A One-Month Wonder: spottiness and brevity characterize 2010 monsoon season

By Zack Guido

The 2010 monsoon season in the Southwest was lackluster at first glance. Clouds arrived late. Storms burst in fits and starts only briefly. And then the rains disappeared. By the middle of September, the seasonal precipitation total was a drab near average.

Describing this monsoon season as average, however, would be a slight. It had many peculiarities, according to climatologists and meteorologists at universities and National Weather Service offices around the Southwest.

"I can't think of another year I would characterize as similar," said Dave Gutzler, professor of earth and planetary sciences at the University of New Mexico and someone who has focused his attention on understanding the monsoon in the Southwest.

The rapid transition from El Niño to La Niña helped set the stage for the delayed arrival. Rain had higher variability from place to place than is typical. Humidity was high even in periods without rain. Storms were glued to the mountains. Nighttime temperatures soared. And most of the rain came in a four-week period, leaving many forecasters and climatologists calling this season a one-month wonder.

While it's too early to have crunched data and weave these pieces into a coherent story—two weeks remain to squeeze monsoon moisture from the atmosphere—exploring the characteristics and their causes will help place this season into a proper context.

The Sun Primes the Monsoon

Monsoon rains contribute more than 40 percent of the annual precipitation total for many places in Arizona and New Mexico, providing important moisture for urban water supply, farming, and agriculture. Forecasting the monsoon and understanding its behavior in future climes is therefore important to many people. While the complexities of the monsoon present challenges to detailed predictions, monsoon basics are well understood and provide a solid foundation for expectations.

The monsoon is driven by the sun heating up the land and the Pacific Ocean at different rates, with land surfaces warming more quickly than the ocean. As the spring transitions into summer, the warming land causes air to rise like a hot air balloon, creating low-pressure zones. Winds from the west and south rush in to fill the void created by the rising air and carry with them cooler, humid air from the Gulf of California. As the moist air wafts over the hot land, it warms, rises, and eventually coalesces to form towering anvil clouds that are precursors to intense thunderstorms.

The monsoon has a built-in amplifying system so that rain begets rain. When the precipitation starts—usually around the first week of July for Arizona and New Mexico—vegetation grows and releases moisture back to the atmosphere, adding humidity to the moist air continuously flowing in from the Gulf of California. This cycle usually continues until around the end of September, when the shrinking temperature difference between the land and water sufficiently reduces the flow of air into the Southwest.

Percent of Normal Precipitation

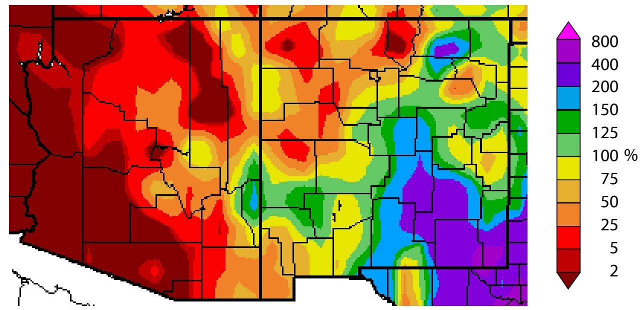

Figure 1a. June 15–July 14, 2010.

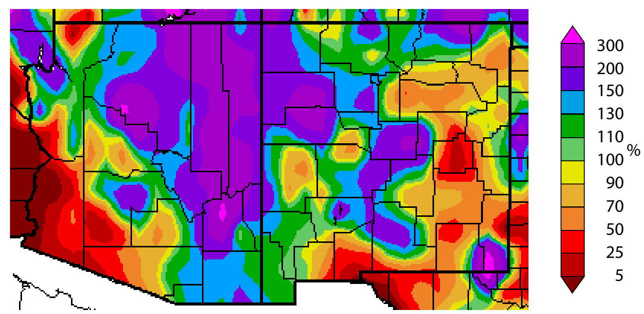

Figure 1b. July 15–August 13, 2010.

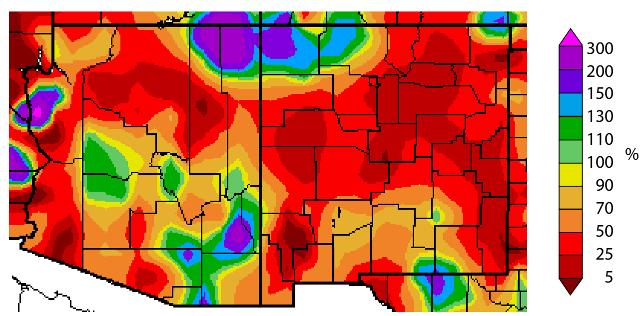

Figure 1c. August 17–September 15, 2010.

