

INTERMOUNTAIN WEST CLIMATE SUMMARY



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ENSO and Intermountain West Water Supply: A Review of Water Year 2010 and Outlook for Water Year 2011

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The Big ENSO Switch

Much of Water Year 2010 in the Intermountain West—in particular the snow accumulation season—played out under the influence of a moderate to strong El Niño event that commenced in summer 2009, and reached a peak around February 2010. In spring 2010, ENSO indicators dropped sharply, about as fast as they have ever changed in the last 60 years, and reached strong La Niña conditions by mid-summer, according to the Multivariate ENSO Index (MEI). In fact, the August-September MEI is at its lowest level since 1955 (Fig. 1).

Furthermore, the strength of this new La Niña event suggests that it may very well persist through Water Year 2011. As we look back on the Water Year that just ended, what was the impact of the El Niño event on the snow accumulation season that built our water supply for WY 2010? And what is the outlook for WY 2011, given the strength and potential for persistence of the current La Niña?

A Brief Review of ENSO

El Niño/Southern Oscillation (ENSO) is the most important coupled ocean-atmosphere phenomenon that causes global climate variability on interannual time scales. It manifests itself as changes in (1) the sea-surface temperatures in the eastern equatorial Pacific Ocean, (2) the sea level pressure difference between eastern Pacific high pressure and western Pacific low pressure (originally defined as the ‘Southern Oscillation’), (3) the direction and strength of the near-surface winds over those same waters, and (4) the preferred location of tropical thunderstorms that in turn drive changes in the atmospheric circulation outside the tropics, including over North America. When these changes exceed a threshold in one direction or the other from “neutral” conditions, then we say that ENSO is in an El Niño event (warm ocean temperatures, so “positive” sign) or a La Niña event (cool ocean temperatures, so “negative” sign).

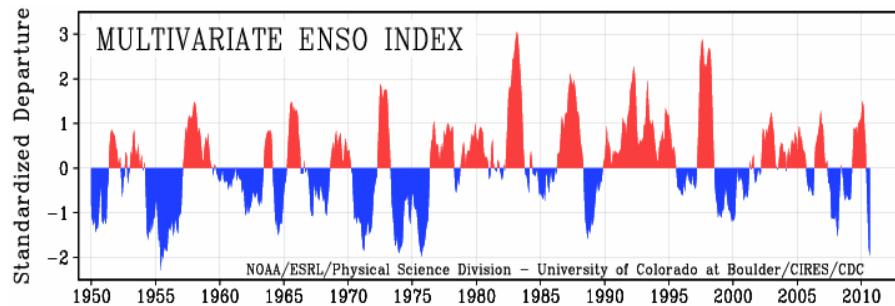


Figure 1: Time series of the Multivariate ENSO Index (MEI) from January 1950 through September 2010. El Niño-like conditions are shown in red, La Niña-like conditions are shown in blue. The current La Niña is the very sharp downturn on the far right. (For more information on the MEI, see the MEI homepage at <http://www.esrl.noaa.gov/psd/people/klaus.wolter/MEI/>)

The tropical Pacific is the main “heat engine” for the global climate system, where colossal amounts of water are evaporated from the ocean surface and entrained in the atmospheric circulation, carrying moisture and latent heat away from the tropics. Changes in the ENSO state, by influencing this redistribution of moisture and heat, alter global weather patterns well into the mid-latitudes, and tend to affect the same regions in the same way, at the same time of year. As we will see below (Figure 2b), winter months often behave differently from the rest of the year in the Intermountain West. Once an El Niño event or La Niña event is established, it tends to persist for several months (for many weaker events) to 2–3 years (for some stronger events, especially of the La Niña variety). Thus, ENSO events impart “memory” and seasonal predictability to the climate system.

El Niño and La Niña events tend to shift—in a somewhat predictable manner—the westerly storm tracks that provide the vast majority of the moisture for the western US during the key snowpack-accumulation period of October through April. They also affect the northward reach of the monsoonal flow that delivers significant moisture to portions of the Intermountain West during the summer. Overall, what predictive skill exists in monthly and seasonal outlooks for precipitation and temperature for the western US, including the Intermountain West region, is mainly due to this “ENSO signal”.



