Office of the Washington State Climatologist

December 4, 2015

November Event Summary

Mean November temperatures were below or near-normal for WA state, which is a marked change from October's extremely warm anomalies. November precipitation was similar to October, however, with western WA receiving above normal precipitation and eastern WA below normal. Two wet periods west of the Cascade Mountains during the month were largely responsible for the wetter than normal conditions: the beginning of November and then an interval during mid-month. Figure 1 shows the response in streamflow to these wet periods and overall improvement in the percentage of streamflows that were at or above normal by the end of the month.

In this Issue

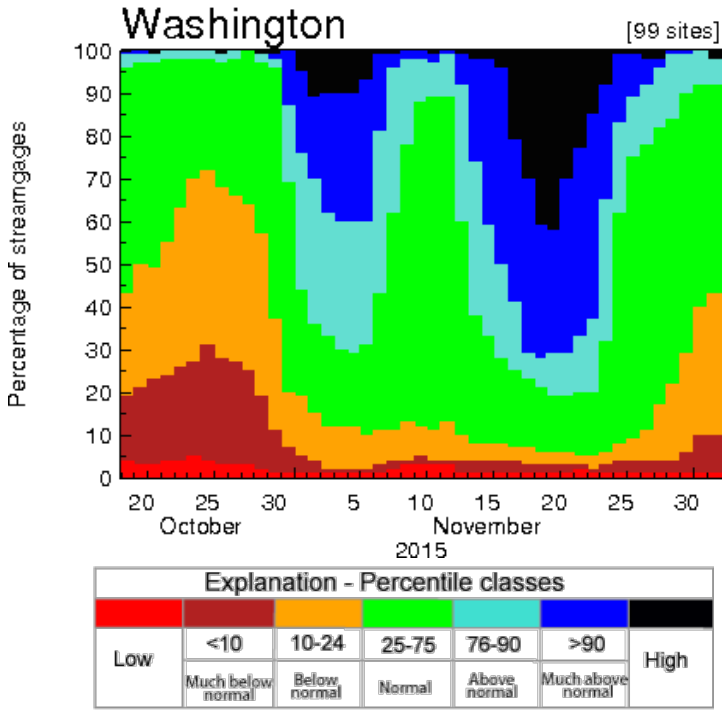


Figure 1: Time series of 7-day average streamflow percentiles for the past 45 days in Washington.

November 1 saw a continuation of a heavy rainfall event that was discussed in last month's newsletter; 24-hour precipitation totals up to 2" were again measured in parts of western WA on the morning of the 2nd with lighter precipitation amounts in eastern WA. The weekend of the 7th/8th was also wet statewide, and it is worth noting that in general, conditions were too warm in the first half of the month for substantial snow in the mountains. More localized precipitation fell in eastern WA, with Pullman recording a record daily maximum (0.59") on the 9th.

But this was all "greasing the skids" for what was yet to come. Precipitation began as snow in the mountains on the 12th before changing over to rain as a warm, atmospheric river event set up. 24-hour precipitation totals ending in the morning of the 13th

were as high as 6.44" in the lower Chehalis Valley, well over 2" on the coast, and between 1 and 3.50" in the Hood Canal area. A CoCoRaHS observer measured a 24-hour total of 8.47" at 7 am on the 13th. Quillayute measured a maximum daily precipitation record of 4.09" on the 13th (calendar day). Moderate flooding occurred throughout western WA due to this event, and continued precipitation through the 17th caused some of the flood warnings to not expire until the 18th or 19th. This period was warm as well, with some record daily high temperatures recorded east of the Cascades on the 13th at Ephrata (64°F), Omak (62°F), Wenatchee (67°F), and Colville (59°F). Landslides occurred over the weekend as heavy rain continued, with two slides impacting rail lines between Tacoma and Nisqually on the 14th. A cold frontal passage on the 15th lowered snow levels in the mountains and there were even some traces of snow at higher locations in the western WA lowlands that morning as well.

More daily precipitation records were set on the 17th at Olympia (2.08"), SeaTac Airport (1.16"), and Wenatchee (0.35"), but wind was the main concern statewide. Gusts in the 40s and 50s mph were common throughout the state with pockets of even stronger winds. For example, Spokane AP (71 mph), Crystal Mountain (107 mph), and Mission Ridge ski area (137 mph) all had extremely strong gusts. Winds caused power outages and there were unfortunately several deaths due to falling trees around the state.

