A Dry El Niño Winter

"When will it rain?" This question has been uttered often this winter by not only END Insight participants, but also by climate researchers and meteorologists all over the West. Winter rainfall is particularly important for many natural and human systems in the Southwest, fueling plant growth and reproduction, renewing range conditions, and replenishing reservoirs. However, this winter is distressingly dry, even after taking into account mid-February's rainy spell. Despite ongoing El Niño conditions, which often herald a rainy winter in the Southwest, and drought-relieving precipitation in the eastern United States, the rainfall levels for the water year (which began in October) remain well below average for most of Arizona and parts of New Mexico although southeastern and northwestern New Mexico have received average to slightly above-average precipitation.

It is much easier to explain why it hasn't rained very much this winter than it is to predict when the dryness will end. During strong El Niño events, the subtropical jet stream typically is strong, which enhances the probabilities of winter rain in the Southwest. This hasn't been the case with this winter's moderate El Niño. Atmospheric conditions since autumn 2002, with the brief exception of mid-December and then again in mid-February, are such that the Southwest remains dry. One reason is that the peak sea surface temperatures associated with the current El Niño are farther west and weaker than during El Niño years that have produced a lot of winter rain in the Southwest. Thus instead of El Niño being the primary factor affecting rainfall amounts this winter, other atmospheric factors have been more important in determining the Southwest's weather: the Pacific/North America teleconnection pattern and the North Atlantic Oscillation.

Pacific/North America Teleconnection

The Pacific/North America (PNA) teleconnection pattern describes the position, strength, and orientation of a trough and ridge pattern of air pressure over the northern Pacific Ocean and North America (Figure 1). Trough and ridge patterns are large-scale, elongated areas of low (trough) and high (ridge) atmospheric pressure. The position and strength of these ridge and trough systems affect how (and if) storm systems traverse the Southwest.

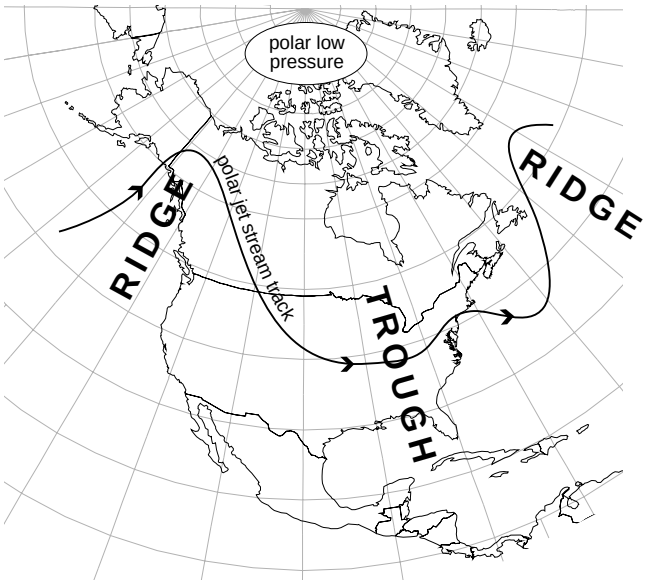

Figure 1. Typical path of the polar jet stream this winter, with the ridge and trough pattern associated with a positive phase of the PNA.

Positive values of the atmospheric index of the PNA are associated with a strong ridge pattern of high pressure over the western United States and a strong trough pattern of low pressure over the eastern United States. The positive phase of the PNA typically is largest and most pronounced in winter and usually brings dry weather to the Southwest. For most of this winter, the PNA has been strongly and persistently positive.

The PNA exhibits substantial interseasonal, interannual, and interdecadal variability. For example, the PNA was predominantly in its negative phase during 1964–1967 and 1989–1990. The positive phase of the PNA was dominant during 1976–1988 and 1991–1993. The winter drought of 1976–1977 has been tied to the concurrent PNA phase, which was strong and persistently positive.

