Cracking the AQ Code

ADEQ Arizona Department of Environmental Quality
Air Quality Forecast Team

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Tools of the Air Quality Forecasting Trade:

Capturing Dust Storms on Doppler Radar

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There are many "tools of the trade" available to help air quality meteorologists track and anticipate air quality trends. One particular tool that is quite useful for completing this task in near real-time: Doppler radar. The National Weather Service (NWS) has a network of more than 150 Doppler radar sites. They are carefully placed across the U.S. to capture severe weather and warn the public of its threat. Arizona hosts four of these located in or near Yuma, Flagstaff, Tucson, and Phoenix (Figure 1). So what is Doppler radar and how can it be used for air quality purposes?

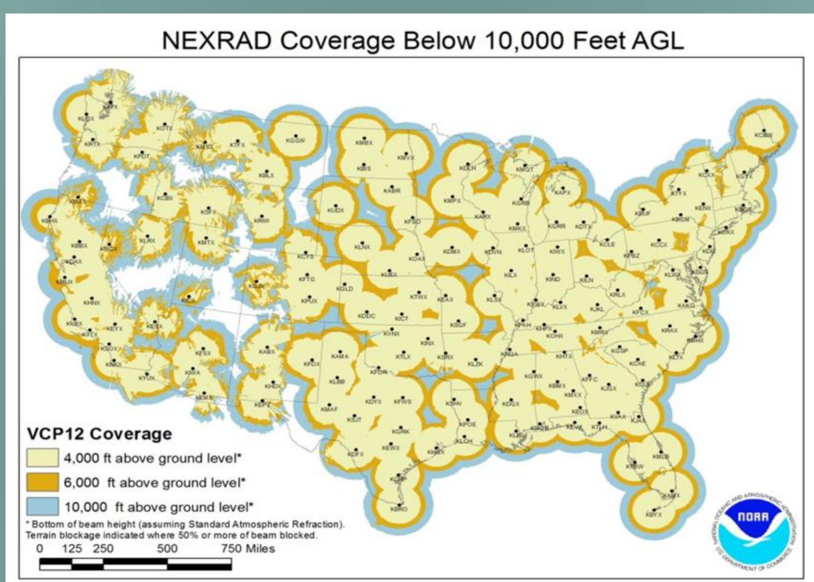

Figure 1: Here are the locations and coverage provided by NWS Doppler radar sites across the U.S. Notice the large gaps in coverage across the west due to mountains.

Source: National Oceanic and Atmospheric Administration (NOAA).

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…

- Ozone, an Invisible Irritant
- The North American Monsoon
- The Genesis of a Thunderstorm

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How Doppler radar works…

Essentially, a radar unit sends out bursts of radio wave energy into the atmosphere. When that energy returns, the unit "listens" to how the energy was altered due to interactions with various objects it encountered. This little bit of information can actually paint a great picture of the lower atmosphere within 100 miles of a radar site. Computers quickly analyze the radio wave energy upon return and reveal useful information. We can see how fast the winds are, how tall nearby storms have grown, if there are hail stones or tornadoes forming, and even the intensity and amount of estimated rain in a particular cell. Since radio waves are moving at the speed of light, a completed scan of the atmosphere surrounding a radar site can be available within five minutes. This is crucial for situations that have rapidly changing severe weather occurring.

Doppler radar is set to look for liquid and solid water particles called small hydrometeors. However, other objects such as birds, bats, and insects can be detected as well. But more importantly, dust and smoke are often captured by radar scans. This is a vital link to air quality monitoring. For example, we all know that dust from an early monsoon season storm or smoke from a major wildfire is not healthy for people. With that in mind, we're going to discuss in more detail how radar captured a significant dust event in Phoenix, Arizona around the onset of the 2014 monsoon season.

Arizona's summer dust storm threat…

April, May, and June are Arizona's three driest months. This raises the likelihood of dust storms leading up to the significantly wetter monsoon season. The amount of rain across Arizona is strikingly lower in June than July as seen in Figure 2. Blazing-hot temperatures and moisture from the south signal the transition from June to July. This is when we start to see daily thunderstorm buildup over the mountains of Arizona.