The weather became much less active in the days that followed, with the onset of a colder than normal period on around the 23rd that persisted through the end of the month. Widespread snow was measured on the morning of the 24th in eastern WA. Figure 2 shows the "new snow" totals from CoCoRaHS observers on that morning. Record low minimum temperatures were recorded west of the Cascades as well, with Quillayute (23°F) and Hoquiam (29°F) setting records on the 26th. Another record low minimum temperature was recorded at Vancouver (19°F) on the 30th.

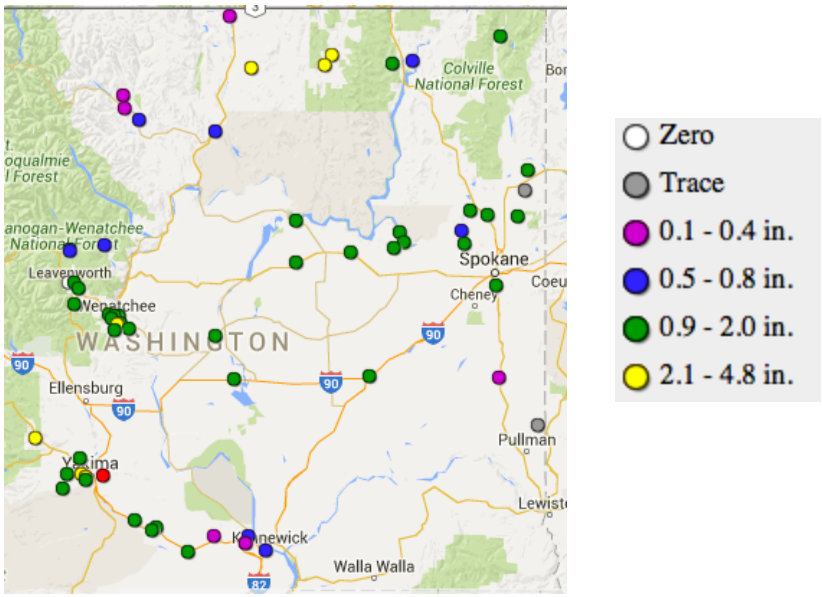


Figure 2: 24-hour snowfall totals from CoCoRaHS observers ending on the morning of November 24, 2015.

Snowpack and Drought Update

Mountain precipitation during the month of November oscillated between rain and snow due to the varying temperatures, leaving snowpack below normal for a majority of the state as of December 1. Figure 3 shows the snow water equivalent (SWE) percent of normal averaged for each basin in WA from the National Resources Conservation Service. The Olympic basin is the state's bright spot, with 118% of normal SWE. The North Puget Sound also has near-normal snow for now, but the rest of the state is sub-par. The Central Puget Sound and Upper Yakima have the smallest basin average SWE, with 23 and 24% of normal, respectively. Other basins are not quite as bad, but are around 50% of normal. The good news is that Cascade snow typically falls in December or January so there is still plenty of time for snowpack to build. Moreover, at least limited skiing was available over the Thanksgiving holiday. In the meantime, the heavy November precipitation west of the Cascades greatly improved the US Drought Monitor (Figure 4); there is currently no drought designation there. Short and long-term precipitation deficits east of the Cascades have limited improvements there.

