Relationships between New Mexico Precipitation, the Atlantic Multi-decadal Oscillation and Pacific Decadal Oscillation

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Previous papers have documented the relationships between the Pacific Decadal Oscillation (PDO) and precipitation in New Mexico. The purpose of this paper is to investigate the relationships between the PDO, the Atlantic Multi-decadal Oscillation (AMO) and New Mexico precipitation.

Considerable research has been performed over the past 20 years investigating relationships between Pacific sea surface temperatures, pressure patterns, and precipitation in the United States. In recent years, Enfield, McCabe, Betancourt, and others found an oscillation of sea surface temperatures over the Atlantic Ocean. This oscillation produces a range of approximately 0.8 degrees Celsius in the region between the equator and 70 degrees north latitude. The period of a complete cycle appears to be 65 to 80 years. Thus, the AMO cycle appears to be even longer than the PDO, which tends to be around 50 years. Enfield, McCabe, Betancourt, and others have also found significant relationships between the AMO and precipitation in the United States.

In short, a positive AMO is associated with less precipitation over a good portion of the United States, especially the West. A negative AMO is associated with more abundant precipitation.

Previous papers have demonstrated a positive PDO is associated with greater than normal precipitation over New Mexico, while a negative PDO is associated with less than normal precipitation. Generally, New Mexico receives 20 to 30 percent less precipitation during negative PDO phases than during positive ones.

Methodology

There are a number of ways to study the relationships between the PDO, the AMO, and New Mexico precipitation. Both signals exhibit long-term regimes during which the sign is predominantly either negative or positive (cold or warm). However, even during these 20 to 35 year regimes, the signal may change sign for as long as one to three years. These spikes in the PDO (in which the sign changes for 1-3 years) occur in response to an El Niño-Southern Oscillation (ENSO) event that is in conflict with the predominant PDO signal. For example, in figure 1, the positive spike from negative to positive in 1957-1958 was due to a strong El Niño that occurred. This El Niño went a long way in helping to alleviate the devastating drought of the 1950s.

One can choose to study the entire regimes (20 to 35 years) of predominant PDO and AMO signals and leave the spikes in. Another method would be to take the “spike years” out. Yet another way would be to look at the PDO and AMO values in terms of standard deviations, and study the precipitation relationships during significantly positive and negative signal years. This was the methodology I employed for a previous PDO study, in which I looked at PDO yearly values that were greater than one half a standard deviation from the long-term mean values.

However, when trying to use the PDO and AMO signals as a long-term forecast tool, it may not be realistic to use standard deviations or to take the spikes out. Use of such methodology would be more valid if there were any skill to forecast the “significant” years, but no such ability exists. For now, the PDO and AMO are only diagnostic tools. There is more confidence in determining which phase (negative or positive, cold or warm) these oscillations are in, while year to year forecasting of the phase or magnitude of the phase is not possible.

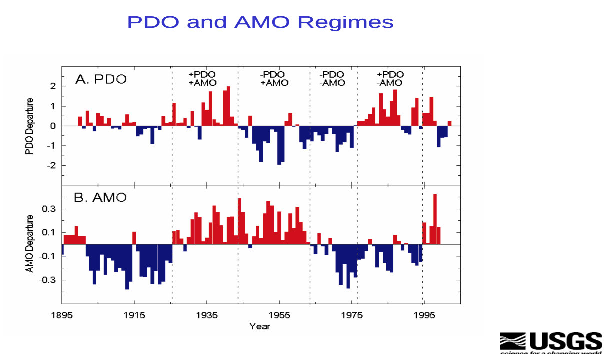


Figure 1 (McCabe, Betancourt, and Palecki, 2004)

Consequently, for this paper, the relationships between New Mexico precipitation, and predominant phase regimes of the PDO and AMO were chosen for study. The negative and positive AMO regime periods were combined with the negative and positive PDO regimes identified by McCabe, Betancourt and Palecki. Transitional years (years in which regime changes occurred) were excluded from the study. The following table shows the periods used in the study.

Positive AMO	1930-1964
Negative AMO	1965-1994
Positive AMO	1995-present
Positive PDO	1923-1944
Negative PDO	1945-1977
Positive PDO	1978-1998

It should be noted that although many researcher believe the PDO entered a negative phase in 1998, this index has actually been positive since the onset of the El Nino in late 2002. This was to be expected, as the PDO and El Nino-Southern Oscillation (ENSO) are either strongly related or part of the same cycle. However, as of early 2004, the PDO has not yet returned to the negative phase. A return to a negative PDO phase may well happen later in 2004, but it could be another few years before we can be confident that we are, indeed, in a 30-year long phase of a predominantly negative PDO.

