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# September Southwest Climate Outlook

**Precipitation**: In the past 30 days, much of Arizona and New Mexico recorded below-average precipitation, although isolated areas received above-average precipitation (Fig. 1). This is consistent with the variable nature of the monsoon, especially during the seasonal transition. Water year precipitation to date (since Oct 1, 2014) offers hope in terms of drought relief, with much of Arizona and New Mexico recording above-average precipitation for the water year (Fig. 2).

**Temperature**: Temperature anomalies in the past 30 days were between 0 and 6 degrees F above average across most of Arizona and New Mexico (Fig. 3). Despite similarly near-record warm temperatures in 2015, temperatures have not felt as hot as they did last year, with above-average humidity suppressing daytime high temperatures and boosting nighttime lows. Arizona recorded near-record high statewide average temperatures from January to August 2015, while average temperatures in New Mexico for the same time period were among the state's top 10 warmest (Fig. 4). Extremely hot days have been rare, with fewer than average very hot days across the region.

**Monsoon**: Variable spatial coverage and intensity along with intermittent frequency of precipitation events makes it difficult to characterize any monsoon as "normal." That said, 2015 has been fairly typical for monsoon precipitation; the storms have been variable, most locations saw regular precipitation events that brought their total precipitation close to long-term averages, and, unlike last year, fewer locations recorded high-intensity precipitation events that dropped a full season or years' worth of precipitation in a single storm event (see Monsoon Tracker on pgs. 6-7 for details).

**Tropical Storm Activity**: During late summer and into fall, tropical storms in the eastern Pacific Ocean have a better chance to recurve back into the Southwest, rather than heading west across the Pacific Ocean. Record sea surface temperatures intensify these storms, upping the chance that an organized system will bring moisture (humidity) and precipitation to the Southwest. Despite regular incursions of tropical moisture, we have not seen many heavy precipitation events associated with tropical storms, as we did with Norbert and Odile in 2014, save for recent extreme flooding in northern Arizona and Utah. However, we are just past the midway point of the tropical storm season, leaving time for tropical storm systems to bring additional (possibly heavy) rainfall to the region.

**Drought & Water Supply**: The U.S. Drought Monitor identifies persistent multi-year drought across the West. Arizona and New Mexico are grappling with years of accumulated drought and water deficits, but water year precipitation has helped scale back drought conditions, particularly in New Mexico (see Reservoir Volumes on pg. 8 for details).

**Precipitation & Temperature Forecasts:** The Sept. 17 NOAA-Climate Prediction Center seasonal outlook predicts above-average precipitation for most of the Southwest this fall (Fig. 5, top). Notable exceptions are northern California and most of the Northwest. Temperature forecasts are split, with elevated chances for above-average temperatures along the West Coast and into southwestern Arizona, and increased chances for below-average temperatures centered over Texas and extending across most of New Mexico (Fig. 5, bottom).

## Tweet Sept SW Climate Outlook

CLICK TO TWEET

Sep2015 @CLIMAS_UA SW Climate Outlook - Monsoon, El Niño Tracker, SW Impacts, plus new El Niño information hub http://bit.ly/1LB03Hk

# Online Resources

**Figures 1-3**
**High Plains Regional Climate Center**
http://www.hprcc.unl.edu/

**Figure 4**
**NOAA - National Center for Environmental Information**
https://www.ncdc.noaa.gov/

**Figure 5**
**NOAA/NWS - Climate Prediction Center**
http://www.cpc.ncep.noaa.gov/

# CLIMAS YouTube Channel

Visit our YouTube channel for videos of content pulled from the podcast

www.youtube.com/user/UACLIMAS/

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# September Southwest Climate Outlook