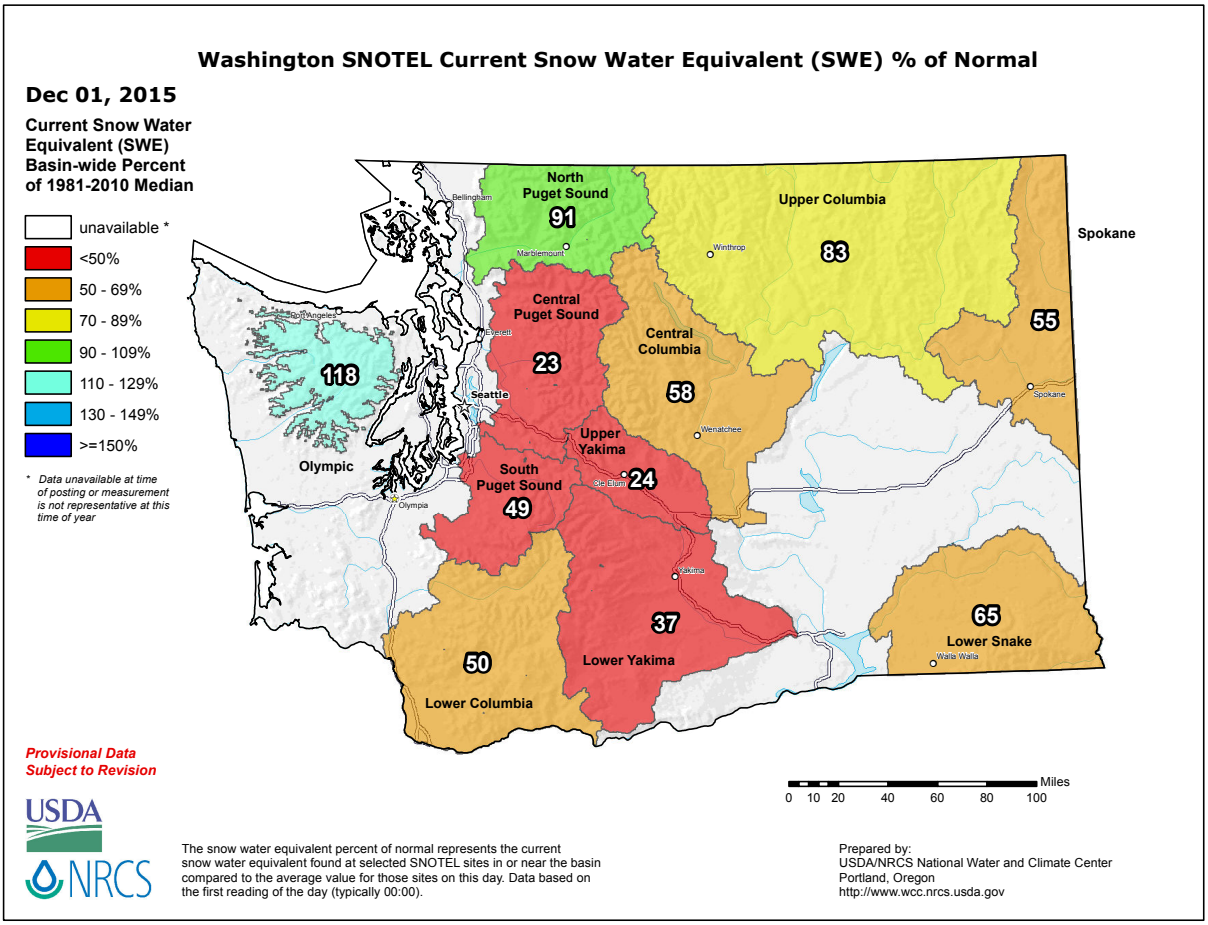


Figure 3: Snowpack (in terms of snow water equivalent) percent of normal for Washington as of December 1, 2015 (from the National Resources Conservation Service).

