Office of the Washington State Climatologist

August 3, 2016

July Event Summary

Mean July temperatures were mostly cooler than normal in WA State, especially east of the Cascade Mountains. In the remaining areas, July temperatures can be classified as near-normal, though as usual there are exceptions. Figure 1 shows the average temperature departure from normal for both June and July, and, refreshingly, the first two months of meteorological summer have had near-normal temperatures for most of the state. While maybe not the most exciting map, it does show a change from the above normal temperatures that have been common through most of 2015 and in recent months. As for July precipitation, it was variable throughout the state with the southeast WA and the Cascades receiving above normal precipitation from showers and thunderstorm activity. The rest of the state received near-normal to below normal precipitation; please see the "Climate Summary" section below for more information.

The beginning of July had some breezy conditions east of the Cascade Mountains, which caused concern for possible wildfires. Though one did start near Vantage, the first half of July had generally near-normal to below normal temperatures, which helped ease wildfire risk. In addition, the second weekend of the month had widespread showers beginning on the 7th, with Walla Walla setting a record high daily precipitation total on the 8th with 0.53". On the 9th, Kennewick measured 0.24" of rain, also setting a calendar day record. Near-normal temperatures persisted for the next week or so, with little rain. On the 22nd, however, widespread showers and thunderstorms returned to WA, with SeaTac Airport tying a daily record rainfall with 0.33". A warm interval began on the last full

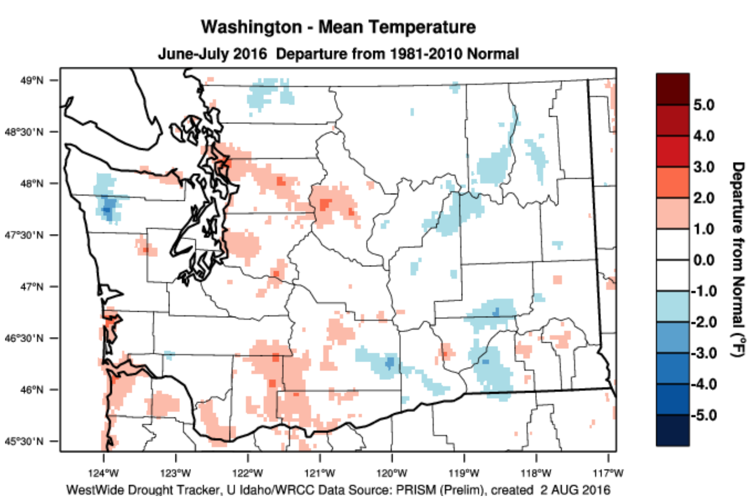


Figure 1: Average temperature departure from the 30-year normal (1981-2010) for June and July 2016 for WA (from WWDT).

week of the month, with temperatures well into the 80s (and low 90s) in western WA and in the 90s and 100s in eastern WA. Yakima tied a daily high temperature record on the 25th with 102°F. The turn to warmer than normal temperatures quickly dried out wildfire fuels and several fires were started in eastern WA from July 28 through the 31st. At the time of this writing, 8 large fires were burning east of the Cascades.

Drought Monitor and Streamflow Update

There have not been any changes to the WA state depiction on the US Drought Monitor since our last monthly newsletter release. The US Drought Monitor map (Figure 2) released on July 26 shows "abnormally dry" conditions throughout the entire state and an area of "moderate drought" in southeastern WA. Even though some portions of the state received above normal July precipitation, longer term precipitation totals are still below normal for a majority of the state. Streams are also running below normal, particularly in western WA. Figure 3 shows the 28-day average streamflow ending on July 31 from USGS. There has been little change to the April through September streamflows forecast by the National Weather Service River Forecast Center. The natural flow forecast shown in Figure 4 projects below normal streamflows in western WA, southeastern WA, and the Spokane area. For example, the April-September flow at the Chehalis River near Doty is expected to be 46% of normal over the period. In eastern WA, Hangman Creek at Spokane is expected to have about 40% of normal April through September streamflow.

