Cracking the AQ Code

ADEQ Arizona Department of Environmental Quality
Air Quality Forecast Team

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El Niño Southern Oscillation

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There is plenty of buzz out there surrounding the current state of the El Niño Southern Oscillation (ENSO) and there should be. There are two extremes when considering ENSO: El Niño and La Niña. We are currently in one of the stronger El Niño episodes since modern record keeping began. Impacts on global weather patterns from prior El Niño events have been significant. Many people still reflect on the powerful '82-'83 and more recent '97-'98 El Niño events, of which are often regarded as measuring sticks for expectations of future strong El Niños.

Specifically for the Desert Southwest, surplus rain and snow are the principal concern during an active El Niño period. With that in mind, now we talk of changing regional reservoir levels, mountain snowpack depth and longevity, flooding risk, short and long-term wildfire potential, and yes, even air quality. The focus of this issue of *Cracking the AQ Code* is on the El Niño or "warm" phase of ENSO.

Before we dive into El Niño's consequences for Arizona's weather and air quality, let's discuss the science behind ENSO.

Finding ENSO

Even though the magnitude of El Niño and La Niña phenomena have only been officially tracked since 1950 using the Oceanic Niño Index (ONI), the presence of El Niño and La Niña phases have been noted on a regional basis across the globe for centuries.

One such location is the open waters off the coast of Peru and Ecuador. How? During an El Niño, relatively warmer waters originating from the central Pacific Ocean begin shifting eastward toward South America. Historically, this has created intermittent disruptions to fisheries along the west coast of South America, which rely on inherently cold nutrient-rich sea water to keep the fish crop abundant. Shut this down and a vital piece sustaining the economy is devastated. The '82-'83 El Niño was particularly

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…

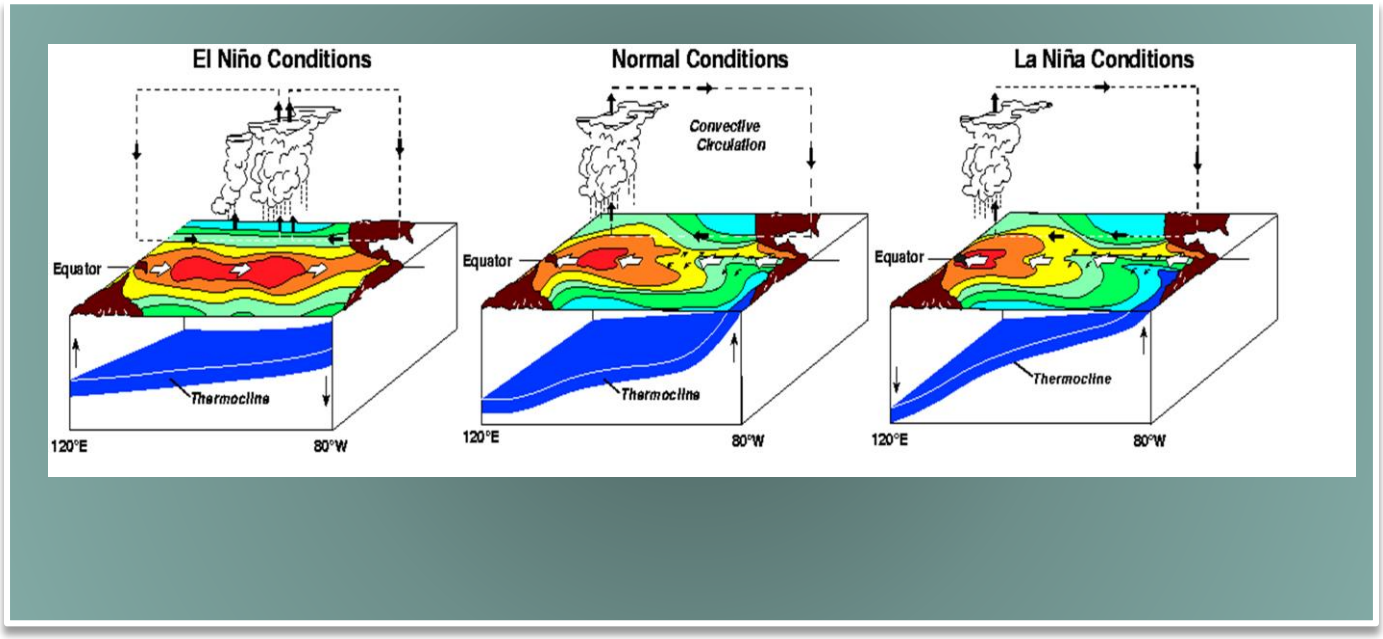
- All About Fog
- The Jet Stream, Cold Fronts, etc.
- Tropical Storms

troublesome for Peruvian fisherman.