How the 2010 Monsoon Evolved

The 2010 monsoon was like a poor Broadway performance. It arrived on stage late, dazzled the viewers while it lasted, but exited too early, leaving the audience wanting.

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monsoon season, continued

Forecasters had expected a later start to the rains and warmer temperatures, in part because the Pacific Ocean was experiencing a rapid shift from El Niño to La Niña conditions.

"We are going to have a hotter-than-usual summer and we're expecting the monsoon high to move north a little late, which is an expectation based on the climatological trend—the Southwest has been heating up over the past 20 years," Erik Pytlak, science and operations officer for the National Weather Service (NWS) in Tucson, said on June 11. "There are also equal chances for experiencing above- or below-average precipitation this summer, in part because in the past years where we've gone from a strong or moderate El Niño to a La Niña very rapidly we tend to have pretty average summer rainfall."

For the most part, this forecast was spot on. Between June 15—the official start date of the monsoon adopted by the NWS in 2008—and July 15, rainfall totals were below average in nearly all parts of Arizona and northwest New Mexico (Figure 1a). Rains did not begin until around July 15—roughly a few weeks later than the average start date—despite high humidity, a clear indication that moisture is available to form storms.

When the rains finally came, they were intense, spotty, and lasted only about four weeks in most of the Southwest except for southeast Arizona, where they continued longer (Figure 1c). Between about July 15 and August 15, monsoon storms doused the high country in the north and the lower deserts with more than 130 percent of average rainfall (Figure 1b).

In July, only the corners of southwest Arizona and southeast New Mexico were drier than average. All climate divisions in New Mexico and most of those in Arizona were well above average. The southeast corner of New Mexico experienced the highest percentage in the region, measuring about 190 percent of average.

The rains, however, lacked staying power, and drier-than-average conditions returned in August (Figure 2). September also has been dry. Rainfall totals in the first half of the month were less than 50 percent of average in both states. While September amounts are not yet final and moisture from the Gulf of California is still penetrating the area, the story is unlikely to change.

High humidity but scant, patchy rain

Humidity is a measure of the water vapor wafting in the air. The more humid the conditions, the higher the likelihood for rain, most of the time.

The dry-wet-dry summer is what Dave Novlan, meteorologist for the NWS in El Paso, Texas, calls a "low-investment monsoon."

"We've had high humidity but low rain, which just makes it more miserable for people," he said.

The Tucson area exceeded the dew point temperature—the temperature at which water vapor condenses to form rain—of 54 degrees Fahrenheit on July 9. Higher dew points mean higher humidity, and historically meteorologists declared the monsoon to have officially begun after three consecutive days exceeded the 54-degree dew point mark. The average onset date under those guidelines was July 9 in Tucson.

From July 11 to September 9 this year, dew points were mostly above the historical average, sometimes by as much as 10 degrees F. Phoenix also spent much of its summer with above-average dew points.

While moisture was present, it often did not rain in the lower elevations, particularly in southern Arizona. Storms often begin on the mountains and as they grow winds aloft push them over the desert valleys. This year, however, saw weak winds and the atmosphere was abnormally warm aloft. This reduced the temperature difference between the surface and mid-altitudes in the atmosphere, creating a more stable environment. The result was that storm clouds often were not blown off the mountains into the valleys; even when they were, the stable atmosphere prevented moisture from rising, condensing, and causing the thunderous storms for which the monsoon is famous.

"The summer had a more hostile environment for storms to form and persist than we would have expected given the high moisture availability and warm surface temperatures," said Gary Woodall, meteorologist-in-charge at the NWS in Phoenix.

The hostile conditions helped create rainfall patches that were more isolated than typical, according to Gutzler and meteorologists at NWS offices in Albuquerque, El Paso, Tucson, and Phoenix.

"What seemed to characterize the monsoon in the Southwest was spottiness," Gutzler said. "My perception is that in years that have been really wet, like in 2006, thunderstorms seemed to cover larger areas. This year, it appeared that the rains did not persist long enough to fill the gaps... . We would have bursts that filled gages here and there and then the rains fizzled."

Precipitation around Albuquerque exemplifies this. Four measuring stations within 25 miles of each other reported June–August rainfall totals that ranged from 60 to 120 percent of average. Rainfall also was extremely variable in southern New Mexico. Places within 10 miles of each other differed by as much as 4 inches of rain.