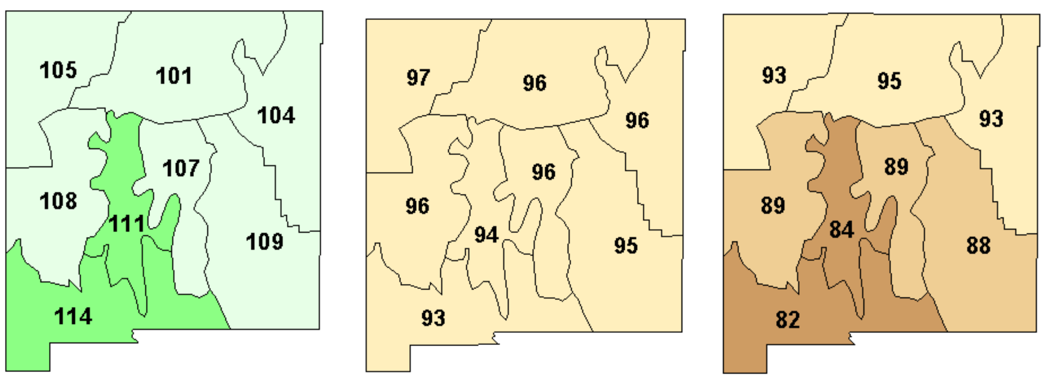
By combing the intersections of the PDO and AMO phases, the periods produced four groups: (1) Negative AMO combined with positive PDO, (2) Negative AMO combined with negative PDO, (3) Positive AMO combined with positive PDO, and (4) Positive AMO combined with negative PDO. “Transitional” years (from one category to another) were not included. The years for these four scenarios are in the table below.

-AMO and + PDO	1977-1994
-AMO and –PDO	1965-1977
+AMO and +PDO	1930-1944 and 1995-1997
+AMO and –PDO	1944-1964

Table I

Results

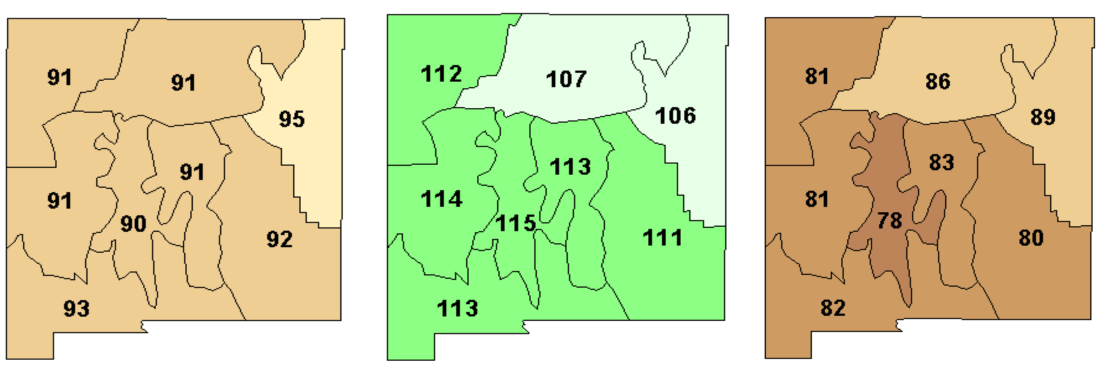
Annual Precipitation Results for AMO Regimes (% normal)



Negative AMO Positive AMO Ratio of – AMO to + AMO

Figure 2

Annual Precipitation Results for PDO Regimes (% normal)



Negative PDO Positive PDO Ratio of – PDO to + PDO

Figure 3

It’s apparent that above-normal precipitation is associated with the negative AMO and positive PDO regimes, while diminished precipitation is associated with the positive AMO and negative PDO regimes. As one can see from table I, there are times when the

AMO and PDO regime relationships with New Mexico precipitation are in harmony, and other times when they are in conflict. A reasonable question arises as to what happens when the signals are in harmony or conflict.

Figure 4 shows the result for conflicting signals. Figure 4a shows the result for when the AMO is positive and the PDO is positive. Recall, the AMO positive regime is associated with diminished precipitation in New Mexico, while the PDO positive regime is associated with enhanced precipitation. Figure 4b shows the result for when the AMO is negative and the PDO is negative. The negative AMO regime is associated with enhanced precipitation while the negative PDO regime is associated with diminished precipitation.

