Cracking the AQ Code

ADEQ Arizona Department of Environmental Quality
Air Quality Forecast Team

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You Ask, We Answer: Part 1

By: ADEQ Forecast Team (ADEQ Air Quality Meteorologists)

Over the past two years, the ADEQ Forecast Team has produced seventeen educational topic papers for its *Cracking the AQ Code* publication. The Forecast Team has covered a wide variety of Arizona weather and air quality topics including dust storms, ozone, wildfires, tropical cyclones, and satellite imagery, to name a few (see the full archive here) (see Figure 1). As the Forecast Team continues to brainstorm future topics, we thought it would be a good idea to open up the floor to our readers and see what kinds of questions they might have regarding Arizona's weather and air quality. This topic paper is the first installment of our "You Ask, We Answer" series where we answer your questions about weather and air quality in Arizona. We hope you enjoy it!

Figure 1. A collage of images taken from several *Cracking the AQ Code* topic papers. Beginning at the top left and going clockwise: a Phoenix dust storm, the ozone molecule, Hurricane Patricia, and a wildfire.

Sources: Dust Storm image: ADEQ; ozone: Public Domain; Wildfire image: John Newman (USFS), modified; hurricane image: NASA's Terra Satellite

About "Cracking the AQ Code"

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…

- Fitness and Air Quality
- Spatial and Timing Variability for Phoenix Pollution

What is "background ozone" and how does it impact Arizona's air quality?

Ozone, also known as O_3, is a naturally occurring, colorless molecule in the atmosphere. Ozone can form near the ground through complex chemical reactions between Volatile Organic Compounds (VOC), Nitrogen Oxides (NO_x), and sunlight. VOCs and NOx, also called ozone's precursors, can come from both human activity (vehicle emissions, refineries, industrial sites, etc.) and natural sources (vegetation/plant life). When ozone forms naturally, apart from human influence, it is referred to as "background ozone".

Essentially, background ozone can be thought of as a baseline for expected ozone concentrations, while human activities tend to add to it. Keep in mind that background ozone can vary from season to season due to such factors as 1) availability of sunlight to start the ozone forming process, 2) frequency of lightning, 3) changes in vegetation cover, 4) periods of active wildfires, and 5) even international transport. In Arizona, the baseline for ozone near the ground will be highest during the summer months due to the greater amount of sunlight and increased vegetation (see Figure 2).

