

Cracking the AQ Code



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Jet Streams and Fronts

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When it comes to our air quality forecast discussions or a weather forecast on TV, two important features almost always mentioned are the jet stream and fronts. Frontal systems may be at the surface while jet streams are at the top of the [troposphere](#), but they are linked closer than you may realize. While most of us have a basic idea what each of these are, here we will try to get a little more in depth. Then, as always, we will look at how it all fits into air quality.



Source: pinnaclepeaklocal.com

The Jet Stream

There are three main jet streams: the Arctic Jet, the Polar Front Jet, and the Subtropical Jet. All three flow from west to east, and are identified as narrow bands of wind with speeds greater than 58 mph. The jet streams are located near the top of the troposphere, but they can change quite drastically in altitude. Their altitude can vary depending on the latitude and season. However, the Polar

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...

- Air Quality Trends and Standard Changes
- Wildfires
- Tools of the Trade - Part 2

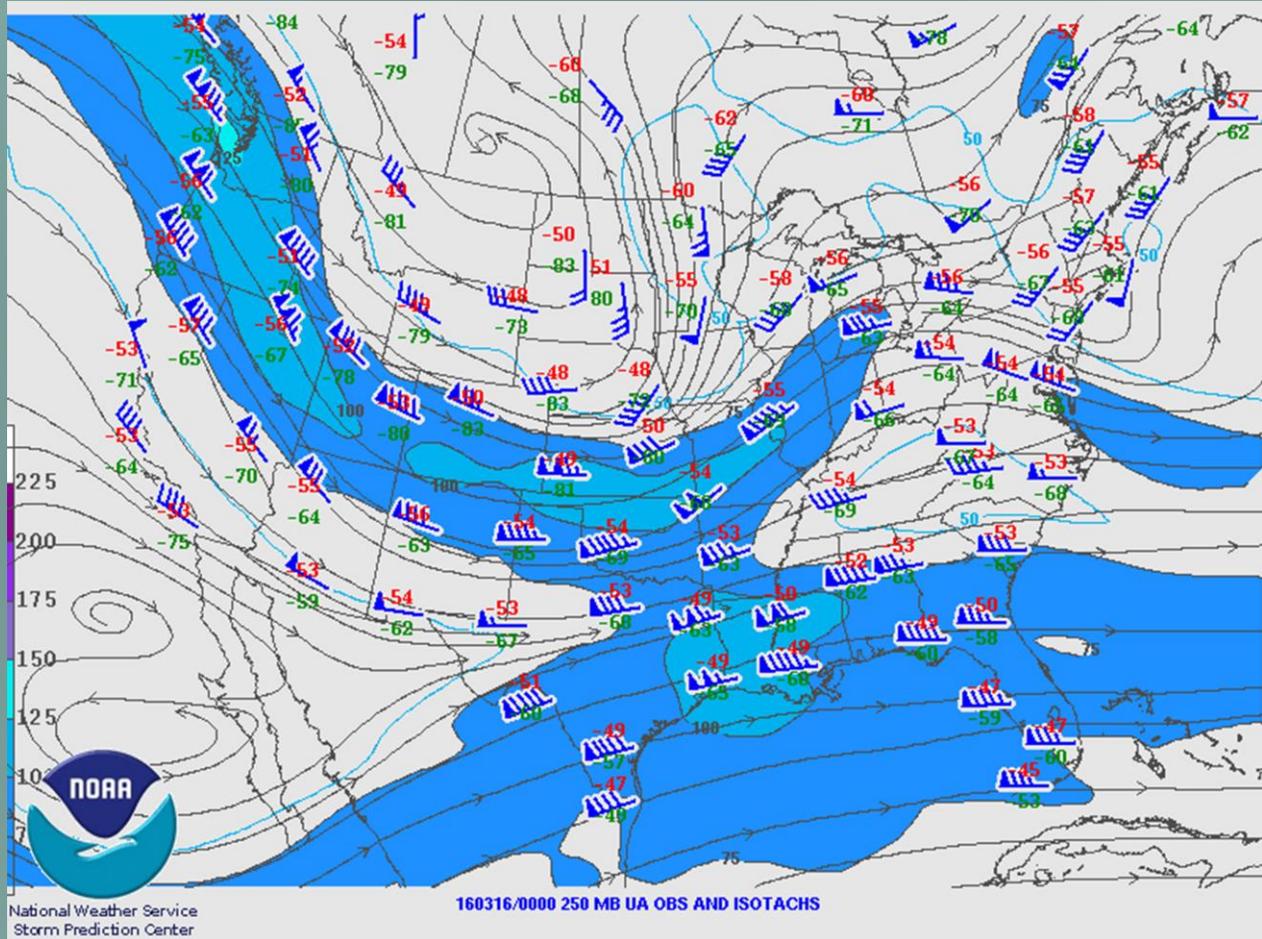


Figure 1: National Weather Service upper-air chart for March 16, 2016, 00UTC. The blue fill indicates areas of stronger winds. In this image the Polar Front Jet can be seen entering the United States over the far northwest and forming a trough