Office of the Washington State Climatologist

September 2023 Report and Outlook

September 13, 2023

http://www.climate.washington.edu/

August Event Summary

Mean August temperatures were above normal for nearly the entire state, with the largest anomalies in portions of western Washington. Averaged statewide, August was the 6th warmest since records began in 1895, with average temperatures 2.3˚F above the 1991-2020 normal. August precipitation was varied, with generally below normal precipitation in western WA and above normal precipitation in eastern WA. The statewide average was just above normal (+0.07") totaling 0.95".

Figure 1 shows the August daily temperature and precipitation time series for SeaTac Airport. There were generally three periods of above normal temperatures during the month, and the mid-month interval was the most notable in terms of records. On the 14th, record high daily temperatures were set statewide; for example,

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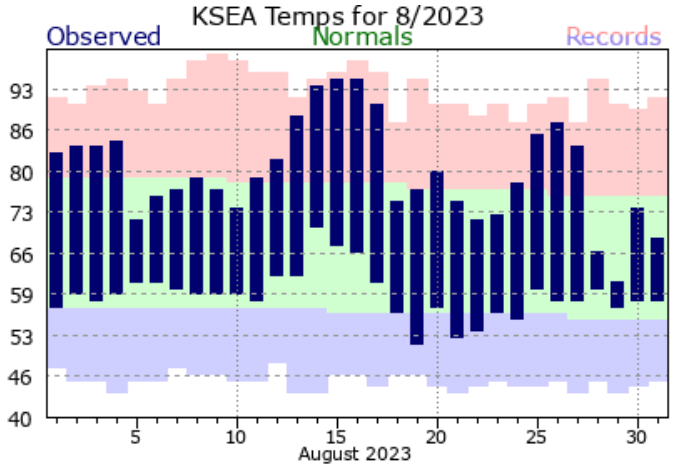


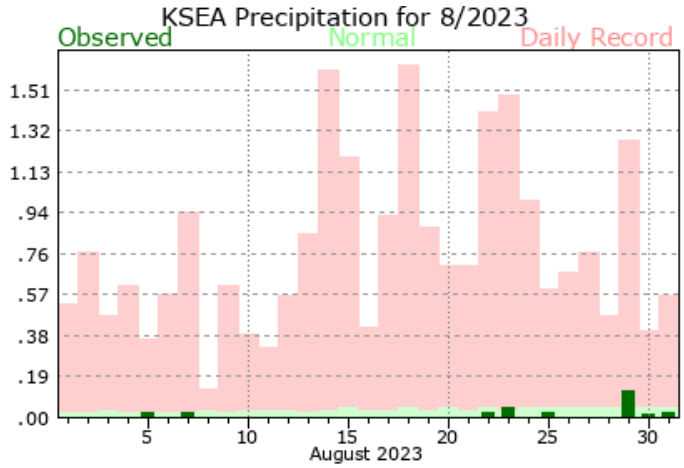


Figure 1: August 2023 daily temperatures for SeaTac Airport compared to the 1991-2020 normal (green envelope) and previous records (blue and red envelopes; NWS).

Dallesport (109°F), Vancouver (108°F), Omak (107°F), Pasco (105°F), Ellensburg (101°F), and Olympia (97°F) all set records. The 108°F recorded at Vancouver ranked as the warmest August day on record. Overnight minimum temperatures were also high during this heat wave, with SeaTac Airport (71°F), the Seattle Weather Forecasting Office (65°F), Hoquiam (65°F), and Quillayute (60°F) setting daily high minimum temperature records on the 14th. SeaTac's minimum temperature marked only the third time that a low temperature was measured in the 70s. Hoquiam's minimum on the 14th tied the warmest low temperature ever recorded at that station (on 6/27/2021). More daily maximum temperature records were set around the state on the 15th and 16th, and high minimum temperature records were also recorded on the 15th. Notably, Olympia reached the triple digits (100°F) on the 15th.

After a relatively quiet summer smoke-wise west of the Cascades, there were a couple days after the heatwave in which wildfire smoke caused unhealthy air. Figure 2 shows an example of the fine particulate matter (PM2.5) in Seattle's Duwamish Valley for the month of August. Thankfully, the poor air quality did not last long west of the Cascades, as a major, and welcomed, shift in the atmospheric pattern arrived with the remnants of tropical storm Hilary. This was not a major rain event for WA, which was spared the flooding seen in other parts of the West; only the far eastern portions of WA received any precipitation at all. In addition to Hilary, much of the precipitation that fell east of the Cascades was associated with thunderstorms. There were several wildfires started over the southern WA Cascades on the 27th and 28th that are burning at the time of this writing.

