Cracking the AQ Code

ADEQ Arizona Department of Environmental Quality
Air Quality Forecast Team

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Ozone: *An Invisible Irritant*

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When referring to ozone in the context of air quality, we immediately think of the negative aspects of this molecule and how damaging it can be for us humans. But, take a closer look and you'll see that ozone is also the reason why life is able to thrive on this planet. Ozone (also known as O_3) is a naturally occurring, colorless molecule in the atmosphere. Without it, the sun would bake all life on the surface with harmful radiation such as Ultraviolet (UV) light.

The Earth's atmosphere is divided into several layers: the troposphere, stratosphere, mesosphere, and thermosphere (Figure 1). For the purpose of this topic, we will focus on the first two layers. The troposphere is the lowest region where weather mostly takes place. It extends from the surface to about seven miles in altitude. The stratosphere continues from seven miles to around thirty-one miles. Most of the atmospheric ozone is situated about 10-19 miles above the surface in a region we call the "ozone layer." The thick layer at this altitude absorbs the dangerous UV radiation from the sun. In a way, stratospheric ozone acts like a natural shield, protecting life on Earth's surface. Without it, excessive UV light from the sun would penetrate to the surface and cause significant health concerns such as increased risk of skin cancer, cataracts, and other tissue damage in plants and animals. By now, you're probably rooting for ozone, but keep

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…

- The North American Monsoon
- The Genesis of a Thunderstorm
- Tropical Cyclones (A.K.A Hurricanes)

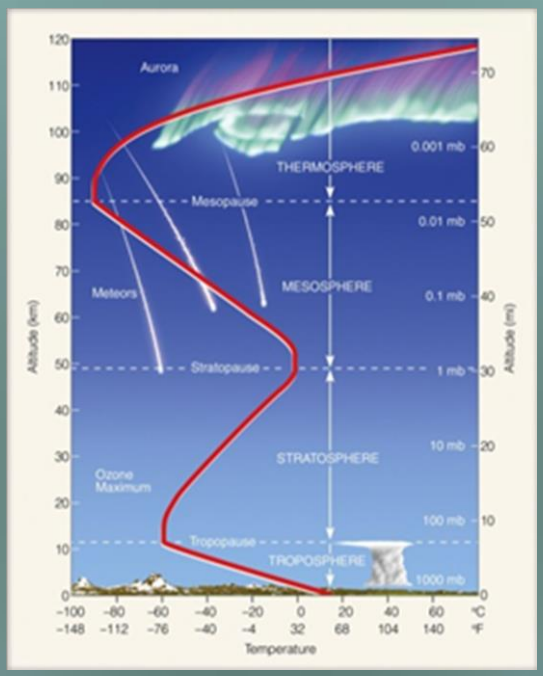

Fig. 1 : This graph represents the vertical cross section of earth's atmosphere. Note the difference in thickness between the layers and how temperatures (red line) warm or cool with height throughout each layer. The stratospheric warming is primarily due to the ozone layer which absorbs UV light from the sun.

Source: Four Interconnecting Spheres

reading and you'll find out why this molecule can also be an invisible irritant.

Good up high, bad nearby...

Contrary to popular belief, ozone is not just an "up there" pollutant. Ozone can form and even be brought down near the surface as well. And like many other pollutants, it also has its own daily and seasonal cycles. Daily ozone concentrations generally peak in the late afternoon, because ozone needs time to form through complex chemical reactions.

In the northern hemisphere, ground-level ozone, commonly known as tropospheric ozone, tends to be more active during the summer months when the sun angle is higher than during the winter months. This is partially due to the sun being out for a longer period during the summer than the winter. We usually start observing the onset of the ozone season in Arizona during early spring.

Even though tropospheric ozone concentrations are minuscule compared to that of stratospheric ozone, elevated concentrations of this molecule near the surface can have negative health implications. The most common among them is lung damage. Along with the elderly, children are also at a greater risk of exposure to ozone because their lungs are still developing and they're more likely to be active outdoors during afternoon peak concentrations than adults. In order to protect the public's health, ADEQ's air quality meteorologists use meteorological data to forecast the behavior of ground-level ozone.