Regardless, the presence of a weak or strong El Niño alters sea surface temperatures (SSTs) more notably during the winter months. It is for this reason that locals coined the term “El Niño” translated as “the boy” or “Christ-child” because of the appearance of these unusually warm waters and failing fish harvest around Christmas. The name has since stuck for both the general public and those engaged in ENSO studies.

El Niño is just one extreme of ENSO. The other La Niña, representing the “cool” phase of ENSO. La Niña is essentially the reversal of abnormal SSTs stretching across the equatorial Pacific. This means warmer waters normally found in the central basin of the Pacific instead transfer westward toward Australia and Indonesia. This is good news for fisheries near Peru in terms of larger hauls. However, rain tends to follow the unstable air mass associated with the oceanic warm pool. Therefore, Southeast Asia and Australia experience more rain and are at a greater risk for flooding, while at the same time, North America may experience drought and increased wildfires. Geographically, these natural disaster risks flip-flop under El Niño conditions.

The key point is that while the ENSO footprint occurs on a global scale, its effects are regionalized. Changes to precipitation patterns spurred by ENSO can be downright devastating to some economies, while welcoming for others. It’s all about location. Diagrams of the two extremes of ENSO are shown in Figure 1.



Transitions from El Niño to La Niña typically recur on a three to seven year cycle (Figure 2). A strong El Niño (red spikes) does not mean that there will be a strong La Niña (blue spikes) afterwards (and vice versa). Keep in mind, Figure 2 indicates a change from normal sea surface temperatures.

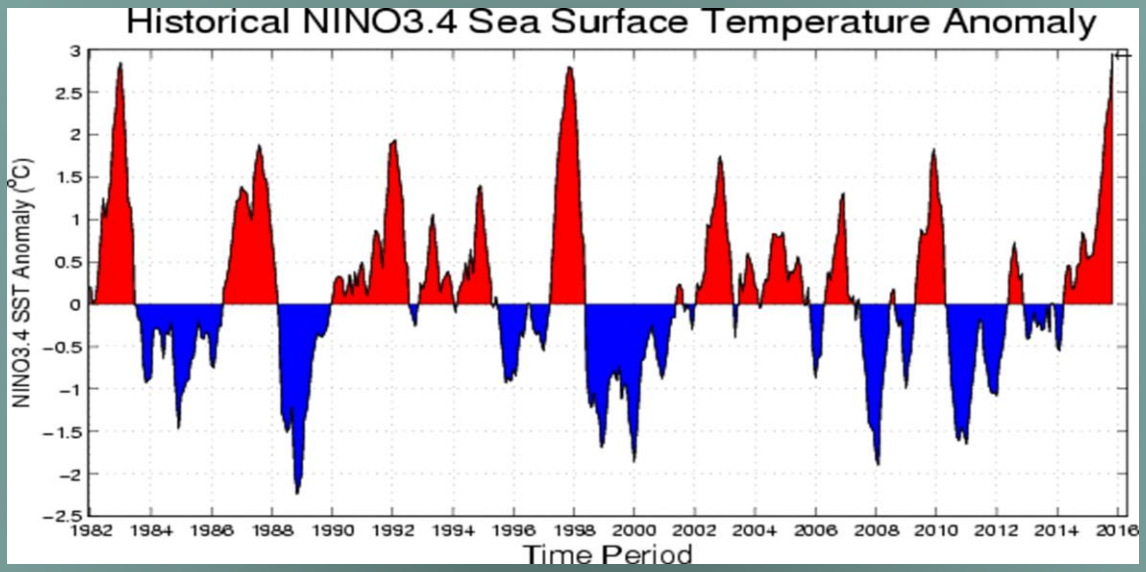


Figure 2: Time series representing periods of El Niño (red and ≥+0.5 anomaly) and La Niña (blue and ≤-0.5 anomaly) conditions. An active El Niño (La Niña) is declared if a ≥+0.5 (≤-0.5) anomaly is observed for five consecutive months using a running three month average. Time periods that are between +0.5 and -0.5 anomaly are considered to represent ENSO-neutral (normal) conditions in the Pacific Ocean.
Source: National Oceanic and Atmospheric Association (NOAA**).**

