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September Southwest Climate Outlook

Precipitation: In the past 30 days, monsoon activity brought above-average precipitation to much of Arizona and New Mexico. But despite large-scale patterns of above-average overall precipitation, the coverage was not universal. Certain areas, such as the Four Corners region, continue to suffer from both short-term drought and accumulated water deficits (longer-term drought). Tropical storm systems complicated the precipitation picture, affecting the accumulated totals by producing record or near-record rainfall and causing widespread flooding.

Temperature: Monsoon storms continue to drive temperature variability on a day-to-day basis, but over the past 30 days, most of Arizona saw slightly below-average temperatures while New Mexico was closer to average temperatures.

Water Supply: In Arizona, total reservoir storage dropped by about 135,000 acre-feet (AF) in August, putting total reservoir capacity at 46 percent (compared to 48 percent last year). In New Mexico, the total reservoir capacity in August was 26 percent, compared to 16 percent last year. Lake Mead continues to receive attention as concerns over drought and water supply persist, and Lakes Mead and Powell are both running well below maximum capacity (39 and 51 percent, respectively). Despite substantial rainfall as part of monsoon and tropical systems, the spatial variability of these storms means they have done little to mitigate the effects of long-term drought on regional water supplies.

Drought: Above-average monsoon precipitation in conjunction with moisture from tropical storm events reduced the scale and extent of short-term drought conditions; long-term drought conditions persist throughout Arizona and New Mexico.

Monsoon: The monsoon has been strong in Arizona and New Mexico, with most of Arizona and much of New Mexico receiving above-average precipitation. Widespread areas received over 100 percent of average precipitation, with a large subset receiving 150-200 percent of average, and smaller areas have even seen 200-400 percent of average precipitation. The notable exceptions to this pattern are in the Four Corners region, northeastern New Mexico, and portions of Pinal and Pima counties in Arizona. A caveat applies to many of the higher measurements, given that in a number of cases, storms dropped an entire month's or year's worth of precipitation in a single storm event. Such occurrences drastically increase the overall totals for the year, but these intense storms do not provide the same kind of drought relief as steadier and more consistent precipitation, not to mention their destructive potential (see the SW climate podcast from Aug 2014 for details).

ENSO: El Niño remains in a holding pattern as ENSO-neutral conditions persist. The projections remain at a 65 to 70 percent probability for the development of an El Niño event, with most projections pointing towards a weak-to-moderate event if and when one develops. A strong event is widely thought to be off the table.

Precipitation & Temperature Forecasts: Longer-term forecasts point toward above-average precipitation for Arizona and New Mexico, especially if an El Niño event eventually develops. As we approach fall and winter, the prospect of an El Niño event, regardless of strength, suggests an increased probability of below-average temperatures for the Southwest.

Tweet Sept SW Climate Snapshot

CLICK TO TWEET

.@CLIMAS_UA Sept SW Climate Outlook: Strong Monsoon, Tropical Storm Q&A, and (still) waiting for El Niño @ http://goo.gl/WCy3uK

Online Resources

Figure 1-3
Climate Science Applications Program - University of Arizona Cooperative Extension
http://cals.arizona.edu/climate/misc/monsoon/az_monsoon.html

Figure 4-6

CSAP - University of Arizona Cooperative Extension
http://cals.arizona.edu/climate/misc/monsoon/nm_monsoon.html

Figure 7.
CSAP - University of Arizona Cooperative Extension
http://cals.arizona.edu/climate/misc/monsoon/az_recent_precip.jpg

For more maps and other climate information, visit the Climate Science Applications Program (CSAP):

http://cals.arizona.edu/climate/

Monsoon Summary (June 15 – Sep 18)

We are nearing the end of the 2014 season, and while it is difficult to characterize the highly variable day-to-day storms of any monsoon as "normal," we have had a fairly typical if not above-average monsoon season in terms of precipitation. Regional assessment is complicated by the effects of a few extreme events that amplified precipitation amounts in parts of Arizona and New Mexico and caused an entire month's or year's worth of precipitation to fall in a single storm.

