COLLEGE OF AGRICULTURE & LIFE SCIENCES
Cooperative Extension

El Niño 2015-2016 : Will It Affect Snowfall in Arizona's Highcountry?

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Although snow depth and snow water equivalent usually are above average in February, March, and April during strong El Niño events, they may vary from near zero to record-high levels. These measures of snowfall at the beginning of February this year were near average at six locations where data collection began prior to 1950.

El Niño events increase the odds for above-average precipitation in Arizona, as the storm track shifts southward and potentially brings more storms to the region[1,2]. Such changes currently are reflected in seasonal precipitation outlooks that show heightened chances for above-normal precipitation across the Southwest over the next few months[3]. What might an increase in moisture mean for Arizona? Should we expect higher-than-average amounts of snow in the state's highcountry? If so, does this expectation of greater snowfall extend well into spring? In this fourth Extension Climate Fact Sheet about the 2015-2016 El Niño event, we address these issues and note their importance to various activities in the state.

How are snow data collected? The Natural Resources Conservation Service provides much of the snow data for the western U.S. through its Snow Course and Snowpack Telemetry (SNOTEL) networks[4]. Originally developed to aid water supply forecasts, these networks now also support a variety of resource management activities such as those related to air and water quality, natural hazards such as floods, and climate. Snow Courses and SNOTEL stations generally are located in high-elevation watersheds. Data from Snow Courses comes from periodic manual measurements, whereas those from SNOTEL stations are automatically collected and communicated in near-real time. In addition to depth, snowfall measurements include snow water equivalent, or the amount of water that would result from melting all of the snowpack.

In Arizona, there are 44 Snow Courses and SNOTEL stations (Figure 1)[5]. Except for five sites in northern Apache County, locations are along the Mogollon Rim from the Grand Canyon to the state border with New Mexico. Six of the Snow Courses in Arizona have snowfall measurements extending back prior to 1950 (Table 1).

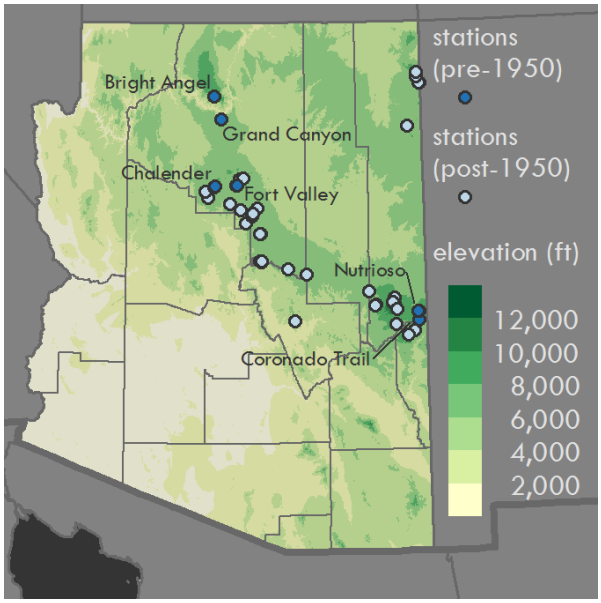

Figure 1. Measurement locations from the Snow Course and SNOTEL networks are confined to areas of higher elevation within the state[5]. The six Snow Courses where snowfall measurements started prior to 1950 are labeled and represented by dark blue circles.

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Snow Course	elevation (feet)	installation year
Bright Angel	8,400	1947
Chalender	7,100	1947
Coronado Trail	8,350	1938
Fort Valley	7,350	1947
Grand Canyon	7,500	1947
Nutrioso	8,500	1938

Table 1. Six locations in the Snow Course network across Arizona have snowfall measurements that start before 1950[5].