Typically, these thunderstorms have a life span between 30 minutes to an hour. You can easily observe this cycle here in the Valley. Distant thunderheads over the higher terrain seem to suddenly disappear, only to be replaced by another rapidly growing cumulonimbus cloud. As a thunderstorm reaches maturity, heavy rain creates strong downdrafts that fall to the surface. Think of glass of water being poured out on a table. Once the water hits the table, it quickly spreads out in all directions. That's essentially what happens

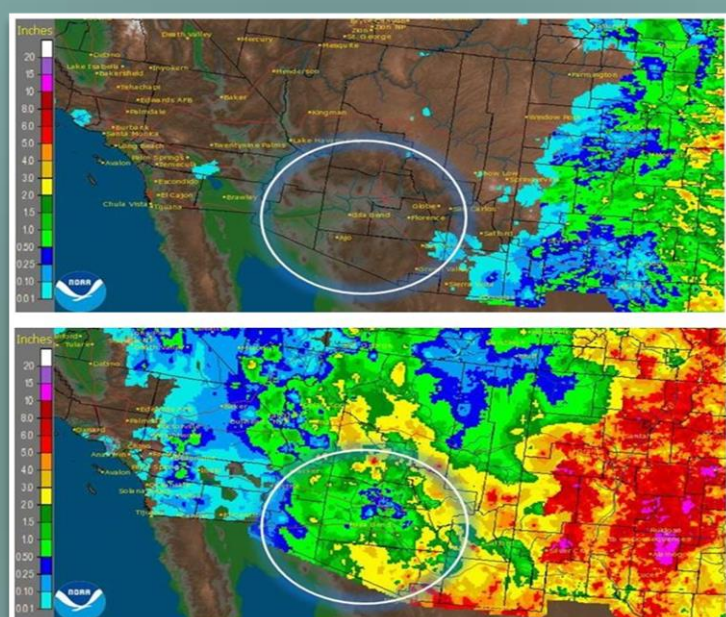

Figure 2: Observed precipitation for the Arizona region for June (top) and July (bottom) 2014. Note the dramatic increase in rainfall over the major dust sources south of Phoenix (circled white) by July when the monsoon pattern typically becomes established.

Data provided by the National Weather Service Advanced Hydrologic Prediction Services.

in a thunderstorm. The cold air gets so heavy that it comes crashing to the ground, spreading out in all directions. Think dust stands a chance? The issue for air quality is that gusty winds can easily lift parched desert soils when the leading edge of higher winds passes by. The resultant gust front, or outflow boundary, forms what we visibly witness as a dust storm. Outflows can be quite expansive and cover a lot of territory in a quick manner. The severe dust storm that struck Pinal and Maricopa Counties on July 3, 2014 was a prime example. And it was all caught on radar!

Tracking the July 3, 2014 dust storm…

It was a typical warm and muggy start to the day. By the afternoon, radar could see intense thunderstorms forming to the north, south and southeast of Phoenix (Figure 3).