+ AMO/ + PDO (% normal)   - AMO/ - PDO (% normal)

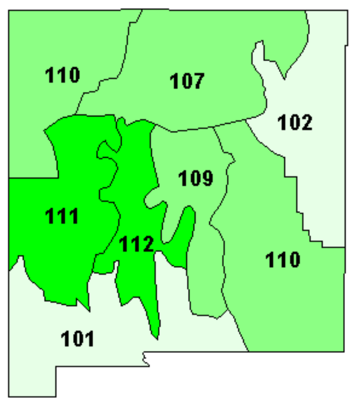


Figure 4a

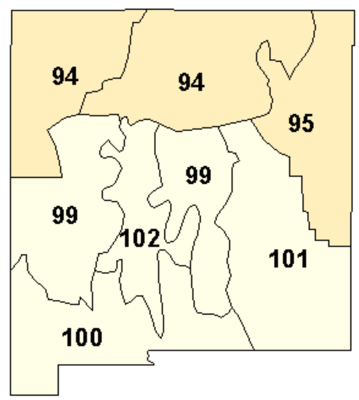


Figure 4b

Results shown in figure 4 suggest the relationship between New Mexico precipitation and the PDO is more significant than the relationship with the AMO. However, a comparison between the results for conflicting signals with results shown in figures 2 and 3 also suggests that, during conflict, the relationship between the AMO or PDO and New Mexico precipitation is mitigated to some degree by the conflict.

Figures 5a and 5b show the results for when the AMO and PDO regimes are in harmony with relationship to New Mexico precipitation.

+ PDO/ - AMO (% normal)

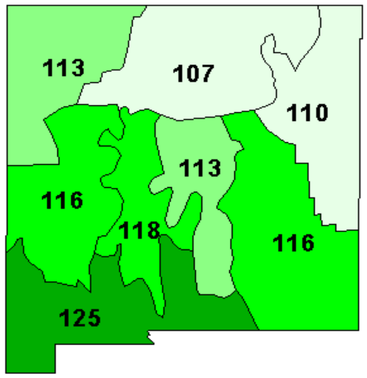


Figure 5a

- PDO/ + AMO (% normal)

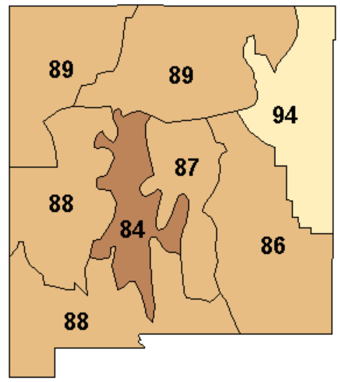


Figure 5b

Results for harmonious regimes shown in figure 5 indicate the combined relationships are more significant than either the PDO or AMO by itself.

The Effect of Regime Changes

It's worthwhile to investigate the changes that take place when regime changes occur, especially from one harmonious relationship to another. People tend to develop their sense of what is normal over a period of years, and if the conclusion is made during a harmonious AMO/PDO regime, the conclusion is likely to be faulty.

For example, the positive PDO combined with a negative AMO during the period from 1978 through 1994. Instrument studies (rain gauges) indicate this was the wettest 17-year period in New Mexico in recorded history. Tree-ring studies indicate this was certainly one of the wettest periods of the past 2000 years.

While the AMO became negative in 1995, the PDO remained positive (creating a conflicting relationship) until 1998. Historical relationships suggest the PDO may exhibit a predominantly negative regime from the late 1990s until the 2020s. As mentioned previously, it may be another year or two before this can be stated with a significant degree of confidence. Also, the AMO, which seems to be a bit more consistent, is likely to experience a continued positive regime (that began in 1995) through the 2020s. Consequently, if historical relationships can be applied to produce a long-term outlook, one has to consider the significant possibility that, between now and the 2020s, a negative PDO coupled with a positive AMO is likely to occur for a substantial period of time.

Figure 6a shows the ratio of precipitation associated with historical negative PDO to positive PDO regime change. Figure 6b shows the result of positive AMO to negative AMO regime change. Figure 6c shows the result of an unfavorable (dry) – PDO/+AMO combination to favorable (wet) +PDO/-AMO regime.