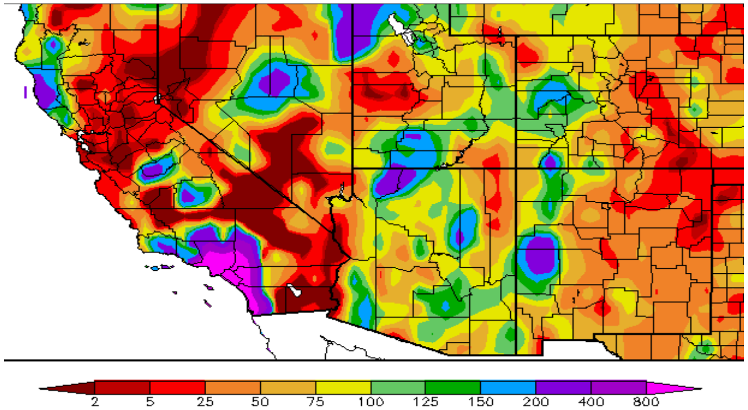

Figure 1: Percent of Normal Precipitation - Past 30 Days

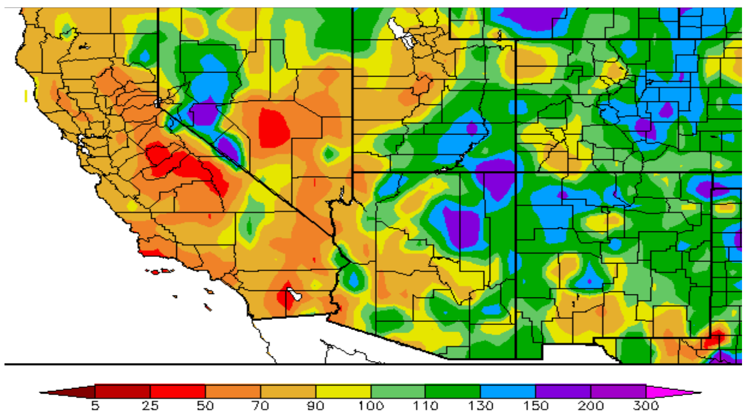

Figure 2: Percent of Normal Precipitation - Oct 1, 2014 - Sep 16, 2015

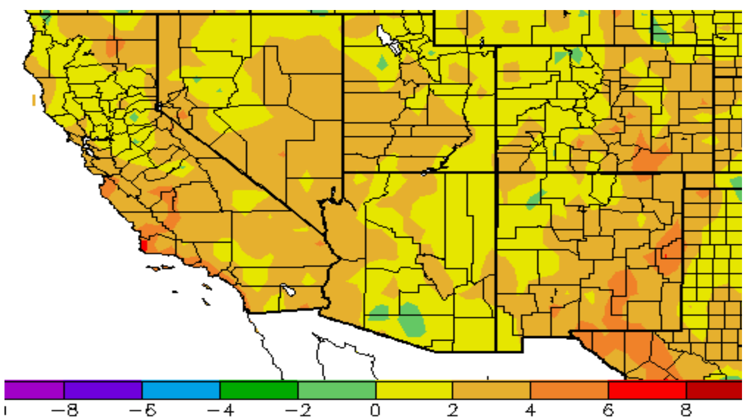

Figure 3: Departure from Average Temperature - Past 30 Days

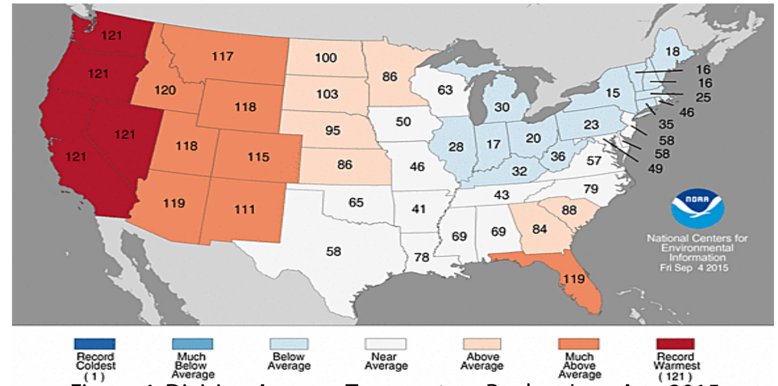

Figure 4: Division Average Temperature Ranks - Jan - Aug 2015

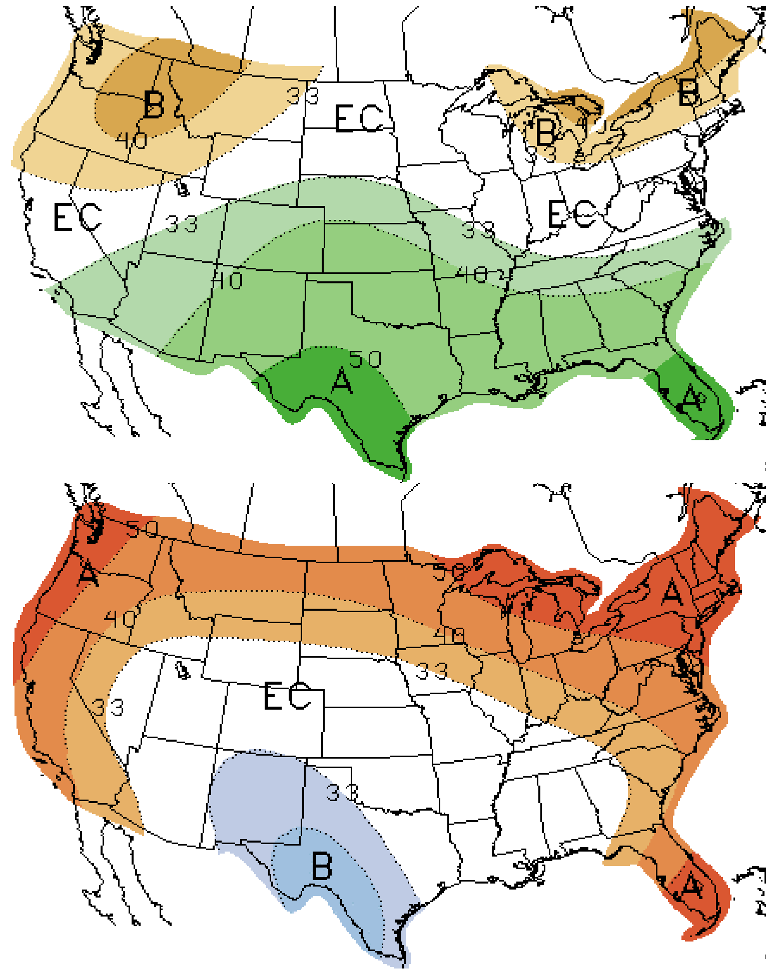

Figure 5: Three-Month Precipitation & Temperature Outlook - Sep 17, 2015

# El Niño-Southern Oscillation (ENSO)

We spent the better part of 2014 (and the first part of 2015) waiting in anticipation for an El Niño event that was initially forecast to be one of the stronger events on record. By early 2015 the event in question had not yet materialized, and some questioned whether El Niño would ever arrive. Eventually it did, and has been going strong for months, with most forecasts indicating that it will remain a strong event through the winter. As this event unfolds, there are numerous impacts we might expect to see across the southwest over the course of our cool season (approximately Oct - Mar). In the coming months, CLIMAS will aggregate news, information, and commentary about the possible and expected impacts of El Niño, from the perspective of what is most relevant and applicable to the Southwest. This will include what we have learned from past events, and what forecasting and models can tell us about planning for this event.

Please visit www.climas.arizona.edu/sw-climate/el-niño-southern-oscillation for more information. We will use that page as a central repository for our ENSO related outreach materials, and will update this information hub with timely and relevant information about El Niño throughout the winter.