Southeast, southern, west-central, and the high-elevation areas of central Arizona have all seen impressive monsoon totals, with precipitation ranging from 200 to 400 percent of average. Most of Arizona, in fact, has seen above-average seasonal monsoon precipitation (100-200 percent of average) with the exception of the Four Corners region, which is struggling with below-average precipitation and long-term drought (Figure 1). The intensity of these storms, measured as the ratio of total precipitation over the time period to the number of days observing rain, in inches per day (Figure 2), reveals that some areas—western Arizona in particular—received a significant portion of their monsoon precipitation in a few extreme events, and in some cases a single storm. These intense storms offer little in the way of long-term drought relief but pose major threats in terms of their destructive potential, especially in urban/metropolitan areas. Figure 3 (the percentage of days observing 0.01 inch or more) illustrates which areas received more consistent and steady rain.

New Mexico has seen a strong monsoon as well, with most of the state receiving well-above-average precipitation, and large portions of central and southern New Mexico receiving 200 percent or greater of average precipitation. As with Arizona, the Four Corners region is below average, as is the northeastern corner of the state (Figure 4). Maps of the intensity and frequency of monsoon precipitation in New Mexico (Figures 5 and 6, respectively) show larger areas of more frequent, less intense storms. This precipitation should help mitigate short-term drought conditions, but long-term deficits remain.

Tropical storms have been active in the Pacific, and while early-season storms veered into the Pacific Ocean, recent storms (Marie, Norbert, and Odile) have followed the later-season pattern of re-curve into the Pacific coast, boosting precipitation in the Southwest (albeit in a highly variable way). Norbert caused considerable flooding in Phoenix and to a lesser extent in Tucson, and on September 17 Odile caused most of southern Arizona and New Mexico to brace for the worst, with projections of 3-6 inches of rain for those in the direct path. The storm eventually swung south, and most of the impacts were felt in northern Mexico and far-southern Arizona (Figure 7).