The ENSO “footprint” in the Intermountain West

ENSO has a fairly reliable effect on climate variability in the Southwest (AZ, NM) and in the Pacific Northwest (WA, OR, ID). Those two regions comprise a “dipole” in which El Niño events usually lead to wet conditions for the Southwest and dry conditions for the Northwest, while La Niña leads to the reverse situation. The Intermountain West is often referred to as a “transition area” with respect to ENSO, meaning that climate impacts of ENSO are more seasonally variable than in the regions to the northwest and southwest. Overall, the ENSO influence tends to be the weakest in the northern part of the Intermountain West (Wyoming).

Figures 2a through 2c show the spatial pattern and strength of the ENSO “footprint” in the Intermountain West through the three meteorological seasons that coincide with the first 8 months of the water year: the snowpack accumulation period. The colors indicate the correlation between seasonal precipitation (from the PRISM gridded data set) and the MEI (modified version), from 1956–2005. Orange colors indicate areas that tend to be wetter during El Niño in that season, while blue colors indicate areas that tend to be wetter during La Niña.

The upshot of Figures 2a through 2c is that El Niño events over the past 50 years have tended to be wet in the fall and spring across Utah, Colorado, and southern Wyoming, while central and northern Wyoming either has little ENSO signal, or a slight preference for drier-than-average fall and spring seasons with El Niño. During the core winter months (December–February), wet El Niño conditions retreat to southern Utah and southeast Colorado, while it tends to be dry at the higher elevations in Colorado (especially northern Colorado) and from the northern Wind River mountains to the Absarokas and east towards the Big Horn mountains in Wyoming.

La Niña events, conversely, have tended towards drier conditions in those orange areas, and wetter in the blue. Since the winter months tend to be the wettest time of year in the higher elevations of the Intermountain West, a typically wet La Niña core winter can sometimes balance out typically dry La Niña conditions during the rest of the year. Nevertheless, averaged across Utah and Colorado, El Niño tends to produce wetter overall fall-winter-spring precipitation, and also higher regional streamflows, e.g., for the Upper Colorado Basin, although that correlation is weak (less than +0.3).

Figure 2d shows the footprint for the Summer (June–August) season, which favors wet conditions in El Niño (and dry in La Niña) across the Intermountain West. While summer precipitation is not as important for generating runoff, it strongly influences residential and agricultural water demand.

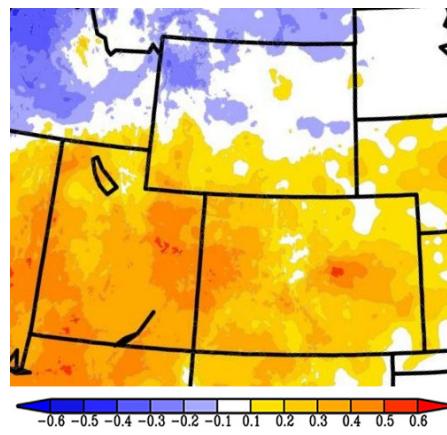


Figure 2a: Correlations between Multivariate ENSO Index (MEI) and precipitation for the Fall (September–November) season. Orange colors indicate a tendency towards wetter conditions during El Niño (positive MEI); and blue indicates a tendency towards wetter conditions during La Niña (negative MEI). (Maps by Jon Eischeid, NOAA ESRL PSD)

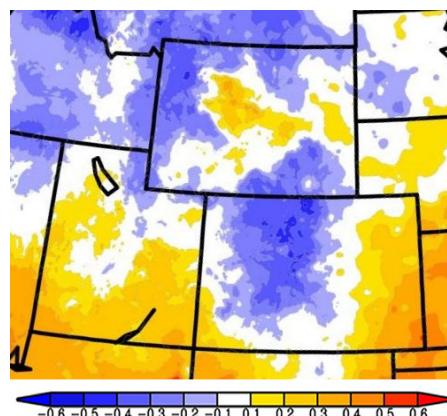


Figure 2b: Same as 2a, but for the Winter (December–February) season.

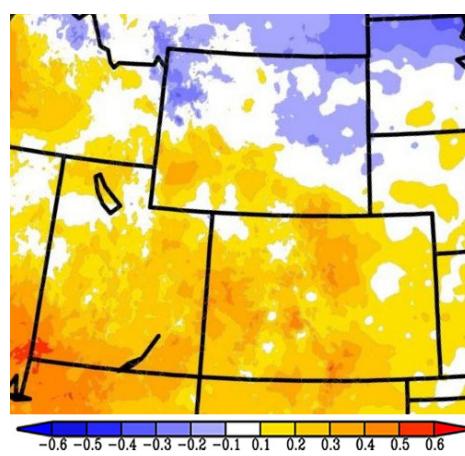


Figure 2c: Same as 2a, but for the Spring (March–May) season.