ENSO in Constant Motion

The atmosphere above the ocean is thought to play a vital role in moving warm tropical waters in the Pacific Ocean. Trade winds blowing just to the north and south of Earth's equator are persistent, as evidenced by permanently bent vegetation on islands. The general east to west progression of air flow near the equator is why warm waters found in the tropics have a tendency to be pushed away from South America.

Wind direction in the low latitudes is fairly constant, but wind speeds are in flux from season to season and even year to year. When deviations in trade wind speeds are large and long lasting, the ocean responds. Increase those winds blowing from the east long enough and now a La Niña situation develops (see Figure 1), where the west-east sea-surface temperature (SST) gradient intensifies. Under this setup, warm tropical waters get relocated closer to Indonesia. Diminish the trade winds and a reverse effect occurs. Warm waters can then more easily slosh eastward as if a dam has been breached. The latter scenario represents an El Niño.

The feedback between SSTs and the atmosphere ultimately determines the evolution of the El Niño Southern Oscillation. Variability governing trade wind behavior continues to be a significant puzzle piece to forecasting ENSO. Fortunately, there have been recent advancements for tracking both sea surface temperatures and winds, including satellite instrumentation (Figure 3) and buoy network monitoring (Figure 4). Detailed measurements are aiding weather forecasters and climate researchers alike to gain a better grasp of ENSO.

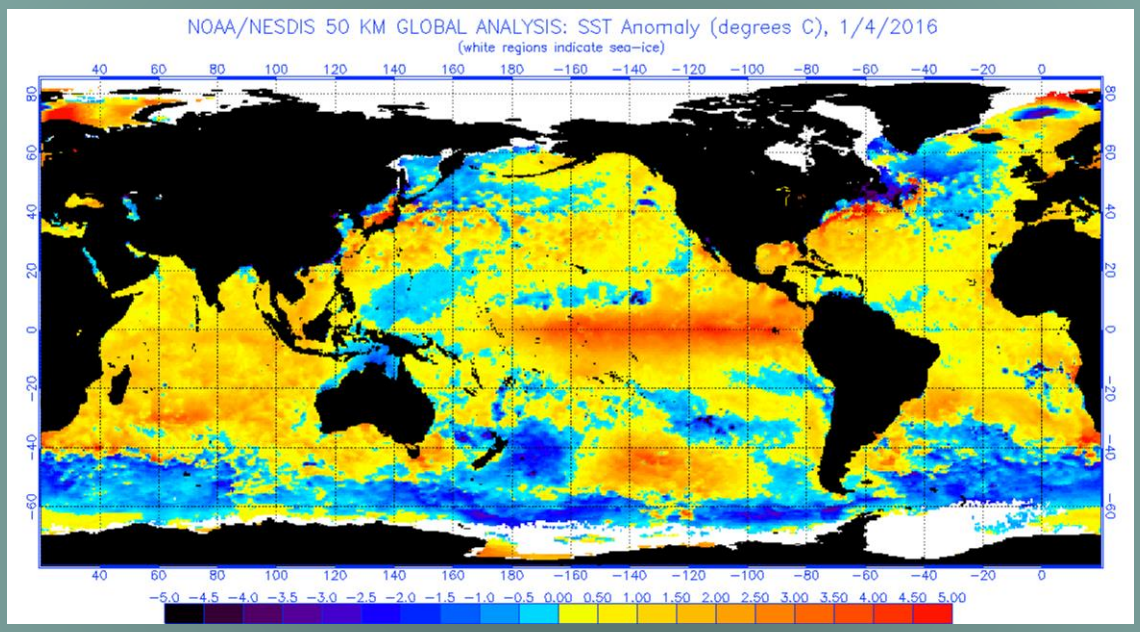


Figure 3: Analysis of global sea surface temperature (SST) anomalies across the globe for early January 2016. Note the brighter reds indicating warmer than usual SSTs. Positive (warmer) anomalies found near South America with negative (cooler) anomalies around Indonesia are consistent with an El Niño phase of the El Niño Southern Oscillation (ENSO).
Source: National Oceanic and Atmospheric Administration (NOAA) and National Environmental Satellite, Data, and Information Service (NESDIS).