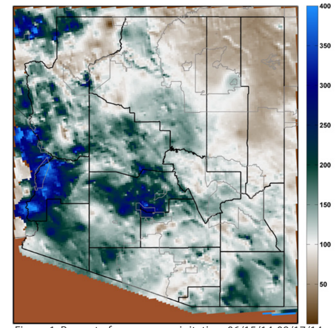


Figure 1: Percent of average precipitation: 06/15/14-09/17/14

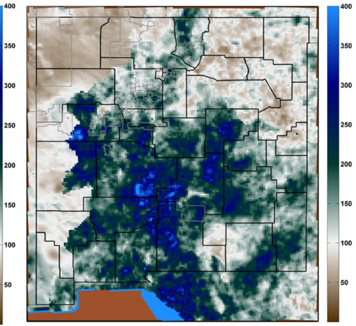


Figure 4: Percent of average precipitation 06/15/14-09/17/14

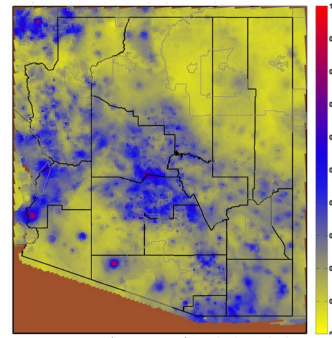


Figure 2: Daily intensity index 06/15/14-09/17/14

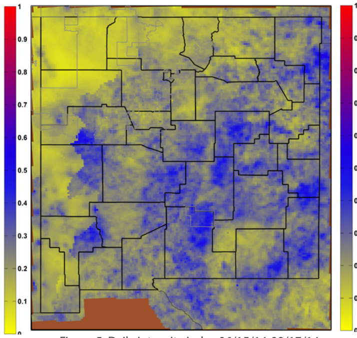


Figure 5: Daily intensity index 06/15/14-09/17/14

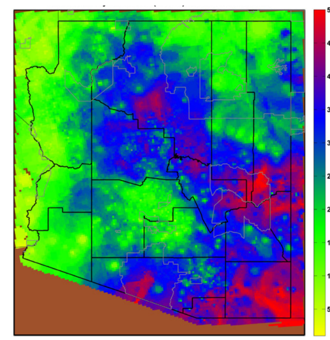


Figure 3: Percent of days with rain 06/15/14-09/17/14

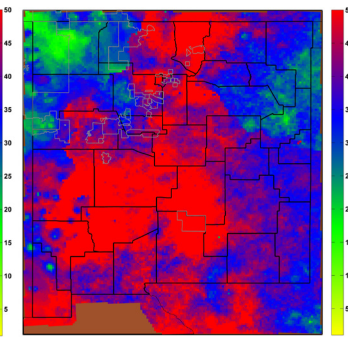


Figure 6: Percent of days with rain 06/15/14-09/17/14

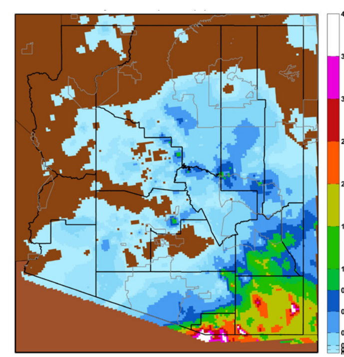


Figure 7: Single day rain total 09/17/14 (Hurricane/TS Odile)

Online Resources

Figure 1.
International Research Institute for Climate & Society
http://iri.columbia.edu/our-expertise/climate/forecasts/enso/

CLIMAS Podcasts

Visit our website or iTunes to subscribe to our podcast feed

www.climas.arizona.edu/media/podcasts

https://itunes.apple.com/us/itunes-u/climate-in-the-southwest/id413143045

2014-15 El Niño Tracker

The song remains the same this month with El Niño not quite here yet, but probably soon. This is now the seventh consecutive month since the NOAA Climate Prediction Center issued an “El Niño Watch” last March. The signs are a bit stronger once again, but it is getting late in the game since El Niño events take several months to build up and typically peak during the mid-winter months. Another slug of warm water (known as a “Kelvin Wave”) has been making its way across the Pacific Ocean from west to east just below the surface and is poised to emerge and help warm sea-surface temperatures in the eastern Pacific over the next month or so. There has also been some activity in the western and central Pacific called “westerly wind bursts” which can help move this warmer-than-average water to the east, but the bursts have been temporary and haven’t helped sustain a steady progression towards El Niño conditions.