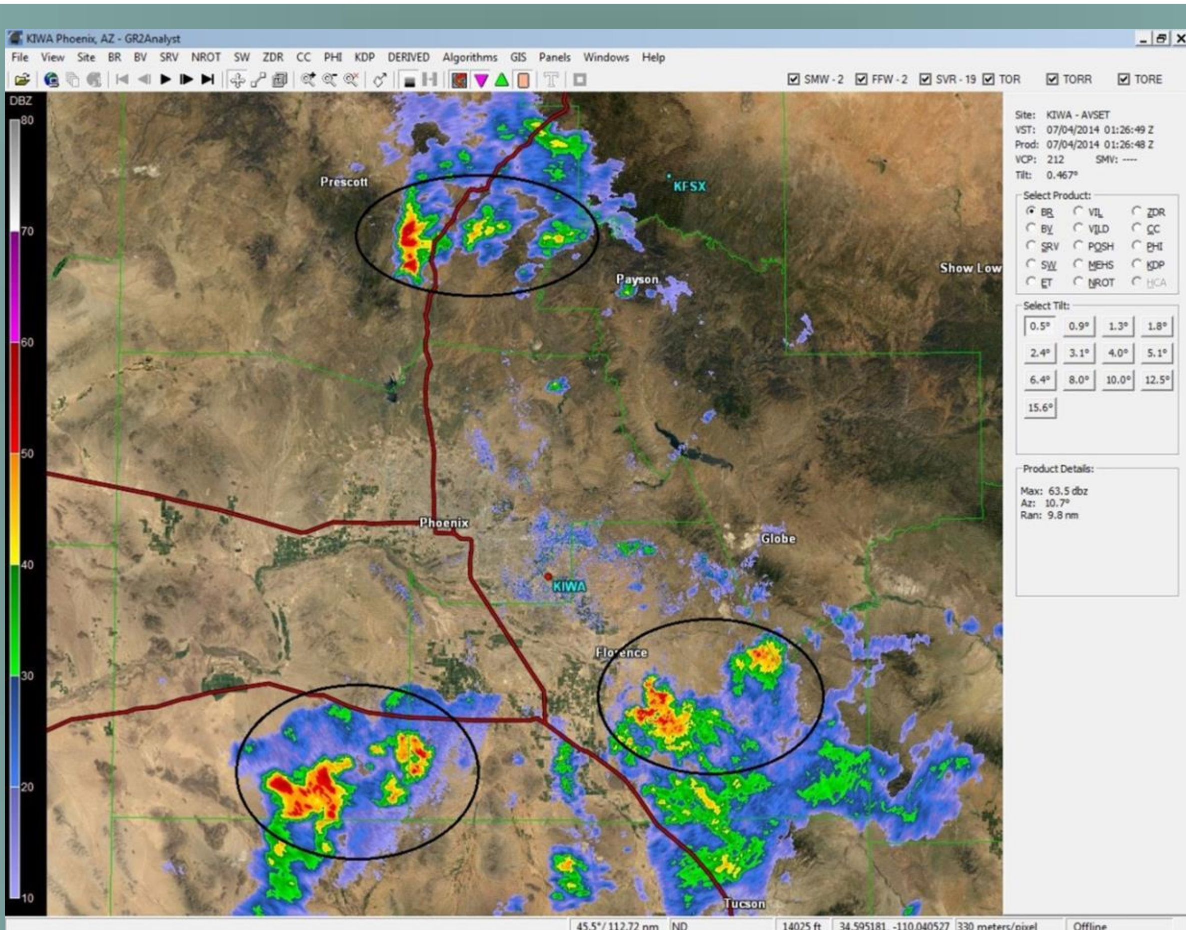

Figure 3: Base reflectivity radar image captured at 6:26 PM July 3rd, 2014 showing three distinct clusters of strong thunderstorms (circled black) north and south of Phoenix. Areas shaded in red and yellow are linked with heavier rain rates.