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monsoon season, continued

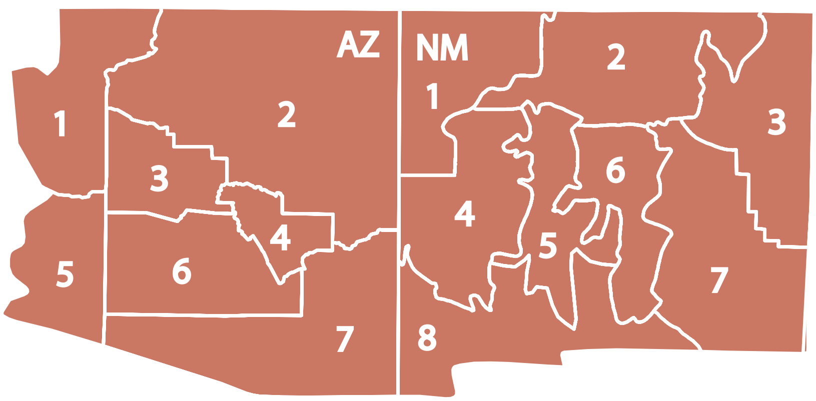
Warmer nighttime temperatures

The monsoon season has been about more than wishy-washy rain. It also has been hotter than average. Temperatures have been between 0 and 2 degrees F warmer than average, and the largest temperature anomaly has occured after the sun goes down.

At night, the daily minimum was about 3 degrees F warmer than average in Arizona and New Mexico for the June–August period. It was even greater in Phoenix. During July, low temperatures were about 4 degrees F warmer than average. What caused this "was probably a combination of a warming trend we have seen in the last 10 years and a lack of thunderstorm activity that would have broken the heat," Woodall said.

Although rains were inconsistent, warm temperatures and high humidity combined to fuel intense storms as long as other conditions were in place. When it rained it poured. Some areas in southern New Mexico and western Texas, for example, received 3 to 4 inches on one day, and 3 inches soaked parts of southeast Arizona in mid-July.

"We saw some monstrous events this summer," Novlan said. "This year we had strong thermal forcing. Occasionally that forcing was able to break through the dry downward air movement [that was helping to suppress the development of thunderstorms] and when it did, we had really big storms."



Climate Division	Jun (%)	Jul (%)	Aug (%)	Summer Total (%)	Summer Rank Driest	Summer Rank Wettest
AZ1–Northwest	53	69	72	65	24th	93
AZ2–Northeast	59	135	108	114	75th	42
AZ3–North Central	46	97	100	92	49	68
AZ4–East Central	40	148	82	105	69	48
AZ5–Southwest	79	51	61	55	25	92
AZ6–South Central	29	107	80	86	43	74
AZ7–Southeast	31	135	88	105	71	46
NM1–NW Plateau	38	150	118	119	86	31
NM2–Northern Mtns	42	140	65	85	35	82
NM3–NE Plains	69	130	92	97	73	44
NM4–SW Mtns	74	144	90	108	84	33
NM5–Central Valley	52	134	64	88	58	59
NM6–Central Highlands	57	171	77	108	87	30
NM7–SE Plains	109	189	70	118	100	17
NM8–Southern Desert	67	167	67	108	91	26

Figure 2. Average precipitation for the climate divisions in Arizona and New Mexico during June, July, and August show that the 2010 monsoon season had a dry-wet-dry pattern. Average summer precipitation for most climate divisions ranked in the middle of the 1895-2010 record. Information for this figure is derived from Parameter-elevation Regressions on Independent Slopes Model (PRISM) data.

The monsoon in a warmer world

What can we learn about future monsoons from 2010? The jury is still out. Basic science principles paint plausible yet contrasting pictures of a drier or wetter monsoon in a warming world.

On the one hand, warming air temperatures would require clouds to ascend to higher altitudes before the vapor condenses into rain. If the atmosphere warms up enough, the mountains—which push air upwards and help develop thunderous storms—would not play as prominent a role in organizing rainfall.

On the other hand, warmer air temperatures carry more moisture and may increase the temperature difference between the Southwest and eastern Pacific Ocean. The monsoon winds would then intensify and deliver more moisture to the region, theoretically increasing rainfall.

The devil is in the details. As the Southwest experienced this summer, high humidity does not always equal more rainfall. There are a host of other influences and complex interactions that need to align and make it extremely difficult to predict future monsoons.

"There is a lot about climate change we will need to analyze over long timescales, and this is particularly true for the monsoon," Gutzler said. "It's hard to say something definitive from one summer."

But the uniqueness of the 2010 monsoon begs important research questions, such as what caused the patchiness in rainfall, that will help move scientists toward a better understanding of current and future conditions.