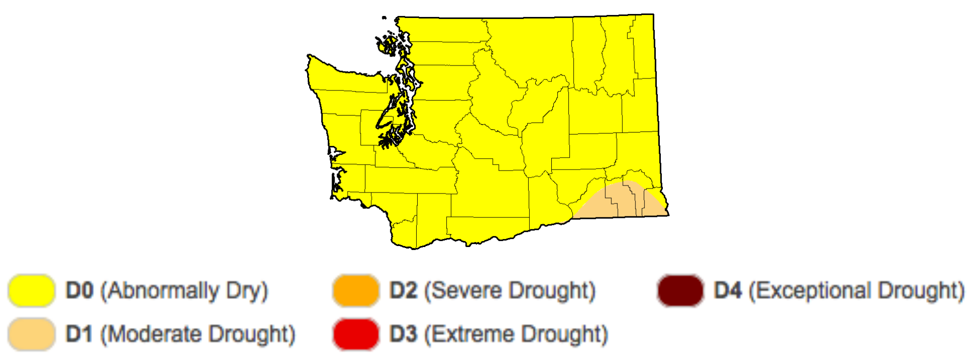


Figure 2: The July 26, 2016 edition of the US [Drought Monitor](#).

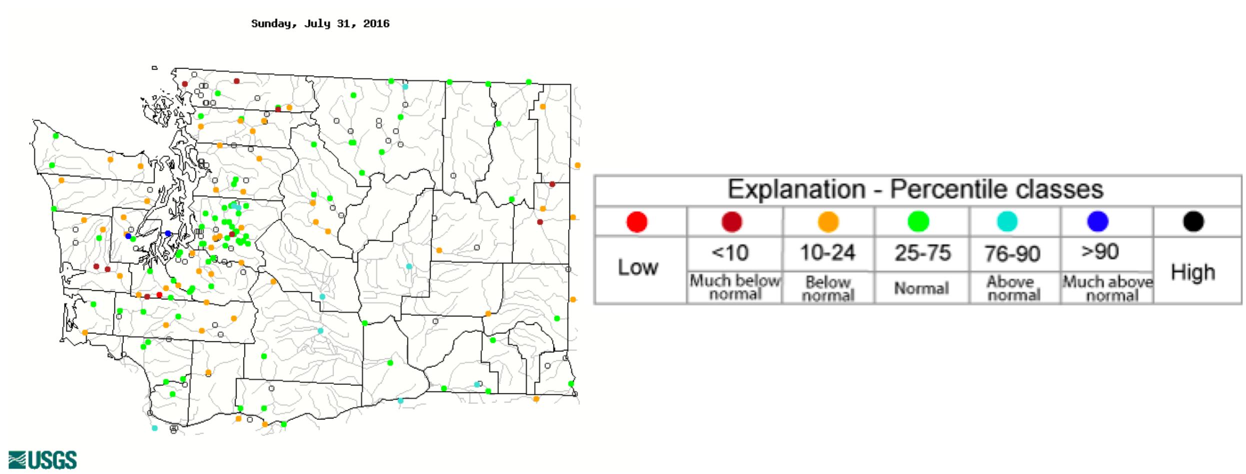


Figure 3: 28-day average streamflow ending on July 31 for WA State (from [USGS](#)).