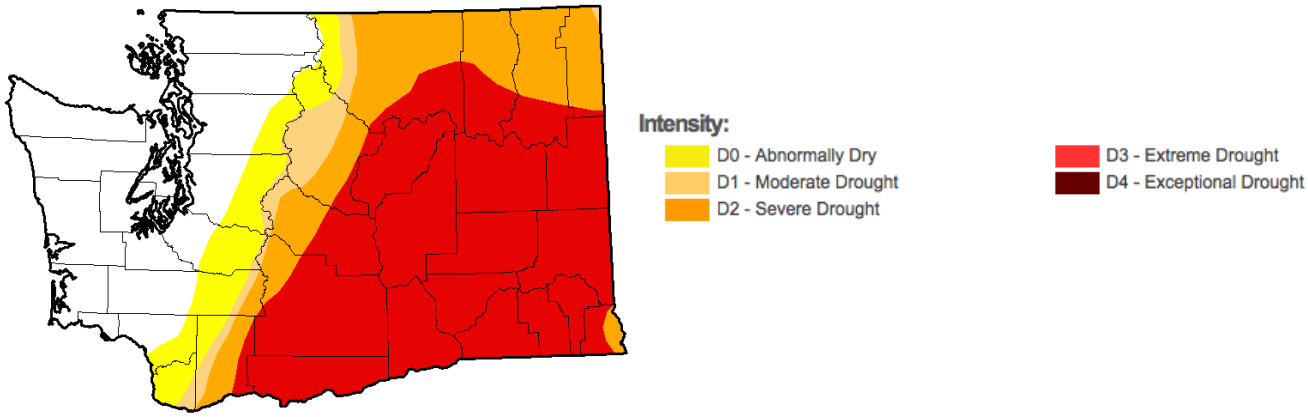


Figure 4: The December 1, 2015 edition of the US Drought Monitor (http://droughtmonitor.unl.edu/).

A New Synthesis Report on Climate Change in the Puget Sound

A message from the State Climatologist

A new state of the knowledge report from the University of Washington's Climate Impacts Group on climate change in the Puget Sound region was released in November (Mauger et al. 2015). A wide range of topics is covered in the report with separate chapters describing how climate change is expected to impact each topic area (e.g., agriculture, human health, sea level, water quality, and ecosystems, among others). The report is specific to the Puget Sound region, which is defined as the Puget Sound and Straight of Juan de Fuca water bodies and all adjacent land that drains into them.

Meant to be accessible by a wide audience, the jointly funded (Puget Sound Institute, NOAA, and State of Washington) report is an update to a previous report released 10 years ago. Additional topics that were not part of the previous report include expanded sections on ocean acidification and landslides, and much more detail on salmon. We will highlight just a few particulars here motivated by the 2015 drought, which has shown that our region, while notoriously wet, can sometimes have a scarcity of water. How is climate change liable to influence the nature of our precipitation events and water supplies, and what might be the impacts?

Of course a lack of water is not the only kind of problem; sometimes there is too much of a good thing. One of the specific subjects in the report (in Section 2 on the climate) relates to extreme rainfall events. There is tentative evidence from observations that there are modest increases in heavy rainfall events (48-hour and shorter in duration) in western WA, as found by Mass et al. (2011) for coastal WA locations. An in-house study carried out by the OWSC revealed that these types of events were tending to become more common in winter in western WA, but not in summer (May 2014 newsletter). To be sure, there is considerable temporal and spatial variability in these trends, and the inherently "noisy" nature of time series of extreme

events complicates attribution to climate change. Nevertheless, present climate models are suggesting that heavy precipitation events will increase in magnitude (by very roughly 20% on average) and frequency (by as much as four-fold) by the 2080s relative to the latter part of the 20th century.

More extreme bursts of rainfall probably mean a greater threat of landslides. This issue is discussed in Section 5 of the report. While the connection between heavy rain and higher soil moisture contents, and ultimately the failure of steep slopes, may seem obvious for low-elevation locations such as bluffs along the shores of Puget Sound, the report also discusses how there is also an increasing threat at higher elevations. A direct effect here will be the warming associated with climate change and hence a greater proportion of rain relative to snow, compared with the present climate. In addition, snowpack serves to slow the infiltration of water into the soil and prevent the erosion caused by pounding rains and hence limit (but not prevent) landslides at higher elevations during the cold season. The effects of heavier rains, and more rain in the mountains, on landslides in the Puget Sound region with the changing climate can either be mitigated or exacerbated by concomitant changes in land use and land cover.

Warming temperatures will almost certainly lead to changes in the timing of streamflow in many area rivers. Western WA has three basic types of rivers: rain-dominant, "mixed rain and snow", and snow-dominant (Figure 5). Low-elevation watersheds will continue to receive the vast majority of their precipitation as rain, with both average and peak flows remaining generally highest in winter during the wet season. Mixed rain and snow watersheds, which now experience high flows in winter (especially during periods of warm, wet weather) and spring (due to snowmelt) will undergo a transition to seasonal cycles of present rain-dominant streams (Figure 6). And the hydrographs of present snow-dominant rivers, such as the Sauk and upper Skagit, are apt to resemble those of today's mixed rain and snow rivers.