Do strong El Niño events lead to deeper snowpacks? Recent observations indicate that the 2015-2016 El Niño event is one of the strongest on record[6,7]. Before this event, seven strong El Niño events have occurred since 1950 (Table 2)[8]. On average, snow depth measured near the beginning of February at the six long-term Snow Courses in Arizona was above normal during these prior events (Figure 2).

winter	maximum seasonal value of the Oceanic Niño Index
1957-1958	+1.7
1965-1966	+1.8
1972-1973	+2.0
1982-1983	+2.1
1991-1992	+1.6
1997-1998	+2.3
2009-2010	+1.3
2015-2016*	+2.3

* through January 2016

Table 2. Prior to winter 2015-2016, seven strong El Niño events have occurred since 1950[8]. The Oceanic Niño Index, one of several ways to measure the strength of an El Niño event, characterizes how much the temperature of surface water in the central and eastern tropical Pacific Ocean is above average[2,9]. Higher index values represent stronger events.

Five of these six Snow Course locations – Chalender, Fort Valley, and Grand Canyon in central and northern Coconino County and Coronado Trail and Nutrioso in southern Apache County – recorded their deepest

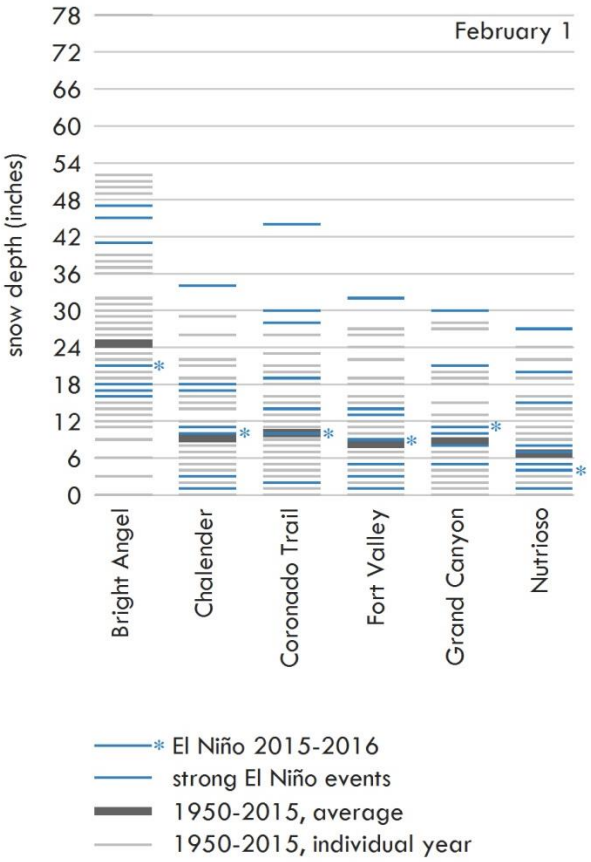

Figure 2. On average, snow depth in Arizona's highcountry during past strong El Niño events since 1950 was above normal at the beginning of February. Although snow measurements often are reported for the first day of the month, actual measurement dates may be up to a few days before or after as Snow Courses require manual acquisition of data. Snow depth at the beginning of February this winter was close to normal at all six long-term Snow Courses.

snowpack during the 2009-2010 strong El Niño event. The remaining location – Bright Angel in northern Coconino County – recorded its sixth-deepest snowpack during that same winter. The deepest snowpack measured at the Bright Angel Snow Course – 78 inches – was in winter 1978-1979 when no El Niño event was occurring.

Contrasting with record-deep and above-normal snowpacks during some of the past

strong El Niño events are others in which snow depth was below average or even close to zero at the beginning of February (Figure 2). For instance, snowpack was almost absent during the strong El Niño event in 1957-1958 at the Chalender, Coronado Trail, Fort Valley, and Nutrioso locations. Snow depth at the beginning of February this winter was close to normal at all six long-term Snow Courses.

At the beginning of March and April during past strong El Niño events, snow depth in Arizona also tended to be greater than average (Figure 3). As with measurements at the beginning of February, some of the deepest snowpacks at the six long-term Snow Courses occurred during these events. Chalender tied its record March 1 snowpack depth during the 2009-2010 strong El Niño event. Coronado Trail and Nutrioso set theirs that same winter. All six locations recorded their deepest April 1 snowpack during the 1972-1973 strong El Niño event. The exceptionally deep snowpack that winter led to a rare avalanche on the southeast face of Humphreys Peak north of Flagstaff[10].