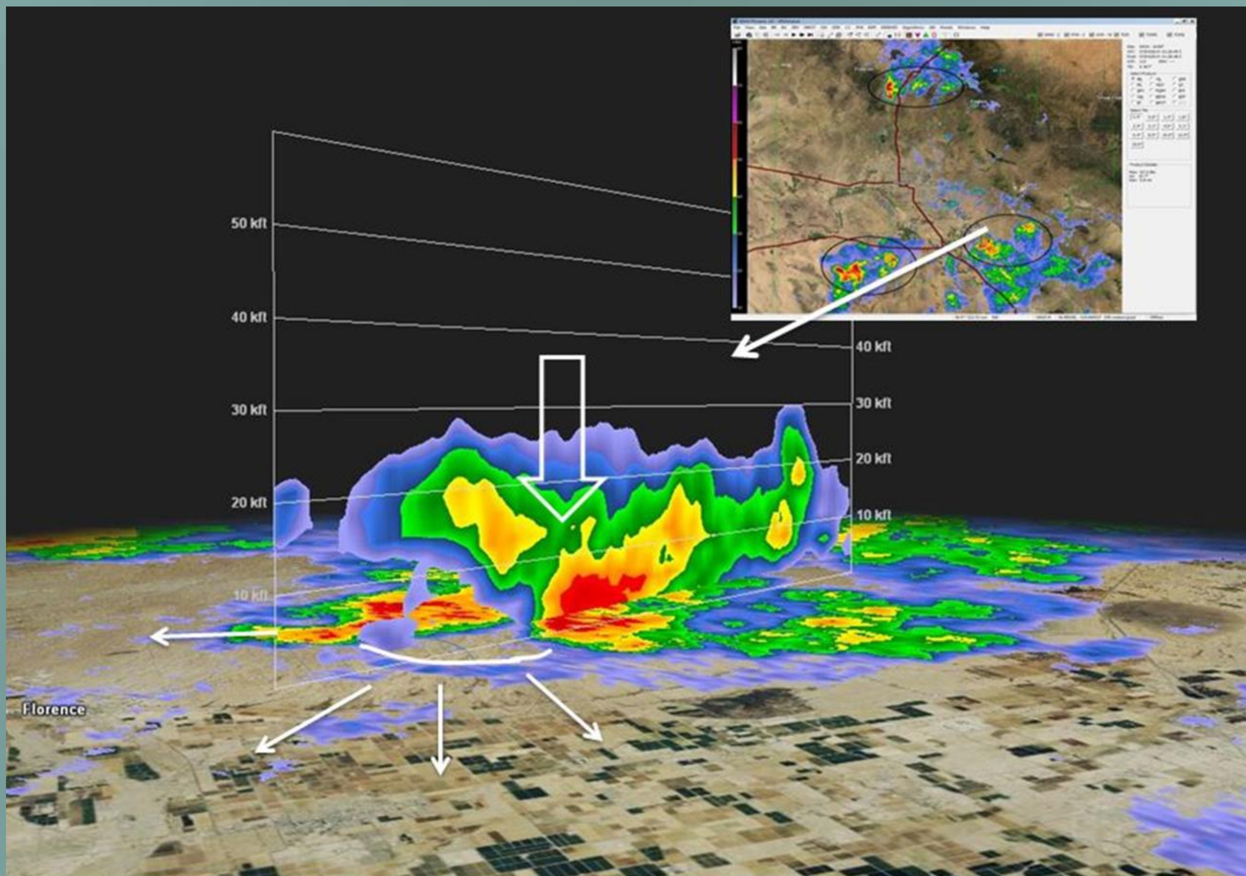

Figure 4: This cross-sectional view shows a thunderstorm near Florence, AZ producing a downdraft (hollowed white arrow) at 6:26 p.m. on July 3, 2014. The outflow would eventually expand and merge with other nearby gust fronts to help carry a large dust storm northward into the Phoenix area later that evening.

Dust storms need dust. Thunderstorms over the open deserts are more of a dust threat than those over more vegetated foothills and mountain peaks north and east of the Valley. With rain being largely absent from the region the month prior, soils were primed for a major dust event. As the July 3rd thunderstorms began collapsing during the late afternoon, their downdrafts could be tracked by radar (Figure 4). Rural areas often lack weather information. Fortunately, radar has different modes. The “base velocity” mode is great for seeing outflow boundaries as they form and tracking their movement across rural areas. In this case, it did not take long for radar to detect a large swath of fast-moving, 40 to 50+ mph winds traveling along the surface carrying potential dust northward toward Phoenix (Figure 5).

Do you know what to do if you’re suddenly caught driving in a dust storm?