Finally, with climatological summer (June-August) now in the rearview mirror, it's worth taking a look at how the season measured up. Averaged statewide, June-August tied last year (2022) as the 5th warmest summer on record (+2.3 above the 1991-2020 normal). 2015 remains the warmest summer on record for WA. June-August 2023 ranks as the 17th driest on record, averaged statewide, with 60% of normal precipitation. The statewide records go back to 1895.

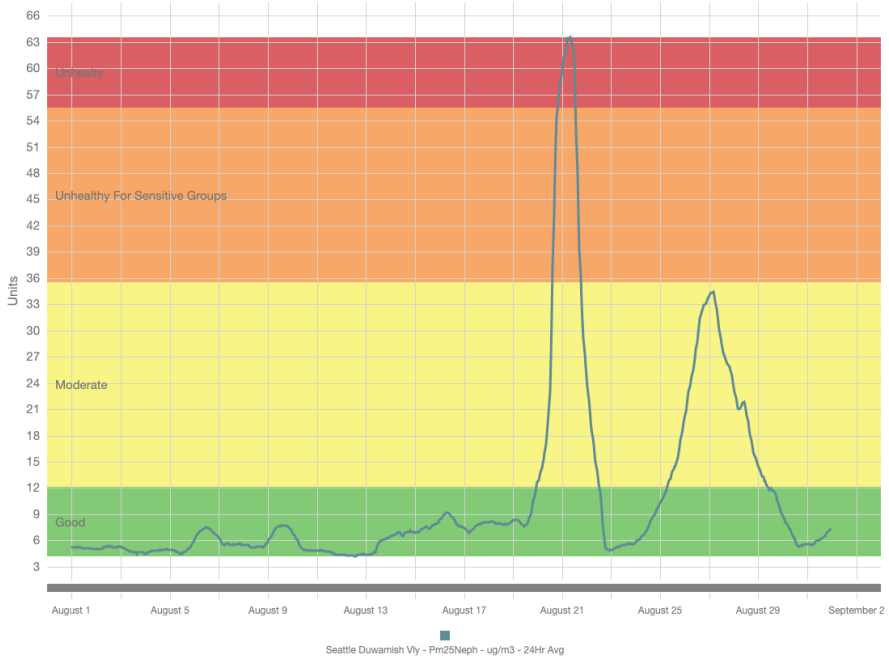


Figure 2: August 2023 24-hr average PM2.5 from the Seattle Duwamish Valley sensor color coded by the Air Quality Index (Puget Sound Clean Air Agency).

Streamflow and Drought Summary

Average August streamflow (Figure 3) stayed the same or declined in western WA compared to the July percentiles. Some August streamflows were slightly better in eastern WA compared to July, but overall the streamflow picture has worsened. Figure 4 shows the percentage of stream gauges in each percentile category over the last 45 days. About 85% of Washington's stream gauges were in the below normal category at the end of August, up from about 80% in early August.

The drought depiction on the U.S. Drought Monitor (Figure 5) has worsened since the last edition of our newsletter, mainly in the western portion of the state. "Extreme drought" (D3) was introduced to parts of Whatcom, Skagit, and Snohomish counties, and both "severe drought" (D2) and "moderate drought" (D1) was expanded.

The drought declared by the Washington State Department of Ecology in 12 watersheds on July 24 (press release) is still in effect. In order for a drought emergency to be declared, there also has to be undue hardship expected or already occurring for people, farms, or fish within the area experiencing drought conditions. Therefore, the WA state declared drought area is smaller than those areas on the Drought Monitor in drought conditions. The "Drought Advisory" issued on July 5 is still applicable for the rest of the state not in "emergency" status. If you're experiencing impacts from the drier than usual conditions, we wish to hear from you! Please contact OWSC or see the "Report Your Drought Impacts" call-out box below.