# El Niño-Southern Oscillation (ENSO)

El Niño and La Niña are part of the El Niño-Southern Oscillation (ENSO), a natural fluctuation in oceanic sea surface temperatures (SSTs) and surface air pressure between the east and west tropical Pacific Ocean. During an El Niño event, easterly trade winds weaken, allowing warmer surface water from the western tropical Pacific Ocean to flow eastward. During a La Niña event, these trade winds intensify, preventing warmer water in the west from moving east, and stacking warm surface water in the west. Large areas of lower surface air pressure and convective precipitation follow the warmer water as it migrates across the tropical Pacific Ocean, altering broad-scale atmospheric circulation patterns (e.g., the Walker Circulation), which can influence weather around the world (Fig. 1).

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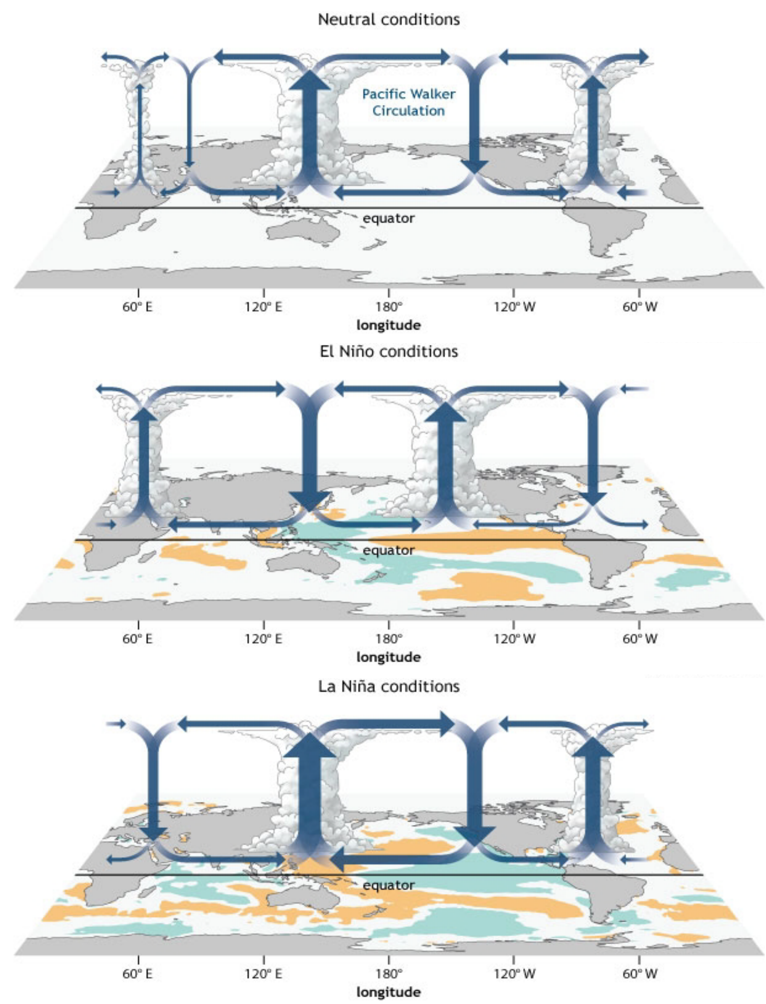


Figure 1: Global Atmospheric Circulation Patterns - Walker Circulation NOAA Climate.gov

## Online Resources

**Figure 1**
**NOAA - National Climatic Data Center**
http://www.ncdc.noaa.gov/teleconnections/enso/

## El Niño-Southern Oscillation

Information on this page is also found on the CLIMAS website:
www.climas.arizona.edu/sw-climate/el-niño-southern-oscillation

## Online Resources

**Figure 1**
**NOAA - Climate Prediction Center**
http://www.cpc.ncep.noaa.gov/

## El Niño-Southern Oscillation

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# The Effect of ENSO on SW Weather

El Niño and La Niña events tend to develop between April and June and peak between December and January, which means the U.S. Southwest sees the most prominent effects of ENSO circulation changes over winter and into early spring. The influence of ENSO on weather in the Southwest is tied to its ability to change the position of the jet stream—the winds aloft that steer storm systems and dictate where areas of high and low pressure are positioned. During El Niño events, the jet stream over the Pacific Ocean becomes less wavy and splits into a strengthening subtropical jet stream near the equator and a weaker polar jet stream (Fig. 2a), and can result in a greater number of storms and above-average precipitation across the Southwest during winter and early spring. La Niña events often bring drier-than-average winter conditions to the Southwest, as the jet stream curves and shifts north, diverting storms and precipitation away from the region (Fig. 2b). El Niño does not guarantee a wet winter, just as La Niña does not consistently deliver dry conditions, but these are the patterns most associated with these events.

ENSO's impact on summer weather is less clear, but El Niño events can delay the onset of the monsoon in Arizona and New Mexico by weakening and repositioning the subtropical high that guides moisture into the Southwest. El Niño events also influence development and strength of tropical storms in the eastern Pacific Ocean, and moisture associated with these storms has the potential to deliver above-average rain to the region, typically in late summer or early fall.

Precipitation anomalies influenced by ENSO also vary geographically, and the southern regions of Arizona and New Mexico tend to record larger positive precipitation anomalies during El Niño events when compared to northern regions. During La Niña events the general pattern is reversed, with reduced precipitation across the Southwest.