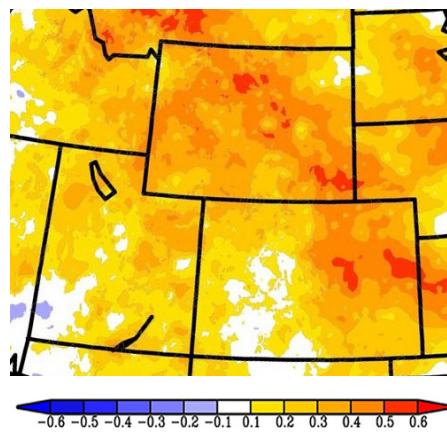


Figure 2d: Same as 2a, but for the Summer (June–August) season.



Another way to look at this ENSO footprint is to select those years in which ENSO events of a particular sign (e.g., El Niño) and strength occurred, and composite the divisional precipitation anomalies that occurred in those years. (You can try this for yourself at <http://www.esrl.noaa.gov/psd/data/usclimdivs/>). Such maps will be shown below as we assess the upcoming Water Year 2011.

Review of Water Year 2010

By Fall 2009, an El Niño event was in place. Thus, a first-order expectation for Intermountain West precipitation would be for the typical El Niño pattern shown in Figure 2: tendency for wet fall, dry winter over the high country, and wet spring. Note that of the 3 El Niño events since 2000, only one (2004–05) conformed to this general pattern, indicating the importance of non-ENSO influences (such as Indian Ocean temperatures and the general tendency of the Pacific Decadal Oscillation to be negative in the last decade), as well as natural or random variability. Furthermore, the new El Niño attained moderate strength relatively late in 2009.

The Fall season (September–November) of WY 2010 indeed departed from the typical El Niño footprint, with below-average precipitation across the Intermountain West except for eastern Colorado and portions of eastern Wyoming (Figure 3a). Arizona and much of New Mexico (not shown) were much drier than average, attesting to the weak ENSO influence in that season.

In the Winter (December–February; Figure 3b), a more familiar El Niño picture emerged, with very wet conditions over the Southwest, extending into much of Utah and into southern Colorado, while areas to the north experienced below-average precipitation. Snowpacks in northern Colorado, northern Utah, and western Wyoming fell well behind the average seasonal accumulation curve. This conformed very well with the footprint showed in Figure 2. The El Niño event maintained moderate strength through the winter, and intensified slightly in January/February.

In Spring 2010 (March–May), (Figure 3c) the storm track made an exaggerated shift to the north compared to the typical El Niño footprint (Figure 2c), bringing above-average precipitation to most of Wyoming, northern Colorado, and western Utah, but drier conditions to the south. During this period, the ENSO indicators did abruptly change towards neutral conditions, but the memory in the climate system is such that El Niño's influence often persists for a few months after its apparent demise.

Overall, the snow-accumulation period (October–April) of WY 2010 was a “mixed bag” for the region, with above-average precipitation in eastern Colorado, eastern and central Wyoming, and southern Utah, and below-average precipitation elsewhere. However, this dry “elsewhere” in-

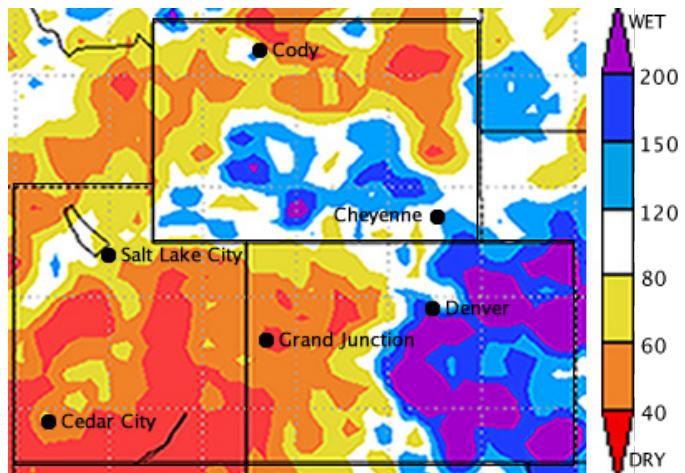


Figure 3a: Precipitation for the Fall (September–November) season 2009 as percent of average precipitation for the Fall season. (Source: NOAA ESRL Physical Science Division)