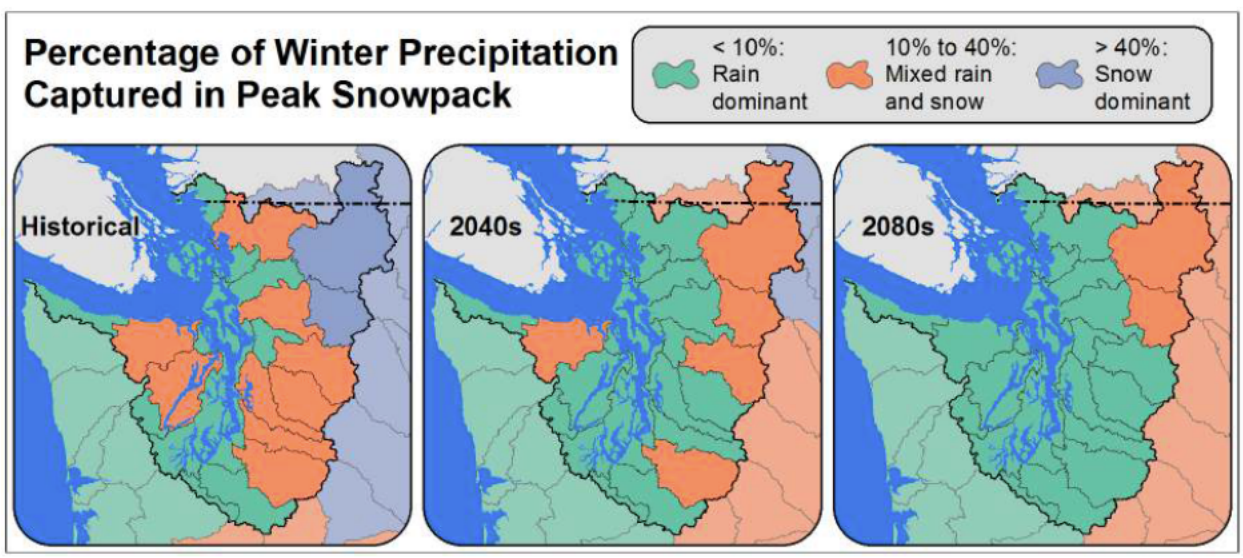


Figure 5: Current watershed classifications and the projected changes by the 2040s and 2080s based on a moderate greenhouse gas scenario (A1B) and 10 global models (Figure 3-1 in Mauger et al. 2015).

We note above that actions can be taken to ameliorate the effects of climate change on the Puget Sound region. The report notes many examples of organizations collaborating with others and preparing for the impacts of climate change, with some preparedness activities already taking place. One such example of adaptation that has been implemented is the newly renovated ($65 million) water treatment plant for the City of Anacortes, completed in 2013. The plant sits on the Skagit River and is responsible for the drinking water supply for about 56,000 residential, commercial, and industrial customers. Climate change projections indicate increased flooding and sediment on the Skagit River, and these projections were taken into account for the new design, with a more effective sediment removal process included. In addition, all electrical controls were moved well above the current 100-year flood levels and other structures were elevated. The new synthesis report should help motivate and guide new efforts of this type, and we recommend further reading of the report and this Seattle Times article for more information.