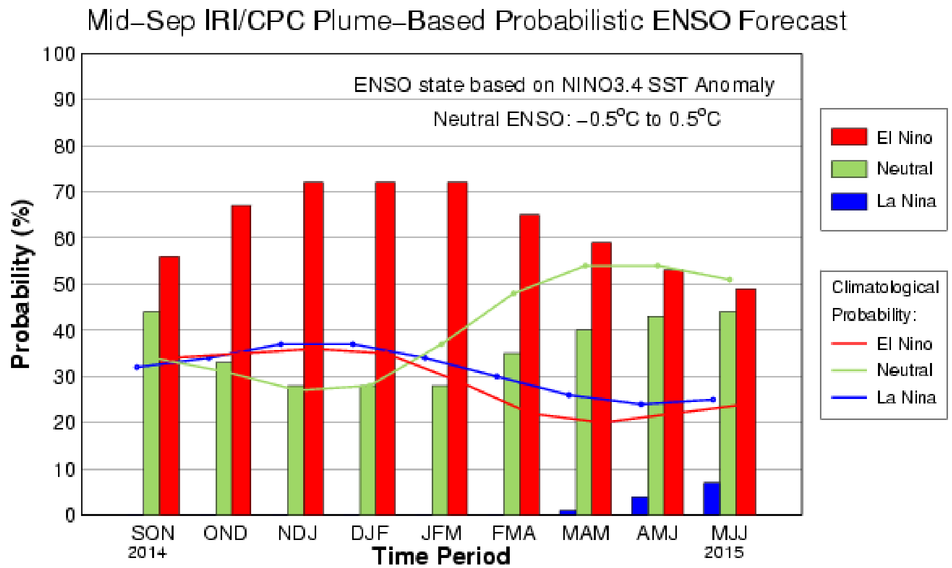


Figure 1: ENSO State based on NINO 3.4 SST Anomaly - Sept 18, 2014

Forecasts models are predicting the current Kelvin Wave and associated warm water in the east Pacific will finally get this fickle event to organize and roll forward as at least a weak El Niño. The mid-September consensus forecast (Figure 1) issued by the International Research Institute for Climate and Society (IRI) and the NOAA Climate Prediction Center (NOAA-CPC) still indicate a greater than 70 percent chance of El Niño conditions developing during the November-December-January period and most likely persisting through early next spring. Most models indicate that the event will ultimately peak at a weak strength, with only a handful of models suggesting a moderate-strength event. The impacts associated with weak El Niño events are much less certain; past events have brought both dry and wet conditions to the southwest U.S. during the winter season. Seasonal precipitation forecasts still indicate an enhanced chance of above-average precipitation over the upcoming winter season, but confidence in this forecast has wavered slightly because of the expected weak nature of the emerging El Niño event.

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

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).

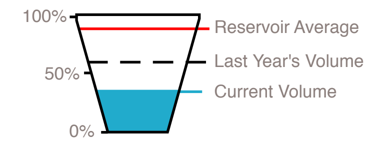
The table details more exactly the current capacity (listed as a percent of maximum storage). Current and maximum storage are given in thousands of acre-feet for each reservoir. One acre-foot is the volume of water sufficient to cover an acre of land to a depth of 1 foot (approximately 325,851 gallons). On average, 1 acre-foot of water is enough to meet the demands of 4 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.

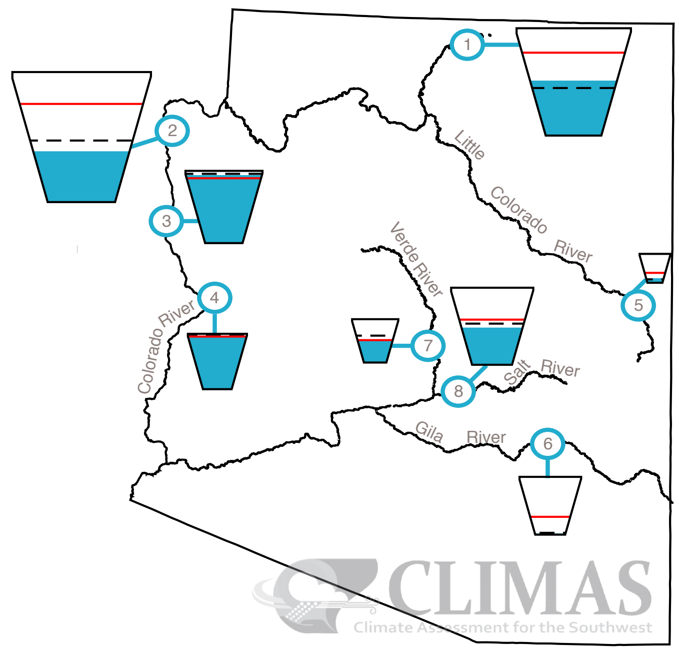
These data are based on reservoir reports updated monthly by the National Water and Climate Center of the U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS).