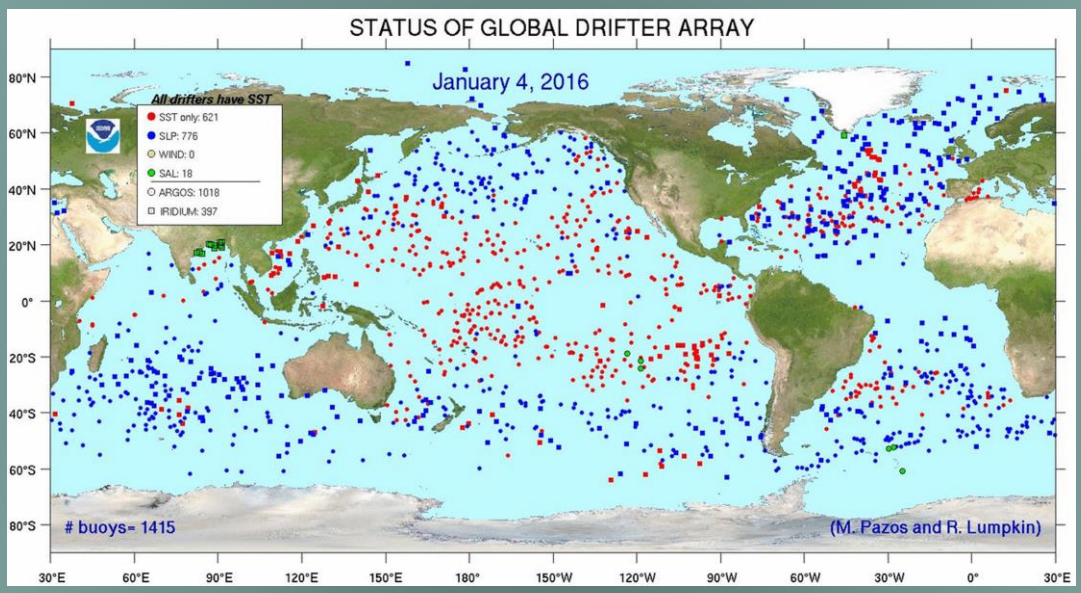


Figure 4: Distribution of buoy monitoring network that samples sea surface temperatures (SSTs), wind speed, and wind direction. Measurements can help indicate that El Niño or La Niña conditions are developing. *Source*: National Oceanic and Atmospheric Administration (NOAA).

ENSO and Arizona Weather

As seen in climate records, El Niño impacts Arizona's weather, too. Based on the Oceanic Niño Index (ONI), the '97-'98 event had the highest rating between 1950 and 2015. The current 2015-2016 El Niño has now matched such index values, making it potentially the strongest measured.

Taking a look back at the late '90s event, a majority of Arizona did receive well above normal rain and snow in the winter months (Figure 5). The precipitation over the deserts from Metro Phoenix stretching westward to California departed most from normal. Periods of deep mountain snowpack and significant flooding in the lower elevations were common. More information concerning impacts in the United States from that historical El Niño can be found here.

