

Cracking the AQ Code



Air Quality Forecast Team

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2017 Air Quality Highlights

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A Good Start to the Year

2017 in Phoenix began on a good note, air quality speaking. On almost any given year, we can count on New Year's Day to have some of the highest [PM_{2.5} \(smoke, soot\)](#) levels of the year. In fact, since 2005 (Table 1), PM_{2.5} has exceeded the federal health standard eight times on New Year's Day. On the first day of 2017, however, Phoenix saw good air quality. Widespread rain stamped out any build-up of PM_{2.5} (Figure 1). Only one monitor observed PM_{2.5} levels in the Moderate Air Quality Index (AQI) category. PM_{2.5} remained in the Good AQI category elsewhere around the Valley. What a difference the weather can make!



Figure 1: Figure 1. A view of downtown Phoenix from ADEQ's webcam on North Mountain (looking southward) on New Year's Day at 7:30 AM. A rain shower can be seen near/over the downtown area.

Source: [ADEQ Visibility Web Cameras](#)

About "Cracking the AQ Code"

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In an effort to further ADEQ's mission of protecting and enhancing the public health and environment, the Forecast Team has decided to produce periodic, in-depth articles about various topics related to weather and air quality.

Our hope is that these articles provide you with a better understanding of Arizona's air quality and environment. Together we can strive for a healthier future.

We hope you find them useful!

Upcoming Topics...

- TBD

But it didn't last long...

Unfortunately, only a week into the New Year, PM_{2.5} was able to exceed the federal health standard in Phoenix. This was the very first exceedance of the year. However, this was a localized event, as only one monitor—West Phoenix—saw exceeding levels of PM_{2.5}. The West Phoenix monitor finished with an AQI of 103; the next closest monitor only reached an AQI of 68. Such events are not very predictable, as they depend on human activity. However, the weather was favorable for PM_{2.5} accumulation—high pressure resulted in calm conditions near the ground.

Unhealthy PM₁₀ in Yuma in February

February was a quiet month air quality-wise for the Phoenix area, but not for Yuma. On the 17th, a strong storm system approached the southwestern U.S. from the Pacific Ocean. Beginning late morning on the 17th and lasting until early morning the next day, strong and gusty winds out of the south-southeast lashed the Yuma area. As a result, the Marine Corps Air Station in Yuma observed elevated dust during this time (Figure 2). [PM₁₀ \(dust\)](#) ended up reaching an AQI value of 235 at the Yuma Supersite monitor. That's the Very Unhealthy AQI category! PM₁₀ had reached this category or higher only seven times before at Yuma Supersite, since 2008. Also, this event's AQI was the monitor's fifth highest during that period of record.

Table 1: This table shows the starting year of the periods of record for pollutant data in this paper.

Start of Pollutant Period of Record (Based on data used for air quality forecasting)			
Forecast Location	Ozone	PM ₁₀	PM _{2.5}
Phoenix	2005	2005	2005
Tucson	2005	2010	2010
Yuma Supersite	2008	2010	
Nogales		2005	2012

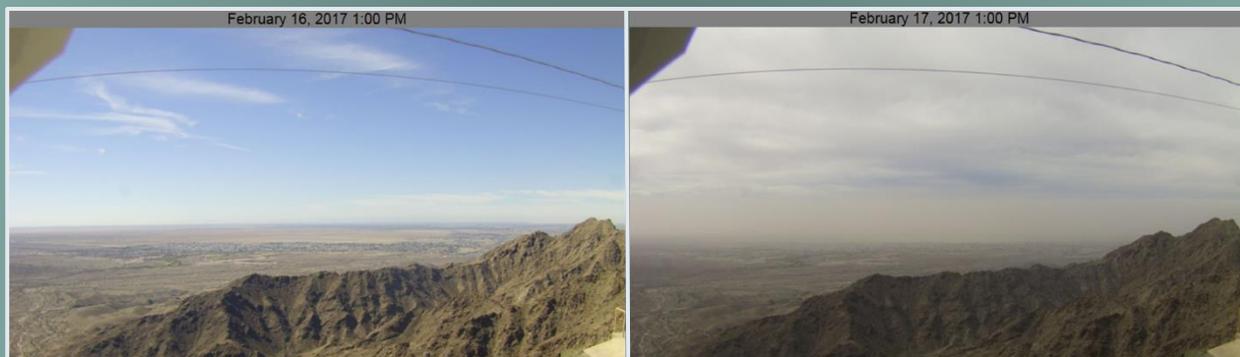


Figure 2. A view of the Yuma area from one of ADEQ's webcams on February 16 at 1:00 PM (left) and February 17 at 1:00 PM (right). The contrast between the two images highlights how weather conditions deteriorated between the 16th and 17th—mostly sunny skies and great visibility on the 16th gave way to cloudy skies and blowing dust on the 17th, which can be seen in the distance on the right.