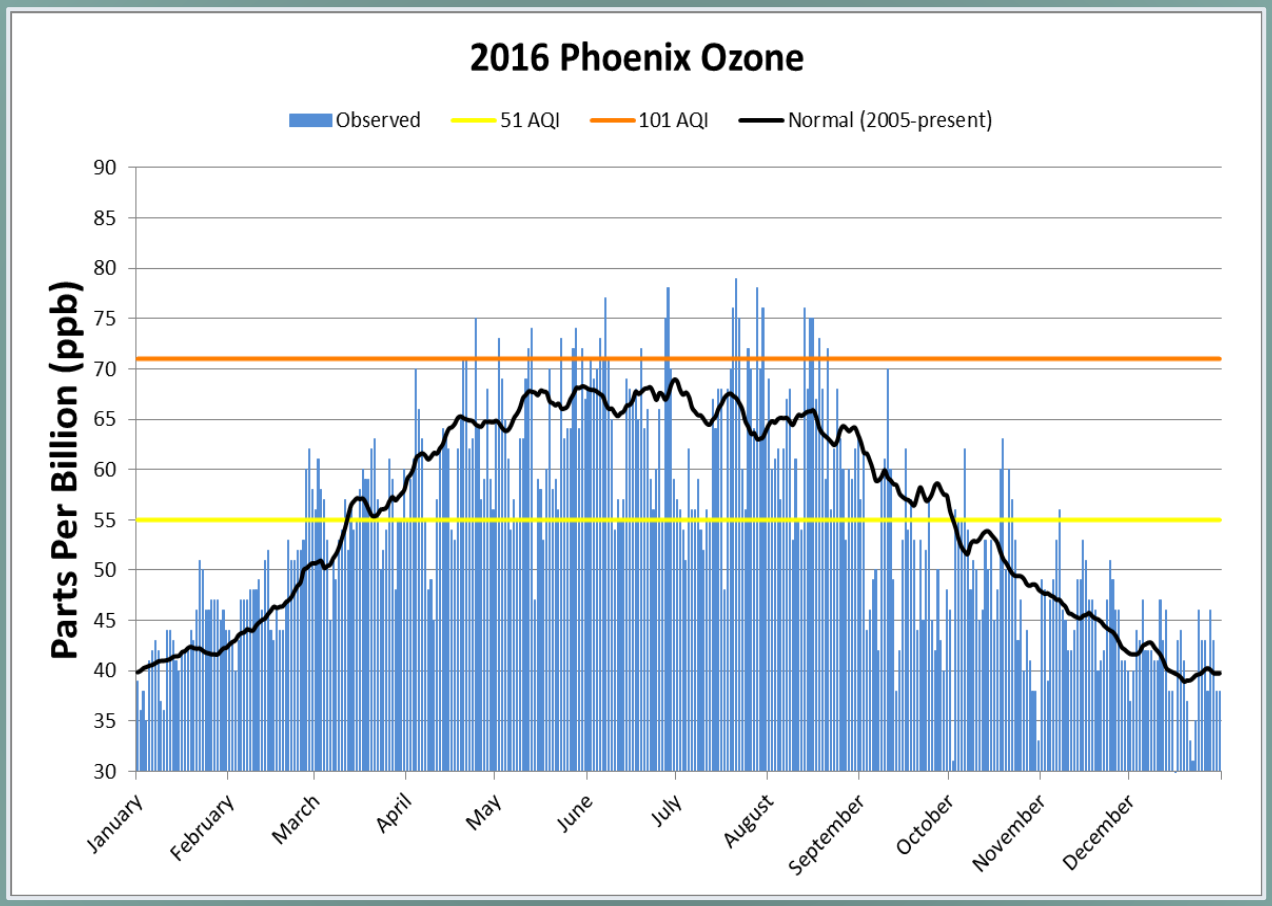

Figure 2: This graph shows the daily ozone trend in Phoenix for 2016. The blue bars represent the highest observed ozone concentration in the Valley for a given day. The black line represents the normal trend line. The horizontal orange line marks the federal health standard and the horizontal yellow line marks the Moderate Air Quality Index threshold. Notice how the normal trend line is much higher in the summer months than in the winter months.

Often, background ozone and its precursors can be transported by prevailing winds toward urban areas. For example, frontal passages and troughs can transport ozone from southern California into Arizona. The result can be increased ozone levels near cities that have background and urban ozone precursor emissions mixing together.

The map of modeled ozone below (Figure 3) gives a visual of how ozone can be distributed across the U.S. This map takes into account both background ozone and ozone produced by human activity. Note how ozone concentrations are not necessarily "zero" in rural zones far removed from major metropolitan areas. This is an example of what background ozone may "look like".

For more information on ozone in Phoenix, see our Cracking the AQ Code topic paper on ozone here.