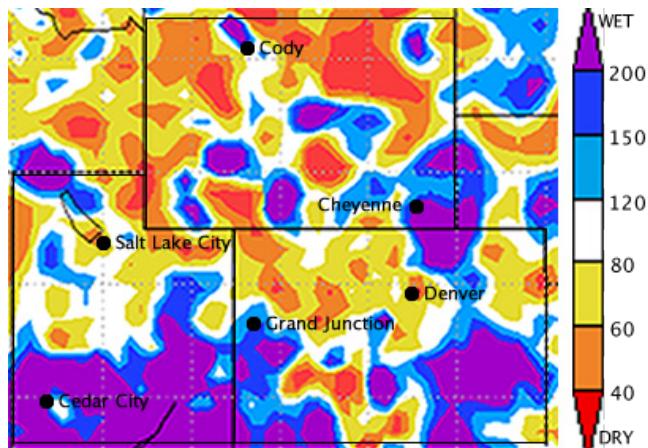


Figure 3b: Precipitation for the Winter (December–February) season 2009-10 as percent of average precipitation for the Winter season. (Source: NOAA ESRL Physical Science Division)

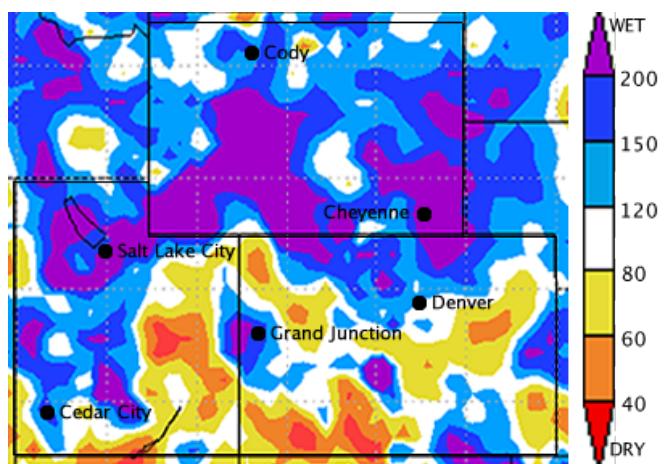


Figure 3c: Precipitation for the Spring (March–May) season 2010 as percent of average precipitation for the Spring season. (Source: NOAA ESRL Physical Science Division)



cluded nearly all of the high mountain regions, particularly in the Upper Colorado Basin, so the regional runoff picture was drier than a glance at the precipitation maps would suggest.

Summer 2010 (June–August) (Figure 3d) likewise continued the “mixed bag” in the Intermountain West, with lingering wet conditions for Wyoming in June, and then an intense but brief summer monsoon period interspersed with significant dry spells in much of the region, and a few storm systems which mainly impacted southern Utah. The fast transition to La Niña during the summer may have played a role in reducing the northward reach of the monsoon in August, which initiated a severe dry spell in much of the Intermountain West that lasted through September.

In the context of El Niño, the way in which water year 2010 unfolded illustrates a couple of points worth repeating. First, the influence of ENSO events on our region amounts to a *tendency* towards certain outcomes—not destiny. Second, that influence competes with other atmospheric and oceanic features, outside of the tropical Pacific Ocean that can interfere with—or enhance—the expected outcome. For example, persistent atmospheric blocking over the North Atlantic last winter, which led to the much-publicized mid-Atlantic snowstorms, may have shifted the storm track

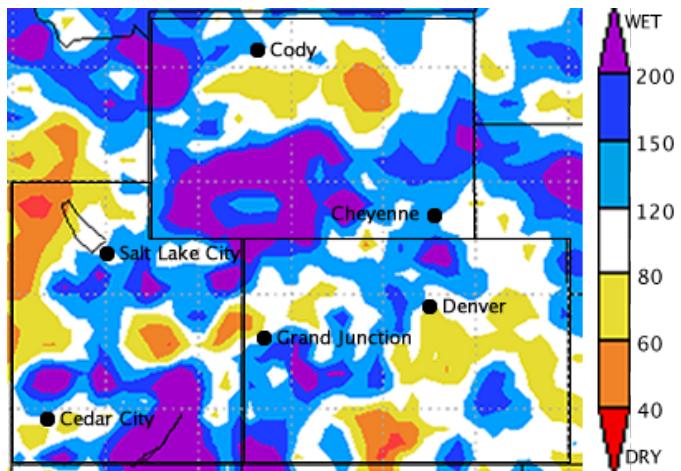


Figure 3d: Precipitation for the Summer (June–August) season 2010 as percent of average precipitation for the Summer season. (Source: NOAA ESRL Physical Science Division)

further to the south than is typical for El Niño winters, and was instrumental in bringing colder temperatures to the Intermountain West than is typical for El Niño.