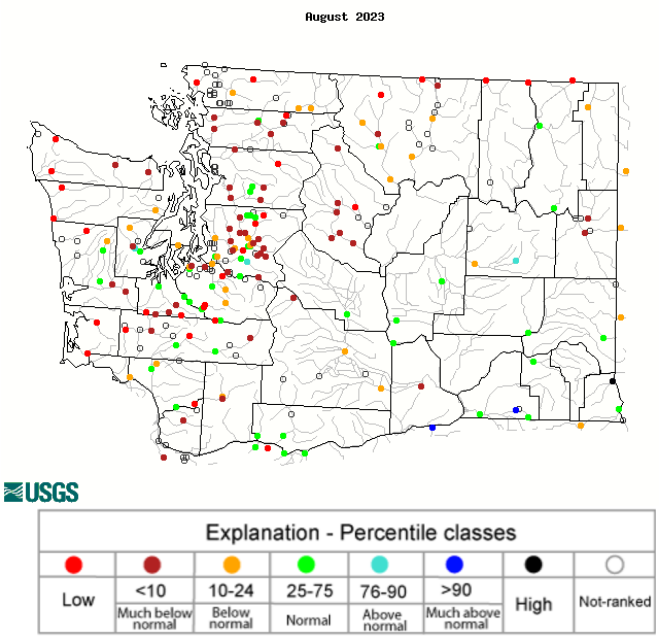


Figure 3: August 2023 average streamflow (USGS).

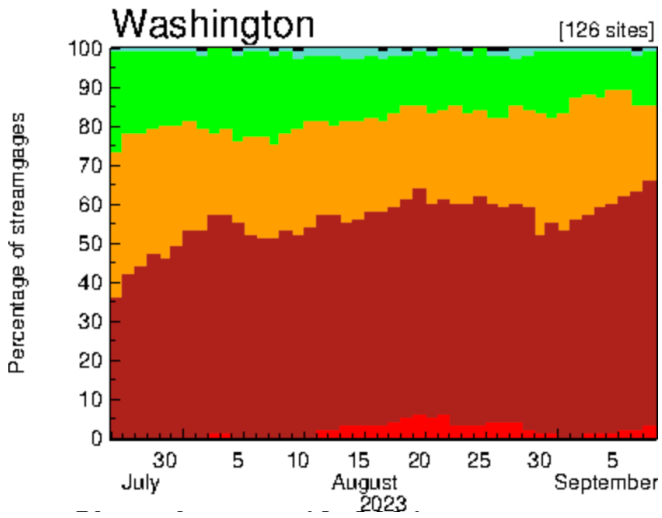


Figure 4: The percentage of stream gauges in WA in each percentile category shown in Figure 3 from late July through early September (USGS).

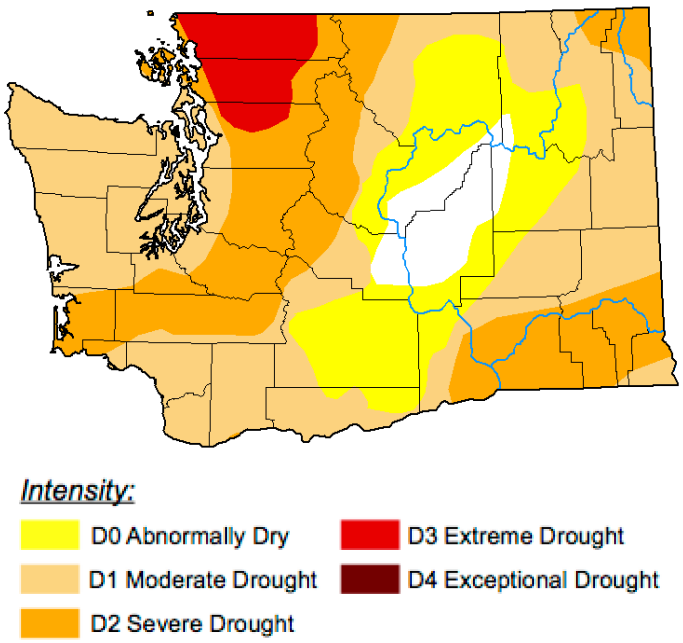


Figure 5: The September 7, 2023 edition of the U.S. Drought Monitor.

Report Your Drought Impacts

Are you experiencing a drought impact? Your on-the-ground observations are critical in helping us understand the broad picture of drought in the state. The National Drought Mitigation Center and partners have developed Condition Monitoring Observer Reports on Drought (CMOR-drought), a short survey that allows the public to enter their observations regarding crops, water supply, fire, etc. We would greatly appreciate your input, and these reports help experts assess drought impacts for both the U.S. Drought Monitor depiction and on the state level.

OWSC Joins UW's Climate Impacts Group

Following two decades of close collaboration, we are excited to announce that the Office of the Washington State Climatologist is joining the UW Climate Impacts Group. With a shared commitment to advancing climate services, this collaboration marks a significant step towards a more unified approach to addressing climate-related challenges in our state and region.

The State Climatologist will maintain its brand, identity and mission, even as the organizations merge. Nick Bond, state climatologist, and Karin Bumbaco, deputy state climatologist, will continue to lead the Climatologist Office. Bond will join the leadership team of the Climate Impacts Group. The Office will continue to prioritize effectively communicating with the public, state and local government and other entities. Read more here.