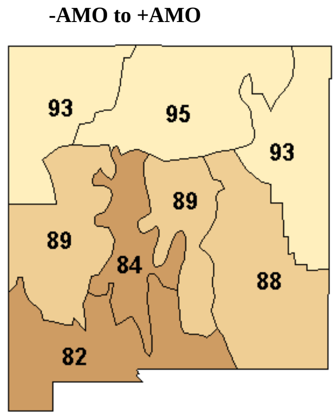


Figure 6a

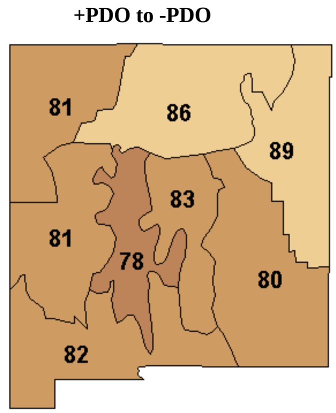


Figure 6b

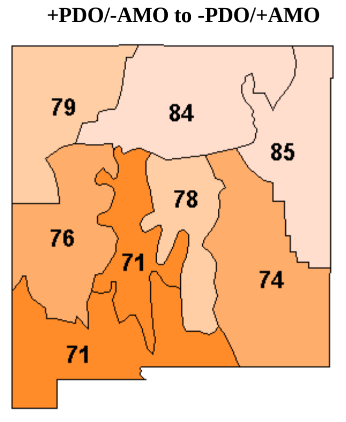


Figure 6c

The results of figure 6 show that a PDO regime change from positive to negative is more significant than an AMO regime change from negative to positive. In both cases, precipitation is reduced, but the amount is greater for the PDO change than the AMO change, except in the extreme southwest part of the state. The statewide average from the values in figure 6a is 89 percent, representing a precipitation "cut" of 11 percent considering only the AMO regime change from negative to positive. For the PDO, the average is 82 percent, representing a precipitation reduction of 18 percent. Figure 6c shows that the effect of a +PDO/-AMO regime combination to a –PDO/+AMO combination is much more significant than either the AMO or PDO relationship by itself. The average of values in figure 6c is 77 percent, representing a precipitation reduction of 23 percent.

Precipitation Amounts For Specific Regimes Relative to Normal

Figure 7 shows precipitation deficits relative to normal (instead of relative to surplus amounts created during wet regimes) for each climate division in New Mexico. As a frame of reference, these are amounts that would be created in a 20-year period according to historical relationships.

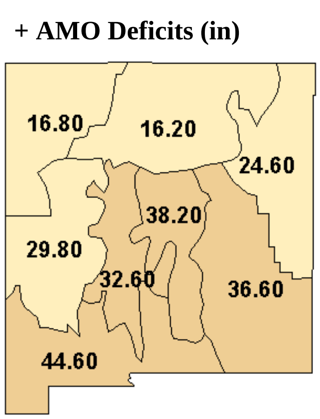


Figure 7a

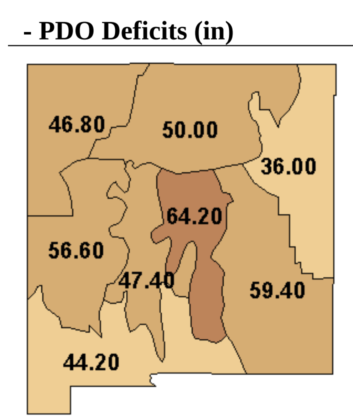


Figure 7b

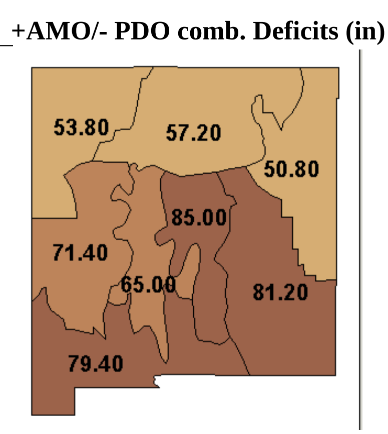


Figure 7c

Except for the southwest part of New Mexico, deficits created during the – PDO phase tend to be much larger than those created during the +AMO phase. As one can see from figure 7c, deficits created during the –PDO/+AMO combination are quite a bit larger than those values calculated from the –PDO alone. The values shown in figure 7c represent the loss of as much as 7 ½ years of precipitation (relative to normal) during a 20 year period in southwest New Mexico, and a loss of approximately 6 years in the Rio Grande Valley from Santa Fe to Truth or Consequences.

Summary/Conclusions/Final Thoughts

There is a significant historical relationship between the PDO, AMO and New Mexico precipitation. For shorter-range extended forecasting, such as seasonal or one or two year time frames, these ocean signals are presently of very limited use. For these time periods, the ocean signals are simply diagnostic tools. However, for longer-terms, these signals may offer significant insight that can be used to predict precipitation that can be used as a component in helping to determine water budget issues.

Among some climate researchers, confidence is relatively high that the AMO entered a long-term positive phase in 1995. If historical trends can be used as a forecast tool, the AMO is expected to exhibit a predominantly positive phase until the 2020s or even 2030s. Although some climate researchers believe the PDO entered a predominantly negative phase in 1998, confidence is not as high (compared to the AMO) because the PDO has remained positive after the demise of the 2002-2003 El Niño event. It will likely be another several years before the climate community will have more confidence in this particular signal. However, if the PDO did enter a predominantly negative phase in 1998, recent history would suggest the negative phase would remain until sometime in the 2020s. If that is the case, a combination of a negative PDO and positive AMO is quite likely over much of the period until sometime in the 2020s. If the historical relationship between this combination and precipitation can be used as a forecast tool, it is likely precipitation in New Mexico for the next couple of decades will be more than 20 percent less than it was during the period from the late 1970s to mid 1990s. Figure 6c shows this decrease has historically ranged from as much as 29 percent in the southwest and Rio Grande Valley to 15-16 percent in the north-central and northeast climate divisions.

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