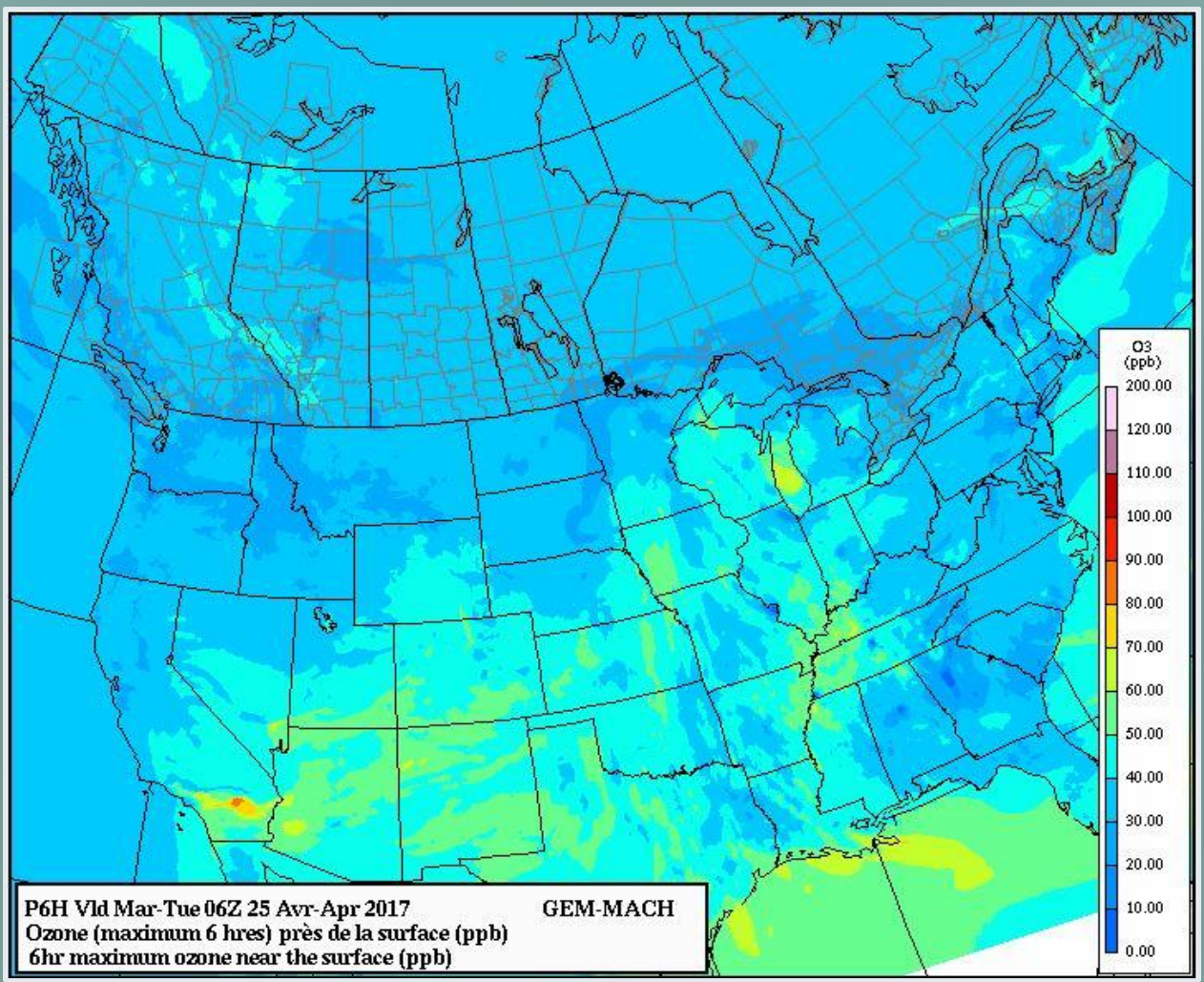

Figure 3. This map depicts forecasted maximum ozone over a six hour period. The forecast is generated from the Canadian air quality model GEM-MACH (Global Environmental Multi-scale – Modelling Air Quality and Chemistry). The GEM-MACH is one of the available air quality models used as guidance for ADEQ air quality meteorologists when creating ozone forecasts. The model takes into account how weather interacts with sources of tropospheric ozone precursors.

Source: Government of Canada

Is human activity considered when forecasting air quality?

Meteorological Factor vs. Human Factor

When predicting how concentrations of an air pollutant (e.g. PM_{10} (coarse particulates), $PM_{2.5}$ (fine particulates), and ozone) will change over time, there are two factors the Forecast Team can take into account: the meteorological factor and the human factor. The former plays the largest role in influencing air quality and therefore, most of the time spent in making an air quality forecast is dedicated to it. However, when the weather is not very active, the weight of the human factor in the forecast becomes greater.

The Human Factor

The hardest part about the human factor is that people are unpredictable. Even though the weather can be difficult to predict at times, it always follows the laws of physics and those laws never change. People, on the other hand, can make decisions on a whim and are not always consistent. The best way to account for the human factor in an air quality forecast is to identify general expected patterns in people's activities and make room for them in the forecast, when appropriate. Below, we'll explore a few patterns of human activity that we often consider.

Seasonal Assumptions

To start off, it is important to note how different seasons of the year have different underlying assumptions regarding the human factor. For instance, in the winter, provided inactive weather, it is normal for $PM_{2.5}$ to be elevated in the Moderate Air Quality Index (AQI) category most days in Phoenix (see Figure 4). This is

Figure 4: A view from ADEQ's webcam on North Mountain, looking south toward downtown Phoenix. During the winter, a haze can be seen just about every morning in the Valley. This is evidence of the constant presence of the inversion trapping pollutants near the surface. The inversion is the culprit for consistent Moderate $PM_{2.5}$ levels throughout the winter.

due to the almost ever-present inversion and the resulting stagnation. The assumption here is that human activity is occurring every day, providing pollutants to accumulate underneath the inversion. We thus almost always forecast $PM_{2.5}$ to be in the Moderate category during the winter for Phoenix. The same is true for Nogales for both PM_{10} and $PM_{2.5}$.