So THAT's what those colors mean…

The Environmental Protection Agency (EPA) developed an Air Quality Index (AQI) for monitoring pollutants (Table 1) regulated by the Clean Air Act of 1990. The AQI is split into six categories (Good, Moderate, Unhealthy for Sensitive Groups, Unhealthy, Very Unhealthy, and Hazardous) and reveals not only how clean or polluted your air is, but also the associated health effects. The different categories in the AQI are represented by a range of concentrations for a given pollutant. For instance, ground-level ozone is measured in parts per billion (ppb), while particulate matter is measured in micrograms per meter cubed ($\mu g/m^3$). These ranges of ppb and $\mu g/m^3$ values are then converted to a standard range of AQI values that are easier to understand. For example, 0-59 ppb of ozone and 0-55 $\mu g/m^3$ of PM_{10} correspond to an AQI range of 0-50, which is considered to be the Good range.

Air Quality Index (AQI) Values	Levels of Health Concern	Colors
When the AQI is in this range:	*..air quality conditions are:*	*...as symbolized by this color:*
0-50	Good	Green
51-100	Moderate	Yellow
101-150	Unhealthy for Sensitive Groups	Orange
151 to 200	Unhealthy	Red
201 to 300	Very Unhealthy	Purple
301 to 500	Hazardous	Maroon

Table 1: The different colors represented in this Air Quality Index (AQI) table are various categories assigned by the Environmental Protection Agency (EPA). A category represents a certain range of concentrations for each pollutant. Air Quality Meteorologists at ADEQ assess the meteorological conditions and forecast for specific pollutants in the designated nonattainment area.

Source: AirNow

Unlike particulate matter (i.e. dust and soot) which is measured over a 24-hour period from midnight to midnight, ozone is averaged in blocks of eight consecutive hours (known as an 8-hr average) throughout the day. While hourly values of ozone may be higher than 75 ppb throughout the day, the highest 8-hr average block within a day must not be greater than 75 ppb (100 AQI) or an exceedance of the federal health standard occurs. If meteorological conditions are favorable for an exceedance to occur, the ADEQ Forecast Team can issue a Health Watch (HW) or High Pollution Advisory (HPA) for a given pollutant to warn the public. In doing so, the public can take precautions and limit outdoor activities to reduce any negative impacts on their health, and stop activities that may cause an exceedance (see ***"So, what can YOU do?"*** below).

Health Watch – issued when a pollutant is expected to *approach* its respective federal health standard
High Pollution Advisory – issued when a pollutant is expected to *exceed* its respective federal health standard

Back to chemistry class…

Since we just discussed how tropospheric ozone is monitored, let's focus on the production side of this pollutant. Even though ozone is a naturally occurring molecule in the atmosphere, anthropogenic (human related) activity can help speed up this process. Ozone is not directly emitted into the air but rather formed through complex chemical reactions in our atmosphere. These intricate chemical reactions consist mostly of NOx (Nitrogen Oxides), VOCs (Volatile Organic Compounds), and photons (light) from the sun (Figure 2). Photons from the sun can hold enough energy to excite certain gases in our atmosphere and alter atomic bonds to produce different molecules. These newly formed molecules can react even further to produce or decimate ozone in the atmosphere. Every second of the day, these chemical reactions are taking place at an unfathomable rate. Ozone is constantly created and destroyed all around us. Generally speaking, it is when the creation of ozone outpaces the destruction of ozone that air quality starts to deteriorate. This can happen in many ways. For example, the burning of fossil fuels generally releases vast amounts of VOCs and NOx into the air. Therefore, oil refineries, industrial sites, highway traffic, and even vegetation/plant life are a major source of NOx and VOCs for tropospheric ozone production. It's not surprising to see elevated concentrations of ozone during the summer months near these types of sources.

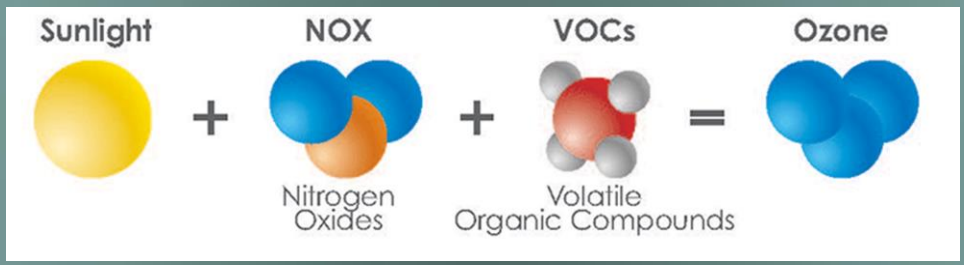

Fig. 2: Diagram of NOx, VOCs and ozone molecules.

