Mangkhut passed directly over the island of Rota. The level of damage to vegetation and older wooden homes made of plywood and weathered corrugated metal roofing was notably below the devastating or catastrophic effects of a major (i.e., Category 3 or higher) hurricane/typhoon. A NOAA-sponsored assessment team (including PEAC scientist Dr. Mark Lander and two WFO Guam forecasters) examined the damage on Rota and the preliminary conclusion of the team was an intensity estimate for Mangkhut during eye passage over Rota of 90-kt sustained winds with gusts to 110 kt (strong CAT 2) (i.e., 103 mph G 127 mph, rounding up to 105 mph G 130 mph). Measured rainfall at the Rota International Airport (4.84 inches) was relatively light for the direct eye passage of a typhoon (but, was likely underestimated during the first half of the storm when winds were from the north with the rain gauge close-to and on the south side of a 3-story building). Damage to infrastructure was moderate, with only a few wooden power poles blown down, and isolated incidences of electrical and phone wires stripped away from poles and lying in the roadways. Rota Island has not had a devastating strike by a typhoon since the eye of Typhoon Chaba passed nearby on the night of August 22, 2004. Residents of Rota Island (who experienced both typhoons) generally indicated that Chaba was a stronger typhoon there than Mangkhut. On Saipan, the winds in Mangkhut rose to severe tropical storm force (50 – 63 kts). Damage was relatively light, and the power was out only for a day or two at most locations. The peak gust at the Saipan International Airport during Mangkhut was 82 mph. On Guam, Mangkhut's winds also rose to sustained severe tropical storm force, with a peak gust to 74 mph at the Guam WFO and to 86 mph at Andersen Air Force Base (AAFB). The big story on Guam during Mangkhut's passage was the extreme amount of rainfall over 24 hours that was near-or-above 10 inches in some locations.

LOCAL SUMMARY AND FORECAST

(6) Trami. (late September). On September 19, the JTWC opened an "Investigative Area" in order to monitor a large tropical disturbance that formed near Chuuk in the Federated States of Micronesia. The system drifted westward and strengthened into a tropical depression on September 20 according to the Japan Meteorological Agency, while the JTWC issued a Tropical Cyclone Formation Alert. On September 21, it gained tropical storm status and was named Trami. PEAC scientist Dr. Mark Lander was on an inbound flight to Saipan on the morning that Trami became a tropical storm just to the west of Saipan. A brief period of gales was experienced, and an inspection of eastern beaches (Tank Beach and the beach at Forbidden Island) revealed that large ocean waves had caused white-water inundation from breaking waves to reach 10-12 feet elevation (about half the height of Mangkhut's inundation). The peak wind gust at the SIA was 47 mph. The rainfall was heavy in the morning, with a 24-hour total on the 21st of September of 4.45 inches.

(7) Kong-rey. (late September). Kong-rey began as a tropical disturbance south of Pohnpei on 26 September. Intensification was slow, and the system was finally declared a Tropical Depression just west of Chuuk on 28 September, .and began tracking toward the Mariana Islands. Tropical Storm Kong-rey passed 75 miles south of Guam on 29 September. A wind gust to 44 mph was recorded at WFO Guam. Kong-rey finally reached typhoon intensity on 30 September about 360 miles north of Yap, where the monsoon tail produced heavy rainfall on Yap Island.

(8) **Yutu.** (late October). Super Typhoon Yutu passed directly over the island of Tinian on the night of 24 October and early morning hours of 25 October. The impacts to Tinian and the southern half of Saipan were catastrophic. Yutu's satellite intensity estimate peaked at 155 kt (178 mph) (Category 5) just prior to landfall over Tinian and the southern half of Saipan. All official ground-based instrumentation failed on Tinian and Saipan as the winds in the storm surged well-above 100 mph. PEAC scientist Dr. Mark Lander was on Saipan during the passage of the typhoon (Figure G1). He had, earlier in the day, set-up a rain gauge and a barometer at his location. The pressure at his location dropped to 921.7 mb. Dr. Lander's pressure reading coupled with a reasonable estimate of the horizontal pressure gradients in Yutu's inner eyewall was deemed supportive of Yutu's satellite-derived central pressure of 905 mb at the time of its passage over Tinian. His rain gauge recorded about 10 inches of rainfall during the storm, which was used to supplement the 2.66 inches of rainfall recorded up to midnight at the Saipan airport. Hundreds of power poles were toppled or leaning over at high angles. Hundreds of homes were severely damaged. All the buildings at the College of the Marianas lost most or all of their roofing. Recovery is still underway, and the complete restoration of water and power may take several months. Infrastructure repair may also take several months. Dr. Mark Lander and Mr. Charles P. (Chip) Guard (Guam WFO Warning Coordination Meteorologist) went to Saipan and Tinian to complete the damage survey to complement the meteorological data and satellite imagery in order to arrive at a final intensity estimate for the typhoon at its landfall. The final assessment was that Yutu was indeed a CAT 5* typhoon (capable of catastrophic damage) with sustained winds of 170 mph gusting to 200 mph. Note: the threshold for a CAT 5 hurricane/typhoon begins with sustained winds greater than 155 mph.

LOCAL SUMMARY AND FORECAST

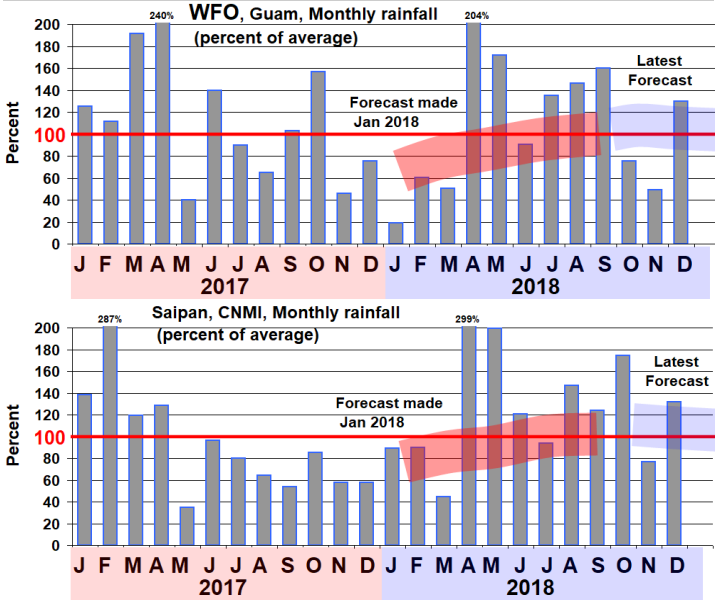


Figure G2. **Top**: A time series of monthly rainfall percentages at the Guam WFO during 2017 and 2018. **Bottom**: Same as the top panel, but for monthly rainfall percentages at the Saipan International Airport. Prior forecasts of rainfall made in January 2018 by the PEAC (just for illustration) are indicated by light red bands. The forecast rainfall going forward from October 2018 is indicated by the light blue bands. Note that the rainy season on Guam and in the CNMI was very wet, in large measure from many passing tropical cyclones.

Guam and CNMI Rainfall Summary: 4th QTR and 2018 Annual						
Station		**Oct**	**Nov**	**Dec**	**4th QTR**	**2018**
GUAM						
GIA (WFO)	**Inches**	**8.87**	**4.51**	**7.75**	**21.13**	**107.65**
	% Avg	**74%**	**55%**	**144%**	**82%**	**118%**
AAFB	**Inches**	**10.40**	**5.45**	**7.00***	**22.85**	**92.68**
	% Avg	**81%**	**60%**	**109%**	**82%**	**94%**
Southern Mountain	**Inches**	**10.25**	**4.95**	**6.48**	**21.68**	**106.12**
	% Avg	**80%**	**54%**	**109%**	**78%**	**108%**
CNMI						
Saipan Intl. Airport	**Inches**	**19.59****	**4.64**	**5.28**	**29.51**	**103.74**
	% Avg	**181%**	**80%**	**137%**	**144%**	**140%**
Capitol Hill	**Inches**	**16.39****	**3.87**	**3.56**	**23.82**	**98.76**
	% Avg	**137%**	**53%**	**74%**	**99%**	**118%**
Tinian Airport	**Inches**	**19.67 #**	**5.82**	**2.61**	**28.10**	**111.55**
	% Avg	**164%**	**80%**	**54%**	**117%**	**134%**
Rota Airport	**Inches**	**14.90**	**3.91**	**6.41**	**25.22**	**108.80**
	% Avg	**118%**	**45%**	**113%**	**93%**	**115%**

* Acknowledged trouble with rain gauge, so estimated from surrounding stations.
** 10 inches added to SIA total to account for rainfall inYutu. Very little rainfall after Yutu during 25-31
October. 7 inches added to Cap Hill for Yutu, was 9.39 during 1-24.
11-31 October Missing; used Tinian 1-10 (5.27") + SIA 11-24 (14.40) + 0.00 25-31= 19.67"

LOCAL SUMMARY AND FORECAST

Sea Level

The sea level at Guam fell during 2018, but had a very dramatic drop in the final 3 months (see Fig. G-3). A survey of Guam surfers reveals awareness in that community of noticeable lowered sea level late in 2018. Lowered sea level on Guam is

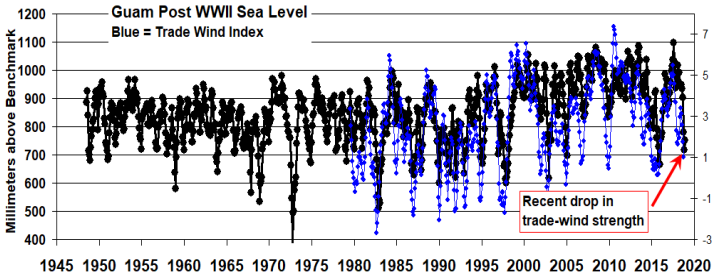


Figure G-3. A time series of Guam monthly sea level (black) and one of NOAA's trade wind indexes (blue). Note the very steep fall late in 2018 of both the sea level and the trade winds.

typically a feature of El Niño.

Breaking news:

(1) Drought Statement

WFO Guam releases Drought Information Statement (11 February 2019). Selected statements from the full document are quoted below:

DROUGHT INFORMATION STATEMENT...FIRST NATIONAL WEATHER SERVICE TIYAN GU
200 PM CHST MON FEB 11 2019

"...VERY DRY WEATHER DEVELOPING ACROSS MANY PARTS OF MICRONESIA..."

SYNOPSIS
"POST EL NINO-LIKE DRY CONDITIONS MAY CONTINUE THROUGH THE SPRING OF 2019."