Another example is the spring and summer months in Phoenix. During this time of year, ozone almost always reaches the Moderate AQI category every day due to abundant sunshine and frequent light winds. The assumption here is that ozone's ingredients are being emitted into the atmosphere every day by vehicles and other sources (see Figure 5). We thus generally forecast ozone to be at least in the Moderate category during these months.

Figure 5. One simple and practical action you can take to help reduce ozone during the summer is to refuel your vehicle in the evening hours. Vapors released into the air from gasoline contain hydrocarbons, which can contribute to ozone formation near the ground. Refueling in the evening hours removes the opportunity for gasoline vapors to add to daytime ozone, which requires sunlight, and gives time for gasoline vapors to disperse overnight. Max Pixel

Weekdays

In Phoenix, the most common weekday human pattern is industrial dust-producing activities south and southwest of the Phoenix metro area. Particularly in the cooler months, PM_{10} will build-up near dust-producing sources due to morning stagnation. This can often lead to monitors in those areas measuring Moderate AQI levels for PM_{10} on multiple days during the week.

Figure 6. Did you know? There are multiple, cleaner alternatives to using wood-burning fireplaces. One example is a gas fireplace, like this one. Gas fireplaces produce much less pollution than their wood-burning counterpart and are acceptable to use on No Burn Days. Public Domain

The Weekend

In Phoenix, there are also weekend signatures in human patterns for PM_{10} and $PM_{2.5}$ that we consider. For Phoenix, industrial dust-producing activities cease over the weekends, resulting in a reduction in PM_{10} levels in areas south and southwest of the metro area, all else being equal. $PM_{2.5}$ levels also typically increase over the weekend in the winter in Phoenix, likely due to increased residential fireplace usage (see Figure 6).

Holidays

Believe it or not, human behavior is easiest to predict on big holidays, including Christmas Eve, Christmas, New Year's Eve, and New Year's Day. On any one of these days, we can expect a significant surge in $PM_{2.5}$ levels, given the absence of winds and rain. In fact, history tells us that we can easily exceed the $PM_{2.5}$ federal health standard on all of these days when weather is inactive. This is due to the substantial increase in fireplace usage for Christmas festivities and the combination of fireplace usage and fireworks for New Year's festivities. Moreover, for New Year's Eve and New Year's Day, PM_{10} levels can also considerably increase due to the great surge in $PM_{2.5}$ levels. Holiday forecasts only become difficult when there is a potential for active weather and the timing is uncertain. If winds and/or precipitation occur at just the right time at night on any of these big holidays, particulate levels will be effectively suppressed and air quality will be good. An example of this can be seen is in Fig. 7.