Source: Washoe County, NV

Another method by which ozone can increase in the troposphere is through a process known as transport. The atmosphere acts as a fluid and constantly flows from one place to another, both vertically and horizontally. Near the surface, winds resulting from pressure differences can transport some pollutants over great distances from their originating source, including ozone precursors. Besides the conventional lateral transport, ozone can also migrate down from the stratosphere. We refer to this phenomenon as "Stratospheric Intrusion." Often times, with strong upper-level troughs, the tropopause (the transition zone between the troposphere and the stratosphere) can fold over and drag stratospheric ozone down towards the surface. While there is a general understanding of when these intrusions are occurring, research is ongoing to better understand how much ozone is brought down to the surface. This specific type of event is usually rare and happens more often in the spring in the western parts of the country when troughs are quite frequent.

Meteorology really matters…

One small detail to keep in mind is that elevated concentrations of ground-level ozone are not always indicative of an increased ozone production. As a matter of fact, meteorological conditions, such as stagnant conditions and daily winds, play a crucial role in the behavior of pollutants. For example, without sufficient mixing near the surface, ozone and chemicals contributing to ozone formation can begin to "pile up" and result in a greater likelihood for more daytime ozone formation.

The daily wind flow typically follows a mountain-valley wind pattern here in Phoenix (Figure 3). Early in the morning, winds move across the Valley out of the north and east from surrounding higher terrain. They become calm during the middle part of the day as the sun overhead provides nearly equal heating. By the afternoon, winds turn westerly as the sun's rays are more focused on the west-facing mountains to the east. This general flow plays a crucial role in regard to pollutant behavior. During the early morning hours, ozone begins to form in the West Valley as the sun rises in the east. Once enough heating takes place during the day, winds can shift out of the west pushing the invisible ozone plume eastward. Under this typical scenario, you can expect the highest ozone concentrations over the East Valley around middle to late afternoon.

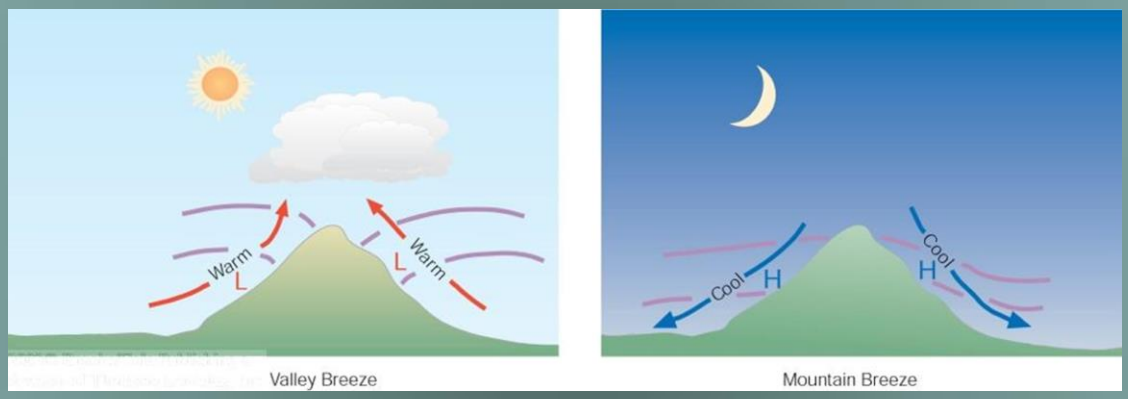

Fig. 3: As the sun rises in the morning, the higher terrain will begin to warm first and result in a Valley breeze. Once the sun sets, the higher terrain will cool off faster than the valley floor and result in a Mountain breeze.

Source: Metropolitan State University of Denver

Seeing is believing, right?

It would be a lot easier if ozone approached us like a wall of dust. You would be able to track changes in its direction and speed of travel, as well as its size. However, ozone is a colorless, odorless gas. Since we know that this invisible irritant can't be seen the traditional way, there are other ways to track it. For example, ozone monitors placed around Maricopa County can give us a decent representation of this pollutant as seen in Figure 4. As ozone moves across the Valley, monitors can record concentrations throughout the day to help "paint a picture" of this invisible plume. This "visual" of an invisible pollutant can help the ADEQ Forecast Team better predict when and where the highest ozone concentrations may occur.