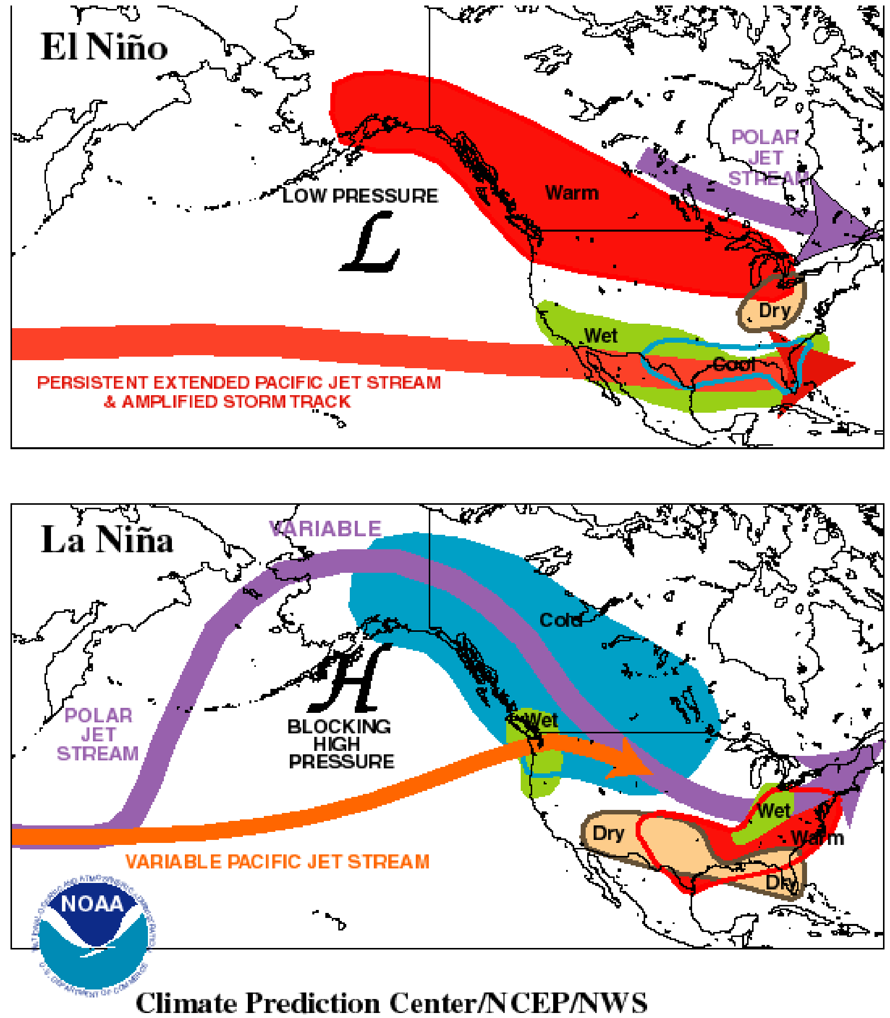


Figure 2: Typical Jet Stream Patterns During El Niño & La Niña Winters

## Online Resources

**Figure 1**
**Australian Bureau of Meteorology**
http://www.bom.gov.au/climate/enso/index.shtml

**Figure 2**
**NOAA - National Climatic Data Center**
http://www.ncdc.noaa.gov/teleconnections/enso/

**Figure 3**
**International Research Institute for Climate and Society**
http://iri.columbia.edu/our-expertise/climate/forecasts/enso/

**Figure 4**
**NOAA - Climate Prediction Center**
http://www.cpc.ncep.noaa.gov/products/NMME/current/plume.html

# 2015 El Niño Tracker

El Niño conditions continued for a seventh straight month, and forecasts and models indicate this event likely will last through spring 2016, remaining strong through the early part of the year. Forecasts focused on the persistence of sea-surface temperature (SST) anomalies (Figs.1–2) and weakened trade winds, ongoing convective activity in the central and eastern Pacific, and El Niño-related ocean-atmosphere coupling. On September 10, the Japan Meteorological Agency identified persistent El Niño conditions in the equatorial Pacific, especially SST anomalies and convective activity, and forecast that the current El Niño conditions were likely to persist through winter. That same day, the NOAA-Climate Prediction Center (CPC) extended its El Niño advisory, predicting a 95 percent chance that El Niño will continue through winter 2015–2016, with gradual weakening into spring 2016 (Fig. 3). The center cited persistent positive SST anomalies in the central and eastern Pacific and ongoing ocean-atmospheric coupling and convection activity as indicators of an ongoing and strengthening event. On September 15, the Australian Bureau of Meteorology maintained its tracker at official El Niño status; a strong event with the potential to exceed the 1997–1998 El Niño in strength. On September 17, the International Research Institute for Climate and Society (IRI) and CPC forecasts corroborated the forecast of a strong El Niño with the potential to rival the strongest events on record.

The North American multi-model ensemble currently shows a strong event extending into 2016 (Fig. 4). Emergent questions have centered on how this event compares to other strong events such as those in 1982–83 and 1997–98. If El Niño remains on this trajectory, it will likely be one of the top three strongest events on record since 1950. Sensationalistic media coverage already has started but it will be important to temper expectations without minimizing possible impacts. Forecast consensus is for a strong El Niño that extends into winter 2015–2016 and would likely bring above-average winter precipitation in the Southwest, particularly later in the season. It is important to note that this relationship suggests that a strong El Niño event gives the Southwest a much better chance at increased precipitation totals by March or April, but it is far from a guarantee of increased precipitation. In the more immediate future, El Niño conditions could lead to a repeat of 2014's above-average eastern Pacific tropical storm season, when conditions favorable to El Niño were thought to be driving increased tropical storm activity in the Southwest in September and October.