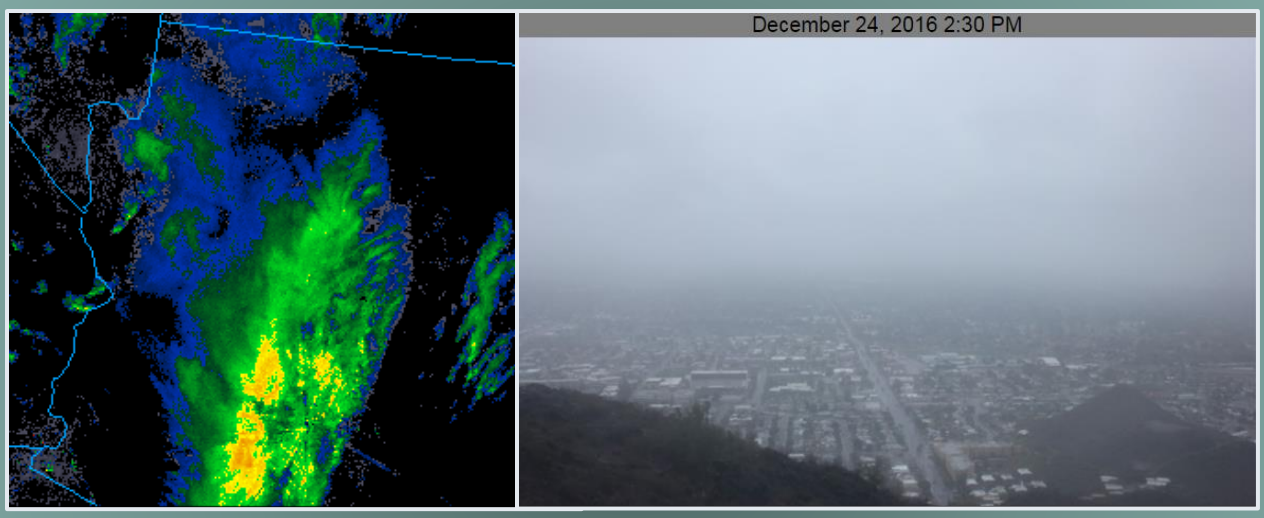

Figure 7. Left: A radar image taken around 2:30 PM on Christmas Eve, 2016, showing widespread rain over central Arizona. Right: A view of downtown Phoenix from North Mountain looking south, at the same time (the street in the middle is Central Ave); low clouds and rain are reducing visibility. If weather had been inactive, $PM_{2.5}$ (fine particulates) would have been significantly elevated due to holiday residential fireplace usage. However, on this day, rain and winds in the Valley kept $PM_{2.5}$ levels down and prevented them from reaching adverse levels. This is an example of weather overriding the human factor.

Source: UCAR Image Archive

In summary, yes, we do consider human activity when forecasting for air quality. But the impact the human factor has on a given forecast depends on the weather. When weather leaves room for human activities to make a difference, we then rely on what history tells us regarding patterns in human behavior.

How do pollen and allergen levels affect the air quality?

Several survey responses inquired about pollen and allergens. We will discuss some general information about this topic as it relates to what we do, but the most important takeaway should be that our air quality forecasts do not take pollen into account. Rather, the ADEQ Forecast Team focuses on several of the *criteria air pollutants* established by the Environmental Protection Agency (EPA). The criteria air pollutants include ozone, particulate matter, sulfur dioxide, nitrogen dioxide, lead, and carbon monoxide; our forecasts include ozone, particulate matter, lead, and/or carbon monoxide.

Particulate matter is broken up into two categories, one is particles less than 2.5 microns ($PM_{2.5}$), and the other is particles less than 10 microns (PM_{10}). While the smallest pollen can be less than 10 microns, most wind-borne pollen is much larger than 10 microns, reaching upwards of 100 microns. Therefore, the vast majority of pollen is too large to be tracked by our monitors. The EPA has established particles less than ten microns to be particularly important due to their ability to penetrate deeply into the lungs when inhaled. Larger particulates, like those of pollen, do not pose the same threat to health.

The issue with pollen, as many of you already know, is the allergies they cause in so many people. For these people, their immune system is triggered into action as if it was being attacked by a virus. This can lead to unwelcome symptoms such as a stuffy nose and sneezing. So, while pollen can certainly be considered a pollutant for some, it does not fall under EPA's criteria pollutants. Hopefully this has cleared up any misconceptions there may have been about our air quality forecasts and pollen.