over the central U.S. The Subtropical Jet flows from Mexico, over the Gulf States, and exits the U.S. over Florida/Georgia. The Arctic Jet is too far north of the United States and is not depicted. Source: <http://www.spc.noaa.gov>

Front Jet, which has the greatest influence over the United States, is generally between 30,000 and 40,000 feet.

How does it form?

The primary forces that create the jet stream are the pressure gradient force and the Coriolis force. A pressure gradient develops as a result of differential heating of the earth. Since the equator receives more energy from the sun than the poles, a north-south temperature gradient develops. This results in upper-level high pressure over the equator and upper-level low pressure over the poles (Fig. 2). Because wind flows from high to low pressure, a southerly wind is produced in the northern hemisphere. If the earth did not spin then that is what we would observe. However, this is where the Coriolis force comes into play. Due to the Coriolis Effect, air moving over the surface of the earth turns to the right in the northern hemisphere and to the left in the southern hemisphere. Thus, wind from the equator to the North Pole turns eastward.

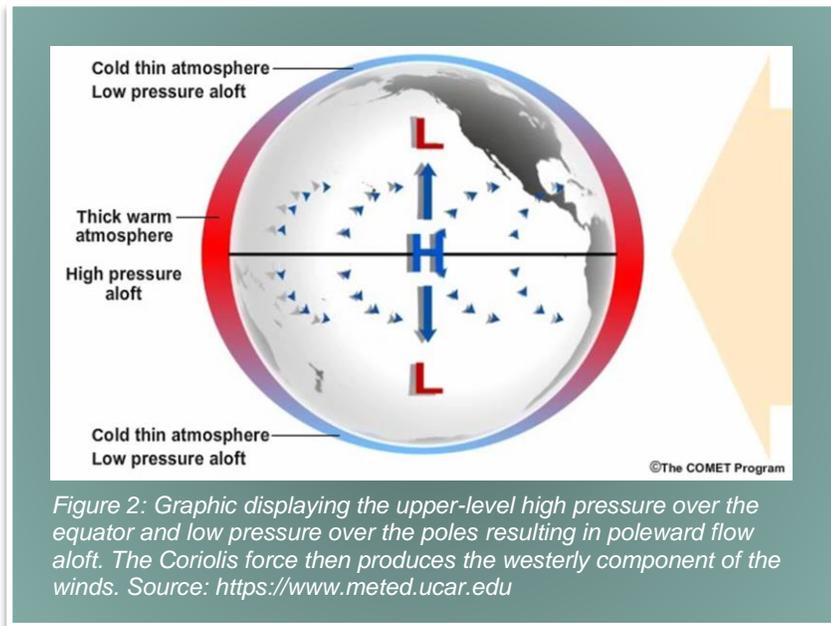


Figure 2: Graphic displaying the upper-level high pressure over the equator and low pressure over the poles resulting in poleward flow aloft. The Coriolis force then produces the westerly component of the winds. Source: <https://www.meted.ucar.edu>