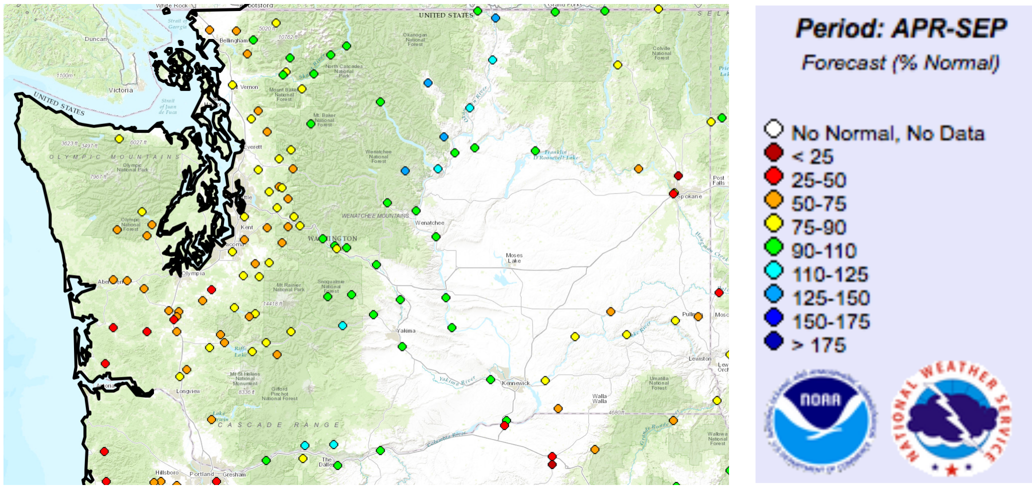


Figure 4: The natural water supply forecast for April through September from NOAA's National Weather Service River Forecast Center (issued August 3, 2016).

Community, Collaborative Rain, Hail, and Snow (CoCoRaHS) Network

Thank you to all of our CoCoRaHS volunteers for taking the time to read your rain gauges and submit your observations. Have you ever wanted to be part of an interactive discussion about the weather? Since December 2011, the CoCoRaHS webinar series, WxTalk, has featured monthly presentations by atmospheric scientists and other experts in related fields. These 60-minute webinars are not only free, but allow you to submit questions that the speaker will answer live. For more information on upcoming webinars or to access past recordings, go to: http://www.cocorahs.org/Content.aspx?page=wxtalk. As always, we are looking for more volunteer precipitation observers, so please help spread the word about CoCoRaHS. New volunteers can sign up at www.cocorahs.org.

Summer Weather in WA: Is it cooler because it is cloudier or cloudier because it is cooler?

A message from the State Climatologist

With exceptions such as a warm spell near the end of July, WA state has experienced relatively cool and cloudy weather since the first week of June 2016, at least as compared with the same period during the last 3 summers. With the long days and high sun angle during our summers, it stands to reason that cloudier intervals will tend to include lower maximum temperatures. But how much blame, or gratitude, should be given to the clouds? Recognizing our treatment is more suggestive than definitive, and that cause and effect cannot always be separated, here we will consider a related set of questions.

1. How well do cloud anomalies on the west side of the Cascade crest correspond with those on the east side?
2. What determines statewide mean maximum temperature in WA during summer months?
3. What determines statewide average cloudiness during the summer?
4. How consistent are the relationships involving maximum temperature and cloud cover for the three different months of June, July and August?
5. How well can maximum temperature be predicted from large-scale atmospheric parameters?

Three data sets are used here in addressing the questions above. For statewide maximum surface temperatures, we use values based on weather station data as compiled and averaged by NOAA's NCEI and available at the "Climate at a Glance" website. With regards to cloudiness, we take advantage of the cloud fraction data from PATMOS-x on a 0.5 x 0.5 degree grid. This product is based on brightness temperatures from the Advanced Very High Resolution Radiometer (AVHRR) sensor that has been flown on polar-orbiting satellites. The PATMOS-x product features complete areal coverage as opposed to station data, which can be prone to highly localized effects. While the PATMOS-x data cannot be used to specify cloud types, it does represent a reasonable means for assessing monthly values in mean cloud cover. Finally, towards specification of regional atmospheric circulation parameters related to maximum temperatures (Tmax) and cloud fraction anomalies, we use our good friend the NCEP Reanalysis. The PATMOS-x data set is available for the period of 1983 through 2009; we focus on the months of June, July and August for those years.