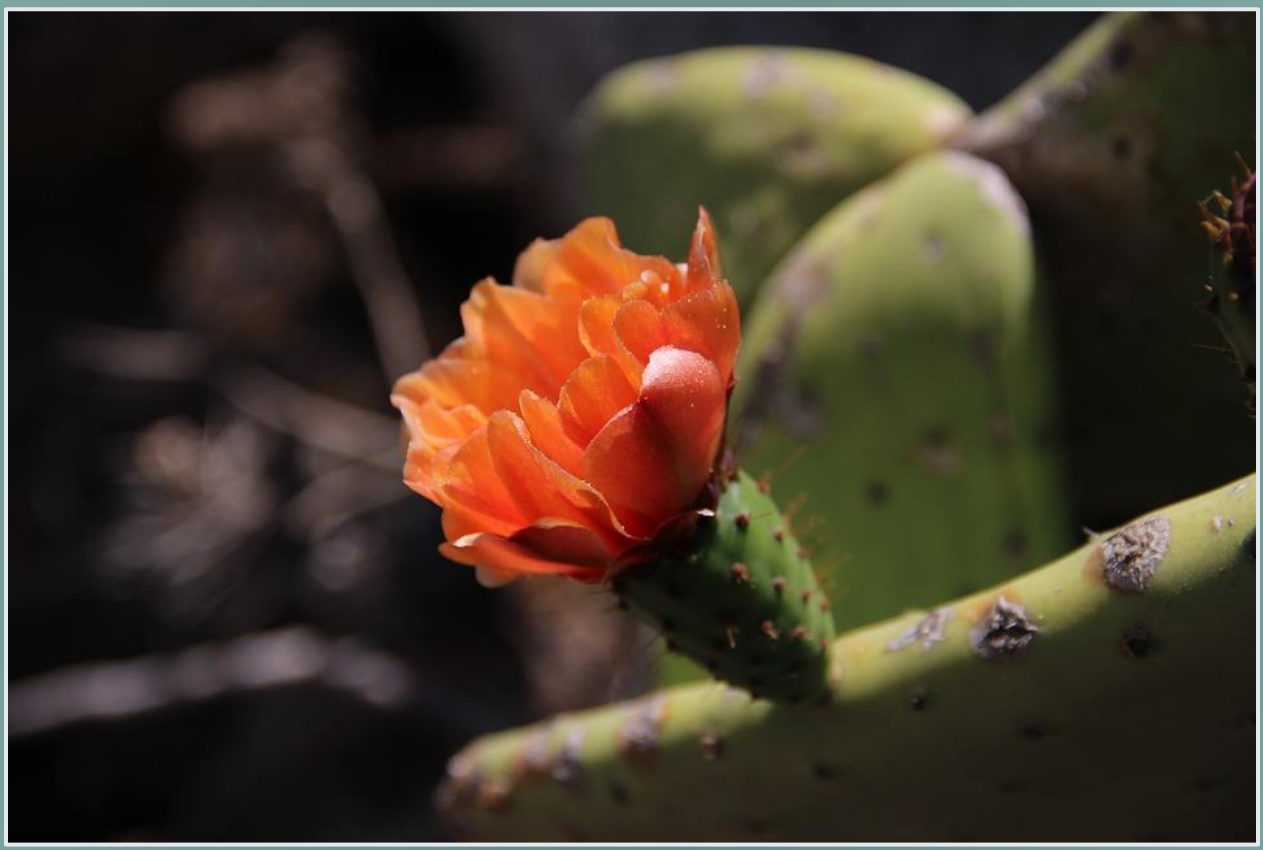

Figure 8. A flower that has budded on a cactus, which can be a source of pollen.

Source: Pixabay, lynnjhansen

What is the Urban Heat Island effect and how does it affect temperatures?

The Urban Heat Island (UHI) effect is simply the phenomenon of warmer air temperatures associated with urban areas compared to that of surrounding rural or less-developed areas. Just imagine a “dome” of heat over a metropolitan area that gradually tails off as you move further away from the city and closer to rural areas. Fig. 9 below illustrates the UHI effect, showing how the air temperature (red line) changes between rural, urban, and other developed areas.