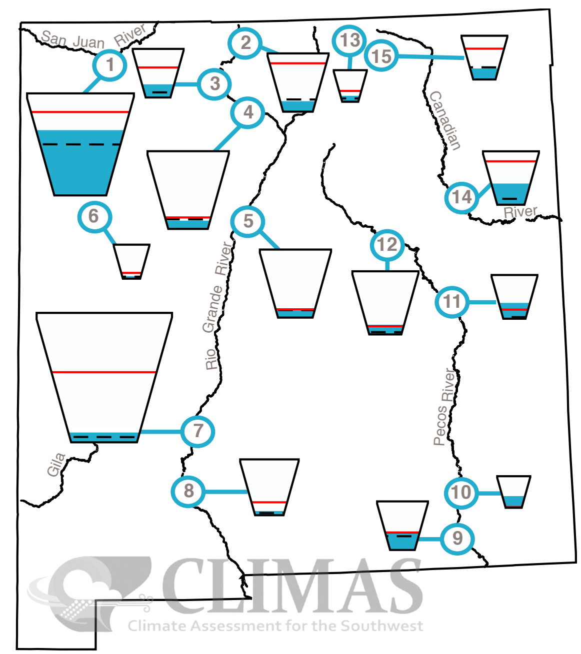
Reservoir Volumes

DATA THROUGH AUGUST 31, 2014

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







Reservoir Name	Capacity	Current Storage*	Max Storage*	One-Month Change in Storage*
1. Lake Powell	51%	12,314.0	24,322.0	-221.0
2. Lake Mead	39%	10,140.0	26,159.0	79.0
3. Lake Mohave	95%	1,710.5	1,810.0	9.2
4. Lake Havasu	94%	581.9	619.0	-3.3
5. Lyman	16%	4.7	30.0	-0.7
6. San Carlos	2%	20.5	875.0	10.0
7. Verde River System	50%	143.1	287.4	16.6
8. Salt River System	48%	979.2	2,025.8	-26.0

*thousands of acre-feet

Reservoir Name	Capacity (% capacity)	Current Storage (KAF)*	Max Storage (KAF)*	Change in Storage (KAF)*
1. Navajo	64%	1088.4	1,696.0	-46.5
2. Heron	18%	70.8	400.0	-6.2
3. El Vado	27%	51.6	190.3	-12.0
4. Abiquiu	11%	129.6	1,192.8	3.5
5. Cochiti	10%	47.7	491.0	-0.9
6. Bluewater	7%	2.8	38.5	-0.1
7. Elephant Butte	7%	154.0	2,195.0	20.1
8. Caballo	7%	22.3	332.0	-9.3
9. Lake Avalon	38%	1.5	4.0	0.1
10. Brantley	37%	374.5	1,008.2	339.6
11. Sumner	36%	36.5	102.0	-9.5
12. Santa Rosa	16%	71.7	438.3	18.4
13. Costilla	19%	3,1	16.0	-0.9
14. Conchas	38.9%	99.0	254.2	-2.3
15. Eagle Nest	24.7%	19.5	79.0	-0.1

* KAF = thousands of acre-feet

Southwestern Oscillations

A longer version of this article can be found on the CLIMAS blog

http://www.climas.arizona.edu/blog

http://www.climas.arizona.edu/blog/notes-applied-climatologist-tropical-storms-and-southwest-qa

Online Resources

Figure 1.
NOAA National Weather Service
http://www.wrh.noaa.gov/twc/tropical/tropical.php

Figure 2.
NOAA National Weather Service
http://www.wrh.noaa.gov/twc/tropical/tropical.php

Figure 3.
NOAA National Weather Service
http://www.wrh.noaa.gov/twc/tropical/Octave_1983.php

Notes from an Applied Climatologist: Tropical Storms and the Southwest

How do (Pacific) tropical storms affect the weather patterns of the Southwest?

The eastern Pacific Ocean along the west coast of Mexico and central America is an area of active tropical storm formation through the summer and early fall (typically between June and September). Warm water and light winds create the perfect conditions in this region for thunderstorms to flare up and eventually organize into tropical storms and hurricanes.