Source: [ADEQ Visibility Web Cameras](#)

The Return of Ozone in March

By late February, [ozone](#) began to rear its ugly head again. Tucson was the first to see Moderate ozone levels, on February 18. This was the earliest Moderate ozone day for Tucson, since 2005 (Table 2). Phoenix was next, seeing its first Moderate ozone day on March 9, which was about normal. Finally, Yuma's first Moderate ozone day was on March 15, the latest for Yuma since 2012. In March, Phoenix saw seventeen Moderate ozone days, Tucson saw twelve, while Yuma only saw four.

March Regional Dust Event

Unfortunately, we didn't escape March without an exceedance. On the 30th, PM₁₀ exceeded the federal health standard in Phoenix. A strong storm system from the Pacific Ocean brought gusty winds that resulted in blowing dust across the deserts of southern California and southwestern Arizona (Figure 3). One monitor in Phoenix, West 43rd, exceeded the health standard, with an AQI of 105. On the morning of the 31st, haze filled the Valley, revealing that this was a regional dust event.

Yuma saw elevated dust levels as well, but it avoided an exceedance. However, Tucson was not so lucky, as PM₁₀ exceeded the federal health standard on the 31st.

Table 2: A table showing the dates on which ozone reached the Moderate Air Quality Index category for the first time in a given year for Phoenix, Tucson, and Yuma. Dates are based on the current, 70 ppb standard. Yuma (Supersite) ozone data only goes back to 2012 in this table because previously, ozone was not monitored all year round.

First Day of Moderate Ozone			
Year	Phoenix	Tucson	Yuma
2005	Mar 12	Mar 09	-
2006	Feb 25	Feb 25	-
2007	Mar 05	Mar 04	-
2008	Mar 13	Feb 28	-
2009	Mar 06	Feb 22	-
2010	Mar 15	Mar 16	-
2011	Feb 22	Feb 28	-
2012	Feb 26	Feb 29	Mar 11
2013	Feb 17	Mar 13	Feb 18
2014	Jan 26	Mar 06	Mar 06
2015	Mar 07	Mar 11	Feb 27
2016	Feb 27	Feb 23	Feb 27
2017	Mar 09	Feb 18	Mar 15

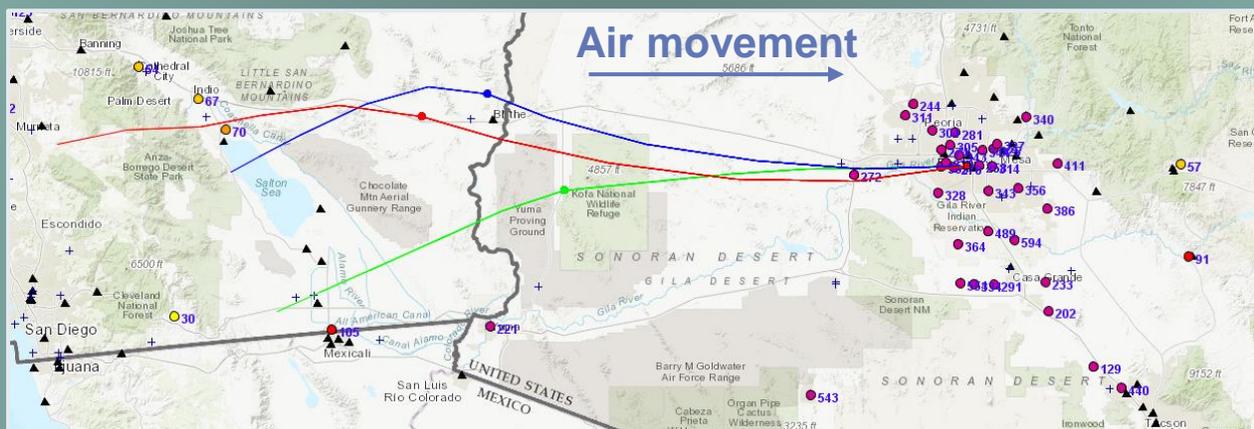


Figure 3: A map showing “back trajectories”, which are used to trace where air—and therefore dust—originated from. Beginning in Phoenix at midnight on March 31, these traces go back 10 hours in time. The green trace represents the path that air 800 feet above ground level took. The blue line corresponds to 1,600 feet; the red line corresponds to 3,300 feet. Here, traces show that air (and dust) in Phoenix came from the deserts in southern California (the general air movement was out of the west).

Source: NOAA Hysplit Model

Rising Ozone in April

If April had an air quality theme, it would have been: “Ozone on the Rise.” Average ozone trends had clearly increased from March to April for Phoenix (Figure 4), Yuma, and Tucson. All three cities also saw their first ozone exceedances of the year this month. One major reason for the higher ozone was the daily increase in sunlight, which is necessary for [ozone production](#).

Another factor could have been a greater amount of Volatile Organic Compounds (VOCs) in Southern California. [VOCs](#) are organic chemicals emitted by motor vehicles, power plants, and natural sources (i.e. plants, trees, etc.). We care about VOCs because they are one of the principal ingredients in the ozone formation process.