MARIANA ISLANDS
"THE COMMONWEALTH OF THE NORTHERN MARIANA ISLANDS (CNMI)... RAINFALL HAS DIMINISHED OVER THE COMMONWEALTH SINCE JANUARY. SAIPAN...TINIAN...ROTA AND THE FAR NORTHERN MARIANA ISLANDS WILL EXPERIENCE DROUGHT IMPACTS DURING THE COMING WEEKS."

"IN PARTICULAR FOR SAIPAN... VEGETATION WILL DRY OUT AND A SEVERE WILDFIRE SEASON COULD DEVELOP...ESPECIALLY WHERE DEBRIS FROM TYPHOON YUTU REMAINS."

GUAM
"GUAM HAS RECEIVED A FEW SHOWERS AT TIMES RECENTLY AND SHOULD RECEIVE A LITTLE BETTER RAINFALL THAN OTHER MARIANA ISLANDS. GUAM RAINFALL IS EXPECTED TO BECOME DRY AND WILL CONTINUE TO BE MONITORED CAREFULLY."

RAINFALL
"REPORTS AND COMPUTER MODELS INDICATE ABNORMALLY DRY WEATHER CONTINUING OVER MUCH OF MICRONESIA. THE CLIMATE PREDICTION CENTER INDICATES THE ENSO ALERT SYSTEM STATUS" HAS BEEN ELEVATED TO EL NINO ADVISORY. THIS IS WELCOMED SINCE THE "WEATHER PATTERNS OVER MICRONESIA DURING THE LAST SEVERAL MONTHS WOULD SUGGEST THAT WE HAVE EXPERIENCED EL

LOCAL SUMMARY AND FORECAST

NINO-LIKE WEATHER. REGARDLESS, IT LOOKS LIKE DRIER CONDITIONS ARE IN STORE FOR MICRONESIA."

(2) Passage of Typhoon Wutip

On the night of 22 February, Typhoon Wutip approached the island of Guam from the southeast on a track passing southwest of the island. For most of the next day (Saturday. February 23) as the typhoon slowly eased past Guam close-by to the southwest, gale force winds and heavy rainfall were experienced across the island. Peak wind gusts reached 63 mph at WSO Guam and 66 mph at AAFB. Guam and the CNMI were lucky that Wutip passed just far enough offshore to the southwest that typhoon conditions did not occur at any island location.

One of the most significant impacts during Wutip's passage was a substantial amount of rainfall on Guam. The storm-total precipitation (STP) as depicted by Guam's NEXRAD radar was in excess of 10 inches in a swath across the southern end of the island, with lesser amounts to the north (Figure G-4). The high rainfall on Guam was the result of the phenomenon of "training", whereby a heavy outer rainband of Wutip remained largely in place for several hours over southern Guam as heavy showers embedded in the rainband tracked in-line along the WNW-ESE oriented band; hence, the metaphor of "training", comparing the rainband to a railway and the cores of the heavy showers rolling by a single location to the passage of the cars of a long train. More details on Wutip will be found in the next newsletter.

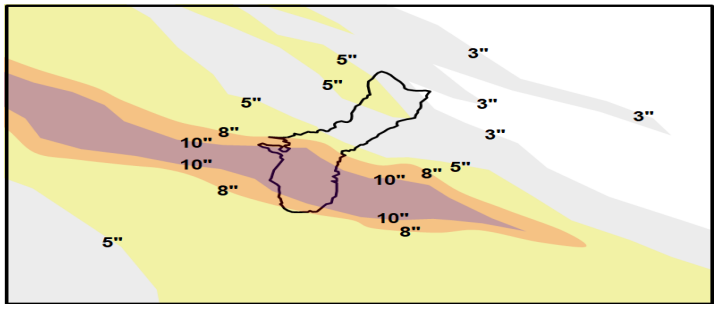


Figure G-4. NEXRAD-observed storm-total precipitation (STP) on Guam during the 2-day (23 - 24 February) passage of Typhoon Wutip to the southwest of the island. Amounts indicated are in inches (as labeled).

Climate Outlook:

After a long climb during 2018 from the cool side to the warm side of ENSO-Neutral, the state of the Pacific climate system finally entered El Niño as per the February 2019 CPC ENSO statement (see the Current Conditions Section). In several ways, the climatic elements (typhoon distribution, sea level and the pattern of rainfall) were, and still are, what one might expect at the maturity of a weak El Niño in late 2018/early 2019. Whether El Niño has recently begun, recently matured, or is undergoing an unusually prolonged period of El Niño-like conditions (e.g., 1986-87 and 2014-15), the forecast of rainfall for Guam and the CNMI will be for average to below-average rainfall through the spring of 2019 (MAMJ). Guam had well-above average rainfall in February (6.90 inches, 152%) as a consequence of the passage of Typhoon Wutip. Saipan and the other islands of the CNMI did not experience nearly as much rainfall in Wutip as did Guam, and thus are starting off drier going into the next few likely dry months. Computer model forecasts are now indicating Micronesia-wide below average rainfall over the next 3 months. Therefore, PEAC will adhere to a forecast of average to below-average rainfall at least through April of 2019 and likely longer. Looking ahead to the next rainy season, the uncertainty in the evolution of ENSO precludes a confident forecast of rainfall or typhoon distribution. Any strengthening of El Niño in the next few months would typically be associated with average to above average rainfall and an increase in the chances for an early-season typhoon. If El Niño fades over the next few months, a dry forecast is prudent, along with an associated reduction and delay of typhoon activity through the first half of 2019. We are opting for the drier scenario.

LOCAL SUMMARY AND FORECAST

Predicted rainfall for the Mariana Islands from January through December 2019:

Inclusive Period	% of long-term average / Forecast rainfall (inches) [1]	
	Guam/Rota	Saipan/Tinian
Jan-Mar 2019 (1st half of next dry season)	95%	80%
Apr-Jun 2019 (2nd half of next dry season)	75%	70%
Jul-Sep 2019 (Onset of next rainy season)	100%	100%
Oct-Dec 2019 (End of rainy season)	100%	100%

* For this time frame, Guam will be held at 95%, despite high rainfall during February in Typhoon Wutip. Saipan and Tinian did not get as much rainfall from Wutip, and thus will go with 80%.

Federated States of Micronesia

Yap State:

Rainfall at the WSO Yap was above average during 2018, but there was very high month-to-month variability (Figure Y1). March 2018 was particularly wet, and October 2018 was very dry. Rainfall during 2018 at other stations across Yap Island (Figure Y2) was near or above average. In the outer atolls, Ulithi had near average rainfall in 2018, while the 2018 total at Woleai was below average. No reports were received by the PEAC concerning problems with water supply anywhere in Yap State during 2018.

Breaking news

An extreme 24-hour rainfall of 9.10 inches occurred at the Yap WSO on 18 January 2019 during the passage through Yap State of an extensive band of heavy showers associated with the long-lasting, but continually disorganized cloud system of Tropical Depression 01W.

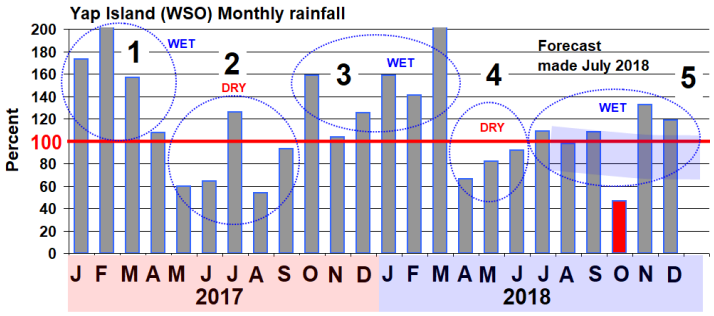


Figure Y1. Time series of monthly rainfall at the Yap Island WSO (gray bars) for January 2017 through December 2018. Five prominent and prolonged rainfall extremes appear within the dotted blue circles: (1) a very wet period extending across the first four months of 2017; (2) a prolonged dry period from May through September; (3) another period of wet weather to finish off the final 4 months of 2017 continuing into the 1st Quarter of 2018; (4) a short 3-month period of dryness during AMJ 2018; and a wet sequence of months – except for October -- during the latter half of 2018. The red bar highlights a very dry October 2018. The PEAC forecast made in July (blue-shaded bar) was reasonable.

LOCAL SUMMARY AND FORECAST

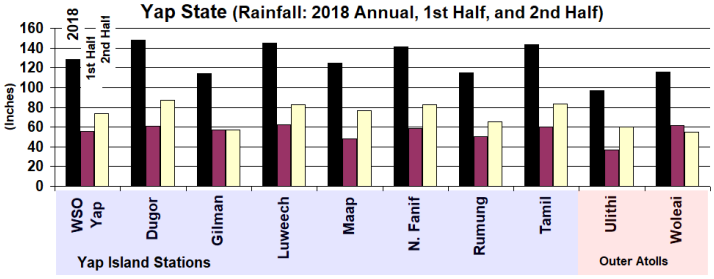


Figure Y2. A medley of rainfall amounts at locations within Yap State. The three bars for each location indicate the 2018 annual, 2018 1st half, and 2018 2nd half rainfall totals, respectively. Locations in the blue shading are on Yap Island, and the locations in the light red shading are two of the State's outer atolls. The annual average rainfall at WSO Yap is about 120 inches.

Sidebar: climatic trends in Yap

(1) Rainfall

Long-term rainfall records at the Yap WSO, starting shortly after WWII, show high variability at all time scales: month-to-month (see Figure Y1 above); interannual (Figure Y3, top panel); and at even longer periods, such as the 5-year running sum shown in Figure Y3 (bottom panel). A simple linear trend slapped onto each time series indicates a modest increase of rainfall since the start of the time series in the early 1950s. The magnitude of the trend is roughly 0.30 inches per decade, for a net gain of about 2 inches of rain per year over the entire 67-year period of the historical record. Because of high variability, the variance explained by the trend is very low (note the near-zero value of R^2).