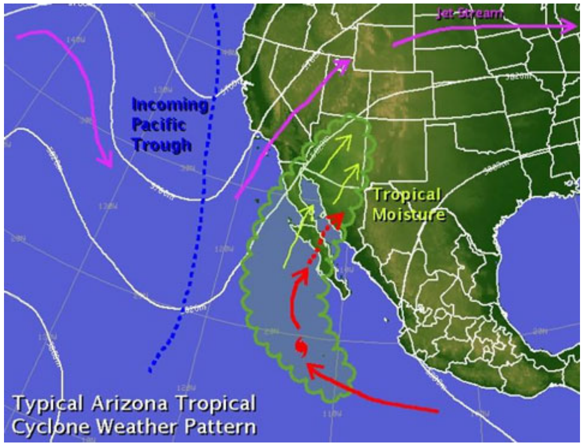


Figure 1: Tropical moisture surges fuel SW monsoons

Surprisingly, these storms impact the landlocked southwest U.S. in a variety of ways. The most common is by inducing surges of moisture up the Gulf of California into Arizona that can fuel widespread outbreaks of monsoon season thunderstorms. Clusters of storms or tropical systems that pass near the mouth of the Gulf of California can produce a cool outflow of winds and create a pressure differential up the Gulf of California. This pressure differential leads to the surge of moisture traveling northward into the low deserts of Arizona and into southern California (Figure 1).

Tropical storms and hurricanes in the eastern Pacific occasionally can impact the Southwest through a direct hit (Figure 2). Easterly winds will typically carry eastern Pacific storms west out to sea, but storms that take a more northwesterly track along the Mexican coast can eventually track north or even northeast. This typically happens in late summer or in early fall as the subtropical high pressure system retreats south, giving way to very light winds aloft in no particular direction or to stronger westerly winds advancing from the north—the sign of fall approaching. When tropical storms move north and aren't steered away from the coast of Mexico, they can continue to wander north or get caught up in westerly flow aloft and move inland towards southern California and Arizona.

Hurricanes weaken quickly when they encounter land and break away from their energy source of warm ocean water, so only weak tropical storms or 'remnant' low-pressure systems actually reach inland locations like Arizona. Still, these systems are often potent rain producers, bringing abundant moisture and a source of lift to produce widespread thunderstorms and associated flash-flooding events. The infamous flash-flooding disaster that occurred in Arizona in October 1983 was caused by tropical storm Octave, which produced record precipitation and catastrophic flooding across much of the state (Figure 3).

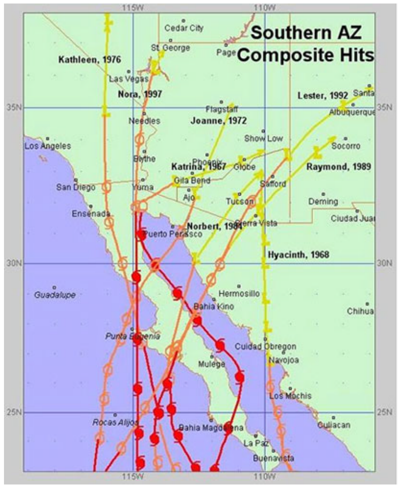


Figure 2: SW tropical storm tracks

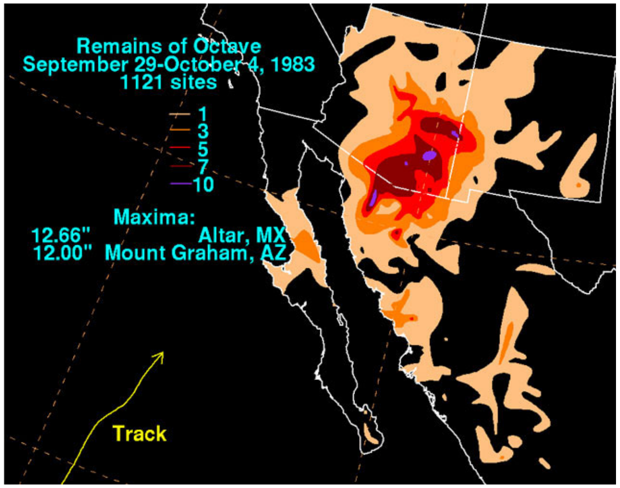


Figure 3: Hurricane Octave (1983) track and precipitation amounts

Southwestern Oscillations

A longer version of this article can be found on the CLIMAS blog

http://www.climas.arizona.edu/blog

http://www.climas.arizona.edu/blog/notes-applied-climatologist-precipitable-water-qa

Online Resources

Figure 1.
Cooperative Institute for Meteorological Satellite Studies (CIMSS)
http://tropic.ssec.wisc.edu/real-time/mimic-tpw/epac/main.html

Notes from an Applied Climatologist: Precipitable Water Q&A

What are the different ways that moisture is tracked?