We begin with question (1) because the answer pertains to how the remaining questions should be considered. Towards that end, for the latitude band of 46 to 49°N, we correlated the interannual variations in mean cloud anomalies in the longitude band of 124 to 121°W (western WA) with that of 121 to 117°W (eastern WA) for the years of 1983 through 2009. The linear correlation coefficients for the months of June, July, and August are 0.90, 0.92, and 0.81, respectively. As another means of illustration, time series of July cloud fraction anomalies in percent for the western and eastern portions of WA are also shown in Figure 5. Western WA is cloudier than eastern WA during the summer on average, of course, but these results indicate a surprisingly tight correspondence in terms of monthly mean anomalies. Therefore, for the remainder of this treatment we will deal with statewide averages.

For the rest of the questions we have examined the relationships between Tmax, statewide cloud fraction anomalies, and regional atmospheric variables using a generalized additive model (GAM). The GAM framework offers a simple way to quantify the co-variability between the quantities of interest. It is akin to multiple linear regression, but can account for the potential of non-linear relationships between predictors and the target variable or predictand. These functional relationships are not prescribed but instead deduced by the GAM from the data. The functions themselves range in complexity from linear to smooth cubic splines; the GAM is designed to seek as simple a set of relationships as possible that adequately fit the data. The R statistical software package (www.r-project.org) was used in the construction of the GAMs.

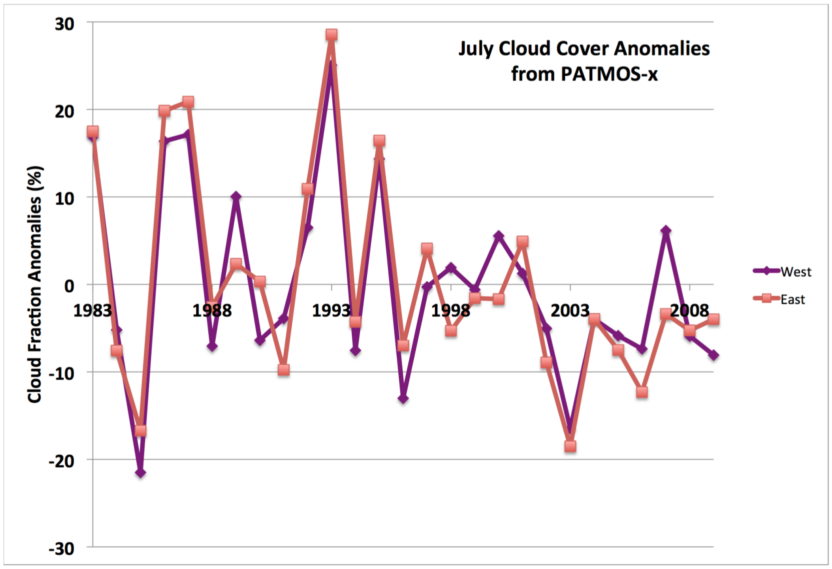


Figure 5: Time series of monthly mean cloud anomalies for western (purple) and eastern (red) WA from 1983 through 2009.

Individual GAMs were constructed for statewide Tmax and cloud fraction anomalies for June, July and August. A variety of regional variables were used as predictors. From the NCEP Reanalysis we considered statewide monthly mean values of the following atmospheric variables: 500 hPa geopotential height (500Z), 1000-500 hPa thickness, 925 hPa zonal wind, 925 hPa meridional wind, 925 hPa specific humidity, total precipitable water, 700 hPa omega (vertical velocity), and surface to 850 hPa temperature lapse rate. We also considered SST for the region off the coast of the Pacific Northwest (45-50°N, 132.5-125°W). All of the GAMs were constructed using data for 1983-2009 and in the interest of simplicity, and to avoid overfitting, were restricted to either two or three predictors. Obviously, there are a large number of different combinations that could be tested, and our approach has been only exploratory. Nevertheless, some recurring results were found.