During the winter of 2016-2017, southern California received an [unusual amount of rainfall](#) (Figure 5). More rain would have meant greater vegetation growth in the region and therefore, more VOCs in the air. Since the prevailing weather pattern was often out of the west, VOCs would have been transported into Arizona and made available for ozone production. This might explain why April 2017 saw much higher ozone levels than April 2016, which followed a drier winter.

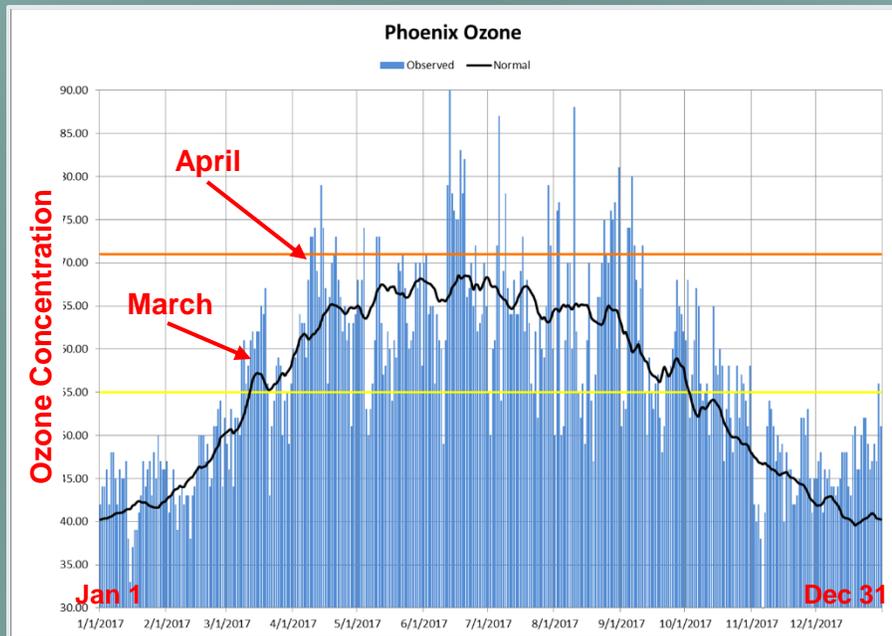


Figure 4. A graph showing daily, observed ozone trends for 2017. The red arrows highlight the general ozone levels for March and April. Notice how much higher April's ozone levels are compared to March's. The orange horizontal line marks where the ozone exceeds the federal health standard; the yellow horizontal line marks where ozone reaches the Moderate Air Quality Index category.

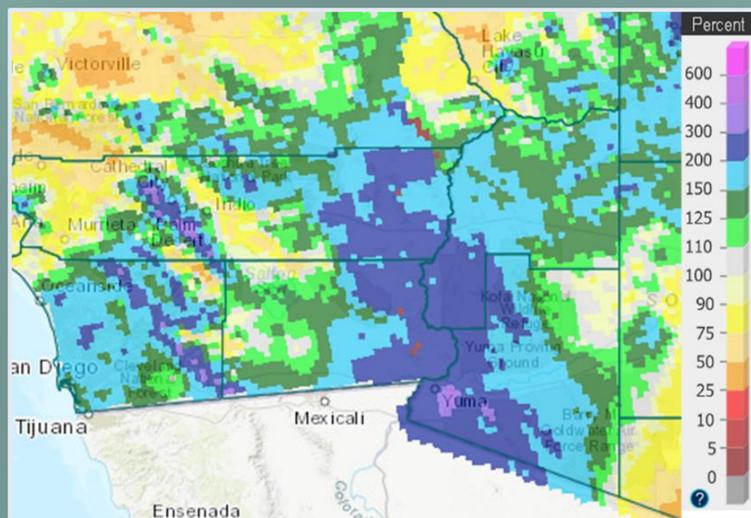


Figure 5. A map showing “percent of normal” precipitation for February 2017 for southern California and southwestern Arizona. Green, cyan, dark blue, and purple colors represent areas that received more than normal (100%) precipitation. Notice the large area of dark blue, denoting where areas received 200% (double) or more of their normal precipitation. February 2017 was a wet month for this region.

Source: [NOAA Advanced Hydrologic Prediction Service](#)

May Regional Dust Event

The next regional dust event occurred on May 6, which affected Phoenix, Yuma, and Tucson. Yet another strong storm system from the Pacific Ocean affected the southwestern U.S., bringing a [cold front](#) (Figure 6) and gusty winds to the region. This time, PM₁₀ only exceeded the health standard in Yuma and Tucson.

Yuma's PM₁₀ monitor registered an AQI in the Unhealthy category, while Tucson saw an AQI in the Unhealthy for Sensitive Groups (USG) category. Phoenix also experienced elevated PM₁₀ levels, but they were spread out over May 6 and 7.