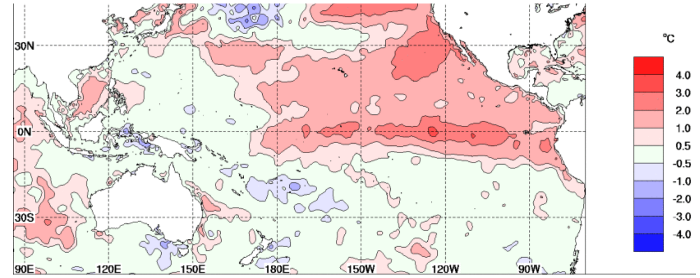

Figure 1: Aug 2015 Sea Surface Temperature (SST) Anomalies

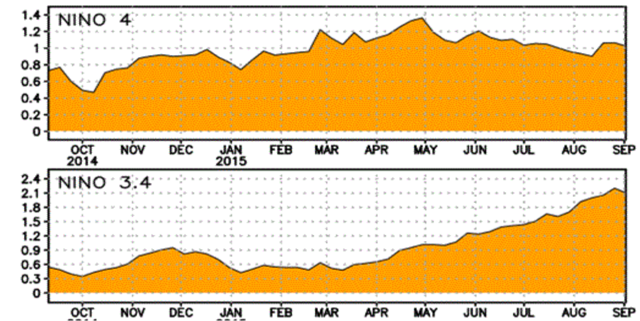

Figure 2: SST Anomalies in Niño Regions 3.4 & 4 (NCDC)

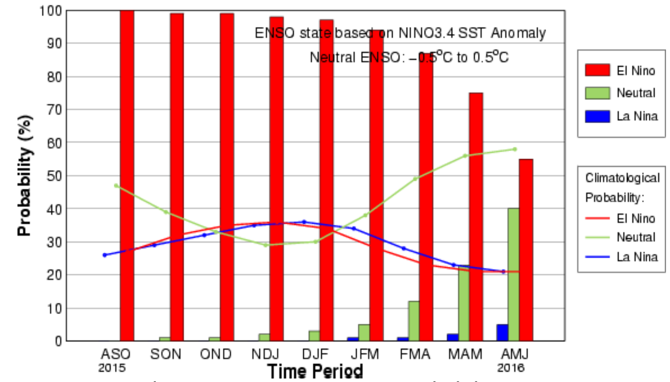

Figure 3: Early-Sept IRI/CPC Consensus Probabilistic ENSO Forecast

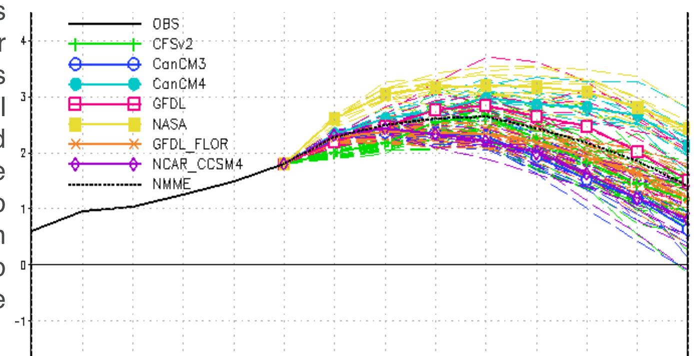

Figure 4: North American Multi-Model Ensemble Forecast for Niño 3.4

## Online Resources

**Figure 1**
**National Center for Environmental Information**
https://www.ncdc.noaa.gov

**Figure 2**
**NOAA - National Weather Service**
http://www.wrh.noaa.gov/twc/monsoon/dewpoint_tracker.php

## North American Monsoon

While the monsoon technically ends September 30, the transition can start sooner. There is some indication we may see one last gasp of monsoon activity in the next week, but we are far more likely to see precipitation as a result of tropical storm activity. In next month's *Southwest Climate Outlook*, and in a special episode of the Soutwest Climate Podcast, we will conduct a monsoon retrospective for 2015, providing overarching commentary on this year's monsoon.

# Monsoon Summary (June 15 - Sept 17)

The monsoon started strong in late June and early July. This early start centered on Arizona, which recorded its second wettest June on record (Fig. 1a), with a return to relatively normal rainfall totals in July. New Mexico saw an increase in precipitation, recording its 10th wettest July on record (Fig. 1b). Rainfall in August and September was mostly below average, which is characteristic of the North American monsoon's sporadic and spatially limited precipitation events.

These shifts in persistence and intensity are tied to the strength and location of the monsoon ridge, which, depending on its location, can facilitate the flow of organized storm activity from the south or east (during increased monsoon activity) or can shift the flow such that we see extended periods of decreased precipitation. The later season weakening of the monsoon ridge since early July is likely due at least in part to increasing El Niño convection. With this El Niño event set to be one of the strongest on record, it is not surprising that it may have had an expected disruptive effect on monsoon circulation. We also continue to watch eastern Pacific tropical storm activity as it helps drive moisture into the region, a pattern we've seen repeatedly in the past few weeks with a number of tropical storm systems, particularly Linda. The effects of these systems can be intense and spatially variable, with southern Arizona experiencing increased humidity and little additional precipitation, compared to serious flooding in northern Arizona and southern Utah. Regional dewpoint readings also illustrate the variability of monsoon activity and the influence of tropical storm activity (Fig. 2).