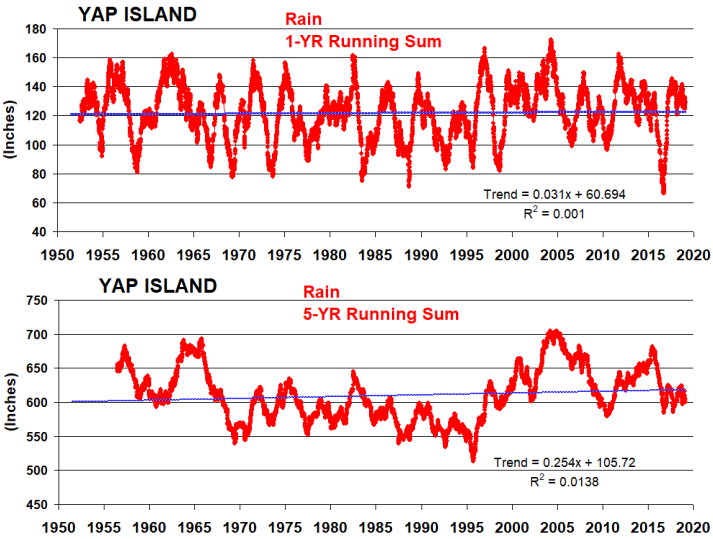


Figure Y3. The Post-WWII historical record of rainfall at WSO Yap Island. Top panel is a 12-month running sum of rainfall, and the bottom panel is a 5-year running sum. Note the high variability of the 12-month rainfall that is in large measure an effect of ENSO. The 5-year running sum brings out longer-period variability, with the dry decade of the late 1980s-to-early 1990s and the wet decade of the 2000s sharply apparent. The long-term trend of each time series (blue lines) show a modest rising trend of .03 inches per year for the 1-year sum, and .25 inches per 5-year block for the 5-year sum (the 5-year sum slightly exaggerates the small trend seen in the 1-year running summation).

(1) Temperature

Long-term trends of temperature at WSO Yap are complicated (Figure Y4). No clear picture emerges, with the daytime MAX temperature seeming to rise overall, and the nighttime MIN temperature clearly falling, at least until the relocation of the WSO in 2008. After April 2008, there was an abrupt increase of 5 °F

LOCAL SUMMARY AND FORECAST

in the MIN T. At the same time, the trace of the MAX T shows substantial warming with unusually large variability.

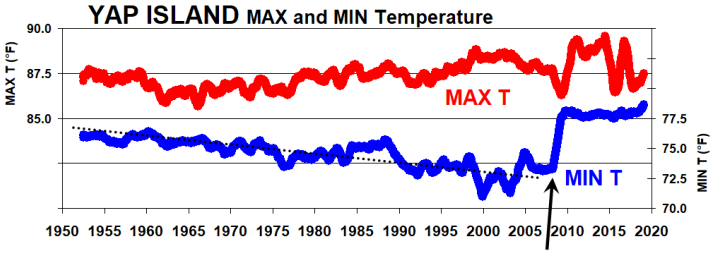


Figure Y4. The Post-WWII historical record of MAX and MIN temperature at WSO Yap Island. Plotted data are 12-month moving averages. The abrupt changes in each of the time series in 2008 (black arrow) are the consequence of a station relocation in April 2008. Note the long-term decline of MIN temperature until the 2008 station relocation, after which the MIN T jumps a whopping 5° F!

Yap State Rainfall Summary: 4th QTR and 2018 Annual						
Station		**Oct**	**Nov**	**Dec**	**4th QTR**	**2018**
Yap State						
Yap WSO	**Inches**	**5.56**	**12.03**	**10.68**	**28.27**	**128.80**
	% Norm	**46%**	**133%**	**119%**	**94%**	**107%**
Ulithi	**Inches**	**5.98**	**9.88**	**4.27**	**20.13**	**101.96**
	% Norm	**59%**	**128%**	**56%**	**79%**	**100%**
Woleai	**Inches**	**3.22**	**4.23**	**9.02**	**16.37**	**116.02**
	% Norm	**24%**	**38%**	**79%**	**46%**	**84%**

Climate Outlook:

After a long climb during 2018 from the cool side to the warm side of ENSO-Neutral, the state of the Pacific climate system finally entered El Niño as per the February 2019 CPC ENSO statement (see the Current Conditions Section). In several ways, the climatic elements (typhoon distribution, sea level and the pattern of rainfall) were (and still are) what one might expect at the maturity of a weak El Niño in late 2018/early 2019. Whether El Niño has recently begun, recently matured, or is undergoing an unusually prolonged period of El Niño-like conditions (e.g., 1986-87 and 2014-15), the forecast of rainfall for Yap State will be for a small reduction over the next few months, notwithstanding the high January 2019 total of 15.90 inches bolstered by a 9.10-inch 24-hour daily extreme. Computer model forecasts are now indicating Micronesia-wide below average rainfall over the next 3 months. Therefore PEAC will adhere to a forecast of average to below-average rainfall for at least through FMA 2019. Looking ahead to the next rainy season, the uncertainty in the evolution of ENSO precludes a confident forecast of rainfall or typhoon distribution. Any strengthening of El Niño in the next few months would typically be associated with average to above average rainfall and an increase in the chances for an early-season typhoon. If El Niño fades over the next few months, a dry forecast is prudent, along with an associated reduction and delay of typhoon activity through the first half of 2019.

LOCAL SUMMARY AND FORECAST

Predicted rainfall for Yap State from February[1] through December 2019 is:

Inclusive Period	% of long-term average / Forecast rainfall (inches) [1]	
	Woleai	Yap & Ulithi
Feb[1] – Mar 2019 (Ongoing Dry Season)	70%	70%
Apr – Jun 2019 (End of the Dry Season)	80%	80%
Jul – Sep 2019 (Heart of Rainy Season)	95%	90%
Oct – Dec 2019 (End of Rainy Season)	100%	100%

[1] Because of extreme rainfall associated with TD 01W, January 2019 was very wet, so it obviously does not fit the anticipated dry scenario.

Chuuk State:

"Warm, but not too bad" and *"plenty wet"*.

(WSO Chuuk staff description of the station weather throughout most of 2018)

In Chuuk State, the calendar year 2018 weather began with a continuation of weather patterns from the latter half of 2017 through March 2018 with above average rainfall, particularly in the Chuuk Lagoon (Figure CH-1). Some dryness was evident in March through June 2018 in the northern atolls, and also at Lukunoch, which had its driest 2nd Quarter (AMJ) rainfall total in its 31-year historical record. Abundant rainfall occurred through the summer of 2018, particularly at Chuuk Lagoon. The final two months of the year were dry. Overall, rainfall during 2018 was below average throughout most of Chuuk State, but was above average at Weather Service Office (WSO) Chuuk. Annual totals were at-or-above 100 inches, except in the northernmost atolls (Figure CH-2). The 2018 annual rainfall of 147.71 inches (110%) at WSO Chuuk was the highest annual total recorded in the State. Normally, Lukunoch in the southern Mortlock Islands has slightly higher rainfall than WSO Chuuk (140.00 inches versus 134.54 inches. Relatively low rainfall at Polowat has been continually observed, and may be the result of an exposure problem with the rain gauge. Despite the apparent low rainfall, no impacts have been reported.

Municipal water supplies and rain catchment have been adequate. There were no excessive rainfall events, and there were no reports of any recent significant sea inundation. The sea level across most of Micronesia fell several inches during 2018. But after having been well above average during 2017 and at the beginning of 2018, sea level across the region is now near average to slightly below average (see the sea level discussion for more details).

Breaking News: Typhoon Wutip (February 2019)

During mid-February 2019, a tropical cyclone (TC) formed south of the Marshall Islands at a very low latitude (~3°N). Over the course of several days, the system moved westward and steadily intensified to become a tropical storm (TS) in Pohnpei State and eastern Chuuk State, a typhoon in western Chuuk State and eastern Yap State, and a super typhoon when it was located to the west-southwest of Guam. Along the way from its birthplace to its demise over open water to the northwest of Guam, Wutip dropped heavy rainfall at many locations across eastern and central Micronesia, including much of Chuuk State. Storm-total rainfall at WSO Chuuk was approximately 6 inches during Wutip's passage. Some of the atolls of the Mortlock Island group likely experienced severe TS conditions. (A more detailed description of Wutip will appear in the next newsletter).

LOCAL SUMMARY AND FORECAST

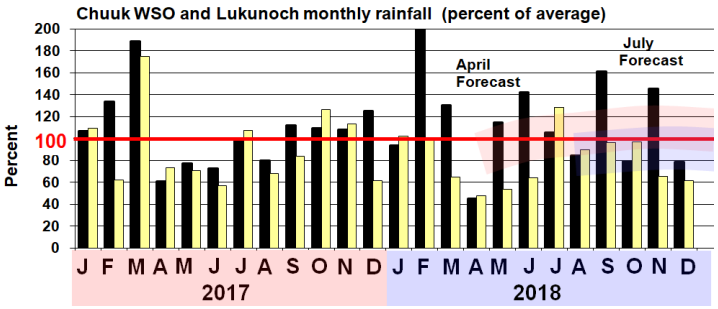


Figure CH-1. A time series of the monthly rainfall at the WSO Chuuk (black bars) and at Lukunoch in the southern Mortlock Islands (yellow bars) during 2017 and 2018. The light blue band is a long-range rainfall prediction made in July, and the light red band is the long-range rainfall forecast made in April 2018.

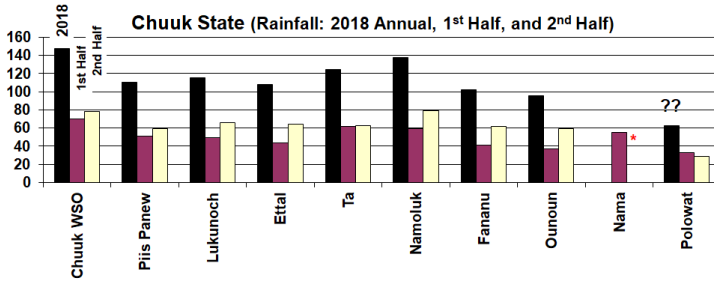


Figure CH-2. A bar chart depiction of 2018 rainfall totals at the indicated locations within Chuuk State. The black bar shows the 2018 annual total; the maroon bar shows the 2018 1st half total; and, the yellow bar shows the 2018 2nd half total. Only the 1st half total was available for Nama Atoll. Polowat almost always is much drier than at the other locations; this might indicate an exposure problem with the rain gauge.

Chuuk State Rainfall Summary: 4th QTR and 2018 Annual						
Station		Oct	Nov	Dec	4th QTR	2018
Chuuk Lagoon						
Chuuk WSO	Inches	10.66	15.02	8.53	34.21	147.71
	% Avg	79%	145%	79%	99%	110%
Southern Mortlocks						
Lukunoch	Inches	10.06	7.12	7.89	25.07	115.56
	% Avg	97%	65%	61%	73%	80%
Northern Atolls						
Fananu	Inches	8.03	6.15	5.33	19.51	104.53
	% Avg	60%	60%	49%	56%	78%
Ounoun	Inches	6.98	6.98	8.76	24.51	95.85
	% Avg	52%	52%	81%	71%	71%
Western Atolls						
Polowat	Inches	3.73*	5.69*	3.93*	13.35*	62.22*
	% Avg	31%	62%	43%	44%	52%

* It is possible that persistent dryness at Polowat is exaggerated by an exposure problem with the rain gauge; although February and March appeared reasonable.