The Coriolis force is a fairly simple concept once understood, but can be difficult to describe. Think about two points on the surface of the earth, one in Hawaii and another in Alaska. One rotation of the earth, or one day, takes the same amount of time at each location, but the point in Hawaii must travel a whole lot further because it's closer to the equator. Therefore, the point in Hawaii must travel faster to keep pace with the point in Alaska. So, when air near the equator moves poleward (towards the North or South Pole), it is now traveling faster than the earth below, and therefore appears to turn eastward. Conversely, when air near the poles moves equatorward, it is

now traveling east at a slower rate than the earth below it, and therefore appears to turn westward. Still confused? Check out this [video](#).

What makes the jet so strong?

The jet stream commonly reaches speeds greater than would be observed from the pressure gradient force and the Coriolis force alone. This is accomplished through the law of conservation of angular momentum. Don't worry if you didn't study this in a physics course. It is a property that everyone has experienced or observed at some point in their life. Most have tried this at one time or another; when sitting in a chair that spins, if you begin to spin with your arms extended, then pull your arms in towards your chest, you will begin to spin faster. That is due to the fact that angular momentum is always conserved.

Another classic example comes from ice skaters. When an ice skater spins, you will notice them begin spinning incredibly fast as they tuck their arms into their chest (Fig. 3). This same process happens on the earth on a much larger scale. As the air flows from the equator to the poles, the air moves closer to the axis of rotation. In order to conserve angular momentum, the air increases in

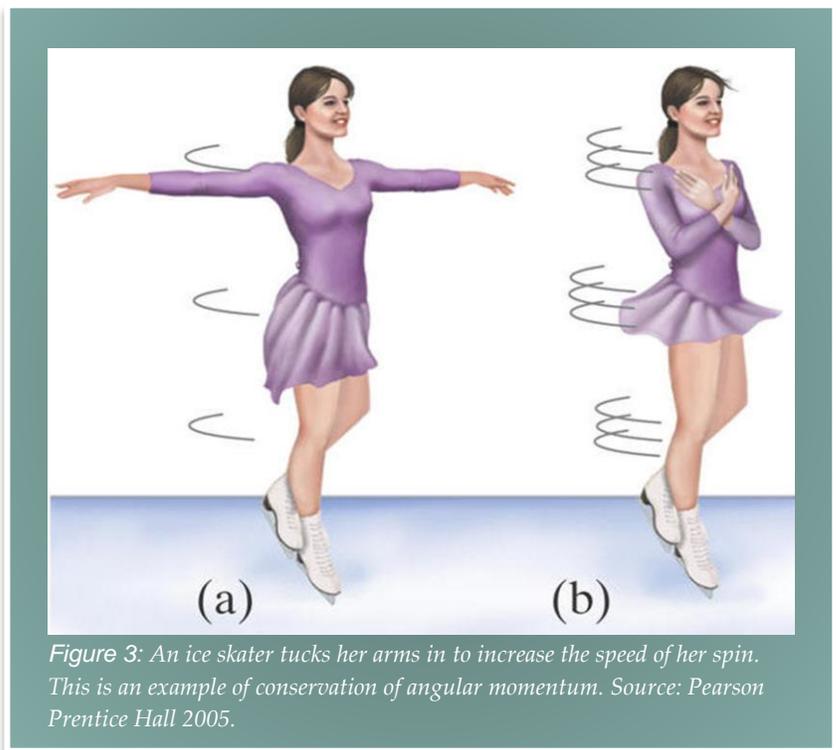


Figure 3: An ice skater tucks her arms in to increase the speed of her spin. This is an example of conservation of angular momentum. Source: Pearson Prentice Hall 2005.

speed. This is why the jet commonly exceeds 100 mph and can even reach speeds greater than 200 mph.