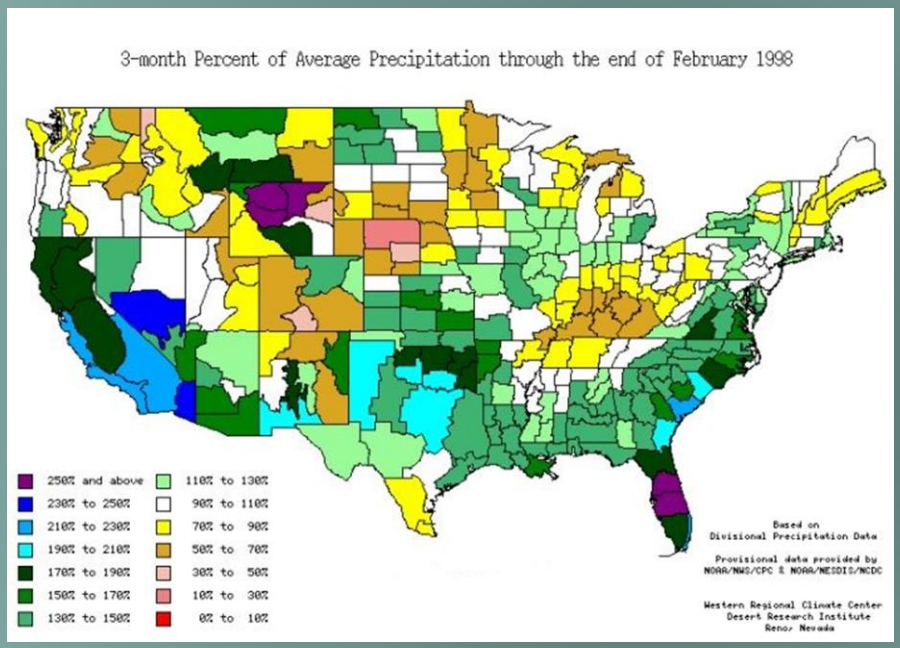


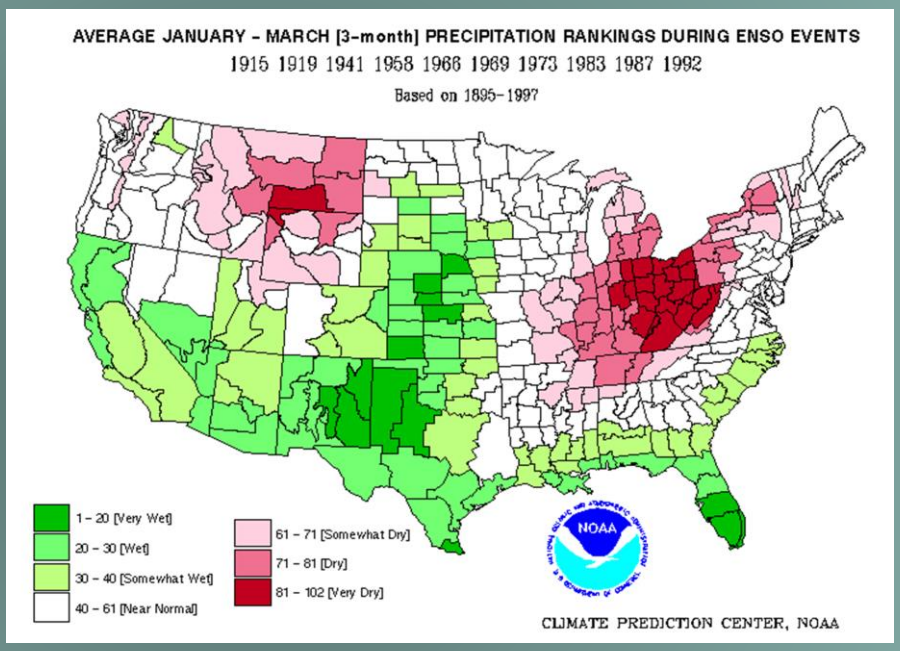
Figure 5: Map showing percent above or below normal winter precipitation during the strong El Niño of 1997-1998. Note the majority of Arizona and the Desert Southwest in general exceeding climatological norms.

Source: Western Regional Climate Center.

Collectively, the average El Niño episode does provide Arizona with excess precipitation for winter and spring months (Figure 6). Why is this? Well, it comes down to having more opportunities for Pacific storm passages. During El Niño conditions, the jet stream, also known as the storm track, shifts southerly in latitude. As a result, frequent storms are steered into the Southwest that would have otherwise been focused toward the states of Oregon and Washington (Figure 7).

Figure 6: Map comparing how winter through early spring precipitation of past El Niño events compare to all years from 1895-1997. The map indicates that some of the wettest January-March precipitation totals have fallen during El Niño years.

Source: Climate Prediction Center (CPC).