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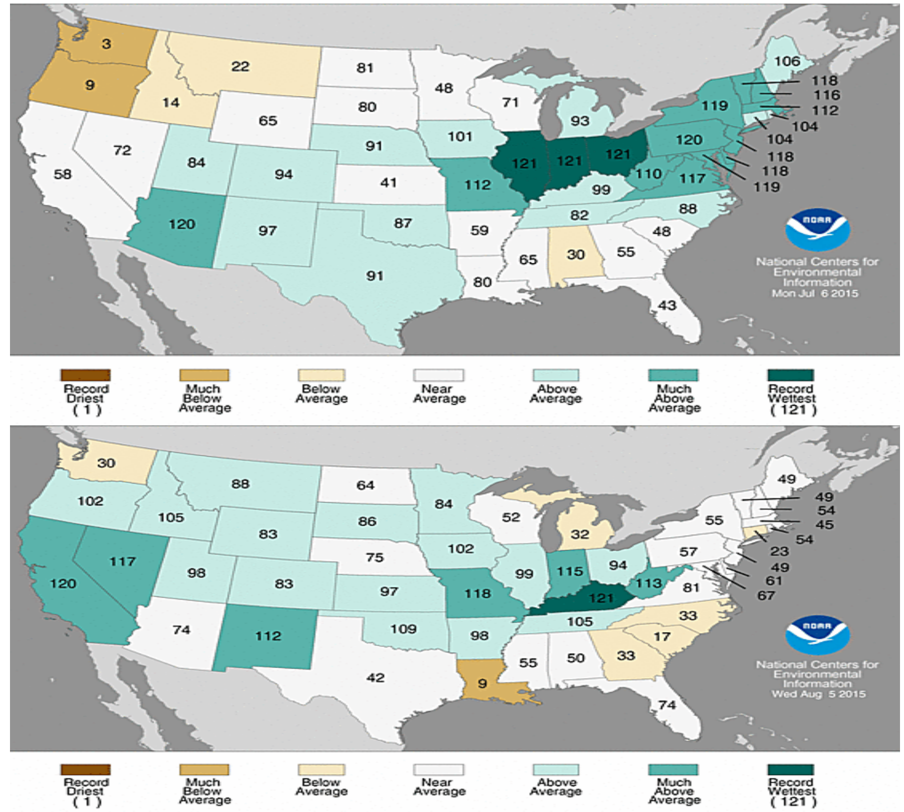



Figure 1: Statewide Precipitation Ranks June (A) & July (B) 2015

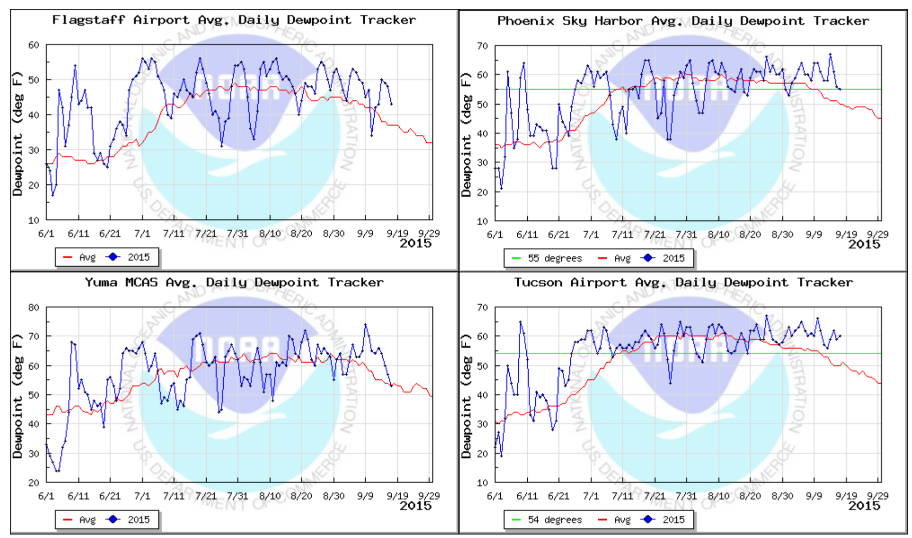



Figure 2: Average Daily Dewpoint Tracker - Flagstaff - Phoenix - Yuma - Tucson

## Online Resources

**Figures 3-6**
**Climate Science Applications Program**
http://cals.arizona.edu/climate/

# Monsoon Summary (June 15 - Sept 15)

Looking at cumulative totals to date for the 2015 monsoon, precipitation as a percent of average demonstrates the spatial variability of monsoon precipitation (Figs. 3a–b), while raw precipitation totals show the wide range of normal precipitation totals we see across the Southwest (Figs. 4a–b). These totals can be skewed by a few strong events or even a single strong storm; the percent of days with rain (Figs. 5a–b) highlights the regularity of monsoon precipitation thus far, with much of Arizona and nearly all of New Mexico recording rain events (greater than 0.01 inch) on at least 25 percent of days since June 15. The daily intensity index (Figs. 6a–b) further illustrates the steady nature of most of this monsoon precipitation; higher values indicate much of the rain fell in a single event and lower values indicate more frequent and less intense events.