Also similar to snow depth measurements at the beginning of February during past strong El Niño events are those on March 1 and April 1 that show below-average or zero snowpack. For example, both Chalender and Fort Valley recorded almost no snowpack at the beginning of March during the 1957-1958 strong El Niño event. Snow depth at the beginning of April was zero at Chalender, Coronado Trail, Fort Valley,

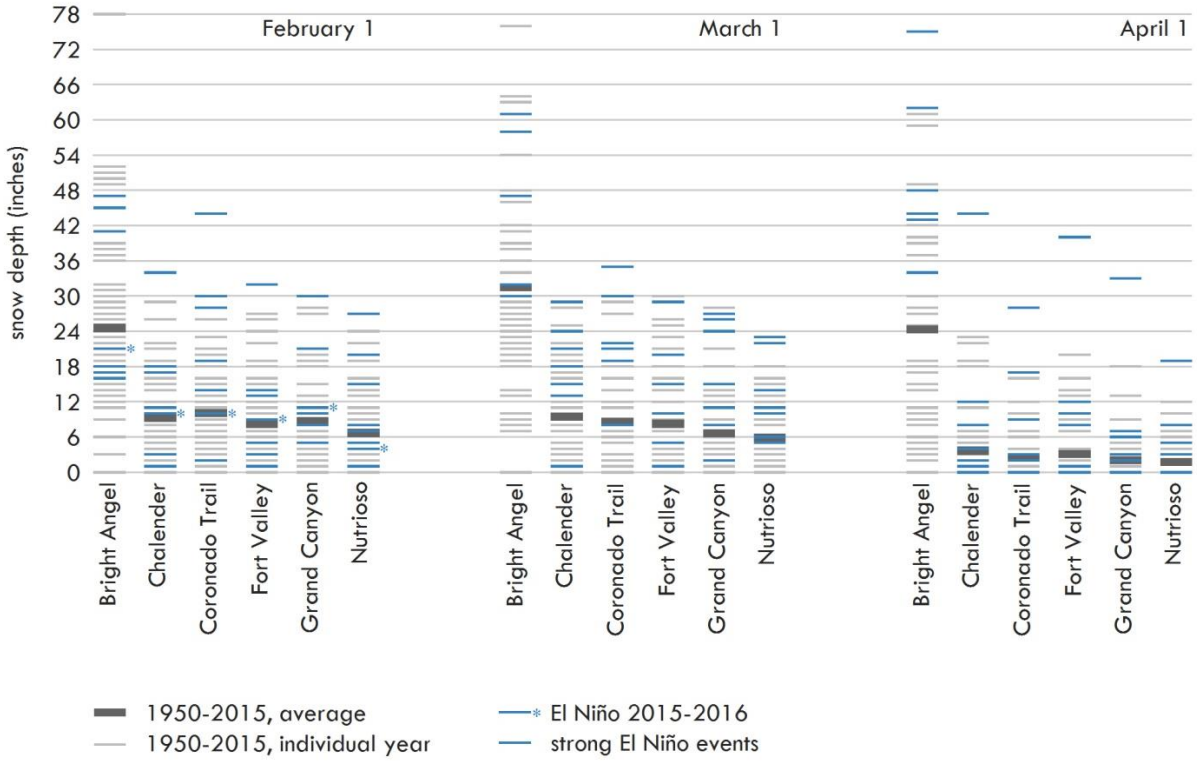

Figure 3. On average, snow depth in Arizona's highcountry during past strong El Niño events since 1950 was above normal well into spring. Snow depth at the beginning of February this winter was close to normal at all six long-term Snow Courses.

Grand Canyon, and Nutrioso during the 1965-1966 strong El Niño event, as well as at Fort Valley and Nutrioso during the 1991-1992 strong El Niño event.

Do strong El Niño events lead to snowpacks with higher snow water equivalent? Much like snow depth, the average snow water equivalent measured near the beginning of February at the six long-term Snow Courses in Arizona during past strong El Niño events was above normal (Figure 4). Chalender and Fort Valley tied their record February 1 snow water equivalent during the 2009-2010 strong El Niño event. Grand Canyon did, as well, with its previous record of snow water equivalent set during the 1972-1973 strong El Niño event. Coronado Trail and Nutrioso recorded their second-highest snow water equivalent during the 2009-2010 strong El Niño event. The highest snow water equivalent on February 1 at Bright Angel during past strong El Niño events was in 1972-1973.