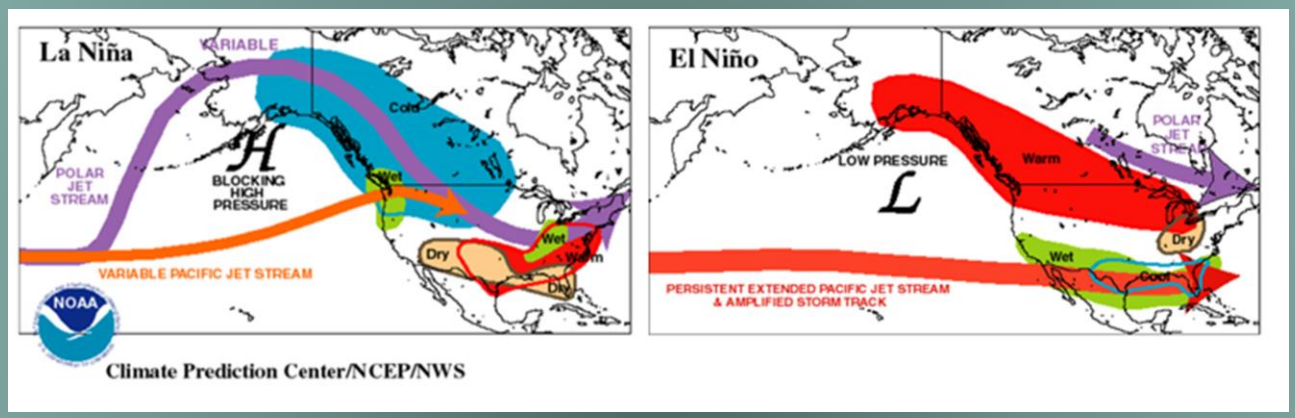


Figure 7: Maps showing the typical storm track occurring during a La Niña cycle (left) versus an El Niño cycle (right). Note that the storm track associated with El Niño would be more favorable to bring Pacific storms through Arizona.

Source: Climate Prediction Center (CPC), National Centers for Environmental Prediction (NCEP), and the National Weather Service (NWS).

ENSO and Arizona Air Quality

The boost in low-pressure systems for Arizona is where the tie to air quality comes into play. From an air quality forecaster point of view, one of the best ways to clear the air is to send in wind *with* rain to an area. The wind/rain combo helps in a few ways.

Winds, without rain, can still be an ally to public health by breaking up inversions and dispersing pollutants. Unfortunately, wind is really a double-edged sword. Gusty winds over arid landscapes tend to create long-range transport of windblown dust and other pollutants. Dry cold frontal passages are a prime example when winds can turn against us to deteriorate our air quality. Add rain to the mix and now we have something else entirely.

Precipitation is quite effective at improving air quality drastically in the short-term by stripping particulates from the air. The benefits from rain don't stop when a storm clears out. Saturated soils after a widespread soaking can reduce the threat of windblown dust for weeks, if not longer. Essentially, a rainy period buys us a temporary buffer against those dry cold fronts. Likewise, wet soils make it more difficult for people to loft dust from everyday recreational and work activities, which is very beneficial if stagnant conditions were to set up. Additionally, as an added perk, rainfall implies cloud cover. Cloud cover limits the photochemical chemistry necessary for ozone formation. Needless to say, in one fell swoop an active storm track through Arizona can prevent a buildup of pollutants and improve air quality all the way from particulates to ozone.

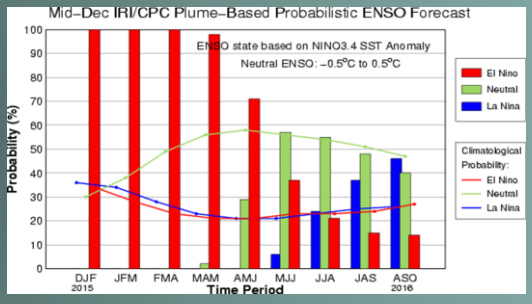
Indeed, looking back at the January through March periods between 2005 and 2015, the Oceanic Niño Index (ONI) shows two years officially in El Niño status (2005 and 2010), three covered by La Niña (2008, 2011, and 2012), and six winters designated as ENSO-neutral (normal conditions). This is a limited time period; however, it is still possible to find differences in Phoenix's winter and early spring air quality between the three ENSO states.