Monsoon Season (June – September)

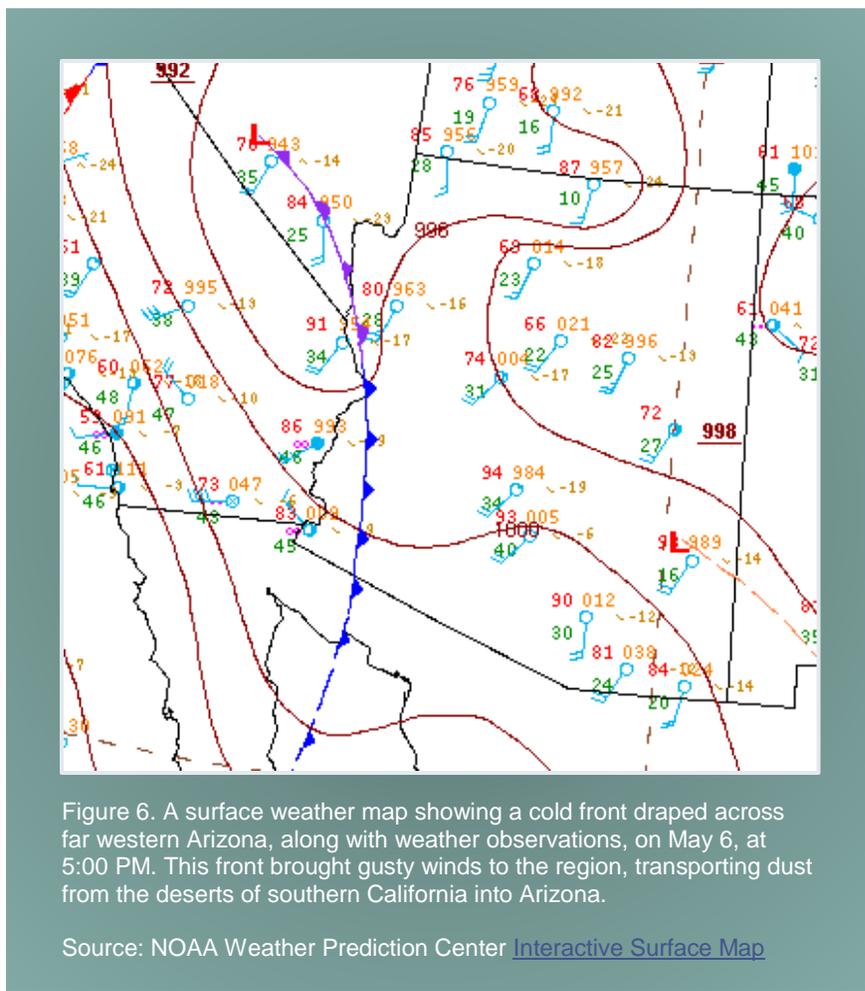
[The monsoon season](#) is usually the most interesting and complex time of the year for air quality in Arizona. This is due to the greater risk for [dust storms](#) impacting the lower deserts, the almost constant high ozone in Phoenix, the potential for ozone transport from long distances into Arizona, and the uncertainty of [thunderstorm activity](#) around the state. We'll mention a few highlights from 2017's monsoon season:

Yuma's Ozone Streak

In June, the Yuma Supersite monitor saw a total of eleven days on which ozone reached the Moderate AQI category or higher. During the middle of the month, eight of those days were consecutive. Out of those eight days, ozone exceeded the federal health standard six times. In fact, ozone exceeded the standard four days in a row from the 17th to the 20th. Since 2008, this was the first time ozone exceeded the standard on four consecutive days at the Yuma Supersite monitor. Before this, there were only six times when ozone exceeded the standard on three consecutive days at the monitor.

High Ozone in Phoenix

2017 ended up being quite an active year for ozone in Phoenix (Figure 7). Most notably, the number of times ozone exceeded the health standard in Phoenix—using the current [70 ppb ozone standard](#)—considerably surpassed that of the past three years (Table 3). 2012 was the last year that saw more ozone exceedances. Also, the frequency of Unhealthy ozone days—which was three times—hadn't been seen since 2012. Moreover, the longest streak of consecutive ozone exceedance days in 2017 was nine days.



The last time this happened was also in 2012 and it has only happened a total of six times since 2005. The longest streak of ozone exceedance days since 2005, was 13 days, in 2006.



Figure 7. Here are two images from ADEQ’s webcam on North Mountain, looking southward toward downtown Phoenix. One of them was taken on the day that Phoenix saw its highest ozone levels of the year, at the time of the day when ozone levels were their highest (4:00 PM). The other was taken on a day when ozone stayed in the Good AQI category, at 4:00 PM as well. There is no real difference between the two images because *ozone is invisible*. June 14 (right) was the day with the highest ozone of the year.