Registration is open for the OR/WA Water Year Meeting!

Registration is now open for the Oregon-Washington Water Year 2023 Recap and 2024 Outlook meeting that will take place virtually on the mornings of November 1 and 2, 2023.The goal of this meeting is to share and gather information regarding climate impacts of the 2023 water year. Forecast experts will provide expectations for 2024, including discussion of what El Niño means for the region.

Comparative Analysis of Soil Moisture Products in WA

Written by: Adelina Rodriguez

Soil moisture is becoming an increasingly important parameter in drought indication. However, collecting soil moisture data on a large scale is not easy, due to the multitude of soil properties and environmental factors affecting water accumulation and drainage in soils. The diverse landscapes and soil types here in Washington present an interesting challenge when measuring soil moisture, conducting data analysis, and reaching accurate conclusions. Additionally, there are numerous soil moisture products that collect data and analyze current conditions differently. Sometimes contradictory information from these products can lead to false interpretations of moisture levels and drought across the state. This summer, I investigated the performances of two gridded, satellite-derived soil moisture products from NASA (called GRACE[1] and SMAP[2]) in Washington.

Previous studies have analyzed the performances of different soil moisture products in other parts of the world, although there were none that compared these two products specifically and none conducted within the state of Washington. I chose these two products due to their relatively high spatial resolution across the CONUS (14 km for GRACE and 9 km for SMAP), the accessibility of their large data sets, and their varying instruments used in data retrievals. More specifically, the GRACE satellites use accelerometers to measure gravitational anomalies