First and foremost, it is apparent that either the 500Z or 1000-500 hPa thickness was the best predictor of both Tmax and cloud fraction in each of the summer months. In quantitative terms, GAMs using 500Z or thickness and an additional variable or two explained about 90% of the interannual variance in monthly mean Tmax, and on the order of 60 to 70% of the variance in mean cloud fraction. Most of the signal (~80-90%) in these models with multiple predictors could be attributed to either the 500Z or thickness. Models with 500Z or thickness as predictors (they are essentially interchangeable) but without cloud fraction were more skillful than those with the cloud fraction but lacking 500Z or thickness when predicting Tmax. With regards to the other variables tested, the 925 hPa flow was typically one of the better secondary variables, with the zonal component a superior predictor of Tmax and the meridional component a superior predictor of cloud fraction. Regarding cloud fraction, in some cases the 925 hPa specific humidity was a better predictor than the total precipitable water, and in other cases it was the reverse. In general, the 700 hPa vertical velocity and surface to 850 lapse rate were relatively poor predictors of either Tmax or cloud fraction. We were especially struck how a rather simple GAM using 500 hPa Z and SST reproduced about 90% of the observed variance in Tmax in each of the summer months.

Okay so it is all well and good that GAMs can recreate time series of Tmax and cloud fraction over the period of construction but are the deduced relationships actually robust? In the present application, the functional relationships from GAMs based on the data from 1983 through 2009, and subsequent data from 2010 through 2015, have been used to determine the skill of such a model in predictive mode. Here we show the results of such a test using 500Z and SST as predictors, with the observed versus modeled Tmax in June, July and August for the years of 2010 through 2015 plotted in Figure 6. The mean absolute error was 0.7°F, which is about one-quarter of the standard deviation in the observed monthly mean Tmax. In other words, simple models based on regional parameters can be quite respectable in terms of their skill in reproducing summertime monthly mean maximum temperatures in WA.

The results described here can be interpreted in a variety of ways. Getting back to the ruminations that inspired the analysis in the first place, it appears that the large-scale tropospheric circulation largely controls both surface maximum temperatures and cloudiness, and so neither causal effect in the title of this piece seems strictly proper. Our results do have some implications for extended (seasonal and longer term) weather prediction in WA, and that is the importance of accurate specification of the large-scale flow.