PULL ASIDE · STAY ALIVE

Visit www.pullasidestayalive.org

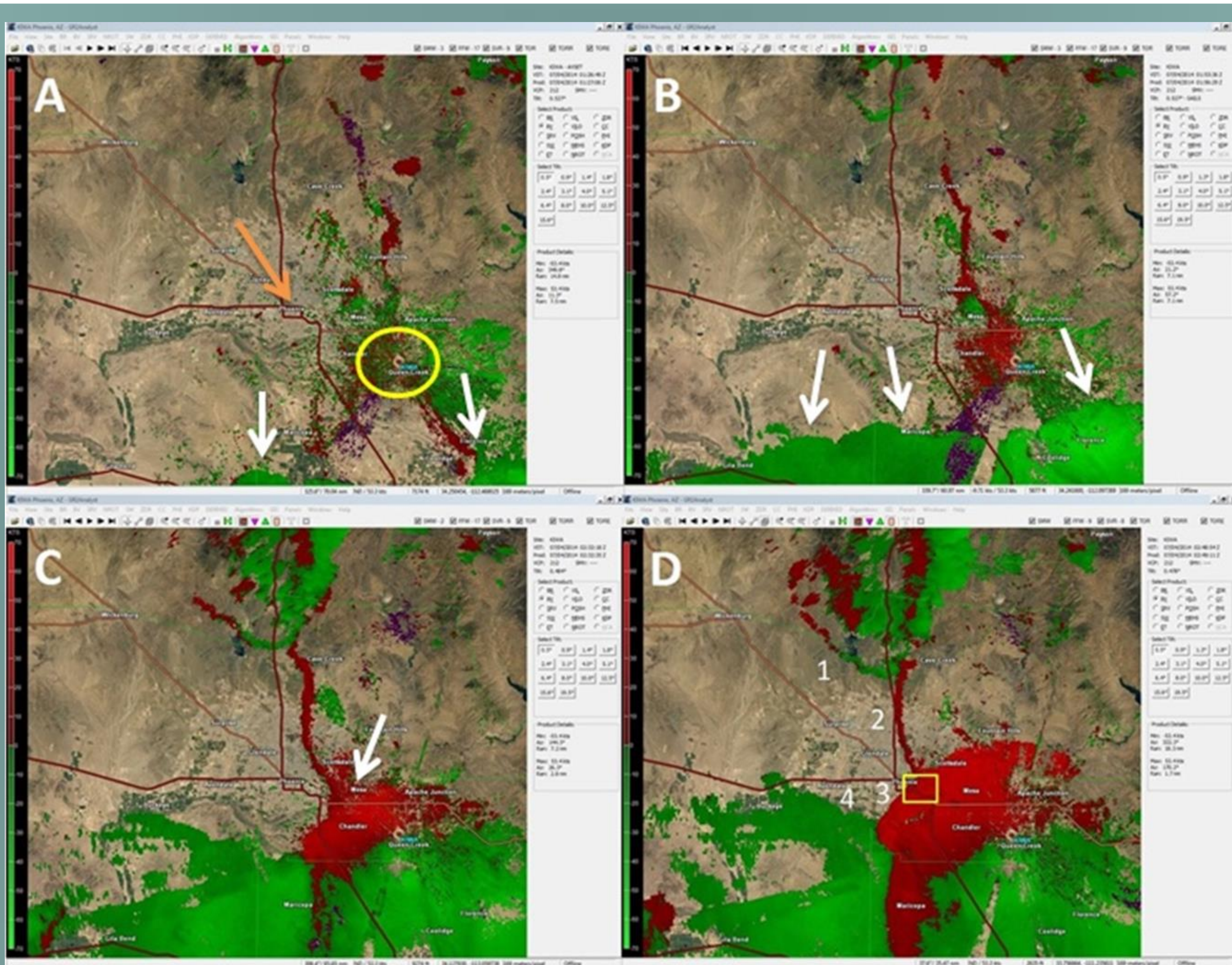

Figure 5: This is a series of base velocity images showing progression of strong outflow winds that carried a large dust storm into the Valley. Bright green areas indicate stronger inbound winds near the surface approaching the Phoenix Doppler radar site (circled yellow in Panel A). Bright red zones show high outbound winds moving away from the radar location. Panel A was taken at 6:26 p.m. The orange arrow points to downtown Phoenix. White arrows point to the leading edge of the gust front crossing Pinal County. Panel B, taken at 6:53, reveals intense winds of at least 40 mph moving further northward through Florence, AZ. By 7:32 (Panel C), multiple outflow boundaries are starting to enter the Valley from all directions. Unlike the ones arriving from the south, outflows originating from the north and east are not as obvious due to a lack of dust being picked up. At 7:48 (Panel D), a wall of blowing dust verified by weather observations at Phoenix Sky Harbor International Airport (boxed yellow) pushes northwestward through urbanized areas of Phoenix. Of the four major gust fronts noted, number "3" is the most powerful and dust laden.