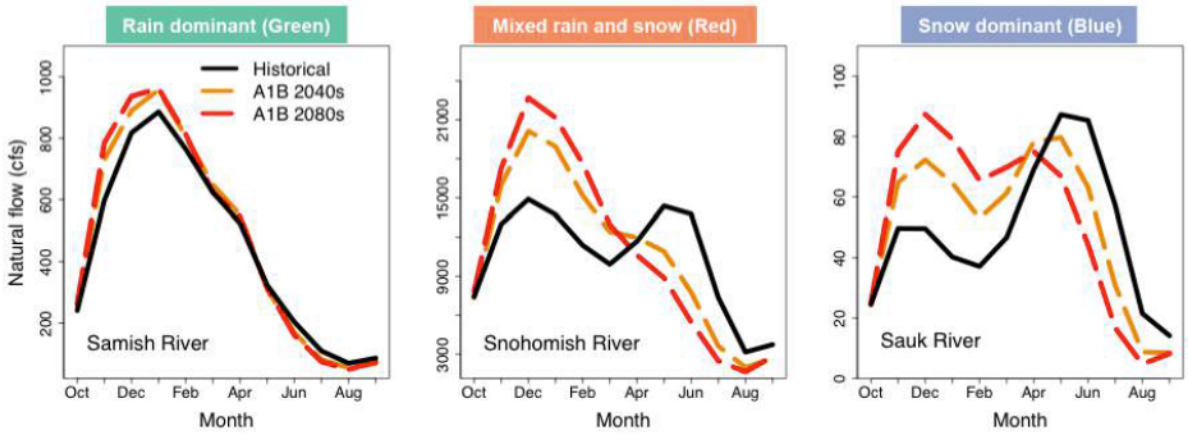


Figure 6: The changes in hydrographs (or monthly timing of streamflow) for examples of the three different types of basins categorized in Figure A (Samish River, Snohomish River, and Sauk River). Figure 3-2 in Mauger et al. 2015.

References

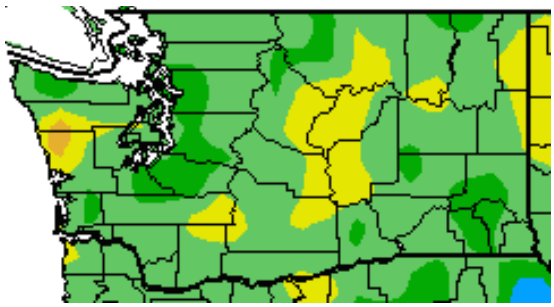
Mass, C., A. Skalenakis, and M. Warner, 2011. Extreme precipitation over the west coast of North America: Is there a trend? *J. Hydrometeor.*, **12**, 310-318.

Mauger, G.S., J.H. Casola, H.A. Morgan, R.L. Strauch, B. Jones, B. Curry, T.M. Busch Isaksen, L. Whitely Binder, M.B. Krosby, A.K. Snover, 2015. State of Knowledge: Climate Change in Puget Sound. Report prepared for the Puget Sound Partnership and NOAA. Climate Impacts Group, University of Washington, Seattle. doi:10.7915/CIG93777D Report available online: https://cig.uw.edu/resources/special-reports/ps-sok/

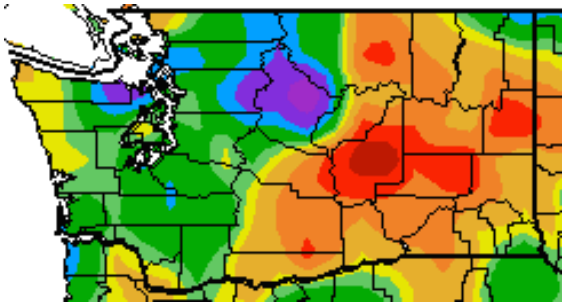
Climate Summary

Mean November temperatures were cooler than normal for a majority of the state, as shown in the temperature departure from normal map below from the High Plains Regional Climate Center. Most of the state was within 2°F of normal, which is a big change from the very warm anomalies seen in October. In western WA, Olympia and Vancouver were cool spots, with temperatures 2 and 2.5°F below normal, respectively. Average temperatures were closer to normal in eastern WA, with most stations listed in Table 1 within 1°F of normal. Ephrata measured exactly normal temperatures for November, a relatively uncommon and thrilling occurrence for climatologists.

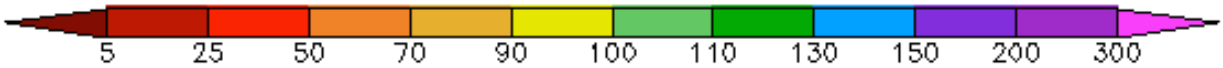
Total November precipitation relative to normal was very different for the two sides of WA state. Most of western WA and the east slopes of the northern Cascades received normal to above normal precipitation. Quillayute and SeaTac Airport received 96 and 127% of normal, respectively. On the other hand, most of eastern WA received below normal precipitation. Ephrata was extremely dry, only receiving 18% of normal, while other locations mainly received between 50 and 70% of normal. Regarding lowland snowfall, Spokane had about 20% of normal while Hanford recorded 170% of normal with 3.4". While some high elevations in western WA received a dusting of light snow on November 15, none of the stations listed in Table 1 recorded snow.