Source: [ADEQ Visibility Web Cameras](#)

Phoenix’s Dust Storm Season

When it came to dust storms in Phoenix, 2017 was a relatively lackluster year. Sure, Phoenix had its share of dust storms and blowing dust throughout the monsoon season, but compared to other years, PM₁₀ AQI levels were not as high.

Figure 8 shows a graph comparing 2017 maximum daily average PM₁₀ levels between June and September to the 2005-2016 average. Notice the numerous times when 2017’s maximum daily

average was below the average of the prior 13 years (especially in July and August). The days on which the 2017 PM₁₀ bars rose above the 2005-2016 average line were likely when blowing dust occurred in 2017. The large spike in PM₁₀ on September 7 was the only time PM₁₀ exceeded the federal health standard in Phoenix during the monsoon season in 2017. This was due to a dust storm.

Table 3: This table shows ozone exceedance and Unhealthy ozone AQI statistics for Phoenix for the period of 2005-2017.

Year	# of Days Ozone Exceeded Health Standard (70 ppb)	# of Days Ozone Reached Unhealthy AQI
2005	65	9
2006	73	9
2007	56	0
2008	50	0
2009	13	0
2010	25	0
2011	46	1
2012	55	3
2013	39	1
2014	27	1
2015	28	0
2016	29	0
2017	42	3

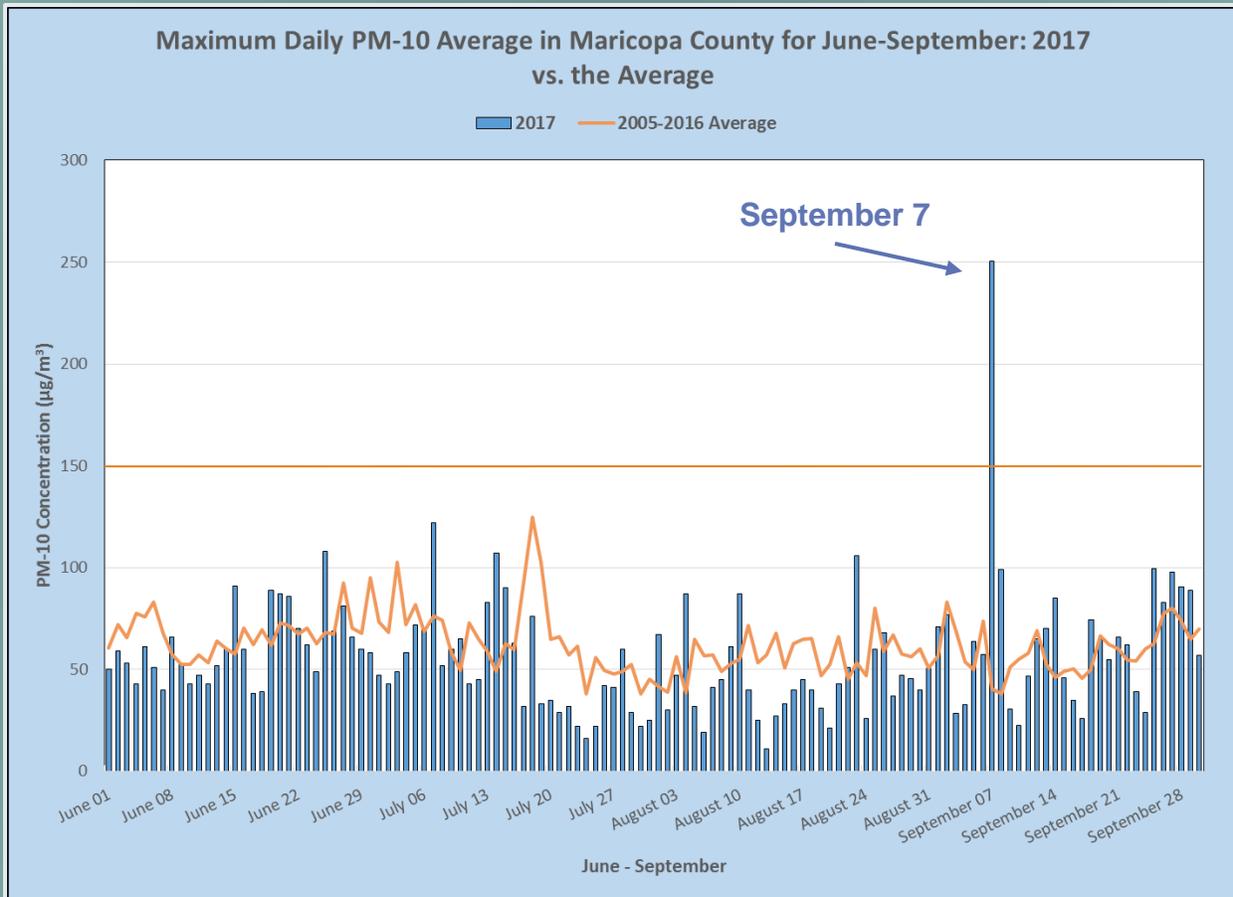


Figure 8. This graph shows the maximum daily PM₁₀ (dust) average between June and September for 2017 (blue bars) and the overall, average for the period of 2005-2016 (orange trend line). The September 7th event is labeled. The orange horizontal line marks where the ozone exceeds the federal health standard.