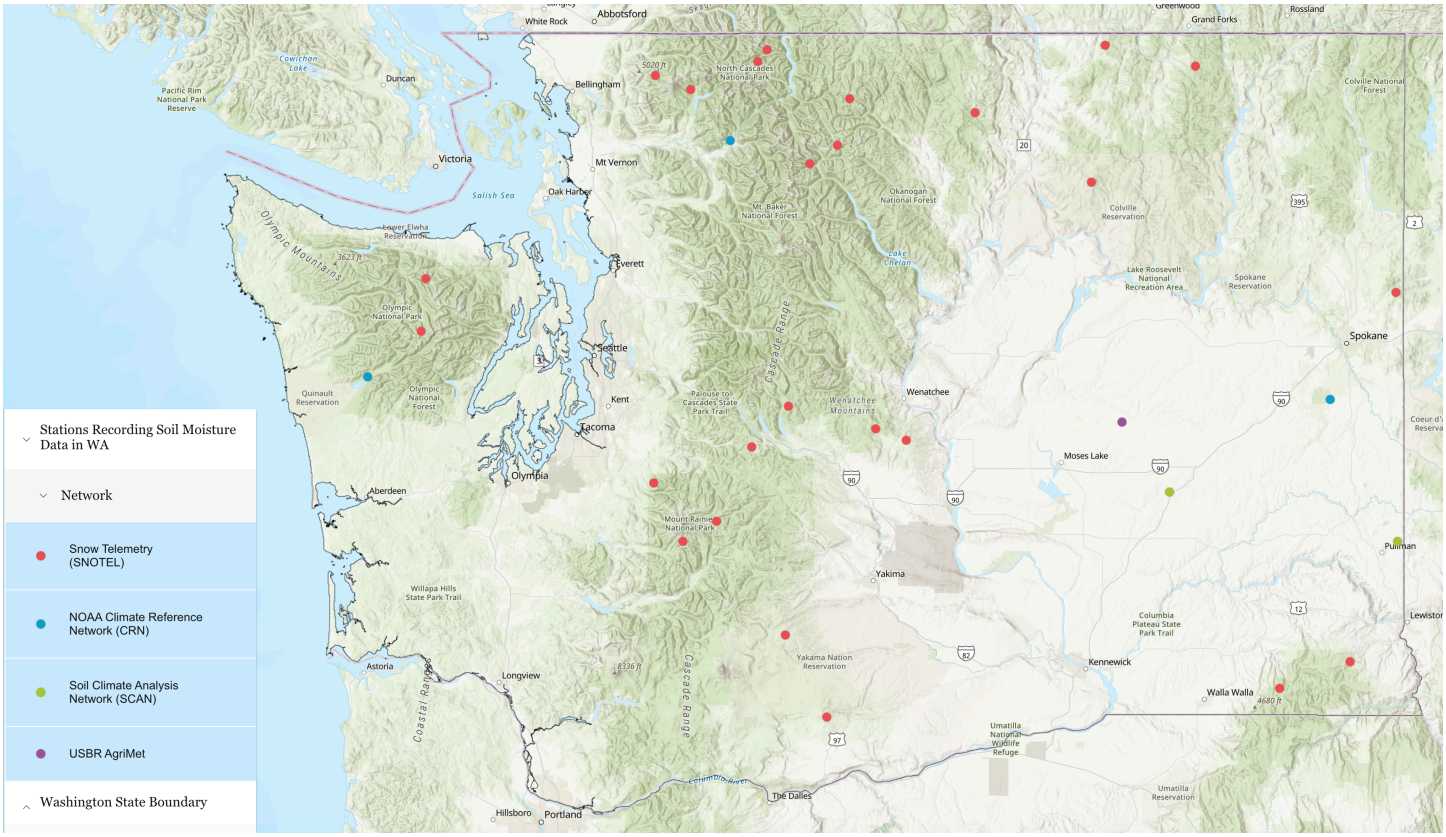


Figure 6: A map of current soil moisture in situ monitoring sites in Washington, color-coded by observational network (Adelina Rodriguez).

associated with fluctuations in soil moisture content. The SMAP satellite uses radar and radiometers to sense microwaves and measure brightness levels. Raw data from both GRACE and SMAP are assimilated into land surface models developed by scientists at NASA that take into account environmental parameters and forcings, which is what allows for the relatively high resolution of the soil moisture data.

In order to analyze the performance of satellite products, I compared the satellite data to in situ data available at select weather stations in Washington. Figure 6 shows the locations in Washington in which soil moisture data were considered. I focused on four case studies, including spring 2021 and 2022 (April to June), summer 2018 (July to September), and fall 2016 (September to November). I also explored how these products represented contrasting landscapes, including forested regions, croplands, grasslands, and snowy areas. A large chunk of my summer was spent pre-processing the data sets I compiled from various sources. After meticulous efforts and plenty of human errors, I was able to work with the data on MATLAB. I used scripts to merge data into 3D arrays and plot dozens of time series graphs. I also created box and whisker plots to display correlation results. Along the way, I ran into several significant obstacles. Each product has different units and depths of measurements and a different sequence of data acquisition, so I was unable to use the Root Mean Squared Error metric and to conduct a Triple Collocation test. Due to the huge datasets that would be required for an analysis over multiple years, I had to shorten my analyses into a couple of case studies each only 3 months long. Still, my investigation yielded interesting results.

GRACE and SMAP provide contrasting data at the same in situ sites, and they perform with varying levels of accuracy for distinct land types across the state. Figure 7 shows an example of a poor SMAP performance during the spring snowmelt season, but excellent performance during a dry summer at the same location. Snow on the ground interferes with the radiative signals which SMAP relies upon, leading to inaccurate soil moisture estimates. The SMAP product represents soil moisture observations in croplands and grasslands best throughout the year, especially