For instance, daily average particulates (i.e., PM-10) during El Niño averaged approximately one to three micrograms per cubic meter less versus ENSO-neutral and La Niña years. Additionally, peak 8-hour average ozone concentrations in El Niño were found to be approximately three to five parts per billion less. Seasonally, the net reduction in pollutant concentrations appears to be consistent with the change in storm track expected during an El Niño. The positive effects on air quality would be much more noticeable the "day-of" when breezy and wet conditions are actually occurring.

The outlook through this spring and summer shows an increasing likelihood of El Niño weakening (Figure 8 and 9). Although the strength of the current El Niño may have peaked, weather pattern shifts caused by ENSO tend to be slow to wind up and wind down. Some of the highest precipitation totals falling over the Southwest during the '97-98 El Niño arrived in February 1998. According to the ONI, this would have been after that El Niño's strongest signal.

Figure 8: Plot showing probability of El Niño, La Niña, or ENSO-neutral conditions through summer 2016. Note that a weakening El Niño is projected late winter into spring.

Source: International Research Institute for Climate and Society (IRI) and the Climate Prediction Center (CPC).



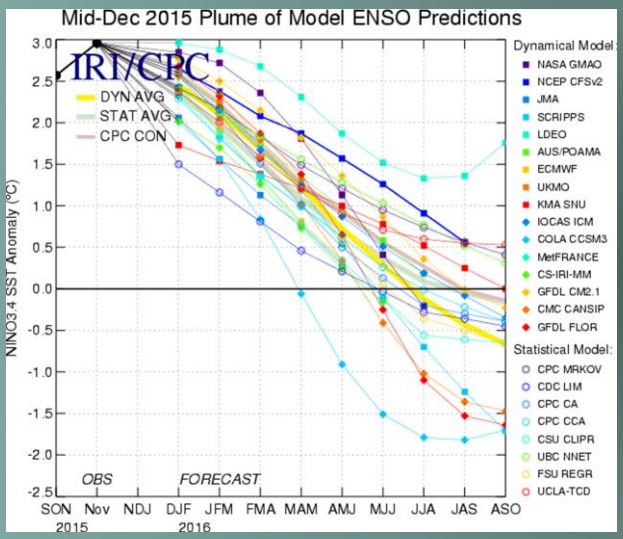


Figure 9: Graphic showing the 2016 ENSO outlook. Note that a majority of forecast models are weakening El Niño dramatically by late spring/early summer 2016. Forecast points represent the corresponding three month sea surface temperature anomaly. Any value ≥0.5 is considered to be an El Niño state, while anomalies ≤-0.5 are La Niña.

Source: International Research Institute for Climate and Society (IRI) and the Climate Prediction Center (CPC).

Not All El Niños are Created Equal

Since weather influences virtually all facets of our lives, there is significant interest in planning for the next El Niño cycle. It is important to remember, though, that the interplay between the ocean and the atmosphere is extremely complex.

At this time, our understanding of the El Niño Southern Oscillation and precise effects on global climate are not complete, especially for locations outside of the tropics such as the Desert Southwest. What this means for us is that there remains a degree of uncertainty regarding how much weather patterns and air quality truly deviate during El Niño and La Niña environments, even when these events are classified as moderate or strong. Fortunately, our knowledge continues to grow on this subject matter. A sample of the latest research from the scientific community can be found here.

Another point to keep in mind is that advances in technology discussed earlier (i.e., satellite and buoy network monitoring) to monitor SSTs and weather in the tropics have only been in operation since the mid to late 20th century. This is why the Oceanic Niño Index used to capture ENSO is only available back to 1950. Otherwise, gauging the appearance of past El Niños and La Niñas would have to come from limited precipitation and temperature records or from anecdotal sources such as shipping and fishery logs. Tree ring analysis and other climate reconstruction techniques could help, as well. Ultimately, it may take some time for us to master the prediction of ENSO. ENSO has and will continue to be a hot topic of interest.

For our next topic, the ADEQ Forecast Team will look at Fog
Thanks for reading!

Sincerely,

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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: **Inversions, Temperature Profiles, and Inversions**

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

– All About Fog
–The Jet Stream, Cold Fronts, etc.
-Tropical Storms

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