** There is no longer an observer on Nama Island.

LOCAL SUMMARY AND FORECAST

Climate Outlook:

After a long climb during 2018 from the cool side to the warm side of ENSO-Neutral, the state of the Pacific climate system finally entered El Niño as per the February 2019 CPC ENSO statement (see the Current Conditions Section). In several ways, the Micronesia regional and local climatic elements of typhoon distribution, sea level and the pattern of rainfall, were, and still are, what one might expect at the maturity of a weak El Niño in late 2018/early 2019. Whether El Niño has recently begun or recently matured, or the western Pacific is merely undergoing an unusually prolonged period of El Niño-like conditions (e.g., 1986-87 and 2014-15), the forecast of rainfall for Chuuk State will be for only a small reduction of rainfall over the next few months, when considering the high rainfall during January 2019 and the passage of Wutip through the State during mid-February. Computer model forecasts are now indicating Micronesia-wide below average rainfall over the next 3 months, and are also supportive of a forecast of average to below-average rainfall across most of Chuuk State at least through FMA 2019 and likely into May. Looking ahead to the next rainy season, the uncertainty in the evolution of ENSO unfortunately precludes a confident forecast of rainfall or typhoon distribution. Any strengthening of El Niño in the next few months would typically be associated with average to above average rainfall and an increase in the chances for an early-season TC. If El Niño fades over the next few months, a dry forecast is prudent, along with an associated reduction and delay of typhoon activity through the first half of 2019. We are leaning toward the drier, less active solution.

Predicted rainfall for Chuuk State from January 2019 through December 2019 is:

Inclusive Period	% of long-term average / Forecast rainfall (inches) [1]			
	Chuuk Lagoon, Losap, & Nama	Polowat	Northern Is.	Southern Mortlocks
Jan - Mar 2019	100%	80%	85%	100%
Apr - Jun 2019	85%	75%	80%	85%
Jul - Sep 2019	100%	90%	95%	95%
Oct - Dec 2019	100%	85%	95%	100%

* Computer outlooks for the past few monthly forecasts have continually suggested dry conditions during the 1st three months of 2019. The passages of TD 01W and Typhoon Wutip through the state during January and February, respectively, were unforeseeable extreme events. The Jan-Mar 2019 rainfall projection at Chuuk Lagoon/Losap/Nama and in the Southern Mortlocks will be left at 100%. The northern atolls may yet fall short in their 3-month Jan-Mar totals. The PEAC did mention in the last newsletter that if a late-season tropical cyclone were to pass through the State in December 2018 or January 2019, the rainfall could be much higher.

Pohnpei State:

"Plenty wet!" Assessment of the recent climate at Pohnpei Island provided by WSO Pohnpei Island station chief, Eden Skilling.

An enormous amount of rainfall occurred on Pohnpei Island and some of the outer atolls during March 2018. The March monthly total of 57.92 inches at the WSO Pohnpei was that station's highest March rainfall total, its highest total for any month, and the highest monthly total for any month at any station across Micronesia! The 1st Half of 2018 was wet throughout most of Pohnpei State (Figure PN-1). Apart from a wet August, the latter half of 2018 was near average to below average. Despite lower rainfall amounts in the latter half of 2018, the extreme wetness in the first half of the year was more than adequate to push the 2018 annual rainfall at WSO Pohnpei to a record high value of 247.99 inches (Table 1, and tabular rainfall summaries).

Rainfall at Kapingamarangi was also very high during 2018. The calendar-year total of 165.08 inches (133%) was the 3rd highest in that station's 20-year climate record. However, the 199.82 inches during the 12-month period November 2017 through October 2018 was the highest such period in the record (Figure PN-2).

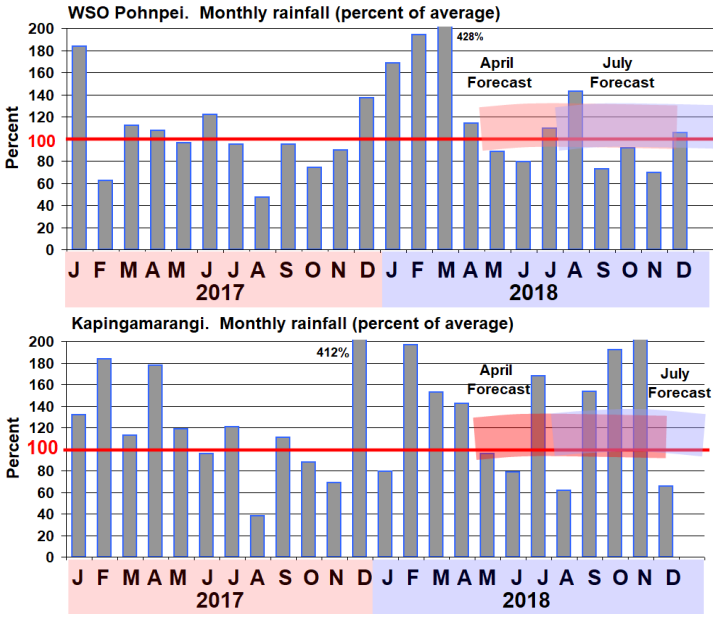


Figure PN-1. A bar chart of the monthly rainfall at the Pohnpei Island weather station (top) and at Kapingamarangi (bottom) during 2017 and 2018. The heavy December 2017 rainfall at Kapingamarangi and the heavy rainfall at the WSO Pohnpei in March 2018 are extreme historical record high values that would seem impossible to anticipate. Two of the PEAC's long-range rainfall forecasts -- one made in April (light red band), and one made in July (light blue band) -- were correct to indicate above average rainfall (based on the anticipated development of El Niño), but certainly could not anticipate some all-time high monthly values nor the extreme month-to-month variability.

Table 1. The top 8 annual rainfall totals in the historical record at WSO Pohnpei and at Kosrae SAWRS. Color coding depicts categories as shown by the key below the table. Note that 2018 annual rainfall at WSO Pohnpei was a record high value.

Pohnpei	247.99 2018	236.29 1976	228.54 1991	225.94 1955	219.84 1989	217.80 1959	216.87 2015	215.60 1962
Kosrae*	237.67 1996	231.30 1993	230.10 2017	224.06 2002	220.25 2001	214.51 1999	213.87 1991	213.41 2004

> 225 inches > 200 inches

* The Kosrae period of record is from 1986 to present, while the Pohnpei record is from 1953 to present.

LOCAL SUMMARY AND FORECAST

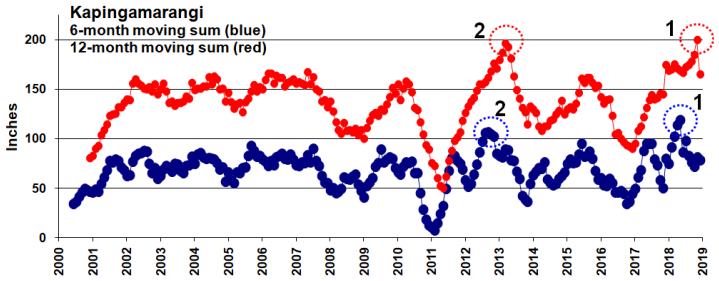


Figure PN-2. A time series of a 6-month moving sum (blue) and a 12-month moving sum (red) of monthly rainfall at Kapingamarangi. Numbers in the red and blue circles indicate relative rankings of the wet extremes.

2018 weather impacts: Record high rainfall

The high rainfall of March 2018 on Pohnpei Island included some very high 24-hour rainfall amounts. During the two-day period of 16 and 17 March, a total of 21.15 inches of rain (12.21 inches on the 16th plus 8.94 inches on the 17th) was recorded at WSO Pohnpei (Figure PN-3). This heavy short-term rainfall caused damage and there was one fatality and one injury in a landslide. There were 24 identified landslides. Many homes, and 11 bridges and culverts were damaged. During the course of this event, WSO Pohnpei issued a landslide warning and 6 flood statements. Including the heavy rainfall on the 16th and 17th, there were 16 days in March 2018 with over 1 inch of rainfall. In July, President Donald Trump declared a Presidential Disaster under the Compact of Free Association for the FSM due to the flooding and mudslides that occurred on Pohnpei Island on 16 and 17 March 2018

Abundance of tropical cyclones

Another big story of 2018 was the number of tropical systems that directly or indirectly affected Pohnpei State. While these disturbances were not significant wind events for Pohnpei State, they did increase the rainfall slightly. Most of the tropical cyclones (TCs) passed to the north of the State, bringing temporary enhancement to southwest monsoon conditions. From July to October, the Pacific weather pattern was typical of a maturing El Niño, despite the Oceanic Niño Index (ONI) not meeting the El Niño threshold. Several tropical disturbances developed in the Marshall Islands and subsequently intensified as they moved westward. During this period, the US Climate Prediction Center (CPC) issued an El Niño Watch, indicating that the equatorial Pacific region climate pattern was close to reaching the threshold of El Niño. The TC activity included the early stages (with respect to Pohnpei Island) of: Super Typhoon Cimaron (400 miles north on 17 August), Super Typhoon Jebi (460 miles north on 27 August), Typhoon Mangkhut (500 miles north on 8 September), Super Typhoon Kong-rey (180 miles south-southwest on 26 September), and Super Typhoon Yutu (100 miles northwest on 22 October). There were additional non-developing disturbances in November. Despite the TC activity, the rainfall summaries below show a general drying at Pohnpei Island and at most of the outer atolls, especially the eastern atolls (e.g., Mwokilloa), in the 4th Quarter.

Breaking news

During late January through mid-February 2019, dry conditions became established across Pohnpei Island. Stream flow lessened. Vegetation started to turn brown. Gusty trade winds kicked-up dust that caused an increase in reported occurrences of "pink eye" (conjunctivitis) infections.

LOCAL SUMMARY AND FORECAST

Then, in the third week of February, Super Typhoon Wutip, while just becoming a tropical storm, passed through Pohnpei State, with WSO Pohnpei logging over 5 inches of rain during the two-day passage of the storm and low-latitude Nukuloro Atoll was placed into a Tropical Storm Warning by the Guam Weather Forecast Office. More details on Wutip will be placed in the next newsletter.