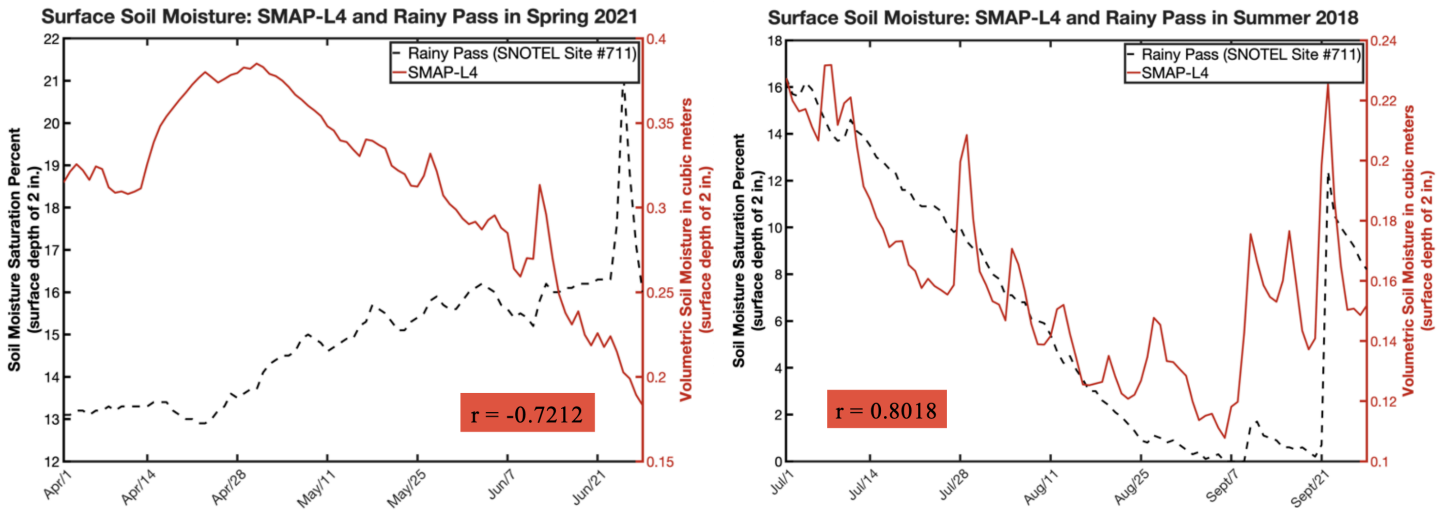


Figure 7: Soil moisture saturation percent at Rainy Pass during spring 2021 (left) and summer 2018 (right) compared to the SMAP volumetric soil moisture (m3) at the grid cell containing Rainy Pass during those two time periods.

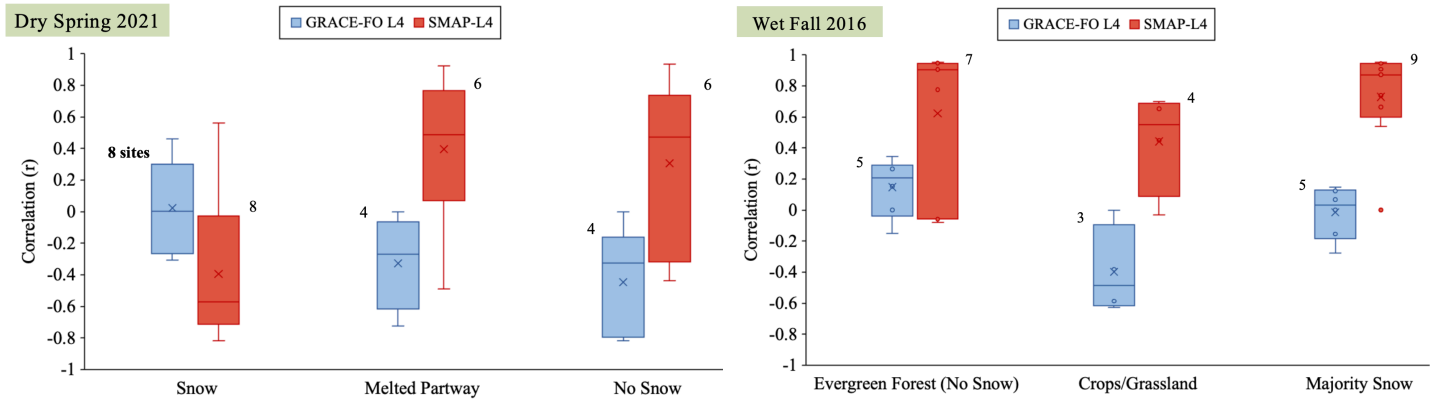


Figure 8: Pearson correlations between satellite-derived products and in situ observations. Correlations are between daily variations in in situ data and respective satellite-derived data retrieved at the same spatial coordinates, during a dry spring (left) and a wet fall (right). The number of in situ data sites used in the analysis is indicated above each box and whisker plot.

in summer. GRACE, however, performed poorly in most areas during all seasons (Figure 8). This is likely due to the fundamental measurements of GRACE related to large-scale distributions of soil moisture while the station observations are sensitive to unresolvable local effects.

Despite discrepancies in the datasets and the limited periods of analysis, my results (Figure 8) show that SMAP is generally more useful than GRACE when using satellite products for soil moisture monitoring in Washington. The main takeaway from my project is that drought coordinators, agricultural interests, and public officials should take land type and seasonality into careful consideration and gather soil moisture information from multiple sources. There is still plenty of work to be done on making soil moisture monitoring more cohesive in Washington state.