In contrast to record-high and above-normal snow water equivalent during some of the past strong El Niño events are others in which the water content of the snowpack was below average or even close to zero at the beginning of February (Figure 4). For example, low snow water equivalent corresponding to an almost absent snowpack during the strong El Niño event in 1957-1958 occurred at the Chalender, Coronado Trail, Fort Valley, and Nutrioso locations. Snow water equivalent at the beginning of

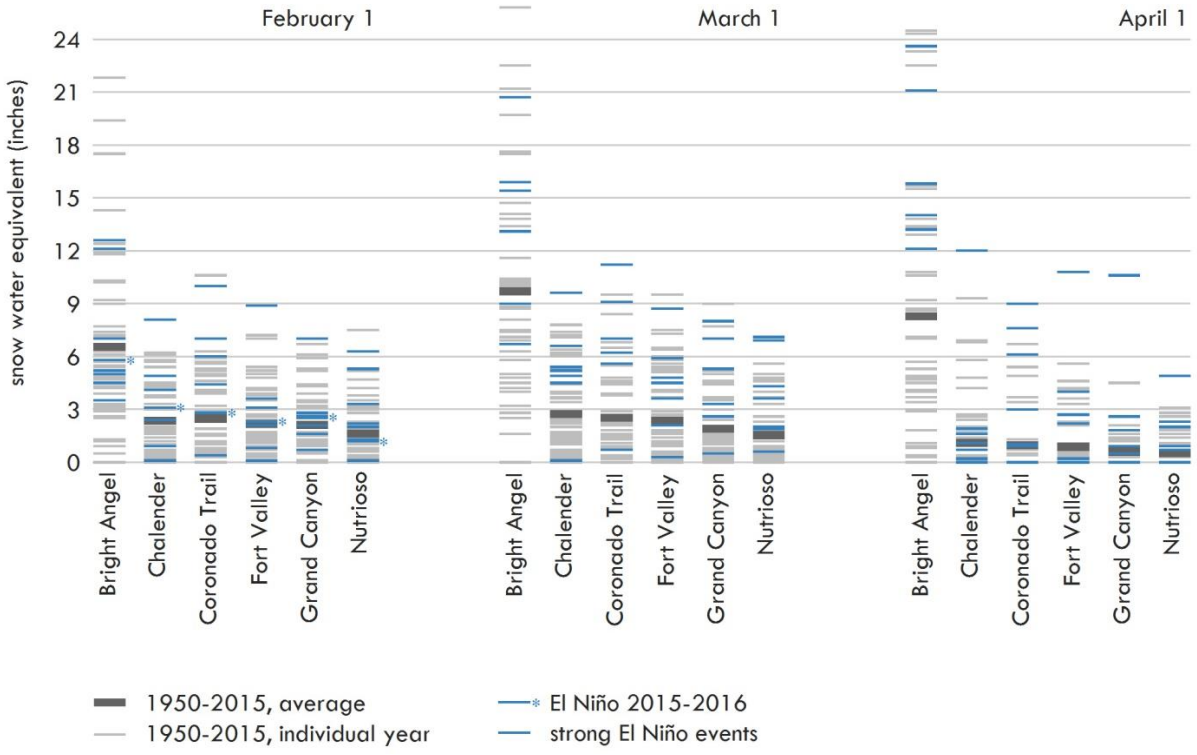

Figure 4. On average, snow water equivalent in Arizona's highcountry during past strong El Niño events since 1950 was above normal well into spring. Snow water equivalent at the beginning of February this winter was close to normal at all six long-term Snow Courses.

February this winter was close to normal at all six long-term Snow Courses.

Water content of the snowpack also tended to be higher than average at the beginning of March and April during past strong El Niño events (Figure 4). As with snow water equivalent at the beginning of February, some of the wettest snowpacks at the six long-term locations in the Snow Course network occurred during these events. Chalender, Coronado Trail, and Nutrioso set their record March 1 snow water equivalent during the 2009-2010 strong El Niño event, whereas Fort Valley set its second-highest and Bright Angel its fourth-highest. The highest March 1 snow water equivalent at the Grand Canyon location happened during the 1972-1973 strong El Niño event. April 1 records of snow water equivalent also occurred during this same winter at all locations except for Bright Angel, where the third-highest was measured.