Pohnpei State Rainfall Summary 4th QTR and 2018 Annual

Station		Oct	Nov	Dec	4th QTR	2018
Pohnpei WSO	Rain (Inches)	15.31	10.97	16.11	42.39	247.99
	% of Average	92%	70%	106%	89%	131%
PNI Airport	Rain (Inches)	9.01	11.39	16.98	37.38	199.15
	% of Average	66%	88%	136%	95%	128%
Atolls of Phonpei State						
Station		**Oct**	**Nov**	**Dec**	**4th QTR**	**2018**
Nukuoro	Rain (Inches)	10.44	17.15	6.27	33.86	134.21
	% of Average	97%	143%	52%	97%	90%
Pingelap	Rain (Inches)	8.05	4.02	10.58	22.65	156.20
	% of Average	59%	31%	85%	58%	101%
Kapinga	Rain (Inches)	12.98	20.71	6.56	40.25	165.08
	% of Average	192%	239%	65%	158%	133%

Climate Outlook:

After a long climb during 2018 from the cool side to the warm side of ENSO-Neutral, the state of the Pacific climate system finally entered El Niño as per the February 2019 CPC ENSO statement (see the Current Conditions Section). In several ways, the Micronesia regional and local climatic elements (typhoon distribution, sea level and the pattern of rainfall) were, and still are, what one might expect at the maturity of a weak El Niño in late 2018/early 2019. Whether El Niño has recently begun, recently matured, or is undergoing an unusually prolonged period of El Niño-like conditions (e.g., 1986-87 and 2014-15), the forecast of rainfall for Pohnpei State will be for a small reduction of rainfall over the next few months, notwithstanding the high January 2019 total of 15.90 inches bolstered by a 9.10-inch 24-hour daily extreme, and notwithstanding the passage of Wutip through the State at the time of this writing. Computer model forecasts are now indicating Micronesia-wide below average rainfall over the next few months, at least through FMA 2019. Looking ahead to the next rainy season, the uncertainty in the evolution of ENSO precludes a confident forecast of rainfall or typhoon distribution. Any strengthening of El Niño in the next few months would typically be associated with average to above average rainfall and an increase in the chances for an early-season TC. If El Niño fades over the next few months, a dry forecast is prudent, along with an associated reduction and delay of typhoon activity through the first half of 2019.

LOCAL SUMMARY AND FORECAST

Inclusive Period	% of long-term average	
	Pohnpei Island/ atolls	Kapingamarangi
Jan - Mar 2019	100%*	100%
Apr - Jun 2019	90%	90%
Jul - Sep 2019	95%	95%
Oct - Dec 2019	100%	100%

* The impact of heavy rainfall from Typhoon Wutip has not been factored into this estimate. Will leave at 100%.

Kosrae State:

After a prolonged period of abundant rainfall from the latter half of 2017 through August 2018, conditions across Kosrae then became dry (see Figure KS-1). Some extremes for dryness included:

(1) The 3-month (SON) total of 20.98 inches at Kosrae International Airport was the lowest such total in the airport record (1986-present), although there was one lower 3-month total of 19.68 inches during the SON of 1969 when the rainfall was recorded at Lelu Island (east-northeast);

(2) The 4-month (SOND) total of 28.14 inches was the lowest such 4-month total (by far), with the 41.12 inches of rainfall during SOND 1990 a distant 2nd;

(3) Because of earlier abundant rainfall, accumulated rainfall totals over longer time intervals such as the 2nd half of 2018, and the calendar-year of 2018 were not so dry, the former registering as the 3rd driest, and the latter ranking as the 13th driest annual total in the 33-year climate record at the airport.

The rainfall at the airport on the northwest side of the island tracks closely with the rainfall at the Kosrae Nautilus Resort located on the east-northeast side of the island (Figure KS-2). These two stations have very similar rainfall amounts and interannual variability. The sudden onset of dry periods often accompanies the latter stages of El Niño. Despite the drier conditions, the Official in Charge of the Pohnpei Weather Service Office (WSO), a native of Kosrae, indicated that there were no reports of water rationing or outages or grass fires, and that the island maintained its lush green appearance.

Breaking News:

Rainfall in Kosrae during January 2019 was near average, and February 2019 is off to a wet start, with an early season tropical cyclone affecting the island at the time of this writing.

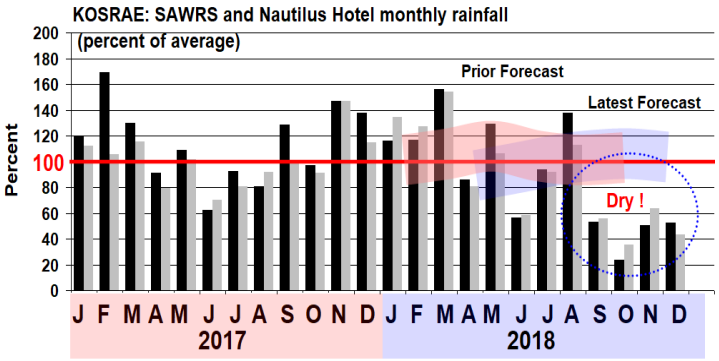


Figure KS-1. A time series of the monthly rainfall at Supplemental Aviation Weather Reporting Station (SAWRS) at the Kosrae International Airport (black bars) and the Nautilus Hotel (gray bars) for the period January 2017 through December 2018. The PEAC rainfall forecast made in January 2018 (light red band) was accurate through the 1st Quarter of 2018, but missed the dry April and dry June. The light blue band shows the PEAC forecast made in May 2018 which went well through August, but then missed the extreme dryness in the latter 4 months of the year.

LOCAL SUMMARY AND FORECAST

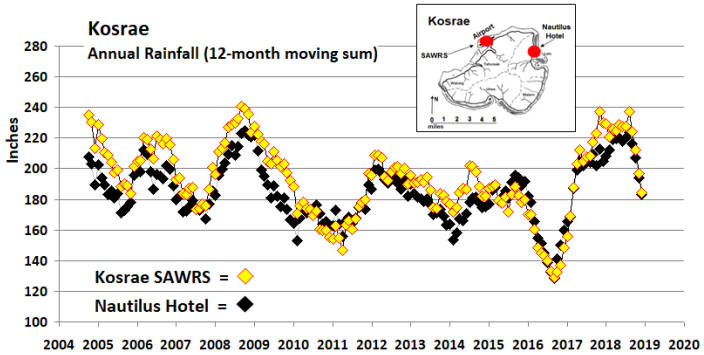


Figure KS-2. A plot of the 12-month moving sum of rainfall at (SAWRS) at the Kosrae International Airport and at the Nautilus Hotel (locations indicated by the red dots in the inset). Rainfall across the relatively small island seems to be coherent. Note the big dip of rainfall amounts in response to the 2015-2016 El Niño, with the subsequent rapid recovery to wet conditions during 2017 and early 2018. Recent dryness is responsible for a sudden plunge in the values.

Kosrae State Rainfall Summary: 4th QTR and 2018 Annual						
Station		Oct	Nov	Dec	4th QTR	2018
Airport (SAWRS)	Rain (Inches)	3.70	7.91	7.50	19.11	184.60
	% of Average	23%	50%	52%	41%	90%
Nautilus Hotel	Rain (Inches)	5.78	10.12	6.27	22.17	183.42
	% of Average	36%	64%	43%	48%	89%

Climate Outlook:

For many months (from late 2017 through the first half of 2018), computer models favored above average rainfall at Kosrae. By September 2018, however, these same models started to be mixed: with some above-average, some near average, and some below average. The PEAC team in September decided to favor near average rainfall for Kosrae, but in doing so, missed the abrupt start of very dry conditions during SOND. The latest available computer models (with projections for rainfall during FMA 2019), now indicate average to below-average rainfall amounts during that 3-month period. The rainfall at Kosrae and the distribution of tropical cyclones there are strongly affected by ENSO.

After a long climb during 2018 from the cool side to the warm side of ENSO-Neutral, the state of the Pacific climate system finally entered El Niño as per the February 2019 CPC ENSO statement (see the Current Conditions Section). In several ways, the regional and local climatic elements (typhoon distribution, sea level and the pattern of rainfall) were (and still are) what one might expect at the maturity of a weak El Niño in late 2018/early 2019. Whether El Niño has recently begun, recently matured, or is undergoing an unusually prolonged period of El Niño-like conditions (e.g., 1986-87 and 2014-15), the forecast of rainfall for Kosrae State will be for a small reduction of rainfall over the next few months, notwithstanding the high January 2019 total of 15.90 inches bolstered by a 9.10-inch 24-hour daily extreme, and notwithstanding the tropical depression passing through the State at the time of this writing (mid-February). Computer model forecasts are now indicating Micronesia-wide below average rainfall over the next 3 months, and are also supportive of a forecast of average to below-average rainfall at Kosrae at least through FMA 2019. Looking ahead to the next rainy season, the uncertainty in the evolution of ENSO pre-

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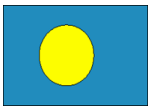
cludes a confident forecast of rainfall or typhoon distribution. Any strengthening of El Niño in the next few months would typically be associated with average to above average rainfall and an increase in the chances for an early-season tropical cyclone. If El Niño fades over the next few months, a dry forecast is prudent, along with an associated reduction and delay of typhoon activity through the first half of 2019.

Predicted rainfall for Kosrae State from January through December 2019 is:

Inclusive Period (Kosrae)	% of long-term average / Forecast rainfall (inches) [1]
Jan - Mar 2019	95% *
Apr - Jun 2019	90% *
Jul - Sep 2019	95%
Oct - Dec 2019	100%

* If El Niño conditions intensify during the first few months of 2019, Kosrae could be wetter than indicated. Will leave the Jan-Mar 2019 rainfall at 95%, notwithstanding heavy rainfall during Wutip's passage in mid-February.



Republic of Palau:

By August 2016, a record-breaking drought during the course of the epic 2015-2016 El Niño event led to the accumulated loss (with respect to average amounts) of 85.73 inches of rainfall at WSO Koror (Fig. PL-1). This is well over half a year's typical annual total of 148 inches! With the return of some above-average monthly totals during 2017, the long-term deficit recovered to -49.24 inches by the end of that year. However, dryness throughout most of 2018 (Fig. PL-2) led to a renewed increase in the long-term accumulated deficit of rainfall, which stood at -67.33 inches on the last day of the December 2018. Recovery from the severe dryness of the 2015-2016 drought is ongoing, and long-term summations of rainfall (for example, the 3-year and 5-year running sums shown in Figure PL-3), reveal the depth of the severe drought and the long climb out that has yet to reach the average values for these statistics.