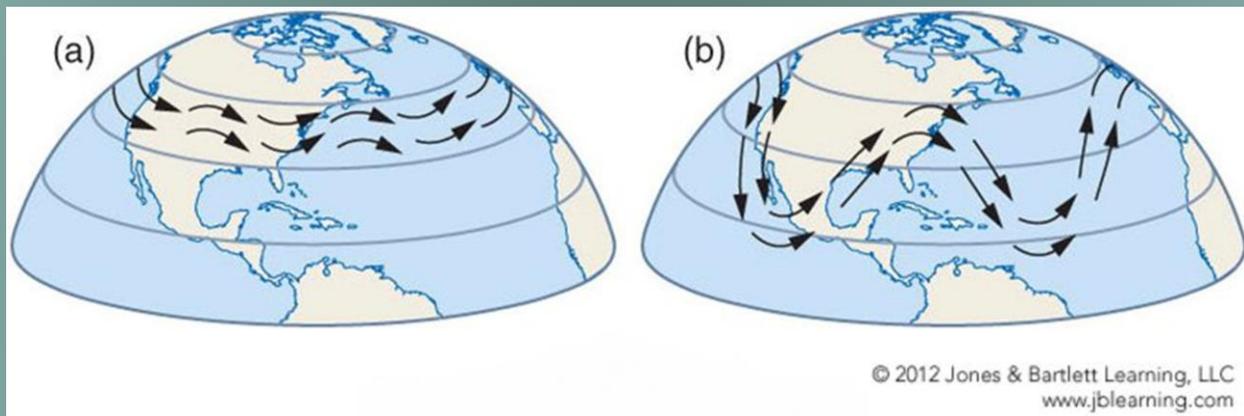


Figure 3: The image on the left represents zonal flow and the image on the right represents meridional flow. Source: www.jblearning.com

In addition to wind speed, another jet stream characteristic that can vary considerably is its direction. Sometimes, the jet does flow in a relatively straight west to east direction. This is called “zonal” flow. However, commonly, it flows in a much wavier pattern, which is called “meridional” flow (Fig. 4). During meridional flow, there are upper-level troughs and ridges. Often times, these troughs and ridges result in low pressure systems and high pressure systems at the surface, respectively. When an active low pressure system develops, frontal boundaries will develop as well. This is where the link between jet streams and frontal systems comes into play.