October Storms and Dust

Believe it or not, October has been, historically, a severe weather month for Arizona. For instance, eight tornadoes touched down in northern Arizona on October 6, 2010. This was Arizona's largest, single-day [tornado outbreak](#) in its recorded history. During this time of the year, the [jet stream](#) over Canada usually begins to shift southward into the U.S. due to cooling temperatures. As a result, the frequency of low pressure systems, or "storms," from the Pacific Ocean increases. This, in turn, increases the chances for thunderstorms/severe weather and rain in Arizona.

However, October 2017 was not a normal October. According to the National Weather Service, October 2017 ended up being the fifth warmest October on record (since 1895) for Phoenix. This likely contributed in limiting the jet stream's southward movement into the southwestern U.S. Therefore, low pressure systems could never reach far enough south to provide Arizona with any decent rain chances. Instead, they just brought strong winds and mild temperatures to Arizona.

Air quality-wise, two such windy and dry systems resulted in PM₁₀ exceeding the federal health standard: twice in Yuma (October 9 and 20) and once in Phoenix (October 20). The event of October 20 turned out to be another regional dust event, resulting in haze filling Phoenix's air. The haze lingered throughout the next day (Figure 9).

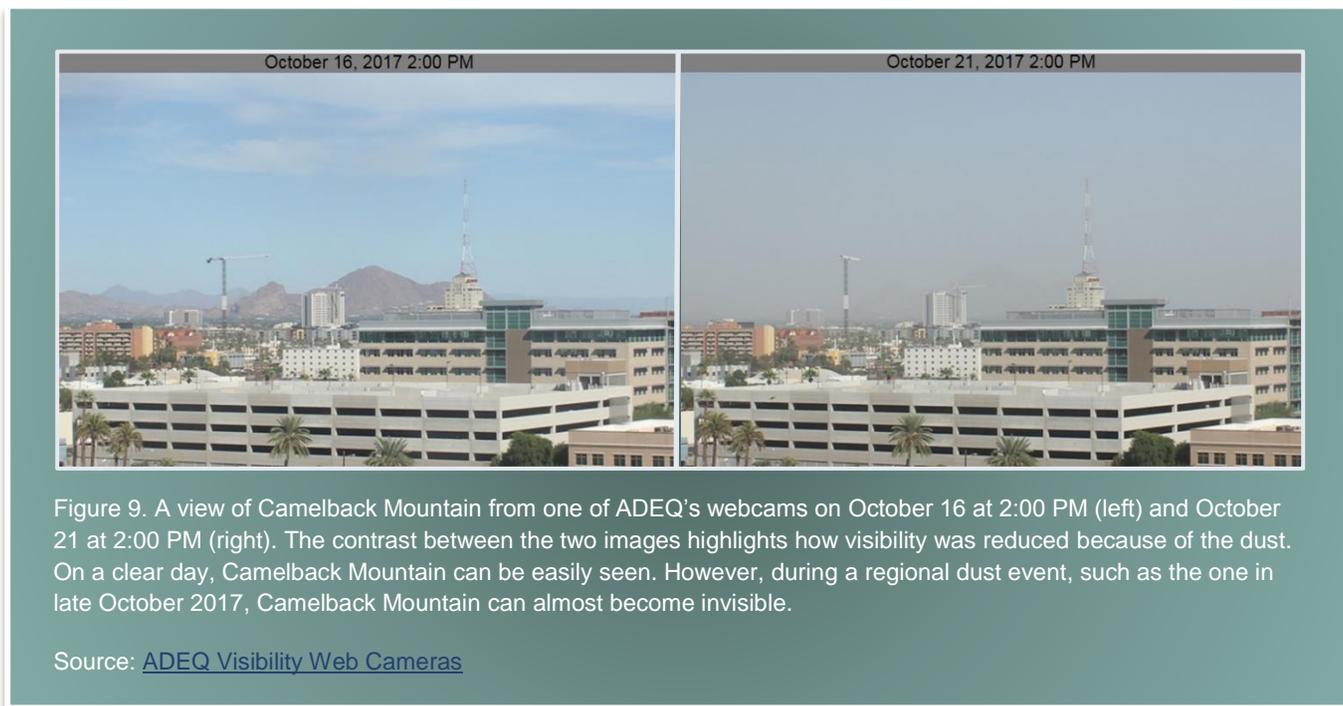


Figure 9. A view of Camelback Mountain from one of ADEQ's webcams on October 16 at 2:00 PM (left) and October 21 at 2:00 PM (right). The contrast between the two images highlights how visibility was reduced because of the dust. On a clear day, Camelback Mountain can be easily seen. However, during a regional dust event, such as the one in late October 2017, Camelback Mountain can almost become invisible.