Data

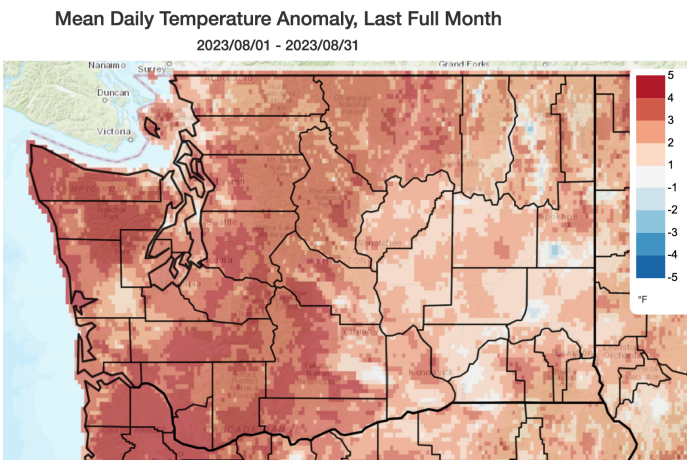
1: **GRACE-FO L4 Data:** Matthew Rodell and Hiroko Kato Beaudoing, NASA/GSFC/HSL. (2021). Groundwater and soil moisture conditions from grace and grace-fo data assimilation l4 7-days 0. 125 x 0. 125 degree u. S. Version 4. 0. NASA Goddard Earth Sciences Data and Information Services Center. doi: 10.5067/UH653SEZR9VQ. [August 2023].

2: **SMAP-L4 Data:** Reichle, R., G. De Lannoy, R. D. Koster, W. T. Crow, and J. S. Kimball. 2017. SMAP L4 9 km EASE-Grid Surface and Root Zone Soil Moisture Geophysical Data, Version 3. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. doi: 10.5067/B59DT1D5UMB4. [August 2023].

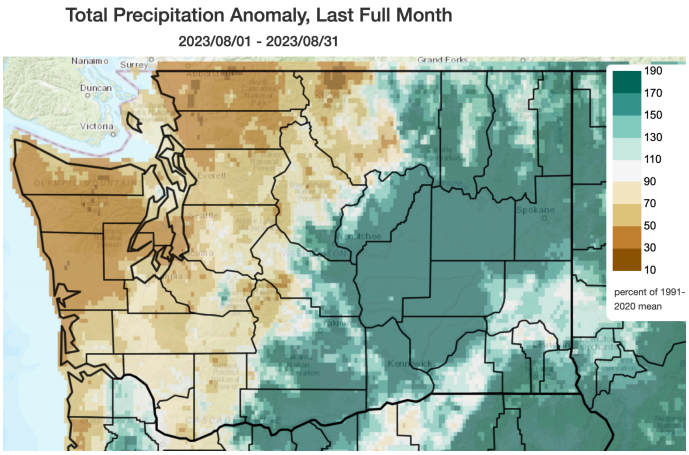
Climate Summary

For the fourth consecutive month, mean monthly temperatures have been above normal for a majority of Washington State. Mean August temperatures were between 2 and 4°F above normal throughout much of the state, with western WA warmer relative to normal than eastern WA. Vancouver and Quillayute were especially warm, with temperatures 4.6 and 6.1°F above normal for the month, respectively. While still above normal, Pullman, Wenatchee, and Hanford had smaller monthly anomalies, with temperatures 1.5, 1.7, and 1.8°F above normal, respectively (Table 1).

In general, August precipitation was below normal in western Washington, and above normal in eastern Washington. SeaTac Airport and Hoquiam were especially dry, receiving only 28 and 30% of normal precipitation, respectively (Table 1). Omak and Hanford, though on the wetter side of the state compared to normal, missed out on precipitation and both totaled only 0.08", about 30% of their normal precipitation. On the other hand, a large area in eastern WA saw more than 200% of normal precipitation. Despite the high percentages of normal shown in Table 1 and on the map on the right-hand side, keep in mind that normal August precipitation is very low for our state, so the high percentages don't translate into excessive precipitation. Ephrata, for example, received 544% of its normal precipitation, but that is for a less impressive total of only 0.98".



August temperature (°F) departure from normal relative to the 1991-2020 normal (Climate Toolbox).



August total precipitation percent of 1991-2020 normal (Climate Toolbox).

Station	Mean Temperature (°F)			Precipitation (inches)		
	Average	Normal	Departure from Normal	Total	Normal	Percent of Normal
Western Washington						
Olympia	67.7	64.2	3.5	0.78	0.96	81
Seattle WFO	69.7	67.1	2.6	0.48	1.00	48
SeaTac AP	69.9	67.4	2.5	0.27	0.97	28
Quillayute	66.1	60.0	6.1	1.15	2.64	44
Hoquiam	66.5	61.0	5.5	0.41	1.35	30
Bellingham AP	65.4	63.9	1.5	0.51	1.13	45
Vancouver AP	74.0	69.4	4.6	0.69	0.52	133
Eastern Washington						
Spokane AP	72.3	70.3	2.0	0.98	0.47	209
Wenatchee	75.4	73.7	1.7	0.41	0.23	178
Omak	76.4	72.8	3.6	0.08	0.27	30
Pullman AP	68.4	66.9	1.5	0.69	0.49	141
Ephrata	75.7	73.7	2.0	0.98	0.18	544
Pasco AP	75.4	73.2	2.2	0.31	0.27	115
Hanford	78.3	76.5	1.8	0.08	0.25	32

Table 1: August 2023 climate summaries for locations around Washington with a climate normal baseline of 1991-2020.