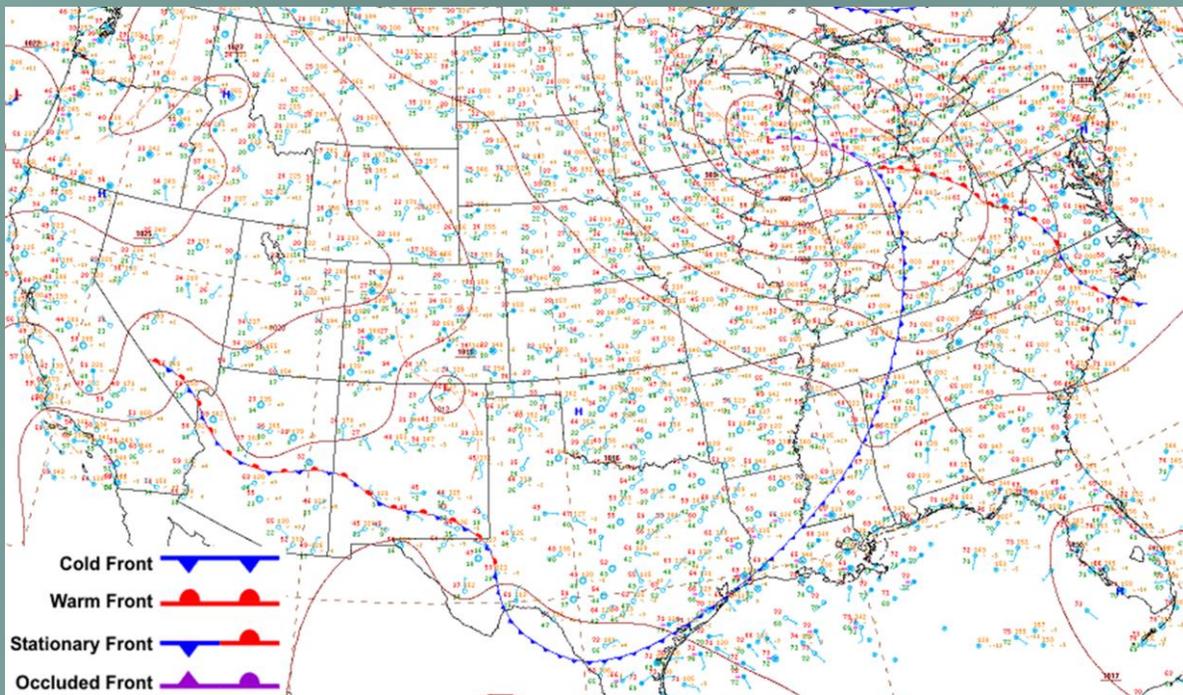


Figure 4: National Weather Service surface analysis for March 16, 2016, 09 UTC. A cold front stretches from northwest Ohio down into Texas. A Warm front extends from northwest Ohio into West Virginia. An occluded front stretches from the low over Wisconsin to the point where the warm and cold front meet. One stationary front is located from western Texas into Nevada. Source: <http://www.wpc.ncep.noaa.gov>

A front is simply the boundary between two air masses with different temperature and moisture characteristics. Here we will discuss the four main frontal types: cold, warm, occluded, and stationary (Fig. 5).

Cold Front

A cold front occurs when cold air advances into warmer air. When a low pressure system develops, winds around the low are counter-clockwise in the northern hemisphere. This causes flow on the west side of the

low to pull down cold air from the north. The cold front is located at the leading edge of this cold air (Fig. 6). Since cold air is denser than warm air, the cold air wedges underneath the warm air. This causes the warm air to rise and is the driving mechanism for weather along the cold front. As the air rises, it cools and the moisture condenses into clouds. When the air reaches saturation it must precipitate out the excess moisture.

Cold fronts are steep (see Fig. 6), causing a quick ascent of the warm air. As a result, a narrow band of unstable weather often develops

along the front. Severe weather, such as thunderstorms, can occur along cold fronts due to this rapid rising motion of the air. Of course, sufficient moisture is a requirement for thunderstorms and precipitation to occur. It is not uncommon here in the desert to have a "dry" cold frontal passage, in which no precipitation occurs.

Warm Front

A warm front on the other hand, is when warm air is advancing into the colder air. In this case, the warm air slides up and over the cold air. Again, this is because the warm air is less dense than the cold air. The surface warm front is positioned at the trailing edge of the departing cold air (Fig. 7). A warm front has a much shallower slope than the cold front. As a result, a widespread area of rain can develop, as opposed to the narrow band associated with a cold front. However, the instability associated with a warm front is not as strong due to the shallow slope,