Temperature (°F)



Precipitation (%)



November 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)			Snowfall (inches)		
	Avg	Norm	Departure from Normal	Total	Norm	% of Norm	Total	Norm	% of Norm
Western Washington									
Olympia	41.3	43.3	-2.0	11.82	8.63	137	0	0.9	0
Seattle WFO	44.5	46.2	-1.7	7.16	5.84	123	0	0.3	0
SeaTac AP	43.8	45.4	-1.6	8.37	6.57	127	0	1.2	0
Quillayute	43.8	44.2	-0.4	14.96	15.52	96	0	1.4	0
Hoquiam	45.5	45.8	-0.3	10.94	11.17	98	0	0.4	0
Bellingham AP	42.1	43.2	-1.1	4.57	5.80	79	0	0.9	0
Vancouver AP	43.9	46.4	-2.5	4.57	5.91	77	0	M	0
Eastern Washington									
Spokane AP	34.9	35.7	-0.8	0.77	2.30	33	1.5	7.4	20
Wenatchee	38.6	37.6	1.0	0.68	1.11	61	M	5.0	-
Omak	36.1	35.9	0.2	0.91	1.61	57	M	M	-
Pullman AP	36.0	37.0	-1.0	2.02	2.29	88	M	M	-
Ephrata	37.0	37.0	0.0	0.19	1.06	18	M	2.6	-
Pasco AP	39.4	41.3	-1.9	0.61	1.09	56	0.5	M	-
Hanford	39.9	40.5	-0.6	0.60	0.95	63	3.4	2.0	170

Table 1: November 2015 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. "M" denotes missing data.

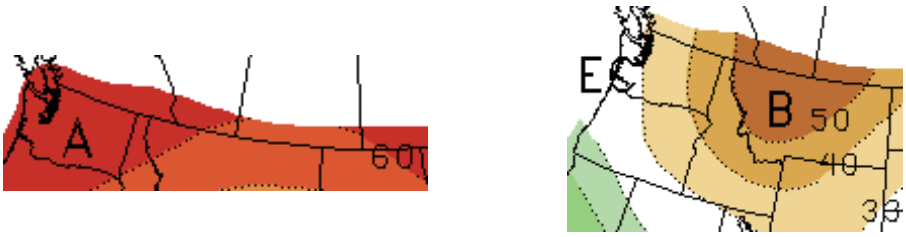
Climate Outlook

El Niño conditions in the tropical Pacific Ocean are still present and are strengthening in some regard, according to the Climate Prediction Center (CPC). Weekly sea surface temperature (SST) anomalies exceed 3°C in the central and eastern equatorial Pacific at the time of this writing, and the monthly SST departures are above 3.5°C in some areas of the equatorial Pacific Ocean. The SST anomalies in the Niño3.4 index region are warmer than any previous El Niño event for this time of year, including the strong 1997-98 El Niño. The "El Niño Advisory" released by the CPC on 5 March is still in effect. ENSO forecast models are unanimous in an El Niño lasting through the winter of 2015-16 and there is over a 70% chance that the conditions will persist through the spring of 2016. The CPC is taking the El Niño into account, as well as other factors in their seasonal outlooks.

The CPC seasonal outlook for December is calling for increased chances of above normal temperatures statewide. There is more variation for the December precipitation forecast with wetter than normal conditions expected in western WA and the Cascades and drier than normal conditions in far eastern WA. There is a zone in central eastern WA where equal chances of below, equal to, or above normal precipitation is expected.

The December-January-February (DJF) CPC outlook is calling for higher than normal temperatures statewide, with the odds of warmer temperatures higher than what is in place for just the month of December. For precipitation, there are higher chances of below normal precipitation for most of the state, with odds of below normal precipitation highest for eastern WA. The Olympic Peninsula and southwest WA have equal chances of below, equal to, or above normal precipitation.

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



December-January-February outlook for temperature (left) and precipitation (right) from the CPC.