Measuring accumulated precipitation is a (relatively) straightforward process that primarily involves a ground-based network of rain gauges that measure the depth of rainfall that accumulates. Some gauges, like tipping bucket gauges, also measure intensity.

Tracking the atmospheric moisture that sets the stage for precipitation events is a much more complicated endeavor. Atmospheric moisture varies at all levels in the troposphere—the lowest level of the Earth's atmosphere and where our weather happens. Therefore a three-dimensional (really four-dimensional when you consider these measurements are made over time) approach is needed to measure and track atmospheric moisture.

The primary way that the vertical dimension of the atmosphere is sampled is with weather balloons. Radiosondes—instrument packages attached to helium balloons—measure atmospheric pressure, temperature, and humidity as they quickly (about 1,000 ft/minute) ascend into the troposphere. Such balloons are released twice a day at approximately 1,000 locations across the globe. The data collected through each launch creates an atmospheric profile of the wind, temperature, and humidity patterns above that location. This atmospheric profile is fed into global weather models and is a critical component of accurate forecasting.

With respect to atmospheric moisture, the vertical profile gives an indication of where and how much moisture is available for supporting the development of precipitation. High amounts of low-level moisture near the surface can be an important source of fuel in the development of unstable air and convective thunderstorms. High amounts of mid-level moisture can sometimes support high-based thunderstorms where the rain that falls evaporates while falling into drier lower levels, producing strong outflows and gusty winds at the surface. When moisture is present at all levels in the atmosphere, widespread, heavy rainfall events can develop.

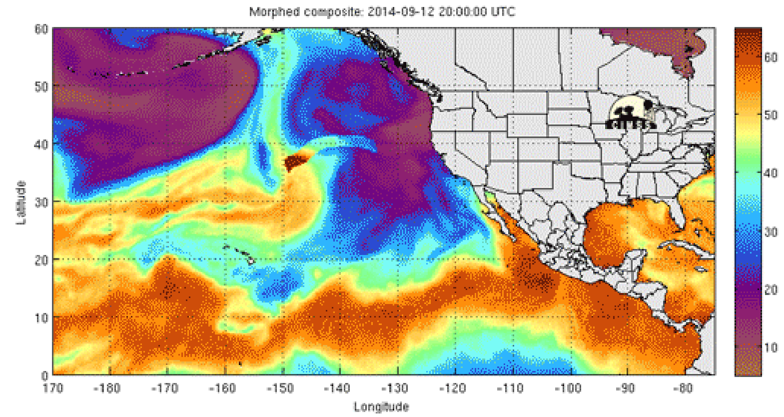


Figure 1: Precipitable Water (mm) during Hurricane/TS Odile

Precipitable Water

One way of quantifying the total amount of moisture in a vertical atmospheric profile is through the calculation of a metric called precipitable water. This is the amount of water (often in a depth of inches or millimeters) that could be condensed out of a vertical column of air extending up through the troposphere. This value is calculated with the data from each twice-daily radiosonde sounding and is also estimated from satellite data (Figure 1).

Precipitable water values are carefully monitored across the southwest U.S. throughout the monsoon season because they help diagnose the amount of moisture available to fuel convective thunderstorms and heavy rain events. Values through the monsoon season can vary widely across the Southwest, but as an example, daily values in Tucson are typically between 1 and 1.5 inches. Higher-elevation areas naturally have a thinner atmosphere, so precipitable water values will be lower.

To put these values in context, the precipitable water value at Tucson collected from the morning radiosonde on September 8, the day that widespread flooding occurred across Phoenix and Tucson, was 2 inches, a record high value for September at that location. Furthermore, the 2 inches of precipitable water actually produced much higher local precipitation amounts. This was able to occur because converging air can cause precipitable water to pile up and feed individual storms, leading to much higher local precipitation amounts than would be achieved by simply squeezing the water out of a single column of air.