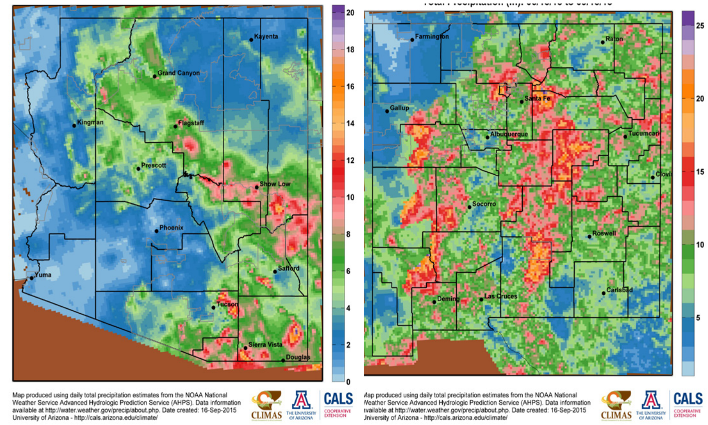


Figure 4a-b: Total Precipitation - Jun 15 - Sep 15

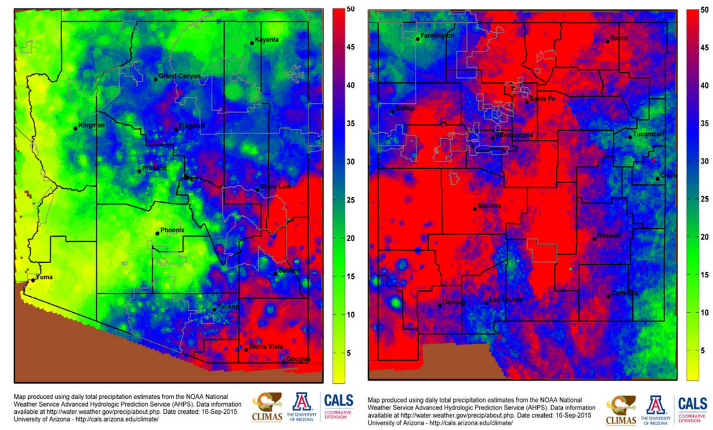


Figure 5a-b: Percent of Days With Rain (>0.01") - Jun 15 - Sep 15

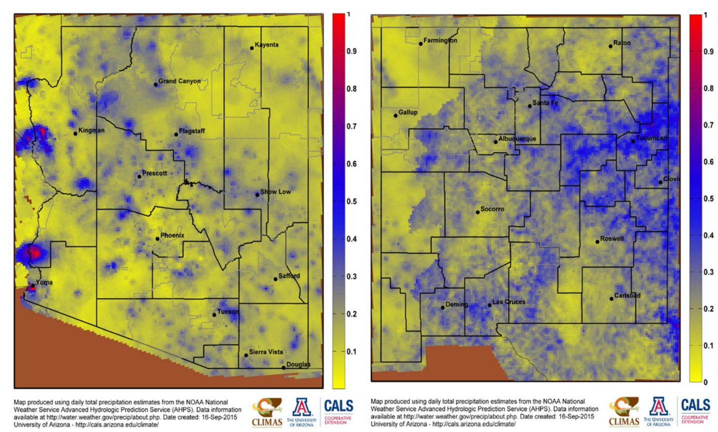


Figure 6a-b: Daily Intensity Index (total precip/days with rain) - Jun 15 - Sep 15

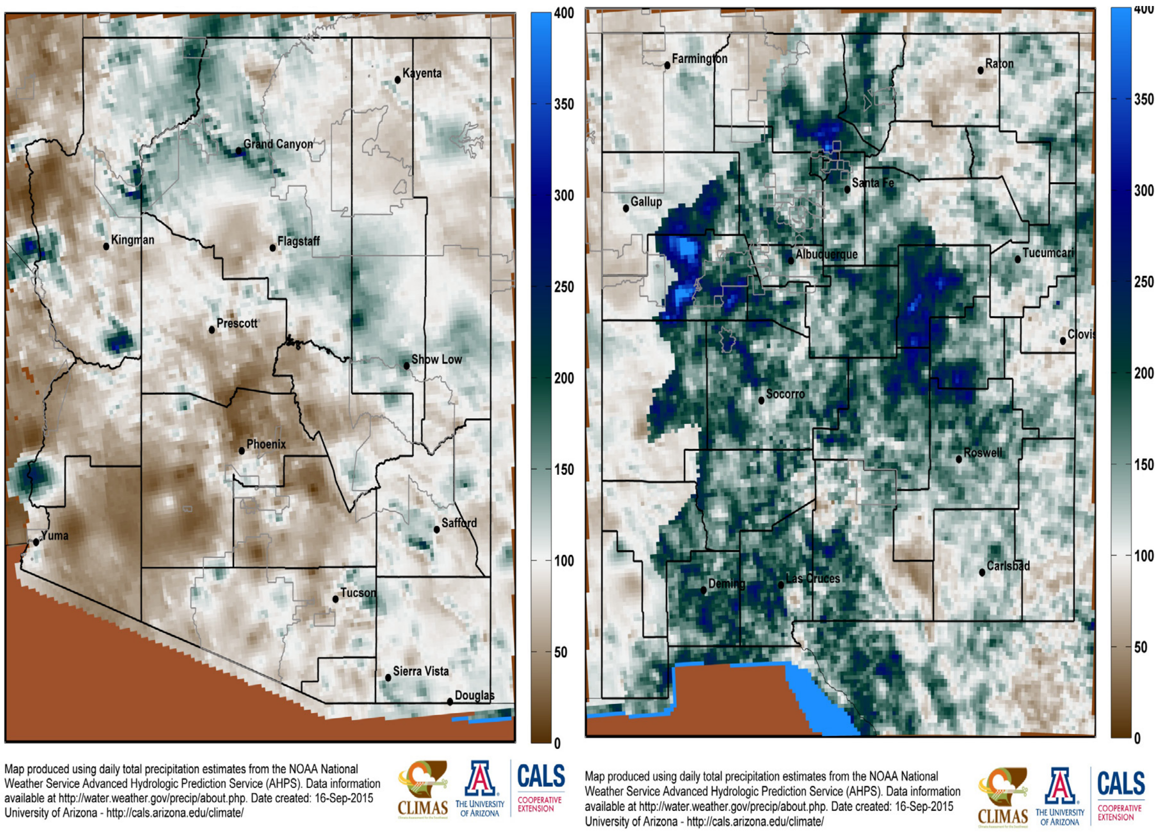



Figure 3a-b: Percent of Average Precipitation - Jun 15 - Sep 15

## Online Resources

**Portions of the information provided in this figure can be accessed at the Natural Resources Conservation Service**

Arizona: http://1.usa.gov/19e2BdJ

New Mexico: http://www.wcc.nrcs.usda.gov/cgibin/resv_rpt.pl?state=new_mexico

We recently updated reservoir conservation storage totals for Abiquiu, Brantley, & Cochiti reservoirs, and added Ute Reservoir. All values are subject to change as we update our database.

Contact Ben McMahan with any questions or comments about these or any other suggested revisions

### Notes

The map gives a representation of current storage for reservoirs in Arizona and New Mexico. Reservoir locations are numbered within the blue circles on the map, corresponding to the reservoirs listed in the table. The cup next to each reservoir shows the current storage (blue fill) as a percent of total capacity. Note that while the size of each cup varies with the size of the reservoir, these are representational and not to scale. Each cup also represents last year's storage (dotted line) and the 1981–2010 reservoir average (red line).