Source: [ADEQ Visibility Web Cameras](#)

November Warmth

As if, though, there hadn't been enough warm weather (Figure 10), the warming trend continued, culminating in November 2017 becoming Phoenix's warmest November on record (since 1895). The average high temperature was 82.9°F, easily surpassing the normal average high temperature of 75.5°F.

Other than the warm temperatures, November was mostly a quiet month for both weather and air quality. But, that changed near the end of the month.



Figure 10. Here is a weather summary of fall 2017 for both Phoenix and Yuma, tweeted out by the National Weather Service office in Phoenix. It was a hot and dry fall.

Source: [@NWSPhoenix](#) on Twitter

November-December Phoenix PM₁₀ Problems

Between November 27 and December 1, PM₁₀ levels were unusually high in Phoenix, particularly just to the southwest of the Phoenix metro area. PM₁₀ levels reached ADEQ Health Watch criteria (AQI of 90 to 100) three days in a row, beginning on the 27th. PM₁₀ levels then exceeded the federal health standard on the 30th and 1st. During this period, there was a very noticeable, dirty look to the air (Figure 11). This poor air quality resulted from the combination of local industry activity, stagnant weather conditions, cloudiness (which enhanced the stagnation), and lack of rain—by December 1, Phoenix hadn't seen measurable rainfall in 100 days.



Figure 11. A view of the Estrella Mountains from one of ADEQ's webcams, taken on November 30 at 2:15 PM. The infamous "brown cloud" can be clearly seen in the foreground.

Source: [ADEQ Visibility Web Cameras](#)

Early December Ups and Downs

Fortunately, by December 2, it was the weekend, and PM₁₀ levels fell below Health Watch criteria due to less workweek activity. Better yet, on the 6th, winds from a low pressure system helped to relieve the Valley of the accumulated PM₁₀. This respite proved to be brief, though, as cloudy, stagnant weather returned on the 11th. PM₁₀ exceeded the federal health standard once again on the 12th. Finally, early morning on the 17th, a low pressure system was able to provide the Valley with thunderstorms and widespread rain, giving the Valley's air a much needed cleansing and reset.

Want to learn more about other weather and
air quality topics in Arizona?

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Out with a Bang

Unfortunately, by December 22, the general weather pattern over the southwestern U.S. began to revert back to what it had been doing in the fall: high pressure and above average temperatures. Though this pattern in and of itself wasn't unpleasant, its timing could have been better—for Phoenix air quality's sake. Christmas Eve and Christmas Day are known for high $PM_{2.5}$ levels as festive fireplace usage significantly increases across the Valley; New Year's Eve is known for even higher $PM_{2.5}$ levels with the additional contribution from fireworks (Figure 12). Given calm weather conditions, we can count on seeing adverse $PM_{2.5}$ levels on these days. And this is what happened.



Figure 12: Fireworks can be seen in this image taken by one of ADEQ's webcams, looking east toward the Superstition Mountains, at 10:30 PM on New Year's Eve.

Source: [ADEQ Visibility Web Cameras](#)