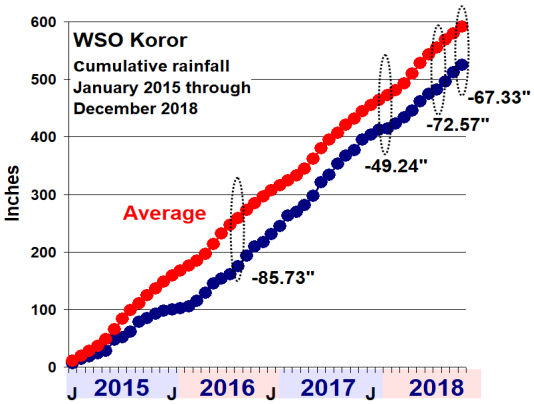


Figure PL-1. Nearly four years of cumulative rainfall at Koror. The red line shows the normal accumulated rainfall from JAN 2015 through DEC 2018, and the dark blue line shows the observed accumulated rainfall over the same time period. The accumulated deficit reached its extreme low of -85.73 inches in August 2016. Abundant rainfall in late 2016 and through 2017 erased 36 inches of the deficit which stood at -49.24 inches in December 2017. Dryness throughout most of 2018 once again increased the long-term deficit by about 23 inches to a deficit of -72.57 inches as of September 2018, improving slightly to

LOCAL SUMMARY AND FORECAST

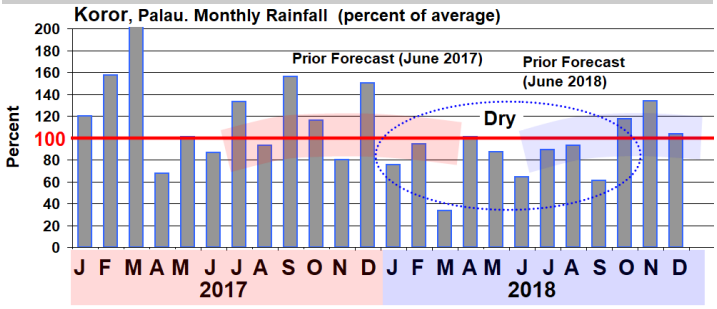


Figure PL-2. A bar chart of observed monthly rainfall (percent of average) at the WSO Koror during 2017 and 2018. The forecast presented in the June 2017 Newsletter for the rest of 2017 is shown by the light-red band. The forecast presented in the June 2018 Newsletter for the rest of 2018 is shown by the light-blue band. Note that the magnitude of dryness throughout most of 2018 was not fully anticipated. Eight of the 12 months of 2018 had below average rainfall, with the year ending at 88% of its average.

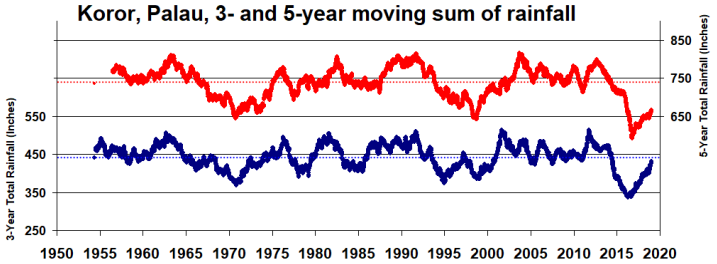


Figure PL-3. Time series of the 3-year and 5-year moving sums (looking backwards) of rainfall at the WSO Koror. Note the historical low-points of each time series during 2016. Note also that the two moving sums have yet to recover to their respective average value (dotted red and blue lines).

Sidebar: Jellyfish Lake

Updated December 13, 2018 (https://palaudiveadventures.com/palau-jellyfish-lake/#):

Jellyfish Lake in Palau is open to the public again!

An ecological impact of the 2015-16 El Niño was a severe die-off of jellyfish in Palau's famous Jellyfish Lake (see Figure PL-4). The lake remained closed to tourists as per official statement of the Palau Ministry of Natural Resources, Environment and Tourism (Ongeim'l Tketau, Jellyfish Lake, 18 May 2017). As recently as February 2018, a dive team sighted only one adult medusa in the lake. On December 13, 2018, the newsletter of the Palau Dive Adventures tour company announced the reopening of Jellyfish Lake to tourists as an estimated 1 million adult golden jellyfish medusa have repopulated the lake:

"Ongoing monitoring conducted by the Coral Reef Research Foundation (CRRF) indicated that the jellyfish populations were now rebounding after the declines that were a result of the drought conditions experienced throughout Palau in 2016."

"Similar conditions were experienced in 1998 which also decimated the populations of jellyfish but eventually recovered fully as conditions returned to normal. …."

"Based on the current conditions and the continued recovery of the site, it was determined that Ongeim'l Tketau or Jellyfish Lake had sufficient numbers of jellyfish to provide visitors with a quality experience".

"Similar to 1998, site managers are confident that the populations of jellyfish will make a full recovery and monitoring data from CRRF supports this expectation. While the jellyfish lake is open, management will continue to integrate appropriate safeguards to ensure the protection and sustainable use of this unique site."

LOCAL SUMMARY AND FORECAST

"As of November 2018, we [Palau Dive Adventures] *have resumed our tours to Jellyfish Lake."*

Figure PL-4. This photo (from http://www.founditgood.com/) shows the typical abundance of jellyfish in Palau's world-famous Jellyfish Lake before they all disappeared during the 2015/16 El Niño). The undisturbed population of jellyfish in the lake is near 10 million. This dropped to zero in 2016. Juvenile polyps lining portions of the lake bottom eventually detached to repopulate the lake to an estimated 1 million adults by the end of 2018.

Republic of Palau Rainfall summary: 4th QTR and 2018 Annual						
Station		**Oct**	**Nov**	**Dec**	**4th QTR**	**2018**
Koror WSO	**Rain (Inches)**	**14.12**	**15.92**	**12.37**	**42.41**	**129.88**
	% of avg.	**117%**	**134%**	**104%**	**118%**	**88%**
WSO Palau**	**Rain (Inches)**	**7.81**	**18.16**	**11.48**	**37.45**	**134.43**
	% of avg.	**59%**	**139%**	**87%**	**95%**	**83%**
Mele-keok*	**Rain (Inches)**	**7.16**	**14.45**	**11.42**	**33.03**	**111.43**
	% of avg.	**59%***	**121%***	**96%***	**92%***	**75%***
Peleliu	**Rain (Inches)**	**4.77**	**7.09**	**8.17**	**20.03**	**94.20**
	% of avg.	**51%**	**70%**	**66%**	**63%**	**74%**

* This is a new station; % of average uses one half of (AVG Koror + AVG Intl. Airport).
**The International Airport rainfall site was shifted to the new WSO Palau site nearby.

Climate Outlook:

After a long climb during 2018 from the cool side to the warm side of ENSO-Neutral, the state of the Pacific climate system finally entered El Niño as per the February 2019 CPC ENSO statement (see the Current Conditions Section). In several ways, the climatic elements (typhoon distribution, sea level and the pattern of rainfall) were (and still are) what one might expect at the maturity of a weak El Niño in late 2018/early 2019. Whether El Niño has recently begun, recently matured, or is undergoing an unusually prolonged period of El Niño-like conditions (e.g., 1986-87 and 2014-15), the forecast of rainfall for the Republic of Palau will be for below average over the next few months. Computer model forecasts are now indicating Micronesia-wide below average rainfall over the next 3 months. Therefore, PEAC

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will adhere to a forecast of below-average rainfall throughout Palau at least through FMA 2019. Looking ahead to the next rainy season, the uncertainty in the evolution of ENSO precludes a confident forecast of rainfall or typhoon distribution. Any strengthening of El Niño in the next few months would typically be associated with at least average rainfall and an increase in the chances for an early-season typhoon. If El Niño fades over the next few months, a dry forecast is prudent, along with an associated reduction and delay of typhoon activity through the first half of 2019.

Predicted rainfall for Palau from January through December 2019 is:

Palau Inclusive Period	% of long-term average / Forecast rainfall (inches) [1]
Jan - Mar 2019	**85%**
Apr - Jun 2019	**95%**
Jul - Sep 2019	**100%**
Oct - Dec 2019	**95%**

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

Republic of the Marshall Islands (RMI)

Wet! Wet! Wet! (Then starting to dry)

During the first half of 2018 rainfall was very heavy across many of the atolls of the RMI (see Figure RMI-1). Both Majuro and Kwajalein experienced new historical records for high rainfall for 6-month totals that didn't just edge-out previous highs, they crushed the old high marks by large margins! (see PEAC 3Q 2018 newsletter). In the latter half of 2018, conditions became drier, with the trend to drier conditions at Majuro (Figure RMI-1, top panel) exhibiting an unusually smooth (i.e., unusually low month-to-month variation) decline after March 2018. The high rainfall in the 1st half of 2018 was sufficient to push annual totals to near-record or record high values:

(1) Majuro 2018 rainfall = 171.64 inches; 3rd wettest; Record value 177.84 inches (1991);
(2) Kwajalein 2018 rainfall = 146.43 inches; Highest! Old record 139.37 inches (1964);
(3) Wotje* 2018 rainfall = 95.45 inches; 4th wettest; Record value 118.54 inches (1997);
(4) Utirik* 2018 rainfall = 101.56 inches; 2nd wettest; Record value 127.35 inches (1997).

* Some of the 2018 months were estimated.

Very heavy rainfall in the RMI early in the year is often associated with El Niño onset; however, a wet spring has also occurred during other phases of ENSO, thus limiting the usefulness of this phenomenon as a predictor of El Niño. In retrospect, the heavy spring rains in the RMI may indeed have been related to the onset and maturation of El Niño through 2018, with implications for Index-based definitions of El Niño versus pattern-based determinations of the status of ENSO (see the ENSO discussion in the Current Conditions Section).

The heavy rainfall during 2018 (and other heavy rainfall periods during 2015, ~~and~~ during late 2016, and late 2017) has been of such high magnitude so as to push long-term (e.g., 3- and 5-year sums) accumulated totals of rainfall to values not seen in many years. Indeed, until the recent heavy rainfall span, Majuro and Kwajalein had undergone a substantial long-term (multi-decadal) decline of rainfall (Figure RMI 2a,b,c). However, the abrupt upswing of precipitation in the last few years, while dramatic, is not yet enough to statistically erase the long-term dry-

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ing trend.

Lastly, the sea level at Kwajalein, and likely across most of the central and northern atolls, has fallen substantially during 2018 in concert with a similar decline of the Pacific trade winds (Figure RMI-3) (see the sea level discussion for more details).

Breaking news

Very dry conditions beginning in mid-January 2019 at some atolls of the northern RMI (e.g., , Kwajalein, Wotje and Utirik) has been of sufficient magnitude to warrant the inclusion of these atolls into a Drought Information Statement issued by the WFO Guam.