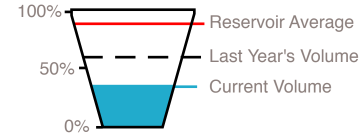
The table details more exactly the current capacity (listed as a percent of maximum storage). Current and maximum storage are given in thousands of acre-feet for each reservoir. One acre-foot is the volume of water sufficient to cover an acre of land to a depth of 1 foot (approximately 325,851 gallons). On average, 1 acre-foot of water is enough to meet the demands of four people for a year. The last column of the table lists an increase or decrease in storage since last month. A line indicates no change.

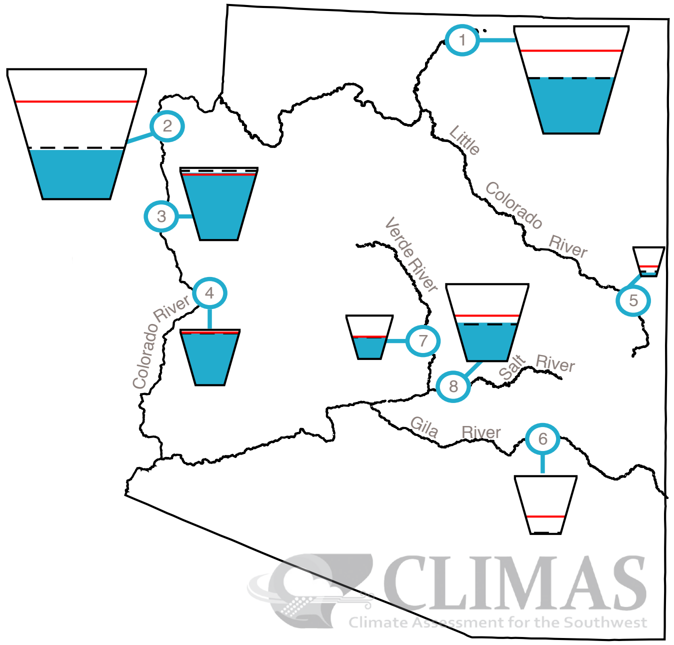
These data are based on reservoir reports updated monthly by the National Water and Climate Center of the U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS).

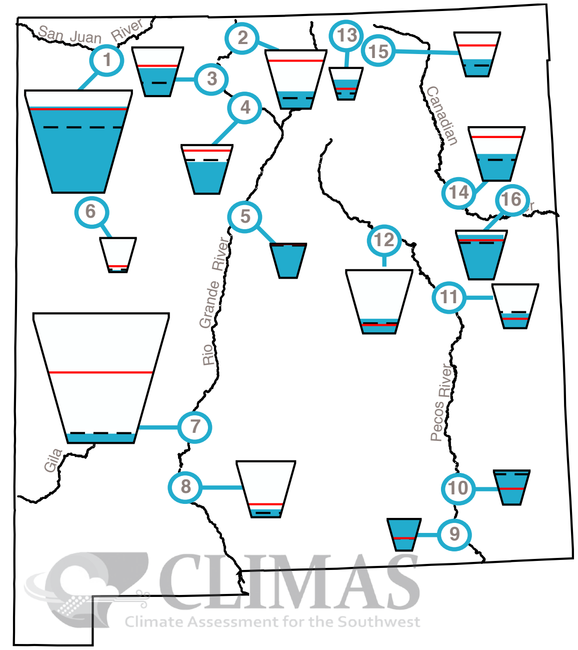
# Reservoir Volumes

DATA THROUGH AUGUST 31, 2015

**Data Source: National Water and Climate Center, Natural Resources Conservation Service**




| Reservoir | Capacity | Current Storage* | Max Storage* | One-Month Change in Storage* |
|---|---|---|---|---|
| 1. Lake Powell | 52% | 12,636.9 | 24,322.0 | -396.7 |
| 2. Lake Mead | 38% | 9,871.0 | 26,159.0 | 13.0 |
| 3. Lake Mohave | 93% | 1,674.7 | 1,810.0 | -12.2 |
| 4. Lake Havasu | 95% | 585.8 | 619.0 | 6.0 |
| 5. Lyman | 13% | 3.8 | 30.0 | 0.4 |
| 6. San Carlos | 1% | 12.1 | 875.0 | -23.8 |
| 7. Verde River System | 51% | 146.9 | 287.4 | -2.7 |
| 8. Salt River System | 50% | 1,007.7 | 2,025.8 | -35.6 |

*KAF: thousands of acre-feet

| Reservoir | Capacity | Current Storage* | Max Storage* | One-Month Change in Storage* |
|---|---|---|---|---|
| 1. Navajo | 84% | 1,419.7 | 1,696.0 | -42.7 |
| 2. Heron | 30% | 118.6 | 400.0 | -20.5 |
| 3. El Vado | 57% | 107.8 | 190.3 | -6.8 |
| 4. Abiquiu | 65% | 121.6 | 186.8** | 1.5 |
| 5. Cochiti | 96% | 48.2 | 50.0** | -0.4 |
| 6. Bluewater | 6% | 2.3 | 38.5 | 0.0 |
| 7. Elephant Butte | 8% | 185.8 | 2,195.0 | -97.7 |
| 8. Caballo | 14% | 45.6 | 332.0 | 28.8 |
| 9. Lake Avalon | 128% | 5.1 | 4.0 | 2.9 |
| 10. Brantley | 122% | 51.3 | 1,008.2 | -20.0 |
| 11. Sumner | 33% | 33.5 | 102.0 | 0.1 |
| 12. Santa Rosa | 23% | 101.6 | 438.3 | 2.7 |
| 13. Costilla | 63% | 10.0 | 16.0 | -1.9 |
| 14. Conchas | 49% | 124.6 | 254.2 | 12.5 |
| 15. Eagle Nest | 39% | 31.0 | 79.0 | 0.1 |
| 16. Ute Reservoir | 91% | 182 | 200 | 21.0 |