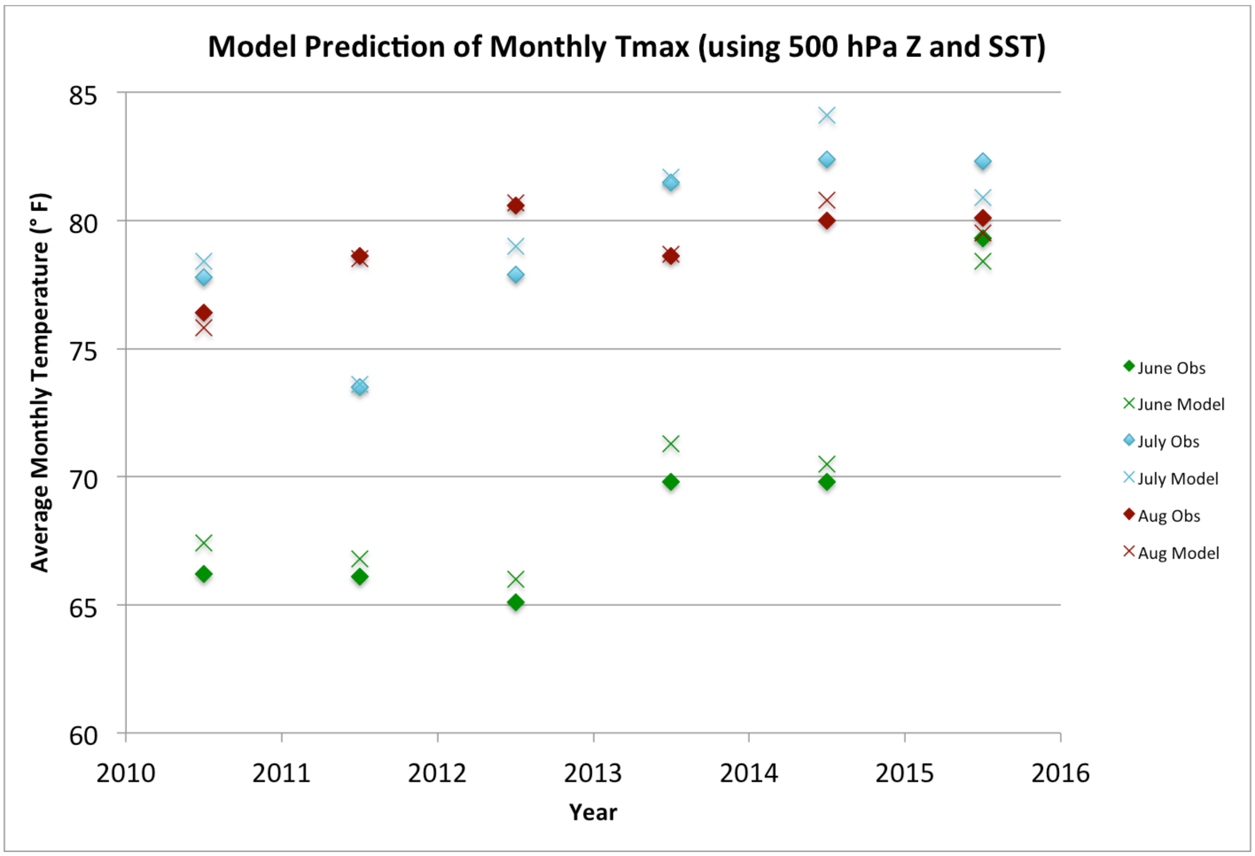
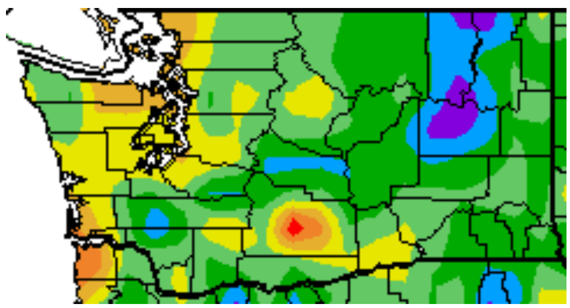


Figure 6: Example of predicted vs. observed Tmax for June (green), July (blue), and August (red) for 2010-2015. This is using a model with only 500 hPa geopotential heights and sea surface temperatures (SSTs) as predictors of Tmax.

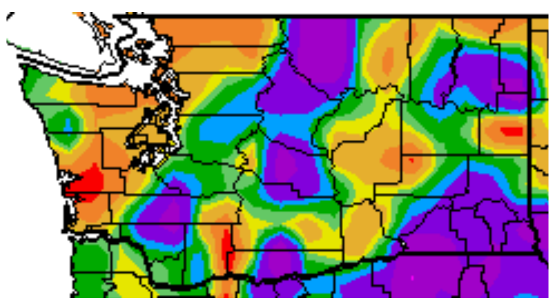
Climate Summary

Mean July temperatures were near-normal to below normal throughout the entire state, with some distinction between western and eastern WA. When it came to western Washington, most areas experienced near-normal to warmer than normal temperatures while eastern Washington had cooler than normal temperatures. Generally, most of the state was within 1°F of normal, but northeastern WA had some larger cold temperature anomalies. Wenatchee, for example, was 1.7°F below normal for the month. Bellingham had a large positive temperature anomaly relative to normal, with July averaging 2.0°F above normal (Table 1). Pasco and Olympia were near-normal with anomalies at 0.1 and 0.3°F above normal, respectively.