North Atlantic Oscillation

The North Atlantic Oscillation (NAO) is a major disturbance of the atmospheric circulation and climate of the North Atlantic-European region and is linked to a waxing and waning of the dominant middle-latitude westerly wind flow during winter. The strength of the NAO is typically measured as the pressure difference between various stations to the north (such as Iceland) and south (such as the Azores Islands) of the middle-latitude westerly wind flow. When atmospheric pressure is high over Iceland, it tends to be low over the Azores Islands and vice versa. The NAO exerts a strong influence on year-to-year climate variability, and there is evidence of longer-term trends in this phenomenon. The NAO has major impacts on European and Mediterranean precipitation and temperature.

Although NAO teleconnections with Europe and the Mediterranean have been the focus of long-standing research, new research has established the connection between the NAO and North American climate. During positive (or high) NAO winters, the middle-latitude westerly winds are stronger than during negative (or low) NAO winters, and more and stronger winter storms cross the Atlantic Ocean on a more northern track. In New England, positive (high) NAO winters are generally warmer and wetter than normal, with below-average snowfall. In the eastern United States, negative NAO winters are associated with below-average temperatures and

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large-scale atmospheric conditions that favor cold Arctic air masses moving into the region. The NAO does not directly impact weather in the Southwest but negative NAO conditions do interact with positive PNA phases to maintain a strong atmospheric ridge, high pressure, and dry conditions over western North America.

This winter, the NAO has been strongly and persistently in its negative phase, and thus, the eastern United States has been unusually cold. In the Southwest, dry conditions have persisted as the atmospheric ridge over western North America has been held in place by the combination of NAO and PNA conditions. This ridge has diverted Pacific storms well to the north and into Canada before driving them south again, around the ridge, and into the eastern United States, bypassing the Southwest along the way (Figure 1).

Winter Precipitation Thus Far…

During most of December through February, the PNA was in its positive phase and the NAO was negative, making it difficult for storm systems to penetrate the Southwest because the strong polar jet stream steered storms farther east. Parts of New Mexico have received some precipitation this winter from the western edge of some of these storms, but Arizona remained dry throughout most of December and January.

In mid-February, atmospheric conditions changed, as the PNA pattern collapsed while the NAO became slightly positive. Atmospheric conditions more typical of El Niño returned, allowing a low-pressure system to enter the Southwest from the equatorial Pacific, bringing much-needed precipitation to the West for several days. Overall, central-western Arizona received several inches of rain from this system whereas southeastern New Mexico received just a trace (Figure 2). Because much of the Southwest's water resources depend on spring melt of the

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A "Perfect Ocean" for Global Drought

A recent study (1) by NOAA researchers attributes drought across the United States, southern Europe, and southwest Asia between 1998 and 2002 to differences in sea surface temperatures (SSTs). According to their research, oceanic conditions from 1998 to 2002 were "perfect" for causing global, mid-latitude drought in the Northern Hemisphere.

During this period as little as 50 percent of the average rainfall fell in these regions. For the United States, this was an abrupt change from what had been ranked the wettest decade since at least the 1890s. This pattern started to change last year, as El Niño conditions eased the drought in the eastern United States and central-southwestern Asia. However, the Southwest remains locked in drought (See A Dry El Niño Winter, page 3).

The researchers used three different computer climate models to assess the impact of the anomalous Pacific and Indian Ocean SSTs on Northern Hemisphere climate from 1998 to 2002. Their results indicate that cold SSTs in the eastern tropical Pacific Ocean (associated with La Niña conditions) combined with unprecedented warm conditions in the western tropical Pacific and Indian Oceans to cause widespread drying in the mid-latitudes as the jet stream shifted north of its usual location. Usually, La Niña conditions would have cooled the entire Pacific Ocean. However, SSTs in the western Pacific Ocean were at a 150-year high. Hoerling and Kumar (1) suggest that the unprecedented warm conditions in the western tropical Pacific and Indian Oceans are due to global atmospheric warming of about 1 degree Celsius since 1950.

This research is the latest in a number of reports linking severe weather problems (e.g., drought, monsoons, melting polar ice) to global warming. The research also suggests increased risk for severe mid-latitude drought in the future because these oceanic conditions are likely to recur in coming decades.