Climate Outlook

According to the Climate Prediction Center (CPC), El Niño is present in the equatorial Pacific Ocean and an "El Niño Advisory" is in effect. Over the last month, the above normal sea surface temperatures (SSTs) have expanded in area over the eastern and central equatorial Pacific. The atmospheric component is also consistent with El Niño. ENSO models are virtually certain that El Niño will persist through the winter of 2023-24, with the dynamical model mean projections showing that it will likely be a strong event.

The CPC September temperature outlook (Figure 9) has equal chances of below, equal to, or above normal temperatures statewide. In other words, there's not much to go on for September temperatures. On the other hand, there are higher chances of a wetter than normal September, which would certainly be welcome considering our recent dry weather. Odds of above normal September precipitation are between 33 and 50% on the three-tiered scale.

The three-month fall (September-October-November; SON) temperature outlook (Figure 10) is calling for higher chances of above normal temperatures statewide. Odds of above normal temperatures are higher in eastern WA (between 40 and 50%) compared to western WA (between 33 and 40%). The SON precipitation outlook indicates elevated chances of below normal precipitation statewide. The odds are highest for western WA, with chances between 40 and 50% on the three-tiered scale. Many previous El Niño events have been accompanied by relatively dry fall seasons in our region, but there have also been exceptions.

Figure 9: September outlook for temperature (left) and precipitation (right).

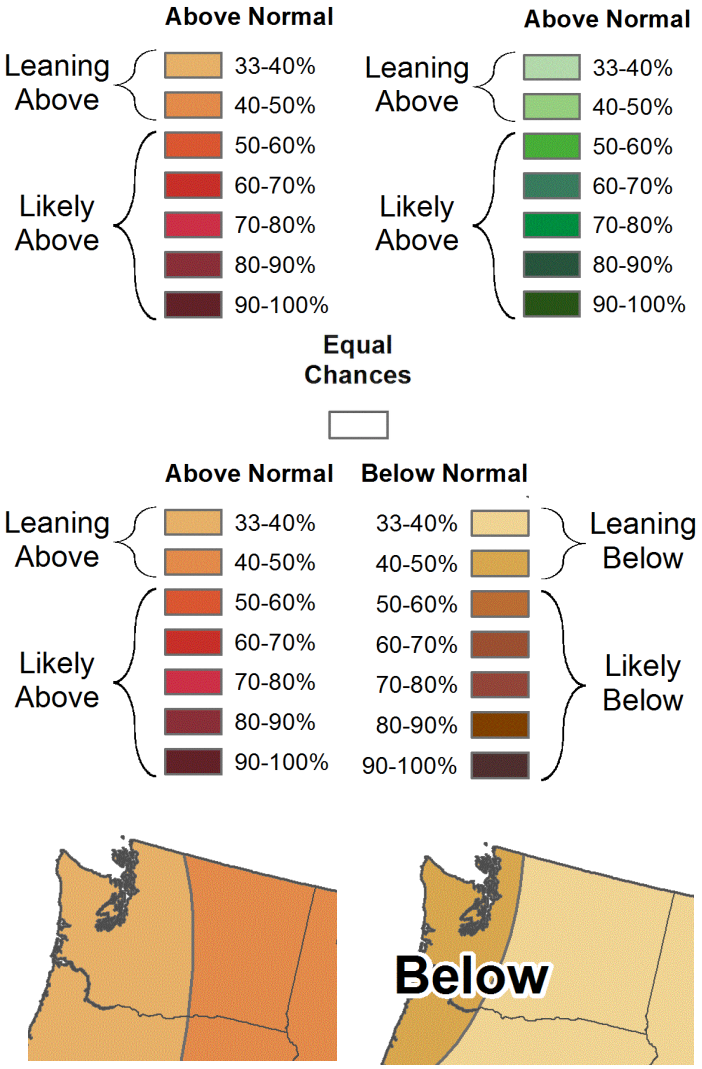


Figure 10: September-October-November outlook for temperature (left) and precipitation (right) (Climate Prediction Center).