A wall of dust originating out of Pinal County entered downtown Phoenix within 90 minutes. Just minutes before 8:00 p.m., visibility at Phoenix Sky Harbor Airport dropped to one mile. There were sustained winds between 30 to 40 mph with gusts exceeding 50 mph at times. This confirmed the arrival of the powerful dust storm seen on radar more than an hour earlier. Similar conditions were eventually felt Valley-wide as the massive dust storm rolled through.

July 3, 2014 dust storm and air quality…

For drivers caught in a dust storm, the fear of not being able to see can be overwhelming (see pullasidestayalive.org for more). Think about your breathing. You wouldn't intentionally stick your head over a campfire and inhale. Likewise, it's not good to be out breathing the microscopic particles that make up these dust storms. Fortunately, Maricopa County has a network of air quality monitoring stations that includes particulate matter concentrations. The coarser particulate matter variety measuring ten microns or less (referred to as PM10) is often the primary pollutant of interest correlated with windblown dust.

The July 3 dust storm imported impressive concentrations of PM10. For instance, a peak hourly concentration of 2,959 micrograms per cubic meter (µg/m3) was recorded at the West Phoenix monitoring site. That's a whopping 80 percent of the allowable dust in a given day. Needless to say, the 24-hr average of 166 µg/m3 at this same site ended up exceeding the Environmental Protection Agency's (EPA) national air quality standard of 150 µg/m3. Two other sites also exceeded the health standard. In fact, many of the remaining PM10 monitors in the network (17 total) were close to the standard. This July 3 dust event highlights the power of radar as a tool for future dust storms. Early anticipation continues to be a priority for air quality meteorologists forecasting in Arizona's lower deserts.

Key Doppler radar advantages…

This dust storm event happened to occur in the early evening. As a result, it was visible on ADEQ's South Mountain webcam (Figure 6). Keep in mind that dust storms can materialize day or night.

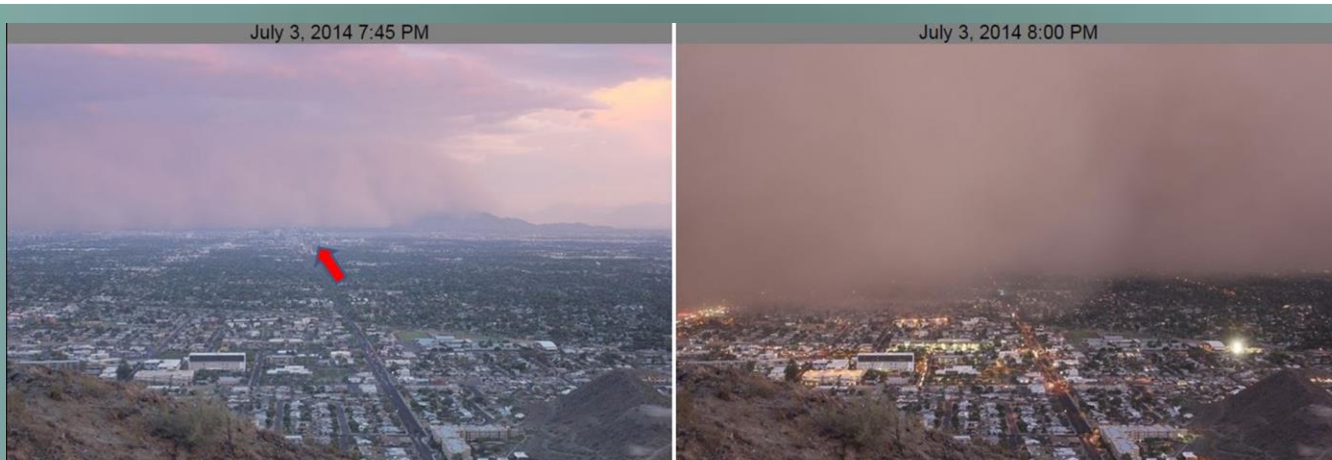

Figure 6: July 3, 2014 dust storm approaching and crossing over South Mountain (left) with Downtown Phoenix noted by red arrow. Downtown is quickly consumed by dust within minutes (right).