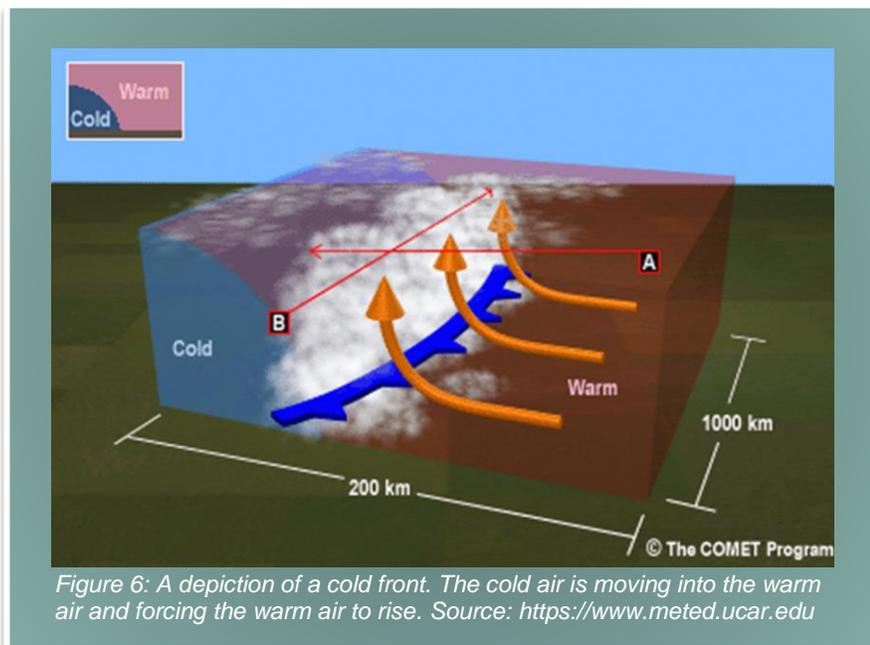


Figure 6: A depiction of a cold front. The cold air is moving into the warm air and forcing the warm air to rise. Source: <https://www.meted.ucar.edu>

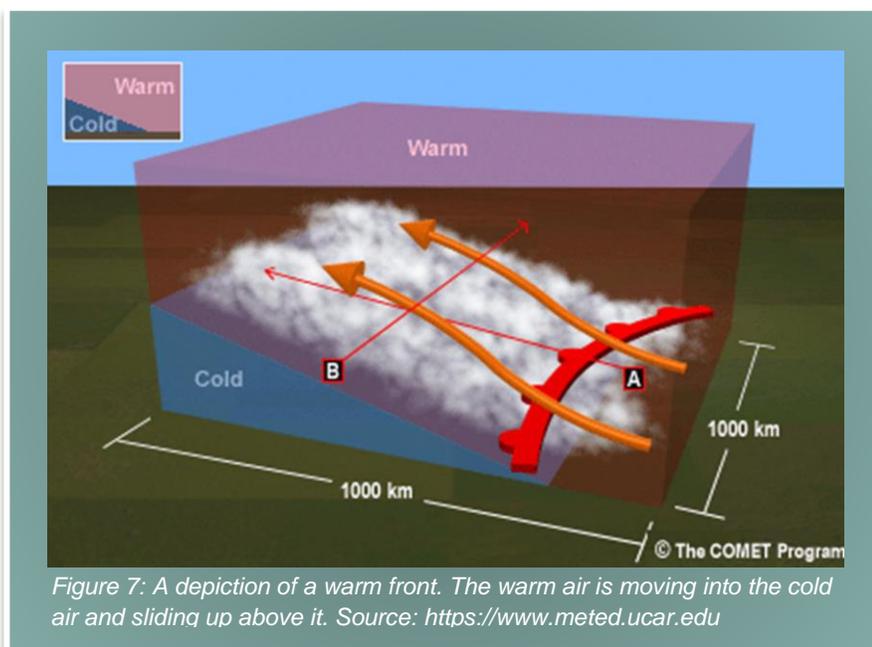
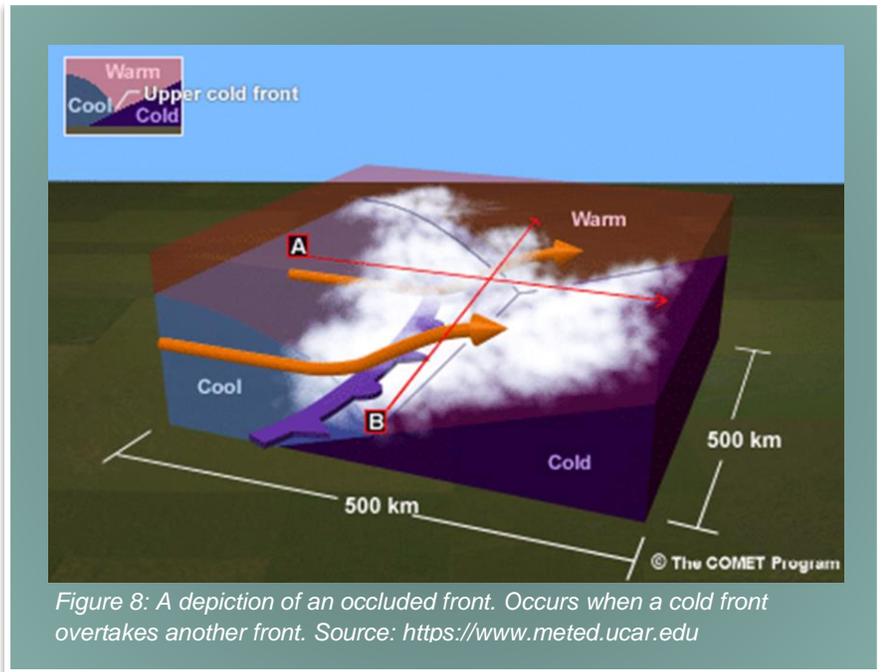