WY 2011: What will the La Niña bring?

As discussed above, the tendency is for La Niña events to be associated with drier-than-average conditions across most of the Intermountain West (except for much of northern Wyoming), and in all seasons except mid-winter in the Colorado high country. In general, then, La Niña tends to lead to lower water year streamflow in the major basins, such as the Upper Colorado River. Since 1999, 3 of the 4 La Niña-dominated Water Years have been associated with drier-than-average conditions with below-average flows, the exception being the Water Year 2008.

The likelihood that WY 2011 will be on the dry side is enhanced by the sheer strength of the current La Niña event; the sea-surface temperatures in the ENSO region in the tropical Pacific are now about as cold, relative to average, as they can physically get. This means that it is more likely to persist well into next summer than other, weaker, La Niña events. Most of the latest ensemble of 23 ENSO models are forecasting that La Niña will maintain at least moderate strength through early spring 2011. Furthermore, the Pacific Decadal Oscillation (PDO)—which captures longer-term ocean-atmosphere variability in the North Pacific Ocean—switched from positive to negative this June as the ENSO indices switched sign. Accordingly, the influence of PDO does not appear poised to interfere with typical La Niña impacts in North America.

If we composite the October through April precipitation anomalies for the seven years with La Niña events of comparable strength to the current one (Figure 4), we see the classic La Niña pattern emerge, with a strong shift towards dry anomalies (yellow–red) in the Southwest, and conversely towards

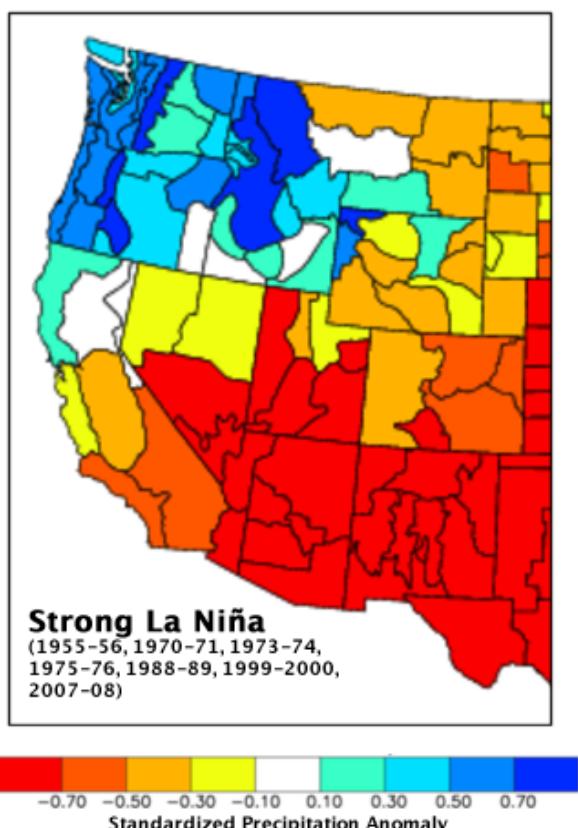


Figure 4: October–April standardized precipitation anomalies, averaged for the 7 “strong” La Niña events since 1950, comparable to the strength of the current La Niña. Note the marked tendency (orange and red) towards dry conditions across much of Utah and Colorado. See text for additional explanation. (Source: NOAA ESRL Physical Science Division)

wet anomalies (blue) in the Pacific Northwest. In the Intermountain West, dry anomalies dominate, with the strongest shift in southern Utah and southern Colorado, with a few divisions in northern Wyoming showing a wet shift. Note that the values plotted are in terms of the standard deviation (SD) for that climate division. Since climate division data are based on COOP weather stations, and do not incorporate SNOTEL data, they tend to underestimate precipitation totals for the higher elevations of the Intermountain West.