Despite record-high and above-normal snow water equivalent at the beginning of March and April during some past strong El Niño events, there have been other events in which water content of the snowpack was close to or at zero (Figure 4). For instance, March 1 snow water equivalent was less than one inch at the Chalender, Coronado Trail, Fort Valley, Grand Canyon, and Nutrioso locations during the 1957-1958 strong El Niño event. This condition continued on April 1 that winter for these locations, except for Coronado Trail. Snow water equivalent less than one inch also occurred at these five locations during the 1965-1966 and 1991-1992 strong El Niño events, and at Nutrioso during the 1997-1998 strong El Niño event.

How then can we interpret seasonal outlooks for wetter conditions in Arizona? In the context of snow depth and snow water equivalent, the potential for the 2015-2016 El Niño event to bring more storms to the region suggests that snowfall in the state's highcounty should be greater than normal during February, March, and April. However, as historical data show, snowfall during strong El Niño events can vary widely from record-high to near record-low amounts at many locations in high-elevation areas of the state.

Low snow depth or snow water equivalent might not reflect total precipitation amounts in Arizona's highcountry during February, March, and April as rainfall also is possible. Although not examined in this Extension Climate Fact Sheet, such circumstances may have occurred during the strong El Niño event in 1957-1958 when precipitation totals appeared to have been bolstered by rain[11,12].

What could be some of the related relevant impacts in Arizona? Snowfall in Arizona's highcountry is important in several contexts, including tourism, water resources, and wildland fire danger. For instance, a deeper snowpack means better and perhaps longer lasting ski conditions in the state's high-elevation areas that attract recreationists who contribute to local economies. Greater snowfall along the Mogollon Rim leads to additional spring runoff into the Salt and Verde rivers, increasing the amount of water in Salt River Project reservoirs that supply water for the Phoenix metropolitan area. More snow also delays the onset of dry conditions conducive to wildland fires during late spring and early summer. Below-average snowfall generally results in the opposite of such circumstances.

How can I get more information? The NRCS provides web-based interactive map applications that display several station-based measurements related to snowfall in the western U.S., including snow water equivalent, snow depth, precipitation, streamflow, and reservoir storage (www.wcc.nrcs.usda.gov/snow/snow_map). Also, the National Operational Hydrologic Remote Sensing Center of the National Weather Service makes a number of remotely sensed and modeled snowfall map products available, such as for snow water equivalent, snow depth, snow melt, and sublimation (www.nohrsc.noaa.gov/nsa).

In addition to periodic Extension Climate Fact Sheets like this one, climate specialists and scientists of Cooperative Extension are working with the Climate Assessment for the Southwest (CLIMAS) to produce a full suite of information related to the 2015-2016 El Niño event (www.climas.arizona.edu/sw-climate/el-niño-southern-oscillation). Please contact us for further information, data, and analysis that could be applied to stakeholder needs in your county.

References

[1] www.pmel.noaa.gov/tao/elnino/impacts.html
[2] Weiss J, Crimmins M, Garfin G, Brown P (2015) El Niño 2015-2016 : An overview of what it might mean for Arizona, University of Arizona Cooperative Extension Climate Fact Sheet, 2pp, cals.arizona.edu/research/climategem/resources/EN20152016overview.pdf
[3] www.cpc.ncep.noaa.gov/products/predictions/90day/
[4] www.wcc.nrcs.usda.gov/factpub/sntlfct1.html
[5] wcc.sc.egov.usda.gov/nwcc/rgrpt
[6] iri.columbia.edu/our-expertise/climate/forecasts/enso/current/
[7] www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_advisory/ensodisc.html
[8] www.climate.gov/news-features/blogs/enso/united-states-el-niño-impacts-0
[9] www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml
[10] www.kachinapeaks.org/pdf/Snow_Avalanches_on_the_San_Francisco_Peaks.pdf
[11] gis.ncdc.noaa.gov/maps/ncei/summaries/monthly
[12] www.cefa.dri.edu/Westmap/Westmap_home.php

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