Figure 7: A depiction of a warm front. The warm air is moving into the cold air and sliding up above it. Source: <https://www.meted.ucar.edu>

making severe weather less likely. Weather associated with a warm front typically includes light to moderate, steady precipitation with only isolated thunderstorms.

Occluded Front

An occluded front is basically the combination of two different fronts, typically created when a cold front overtakes a warm front (Fig. 8). The occlusion extends from the low



pressure center to the point where the warm and cold fronts meet. This point is often referred to as the “triple point”. Since the occluded front is a mixture of two fronts, it can take the weather characteristics of both cold and warm fronts. The weather can vary depending on the temperature of the different air masses associated with the occlusion. However, the weather usually ends up being somewhere in between the severe cold front type weather and the widespread steady rain of a warm front.

Stationary Front

A stationary front, just like the other fronts, is the boundary between different air masses. However, a stationary front, as the name indicates, hardly moves. This occurs when there is weak thermal advection between the two air masses, meaning, neither the cold air to the north, nor the warm air to the south, are actively advancing into one another. Stationary fronts can be associated with long lasting rain events or can even occasionally be a focal point for severe weather.

However, most of the time, especially here in the Desert Southwest, no significant weather comes from a stationary front. A primary reason stationary boundaries are important is because they are an ideal location for low pressure systems to develop. When a