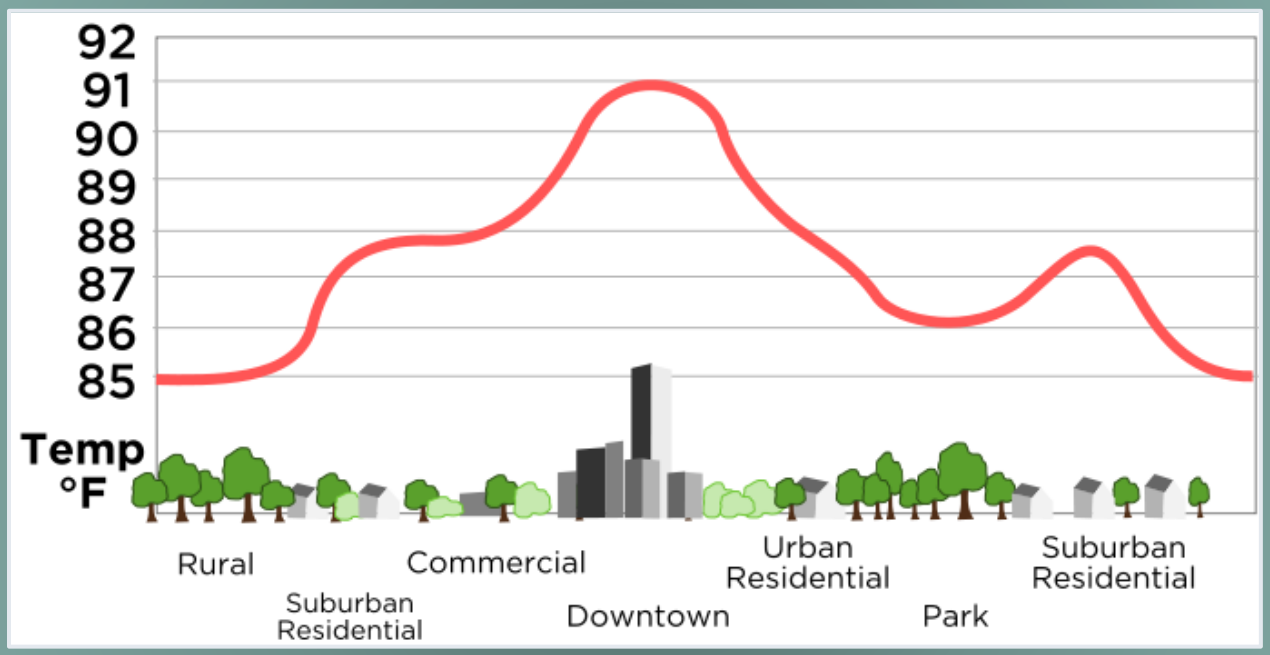

Figure 9. The temperature profile (red line) of the Urban Heat Island effect over various types of land uses. The numbers on the vertical axis are degrees in Fahrenheit. Notice how temperatures are greatest in the metro area, elevated in commercial and residential areas, and lowest in the least developed areas.

Source: Public Domain

So, why the UHI effect? What causes it? The main reason for the UHI is the difference between how urban areas and rural areas absorb and retain heat. In urban areas, buildings, concrete, and pavement absorb heat during the day and retain it at night. In more rural areas, heat is more likely to be used to evaporate water from the ground and plants (which cools the air) during the day and heat is more readily released at night. Of course, the UHI is more complex than this. Many other factors contribute to warmer temperatures in urban areas including:

- Buildings, air conditioners, industries, and traffic emitting heat into the city air
- Buildings reducing wind flow, which decreases evaporation and mixing of air, limiting potential cooling
- Densely-packed tall buildings absorbing the sun’s heat and re-radiating it to one another, keeping radiation from escaping to the atmosphere and therefore, heating the city
- Very little or lack of vegetation, which precludes any cooling from evaporation and reduces shade; etc.

In light of all this, it’s no wonder temperatures between urban and rural areas can sometimes differ by 10°F or more (Hong Kong Observatory, GeoCoops).

Figure 10. A photograph of downtown Phoenix and surrounding developed areas, taken from South Mountain. The UHI effect may be strongest in the middle of downtown Phoenix, but it applies to all urbanized and metro areas of the Valley. Phoenix likely has a very broad UHI due to its great sprawl. To escape the reach of the UHI, one would have to go to the open desert.

Source: Wikipedia Commons, Bigmikebmw, CC BY-SA 3.0

Typically, the UHI is most pronounced at night due to the fact that rural areas cool much faster than urban areas at night. Phoenix's UHI (Figure 10) is unique in that rural areas are desert. Due to their aridity, deserts cool more at nighttime than vegetated areas. Therefore, the difference in temperature between a city (like Phoenix) and an open desert would be amplified at night compared to if the rural areas were more vegetated.

The graph below (Figure 11) illustrates this concept very well. Each line represents the average low temperature (in Fahrenheit) throughout the month of January for various locations in central Arizona. Notice how much warmer Sky Harbor's (urban) minimum temperatures are compared to those of Casa Grande and Maricopa (rural); they are roughly 10 degrees apart throughout January. One location that might seem out of place initially is the Tempe ASU monitor. Its minimum temperatures seem cooler than they should be. However, the monitor is located in between soccer fields and a golf course, which help to reduce the UHI effect.