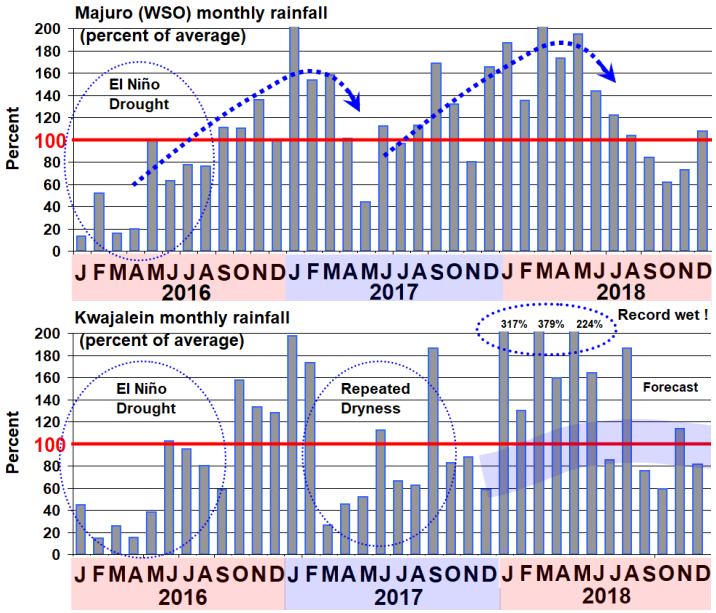
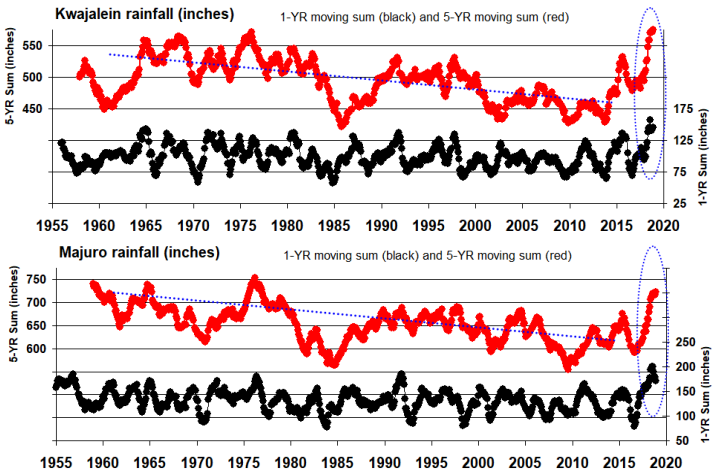


Figure RMI-1. (Top panel) A time series of rainfall at WSO Majuro (gray bars) during 2016 through 2018. Note two repeated dramatic rises (dotted blue arrow-tipped lines) from dry conditions early in the year to the return of abundant rainfall in the both fall of 2016 and the fall of 2017. Rainfall in the first half of 2018 was at record high levels. (Bottom panel) A time series of rainfall at Kwajalein (gray bars) during 2016 though 2018. Long-term fluctuations at Kwajalein are similar to those seen at Majuro in the top panel. Amounts of rainfall in January, March and May at Kwajalein exceed the upper bound of the scale. Blue-shaded bar is a long-term rainfall forecast for 2018 made by the PEAC in December 2017. The El Niño drought of 2016, dryness in early 2017 and extreme rainfall in the first half of 2018 are highlighted.



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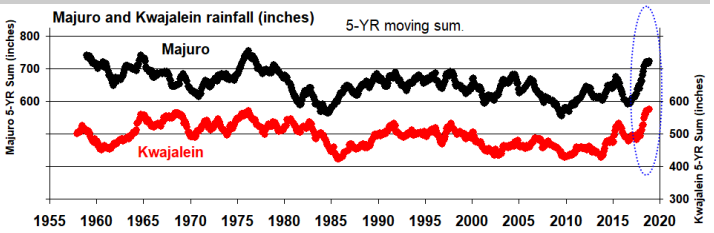

Figure RMI-2. 1- and 5-year moving sums of accumulated rainfall at (a) Kwajalein and (b) Majuro (looking backwards). Note two features of these time series: the long-term downward trend and the abrupt upswing at the end of each time series. Chart (c) is a juxtaposition of the 5-year rainfall sum at Kwajalein and Majuro illustrating a notable similarity of rainfall behavior. Note that by July 2018 the Kwajalein 5-year sum had risen to its highest value in its historical record. Note that prior to the current "spike" of heavy rainfall, Majuro and Kwajalein had undergone a continual decline in rainfall over the span of their post-WWII historical record (blue dotted lines).

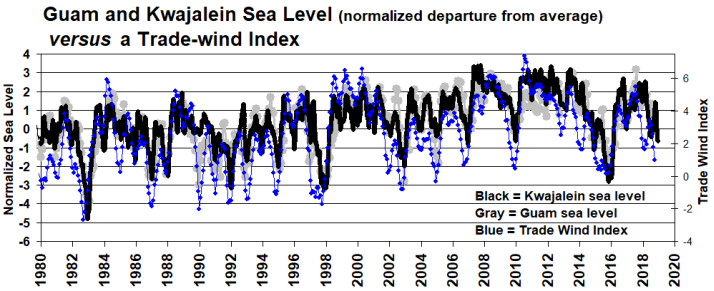

Figure RMI-3. A time series of the sea level at Guam and at Kwajalein for the period 1980 to present. Note the substantial fall of sea level during 2018. Note also the close relationship of the sea level with the Pacific trade winds at these to locations. Plotted values are anomalies normalized to the respective standard deviations.

RMI Rainfall Summary: 4th QTR and 2018 Annual						
Station		**Oct**	**Nov**	**Dec**	**4th QTR**	**2018**
RMI Central and Southern Atolls						
Majuro WSO	**Inches**	**8.53**	**9.29**	**12.71**	**30.53**	**171.64**
	% Avg	**62%**	**73%**	**107%**	**79%**	**131%**
Ailing	**Inches**	**14.25**	**7.65**	**7.28**	**29.18**	**102.57**
	% Avg	**111%**	**65%**	**73%**	**84%**	**88%**
Jaluit	**Inches**	**3.66**	**1.49**	**4.21**	**9.36**	**80.27***
	% Avg	**26%**	**12%**	**36%**	**24%**	**61%**
Mili	**Inches**	**12.06**	**8.17**	**12.00**	**32.23**	**150.15**
	% Avg	**87%**	**64%**	**101%**	**84%**	**114%**
RMI Northern Atolls						
Kwajalein	**Inches**	**7.05**	**12.12**	**6.58**	**25.75**	**146.43****
	% Avg	**85%**	**186%**	**73%**	**59%**	**143%**
Wotje***	**Inches**	**5.37**	**8.43**	**6.63**	**20.43**	**95.45**
	% Avg	**133%**	**150%**	**56%**	**65%**	**157%**
Utirik****	**Inches**	**14.10**	**5.12**	**2.83**	**22.05**	**101.56**
	% Avg	**183%**	**81%**	**69%**	**122%**	**180%**

* The dryness at Jaluit was in part due to poor exposure of the rain gauge. Moved in January.
** A new historical record for annual rainfall!
*** June and July rainfall estimated from nearby stations.
**** December rainfall estimated.

Breaking News: Typhoon Wutip

During mid-February 2019, a tropical cyclone (TC) formed

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south of the Marshall Islands at a very low latitude (~3°N). Over the course of several days, the system moved westward and steadily intensified to become a tropical storm (TS) in Pohnpei State and eastern Chuuk State, a typhoon in western Chuuk State and eastern Yap State, and a super typhoon when it was located to the west-southwest of Guam. Along the way from its birthplace to its demise over open water to the northwest of Guam, Wutip dropped heavy rainfall at many locations across eastern and central Micronesia, including many of the atolls of the RMI.

In its formative stages near the Marshall Islands, the cloud cluster that became Wutip was large, disorganized and slow moving. Over the course of a week, (12-18 February) heavy rainfall occurred first in the central and southern RMI (Figure RMI-4), before later pushing northward into the northern RMI, as the pre-Wutip disturbance expanded northward as it consolidated into a more cohesive cloud system. A daily extreme of 3.51 inches of rain was recorded at Kwajalein on the 18th of February, which represented 73% of February's 4.82 inch monthly total. Earlier, on the 13th of February, Majuro had a similar extreme of 24-hour rainfall (2.26 inches) that comprised the lion's share of its February rainfall. Despite the heavy rainfall in February, the 2-month (January plus February) rainfall total of 6.36 inches at Kwajalein remains about 1-inch below the average sum over those two months. It is likely that most of the northernmost atolls of the RMI did not receive enough rainfall in February to alleviate the recent dry conditions that have become established there. A more detailed description of Wutip will appear in the next newsletter).

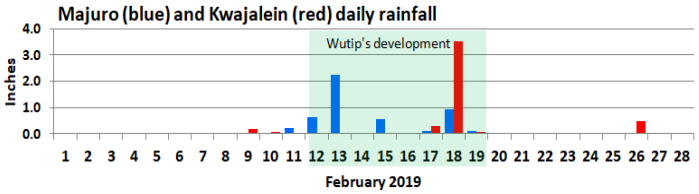

Figure RMI-4. Daily rainfall at Majuro (blue) and at Kwajalein (red) during February 2019. The 3.51 inches of rainfall on the 18th of February represented a whopping 73% of that atoll's February total of 4.82 inches. The green-shadedd region shows the period during which the slow-moving and slow-developing cloud system of the pre-Wutip disturbance affected the RMI.

Climate Outlook:

After a long climb during 2018 from the cool side to the warm side of ENSO-Neutral, the state of the Pacific climate system finally entered El Niño as per the February 2019 CPC ENSO statement (see the Current Conditions Section). In several ways, the Micronesia regional and local climatic elements (typhoon distribution, sea level and the pattern of rainfall) were, and still are, what one might expect at the maturity of a weak El Niño in late 2018/early 2019. Whether El Niño has recently begun, recently matured, or is undergoing an unusually prolonged period of El Niño-like conditions (e.g., 1986-87 and 2014-15), the forecast of rainfall for the RMI will be for average to below-average rainfall over the next few months, notwithstanding the heavy rainfall on many atolls during February 2019. Computer model forecasts are now indicating Micronesia-wide below average rainfall over the next few months; although they are not as aggressive with dryness in the RMI as elsewhere in the region. Also, historical rainfall during the course of weak El Niño events is not as strongly affected or coherent in the RMI as it is during a moderate or strong El Niño event. During the February PEAC conference call, it was decided to let-stand a consensus projection of near-average rainfall at Kwajalein, and average-to-below-average rainfall at Majuro for the 3-month time period FMA.