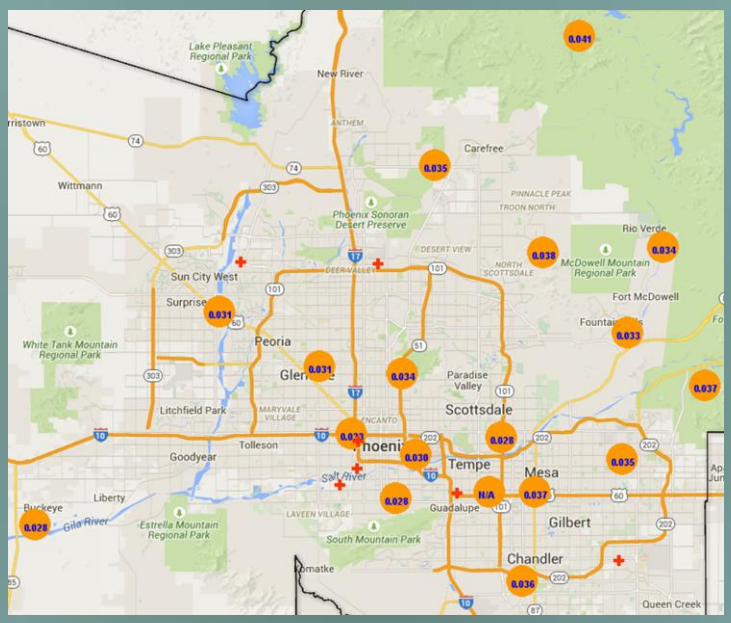

Fig. 4: Maricopa County Air Quality Department's ozone monitors. These monitors are very useful at illustrating a "picture" of the current air quality conditions in Maricopa County. The numbers you see above indicate 1-hr concentrations of ozone in parts per million (ppm) instead of parts per billion (ppb).

Mythbusters…

The most common misconception among the general public is the perception that ozone is directly related to temperature. This is false. The reason why our ozone season takes place during the summer is not because of the hotter temperatures, but rather it is the increased daylight hours and the higher sun angle in the sky that results in more intense UV radiation. Temperature does not have a direct relationship with ozone. For example, we have seen levels in Phoenix exceed the federal standard in April with temperatures in the 70s and 80s. We also see Good levels of ozone in the dead of summer when the thermometer tops 100°F. Instead, it's the combination of meteorological conditions (wind direction/speed, cloud cover, etc.), time of the day, intense/focused sunlight, and ultimately availability of ozone precursors that play a role in the matter. With that said, temperature can play a small role in increasing ground-level ozone. When the environment begins to warm under the intense Arizona sun, more evaporation takes place. As a result, an increased amount of VOCs (paint, cleaning supplies, petroleum, solvents etc.) from the surface break off into the atmosphere, creating more precursors for tropospheric ozone production. Therefore, warmer temperatures can add onto this effect by increasing the availability of particular reactants. However, it is primarily the intense, focused sunlight (usually due to higher sun angle during the day) that drives ozone production, not temperature. For more proof on how temperature is not completely related to higher ozone, see Wyoming Winter Ozone.

So, what can YOU do?

Unfortunately, ozone is not something that we can simply just flip a switch and turn off. It is a naturally occurring molecule in our atmosphere. However, we can do our part to decrease the amount that can form in the troposphere.

- Instead of driving, we can ride bikes or walk more, and if possible, carpool. Cars are an enormous source of VOCs and fewer cars on the road can greatly help reduce ozone concentrations near the surface.
- Conserve energy at home and work.
- Keep cars, boats, and other engines properly tuned.
- Make sure your tires are inflated properly as underinflated tires make the engine work harder and waste more fuel.
- Use environmentally safe paints and cleaning products whenever possible.
- On days when high ozone levels are expected in the Valley, limit vehicle idling when possible, combine errands and reduce trips, defer lawn and gardening chores that use gasoline-powered equipment or wait until evening.

These are some of the actions we all can take to become more environmentally friendly. As mentioned before, ozone can either work for you or against you. This invisible irritant, in a way, is necessary for all life on earth. Though it's good up high, it can be harmful nearby.

I hope you enjoyed reading about ozone and the impacts it has on us and the planet. For our next monthly topic, the ADEQ Forecast Team will explore “The North American Monsoon.”

Thanks for reading!

Sincerely,

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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…

– The North American Monsoon
– The Genesis of a Thunderstorm
–Tropical Cyclones (A.K.A Hurricanes)

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