Images captured by ADEQ's visibility camera network.

The beauty of radar is that it can still "see" even when the sun goes down. Remarkably, the 3-D shape of the July 3 dust wall can be inferred with radar data alone as it moved through Phoenix (Figure 7).

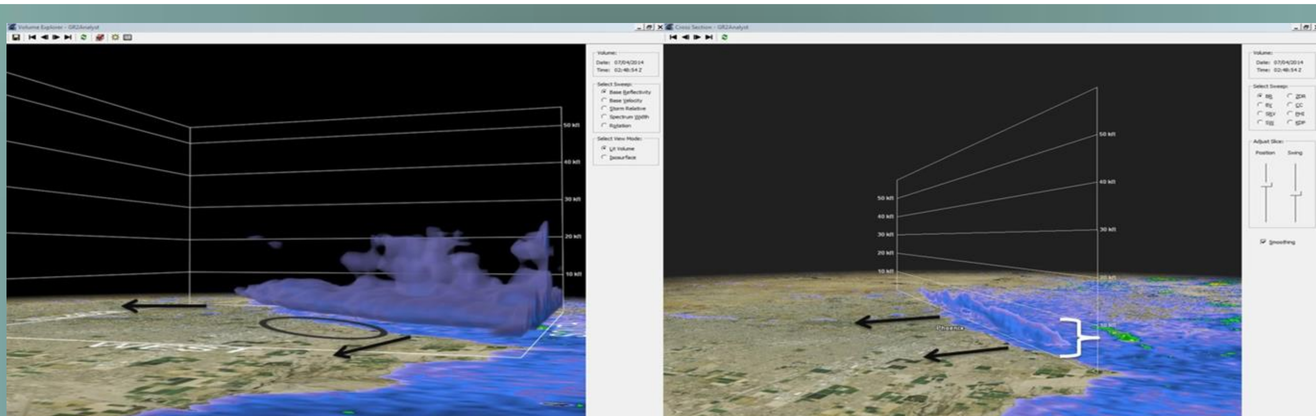

Figure 7: This is a 3-Dimensional view of the July 3, 2014 dust storm (left) as it moved through Downtown Phoenix (circled black). Black arrows show direction of dust storm movement. A two-dimensional cross-section perspective (right) shows leading edge of dust storm approximately being 10,000 feet high as it began moving through Phoenix. Both radar images were taken at 7:48 p.m.

Radar also has its limitations…

Currently, radar is unable to express how much dust is in a particular dust storm. Doppler radar also has inherent “blind spots”, by design. First, radar can’t “see” through terrain. This can be problematic for locations with rugged topography, such as Arizona. The result is a beam blockage (Figure 1). Second, radar installations are fixed and sample the atmosphere in increments between a 0.5° and 19.5° angle off the ground surrounding the site. The resulting beam becomes increasingly higher off the ground with distance. There is a chance that a “target of interest” is too far under or over a radar scan to ever be detected. Even with these three basic limitations, Doppler radar has proven to be a valuable aid for dust storm surveillance. It provides a way to warn the public of a looming dust storm’s arrival. This is why radar will continue to be a go-to “tool of the forecasting trade” for the air quality meteorologist.

Check out the following links for more detailed information on how radar works (NOAA), the development of emerging radar technology (National Sever Storms Laboratory), and where to access the latest radar imagery (NWS, Intellicast, Weather Underground).

I hope you enjoyed reading about radar and how we apply it to air quality forecasting. For our next monthly topic, the ADEQ Forecast Team will explore “Ozone: An Invisible Irritant.”

Thanks for reading!

Sincerely,

Jonny Malloy

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

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

– *Ozone: An Invisible Irritant*
– *The North American Monsoon*
– *The Genesis of a Thunderstorm*

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