For example, the Colorado Division 2 (western Colorado) has a 1971–2000 mean for October–April of 9.39" and a SD of 2.14", while SNOTEL sites in this region often show totals that are 2–4 times as high. Nonetheless, the shift shown in Figure 4 of 0.3–0.5 SD for CO Division 2 (the average of the 7 strong La Niña years) is equivalent to a reduction of 0.64"–1.07", or 7–11% of average October–April precipitation. Again, this is a tendency given similar ENSO states in the past, not a forecast. In fact, composite anomalies below 0.5 SD such as this one, and over the Green River Basin in Wyoming and the Uinta Range in Utah, are not considered statistically significant. On the other hand, all composite anomalies over eastern Colorado and southern Utah exceed that threshold, and imply a significant risk of a reduced local water supply in those regions.

While there is a non-negligible risk of a dry Water Year 2011 for much of the Intermountain West (except northern Wyoming), the bigger threat that is looming is the possibility of an extended La Niña event. Historically, the stronger La Niña events have often continued for a second or even a third year, most notably from 1954 to 1957, from 1973 to 1976, and from 1998 to 2001. While the 1970s event was relatively benign in its impacts to the region, both the 1950s and recent turn-of-the-millennium event were associated with severe drought conditions. In fact, Figure 5 shows that precipitation deficits tend to be more severe in the second La Niña year than in the first one for virtually all climate divisions within the Upper Colorado Basin.

We will continue to evaluate the risk of such an extended La Niña event, and will update our assessment of this situation in future issues of the Intermountain West Climate Summary.

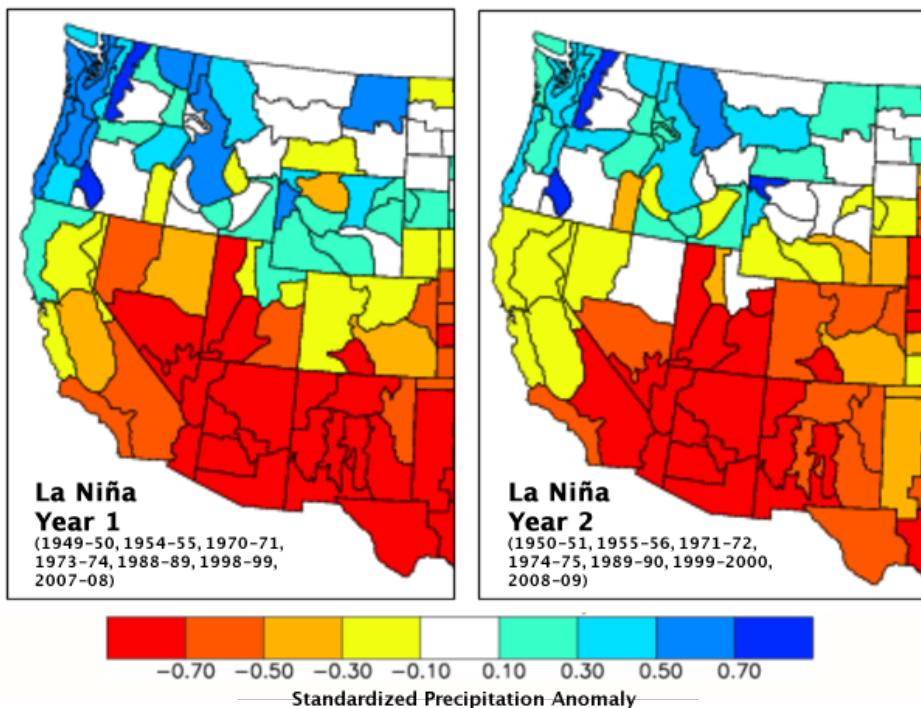


Figure 5. October–April standardized precipitation anomalies for Year 1 (left) and Year 2 (right), averaged for the 7 La Niña events (moderate and strong) since 1950 which lasted into a 2nd year. Nearly all climate divisions in Utah, Colorado, and southern Wyoming tend to have drier conditions in Year 2 than Year 1. (Note: this set of La Niña events overlaps with those shown in Figure 4, but the two sets are not the same.) (Source: NOAA ESRL Physical Science Division)

Additional Resources on ENSO

MEI homepage:

<http://www.esrl.noaa.gov/psd/people/klaus.wolter/MEI/>

NOAA Climate Prediction Center (CPC) ENSO

homepage:

<http://www.cpc.noaa.gov/products/precip/CWlink/MJO/enso.shtml>

NOAA Pacific Marine Environmental Laboratory (PMEL) El Niño theme page:

<http://www.pmel.noaa.gov/tao/elnino/nino-home.html>

International Research Institute for Climate and Society (IRI) ENSO Quick Look:

<http://iri.columbia.edu/climate/ENSO/currentinfo/QuickLook.html>