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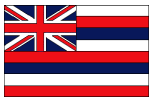
Dryness across the far northern atolls of the RMI (e.g., Wotje and Utirik) is likely to continue through the spring.

Predicted rainfall for the atolls of the RMI from January through December 2019 is:

Inclusive Period	% of long-term average		
	South of 6ºN	6ºN to 8ºN	North of 8ºN*
Jan - Mar 2019	90%	**85%**	**80%**
Apr - Jun 2019	95%	**90%**	**90%**
Jul - Sep 2019	100%	**100%**	**100%**
Oct - Dec 2019	100%	**95%**	**95%**

* This value is not applicable to Kwajalein, where rainfall is likely to be closer to average (i.e., 95%)



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. Following a period of El Nino-like conditions in January, the large scale atmospheric pattern in the northeast Pacific shifted to a high amplitude pattern in late January featuring persistent low pressure systems northeast to east of the state. This general pattern remained in place February 5 with abundant shower activity embedded within moderate to fresh trade winds. Enhanced shower activity along the windward slopes of Maui resulted in minor flooding but no reports of damage.

The atmospheric pattern over the north central and northeastern Pacific amplified further into the second week of the month. This resulted in a strong north Pacific blocking pattern which produced a split jet stream. The southern branch of the jet helped develop a strong Kona low to the north of the main Hawaiian Islands on February 9. This low moved southward and passed within 100 miles northeast of the island chain on February 10. While damaging winds and surf affected the state, bands of rainfall moved through too quickly to cause flooding problems. By February 12, the split jet pattern over the north Pacific shifted westward which put a strong upper level trough north of the state. Periods of heavy rainfall and isolated thunderstorms affected all four counties on February 13 and 14.

A strong low pressure system with an exceptionally close approach to the Hawaiian Islands chain caused record-breaking wave heights on February 10. The PacIOOS wave buoy off Hanalei, Kaua'i, measured 38 ft in significant wave height and the largest wave recorded (Hmax) measured stunning 63 ft! The Waimea wave buoy also broke its 15-year record and climbed to a significant wave height of 29 ft, and the largest wave measured 48 ft. Both buoys are located approximately 4 miles offshore and moored in a depth of 200-240 m.

The combination of strong winds and high waves produced extremely rough ocean conditions at sea and along the shoreline. PacIOOS' suite of coastal forecasts, including the Wave Run-up Forecast for the North Shore of O'ahu and the Hale'iwa Harbor Surge Forecast, provided valuable information for agencies, the boating community, and home owners to better understand what to expect and to prepare for the storm system (also see http://www.pacioos.hawaii.edu/waves/buoy-hanalei/ for more details).Island to Oahu. Only a small pocket of moderate drought remained along the lower leeward slopes of Kauai from Waimea to Barking Sands.

LOCAL SUMMARY AND FORECAST

Climate Outlook: From CPC Long-Lead Hawaii Outlooks. With the predicted continuation of an El Niño, the precipitation forecast for Hawaii follows historical El Nino impacts that indicate strong correlations between El Niño and increased probabilities of below normal precipitation in winter and spring. the precipitation outlook is consistent with North American Multi-Model Ensemble (NMME) dynamical model forecasts and statistical tools, including Constructed Analog (CA), Canonical Correlation Analysis (CCA), and an ENSO-Optimal Climate Normals (OCN) tool (that combines the impacts of El Niño and decadal climate variability), for below normal precipitation for Hilo and Kahului from MAM to MJJ 2019, and for Honolulu and Lihue from MAM to JJA 2019. There is considerable uncertainty across the Hawaiian islands in the precipitation forecast among available forecast tools in JAS 2019 and longer leads, so equal chances (EC) for above, near, or below normal precipitation are indicated (see below)

Climate Outlook (Hawaii):

	Station			
Inclusive Period	**Hilo**	**Honolulu**	**Kahului**	**Lihue**
Apr – Jun 2019	50% chance of Below Median rainfall	50% chance of Below Median rainfall	50% chance of Below Median rainfall	50% chance of Below Median rainfall
Jul – Sep 2019	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
Oct – Dec 2019	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

Seasonal Drought Outlook for Hawaii: Severe drought is no longer present in Hawaii (http://w1.weather.gov/data/HFO/DGTHFO) : Wetter than average conditions over the past month have removed nearly all drought areas across the state. February started with severe drought, or the D2 category on the U.S. Drought Monitor map, in the leeward portions of the Big Island and Maui. Moderate drought, or the D1 category, had spread across most of the Big Island and also covered the lower leeward slopes of the rest of the state. By the first week of March, drought had been eliminated from the Big Island to Oahu. Only a small pocket of moderate drought remained along the lower leeward slopes of Kauai from Waimea to Barking Sands.

Seasonal Sea Level Outlook (Cont.)

From the Global Satellite Picture: *Observations from the recent global satellite picture (Fig. 8, below) revealed that the sea levels have been near or below normal over the western part of the Pacific Basin. This satellite data are supportive to tide-gauge observations.*

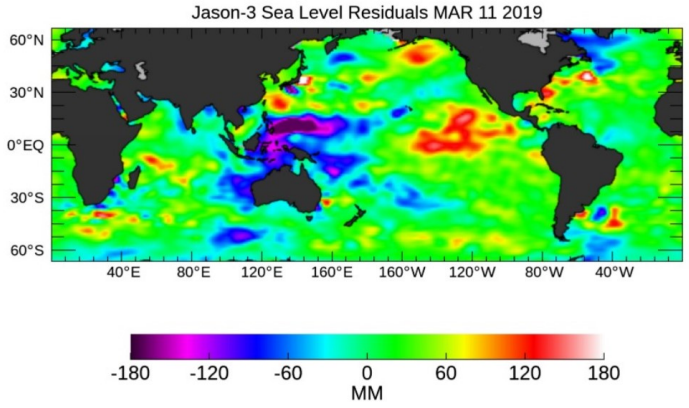


Figure SL-3. Jason-3 sea level residuals (March 11, 2019).

PACIFIC ENSO UPDATE

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

1st Quarter, 2019

SEASONAL RAINFALL OUTLOOK FOR THE US-AFFILIATED PACFIC ISLANDS

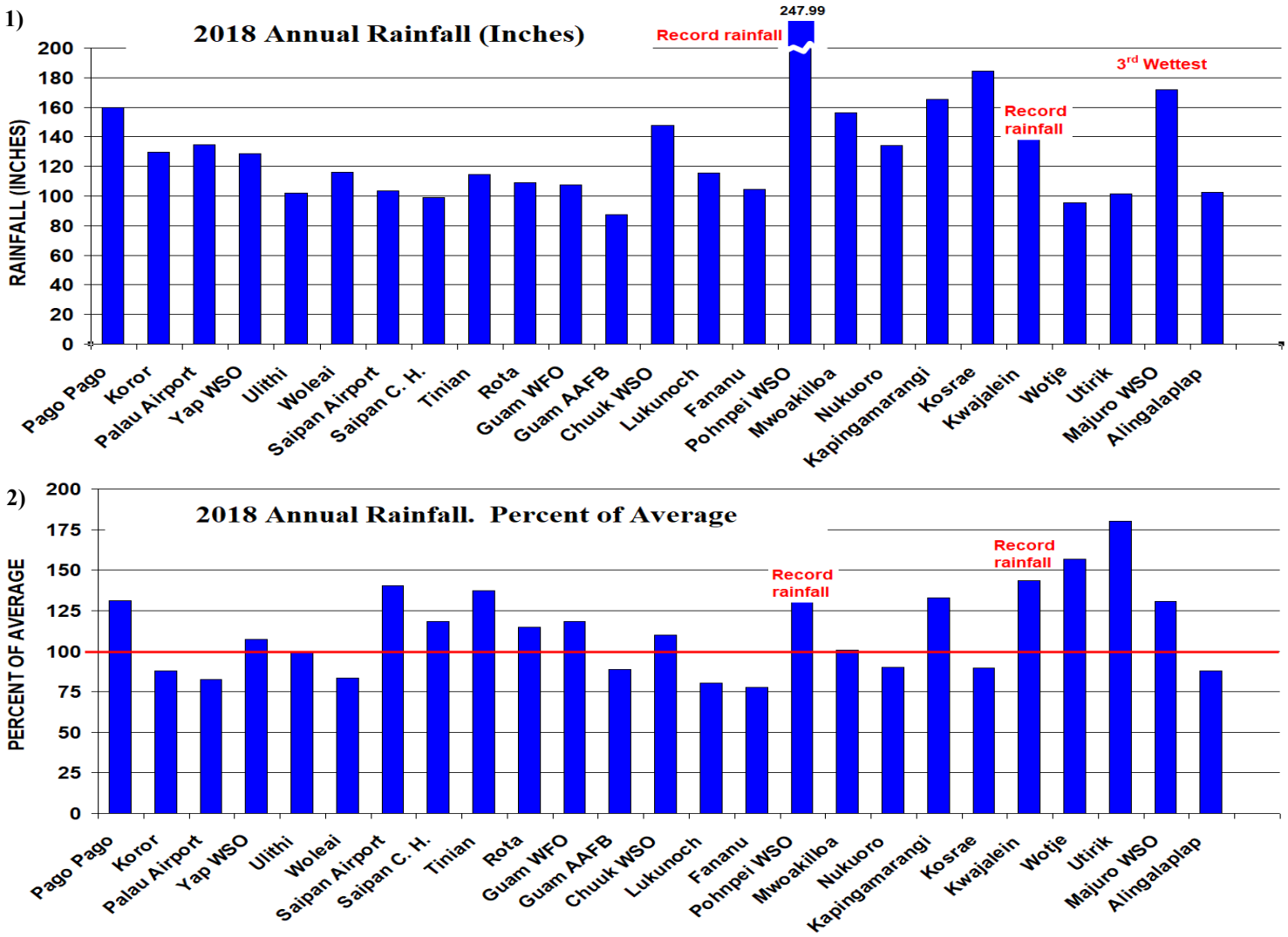


Figure 1 and 2, 2018 Annual rainfall as a percent-of-average at the indicated locations. Rainfall associated with tropical cyclones contributed a large share of the higher-than-average rainfall at Guam, the islands of the CNMI, and at Pohnpei. Drier-than-average annual rainfall was noted in Palau and some of the northern atolls and southern atolls of Chuuk State. Recent dryness developed in eastern Micronesia to lower the annual totals at some of the atolls of Pohnpei State and at Kosrae.

ACKNOWLEDGEMENTS AND FURTHER INFORMATION

Pacific ENSO Applications Climate (PEAC) Center:
HIG #340, 2525 Correa Road, Honolulu, Hawai'i 96822
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NOAA National Weather Service
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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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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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