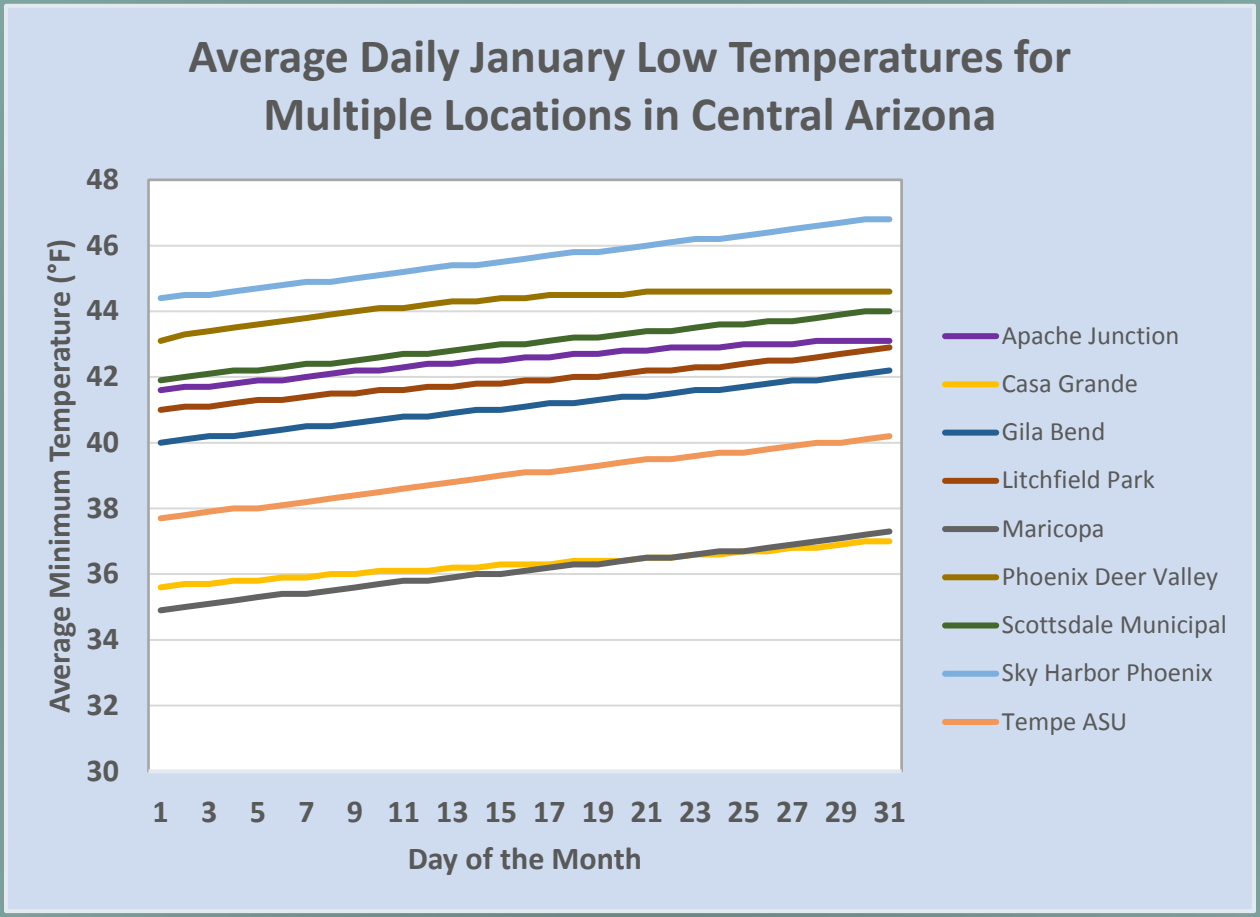

Figure 11. A graph showing the climatological average minimum temperatures of nine locations in central Arizona for each day in January.

Source: NOAA

In summary, every developed area has the UHI effect to some degree. But the intensity of the UHI effect depends on the extent of the developed area, its buildings, its green space and vegetation (or lack thereof), and the type of land of the surrounding rural areas. Of course, the UHI effect is greater for larger cities and Phoenix fits into that category. The UHI is just one example of how human activity can affect local climate.

Thank you to everyone who submitted weather and air quality questions for our first edition of "You Ask, We Answer". We hope you have gained valuable insight into weather and air quality here in Arizona and hope that you share it with others. We look forward to answering more of your questions in a future issue of *Cracking the AQ Code*. If you would like to submit a question, feel free to contact us at the email address below.

Sincerely,
The ADEQ Forecast Team
ForecastTeam@azdeq.gov

If you haven't already, click HERE to start receiving your Daily Air Quality Forecasts (Phoenix, Yuma, Nogales)

In case you missed the previous Issues…

November 2016: Arizona Prescribed Burns
December 2016: $PM_{2.5}$ in Arizona and around the World
February 2017: Outdoor Carbon Monoxide: the Pollutant of Yesteryear
March 2017: Tools of the Air Quality Forecasting Trade Part 3: Satellite Imagery
For Full Archive (2015-2017): Click Here

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

-Fitness and Air Quality
-Spatial and Timing Variability for Phoenix Pollution

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1110 W. Washington Street Phoenix, Arizona 85007 ForecastTeam@azdeq.gov