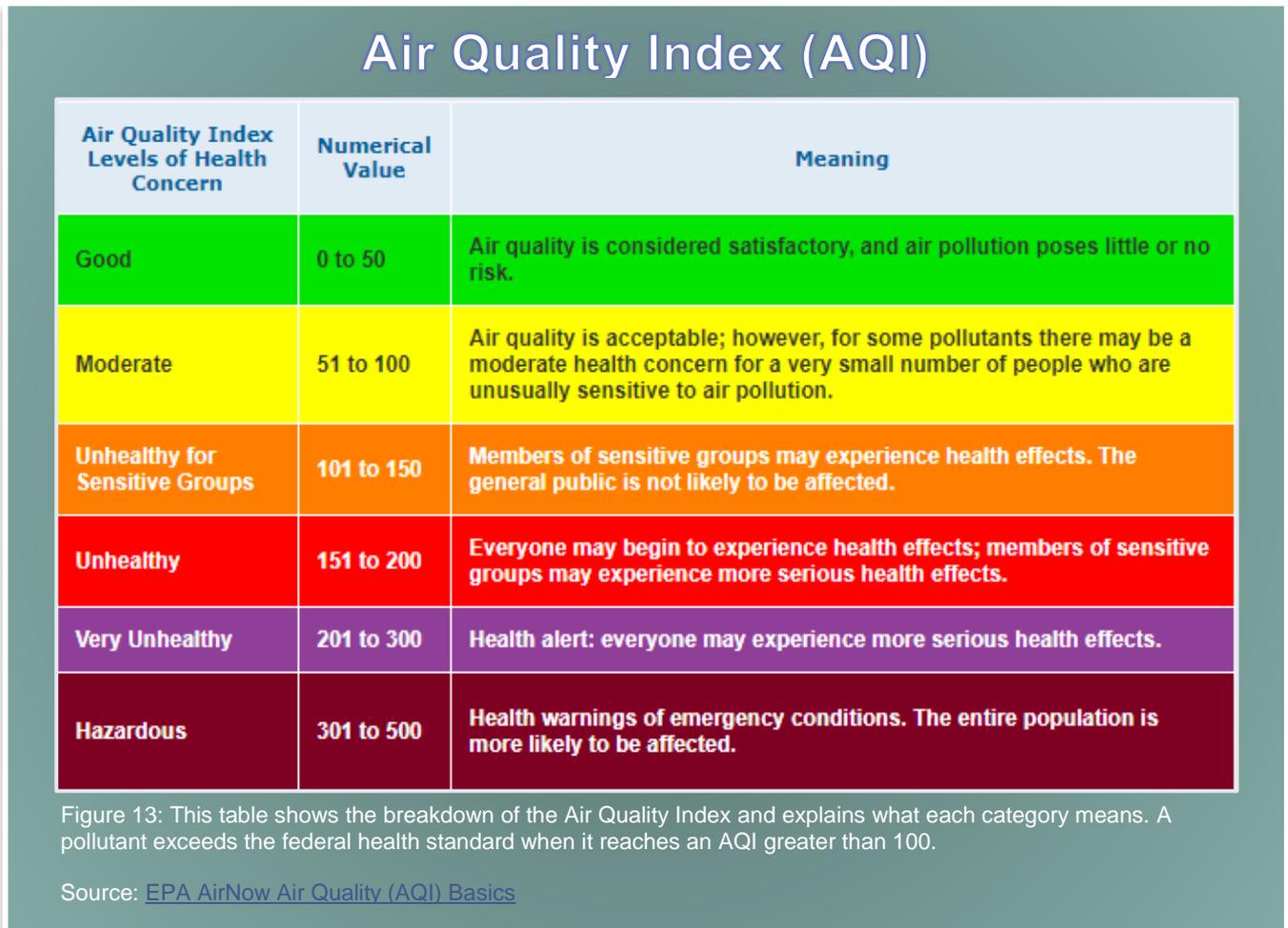
Record-Breaking $PM_{2.5}$ in Phoenix

By the end of December, $PM_{2.5}$ ended up setting multiple records (since 2005) in Phoenix during the holiday season. Below are some noteworthy highlights (Note: Refer to Figure 13 for information on the Air Quality Index categories):

- *The Valley exceeded the $PM_{2.5}$ federal health standard six times from December 23 – January 1.*
- *$PM_{2.5}$ was the highest we have recorded on Christmas Eve. $PM_{2.5}$ reached an AQI of 144 (Unhealthy for Sensitive Groups); the previous record was 141 (2011).*
- *$PM_{2.5}$ was the highest we have recorded on Christmas Day. $PM_{2.5}$ reached an AQI of 167 (Unhealthy); the previous record was 165 (2010).*
- *$PM_{2.5}$ exceeded the federal health standard for the first time on the day after Christmas (Dec 26th). $PM_{2.5}$ reached an AQI of 112 (Unhealthy for Sensitive Groups); the previous record was 84 (2009).*
- *$PM_{2.5}$ was the highest we have recorded on New Year's Eve. $PM_{2.5}$ reached an AQI of 161 (Unhealthy); the previous record was 154 (2011).*

And just because it's worth mentioning:

- $PM_{2.5}$ was the highest we have recorded on New Year's Day. $PM_{2.5}$ reached an AQI of 249 (Very Unhealthy); the previous record was 221 (2014).



Unhealthy $PM_{2.5}$ in Nogales

The city of Nogales also typically sees adverse air quality on the holidays, when weather conditions are favorable. Unsurprisingly, $PM_{2.5}$ also reached adverse levels in Nogales. Christmas Eve and Christmas Day both saw $PM_{2.5}$ in the Unhealthy AQI category. $PM_{2.5}$ also exceeded the federal health standard on the day after Christmas (first time since 2012) and New Year's Eve. Moreover, New Year's Day saw $PM_{2.5}$ in the Unhealthy AQI category.

Wrap-Up

In all, 2017 saw a wide variety of air quality events. It was also a year of new records. What will 2018 bring? Will the first day of Moderate ozone be earlier or later this year? How often will regional dust events occur? Will Phoenix have a more active dust storm season during the monsoon? We'll just have to wait and see.

We hope you enjoyed taking a look back on last year's air quality highlights!

Sincerely,

The ADEQ Forecast Team

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[HERE](#) to start receiving your
Daily Air Quality Forecasts
(Phoenix, Yuma, Nogales)



In case you missed the previous Issues...

July 2017: [Tools of the Air Quality Forecasting Trade Part 4: Weather Forecast Models](#)

September 2017: [Organized Thunderstorms in Arizona](#)

October 2017: [Weather Chaos: Model Uncertainty](#)

November 2017: [Measuring the World above Us](#)

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Here's a look at what we'll be discussing in the near future...

-TBD

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