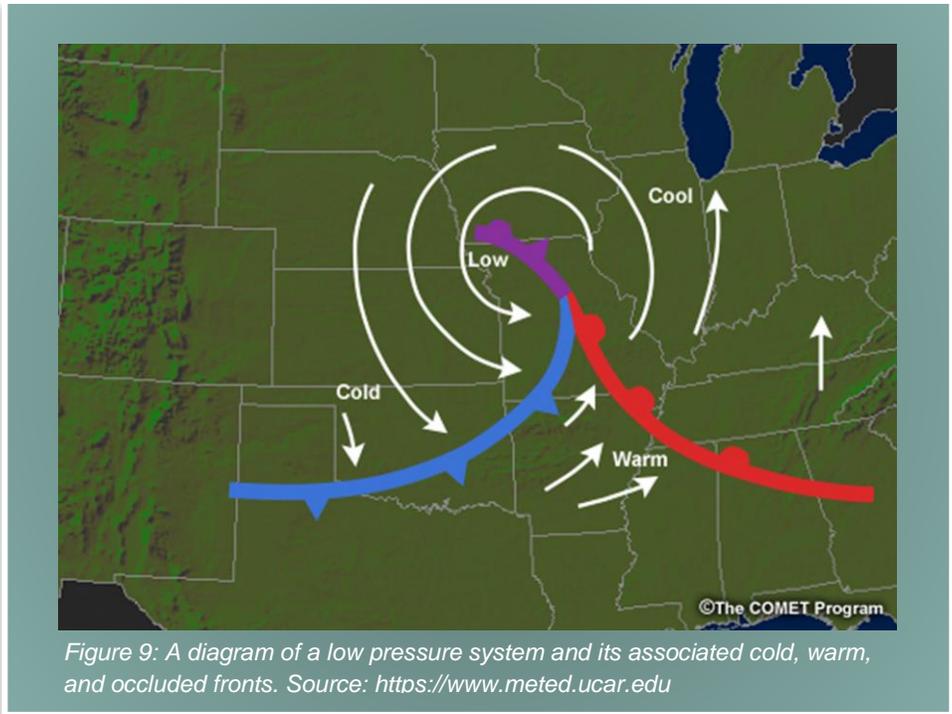


Figure 9: A diagram of a low pressure system and its associated cold, warm, and occluded fronts. Source: <https://www.meted.ucar.edu>

proper mechanism, such as an upper-level trough, moves over a stationary front, it can create enough instability to start the process of developing a low pressure system. This will then lead to the other fronts that produce active weather more often.

Air Quality

Jet streams and frontal systems can impact air quality in different ways depending on the situation. When the jet stream forms a ridge over the region, quiet weather will often be the result. With light winds and mostly sunny skies, windblown dust will not be a concern. However, this pattern during the warm months will lead to increased [ozone](#) levels. Also, particulate levels may increase due to stagnation if the winds in the lower levels are weak and persist long enough.

When the jet stream forms a trough over the area, air quality responds very differently. Generally, more winds throughout the atmosphere will help disperse pollutants. In addition, cloud cover typically increases, which reduces ozone formation by blocking the sunlight. However, if strong enough winds mix down to the surface, blowing dust becomes a concern. Here in Arizona we are all too familiar with the threat of [blowing dust](#).

An upper-level trough increases the chances of a surface low pressure system developing and forming frontal systems, which have their own impacts on air quality. A warm front that is expected to bring light rain most of the day will certainly

create nice, clean air. Similarly, a cold front that is expected to bring plenty of rain will also clear out the air. Breezy winds commonly present around low pressure systems can also help with air quality, but only until a certain point. If winds are forecast to be particularly strong, and little to no rain is forecast (and no recent rain has occurred), then blowing dust becomes a possibility. As mentioned earlier, these dry cold fronts can be fairly common in Arizona and can pose a significant dust threat.

When it comes to air quality forecasting, one has to balance all the factors mentioned above. Winds can clear the airshed, but too strong of winds can loft loose soil into the air we breathe. Warm, sunny conditions can be beneficial by keeping particulates down, but on the other hand, are ideal for ozone. However, if conditions become too stagnant, then particulate levels can increase along with ozone. Ultimately, the one true constant is rain. Rain is the best way to clean the air. That is why the ADEQ Forecast Team is always looking ahead for that next rain event. We enjoy being able to tell Arizonans that their air quality is going to be good. At the same time, we closely monitor the weather for those situations that hurt air quality because our number one goal is to help protect your health!



For our next topic, the ADEQ Forecast Team will look at air quality trends and AQI standard changes.

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)



In case you missed the previous Issues...

June 2015: [Tools of the Air Quality Forecasting Trade: Capturing Dust Storms on Doppler Radar](#)

July 2015: [Ozone: An Invisible Irritant](#)

Sept 2015: [North American Monsoon](#)

Oct 2015: [The Genesis of a Thunderstorm: An Arizona Perspective](#)

Dec 2015: [Temperature Profiles, Inversions, and NO BURN DAYS](#)

Jan 2016: [El Niño Southern Oscillation](#)

Feb 2016: [All About Fog](#)



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

- Air Quality Trends, Comparisons, and AQI Changes
- Wildfires
- Forecaster Tools of Trade – Part 2

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