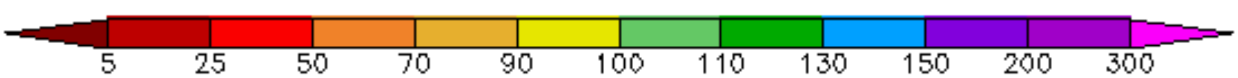
Total July Precipitation was above normal for much of the state, though there was a large area in western WA with below normal July totals. The locations of Hoqiuam and Spokane were particularly dry, having received only 32 and 42% of normal precipitation. Much of the state fared better with precipitation totals at 80% or above of their respective normals. Pasco and Hanford were wetter than normal, with precipitation at 118 and 150% of normal, respectively.



Temperature (°F)



Precipitation (%)



July temperature (°F) departure from normal (top) and precipitation % of normal (bottom). ([High Plains Regional Climate Center](); relative to the 1981-2010 normal).

	Mean Temperature (°F)			Precipitation (inches)		
	Average	Normal	Departure from Normal	Total	Normal	Percent of Normal
Western Washington						
Olympia	64.1	63.8	0.3	0.62	0.63	98
Seattle WFO	67.0	65.9	1.1	0.53	0.79	67
SeaTac AP	66.8	65.7	1.1	0.72	0.70	103
Quillayute	59.7	58.9	0.8	2.17	1.98	110
Hoquiam	60.9	59.9	1.0	0.37	1.14	32
Bellingham AP	64.3	62.3	2.0	0.65	1.18	55
Vancouver AP	67.8	68.4	-0.6	0.43	0.69	62
Eastern Washington						
Spokane AP	69.0	69.8	-0.8	0.27	0.64	42
Wenatchee	72.5	74.2	-1.7	0.26	0.27	96
Omak	71.4	72.7	-1.3	0.75	0.81	93
Pullman AP	64.6	65.6	-1.0	0.75	0.69	109
Ephrata	72.9	74.2	-1.3	0.32	0.40	80
Pasco AP	73.6	73.5	0.1	0.33	0.28	118
Hanford	76.7	77.1	-0.4	0.27	0.18	150

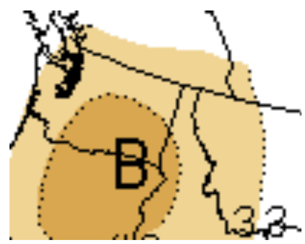
Table 1: July 2016 climate summaries for locations around Washington with a climate normal baseline of 1981-2010. Note that the Vancouver Pearson Airport and Seattle WFO 1981-2010 normals involved using surrounding stations in NCDC's new normal release, as records for these station began in 1998 and 1986, respectively.

Climate Outlook

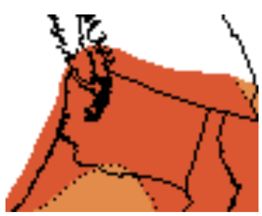
According to the Climate Prediction Center (CPC), ENSO-neutral conditions still continue to persist in the tropical Pacific Ocean. Sea surface temperatures (SST) across the east-central and east Pacific ocean have decreased to be at or below average. The “El Niño Advisory” officially ended and in May 2016 the CPC has issued a “La Niña Watch”. Current models indicate a 55-60% chance of a weak La Niña developing during the fall and winter of 2016-17.

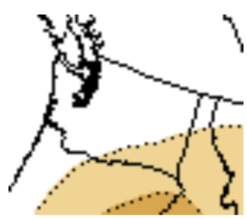
The CPC seasonal outlook for August is calling for slightly higher chances of warmer than normal temperatures for most of the state, while northeast Washington has equal chances for above, normal and below temperatures. The August outlook for precipitation is calling for below average precipitation with much of central and eastern Washington having the highest odds of less precipitation than normal.

The August-September-October (ASO) outlook is calling for higher than normal temperatures statewide, with the odds over 50% on the three-tier system. With regards to precipitation, most of the state has equal chances of above, normal, or below average precipitation, though southeast Washington has slightly greater odds of receiving below average precipitation.



August outlook for temperature (left) and precipitation (right) from the CPC.





August-September-October outlook for temperature (left) and precipitation (right) from the CPC.