References

(1) Hoerling, M., and A. Kumar. 2003. The perfect ocean for drought. *Science*, 299:691–694.

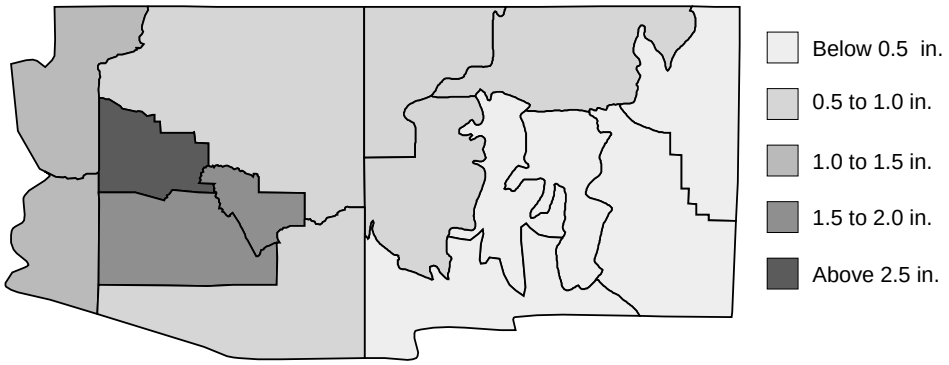

Figure 2. Total precipitation (in inches) in Arizona and New Mexico by climate division for February 9–15, 2003. Source: National Climatic Data Center.

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winter snowpack, it is unfortunate that most of the precipitation fell as rain and not snow. Also, most of the Southwest remains in long-term drought, with many areas still inches below average precipitation levels for the past year. Tucson, for example, is about 4 inches shy of its average precipitation, and Albuquerque, Phoenix, and Winslow are about 2 inches below average. Total precipitation levels in Roswell, Farmington, and Yuma are close to average for the past year, mostly due to late summer and early fall rains.

A Dry Winter…and Spring?

The PNA and the NAO change and influence weather systems on timescales of days and weeks in contrast to the El Niño-Southern Oscillation, which operates on considerably longer timescales of months or years. In early February, the NAO was positive (Figure 3), but the Southwest remained dry as the strongly positive PNA continued to steer storm tracks away from this area. Medium-range forecasts through the end of February are uncertain because forecast models show the NAO remaining positive but the PNA flip-flopping from negative to positive to negative. If the PNA switches to its negative phase while the NAO remains in its positive state, the chances for precipitation in the Southwest increase. The NOAA Climate Prediction Center's official seasonal forecast is for a slightly above-average probability of a wet spring as weak El Niño conditions persist but weaken this spring. However, this seasonal forecast does not place as much emphasis on the PNA and NAO because they change at weekly to monthly time scales and because PNA and NAO forecasts are uncertain for the immediate future. Although this is not the most comforting news for those of us who really want to know when it will rain again, it is more promising than a forecast of a strongly positive PNA combined with a strongly negative NAO—a combination that almost inevitably spells dryness for the Southwest.

–Nan Schmidt, CLIMAS

About END InSight

END InSight is a year-long project to provide stakeholders in the Southwest with information about current drought and El Niño conditions. As part of the Climate Assessment for the Southwest (CLIMAS) project at the University of Arizona, END InSight is gathering feedback from stakeholders to improve the creation and use of climate information.

The *END InSight Newsletter* is published monthly and includes background and topical climate information. All material in the newsletter may be reproduced, provided CLIMAS is acknowledged as the source. The newsletter is produced with support from the National Oceanic and Atmospheric Administration (NOAA).

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Additional Information on the Web:

Climate Prediction Center – North Atlantic Oscillation.
http://www.cpc.noaa.gov/data/teledoc/nao.html

Climate Prediction Center – Pacific/North American.
http://www.cpc.noaa.gov/data/teledoc/pna.html

Welcome to the North Atlantic Oscillation.
http://www.ldeo.columbia.edu/NAO/

Climate and droughts.
http://geochange.er.usgs.gov/sw/changes/natural/drought/

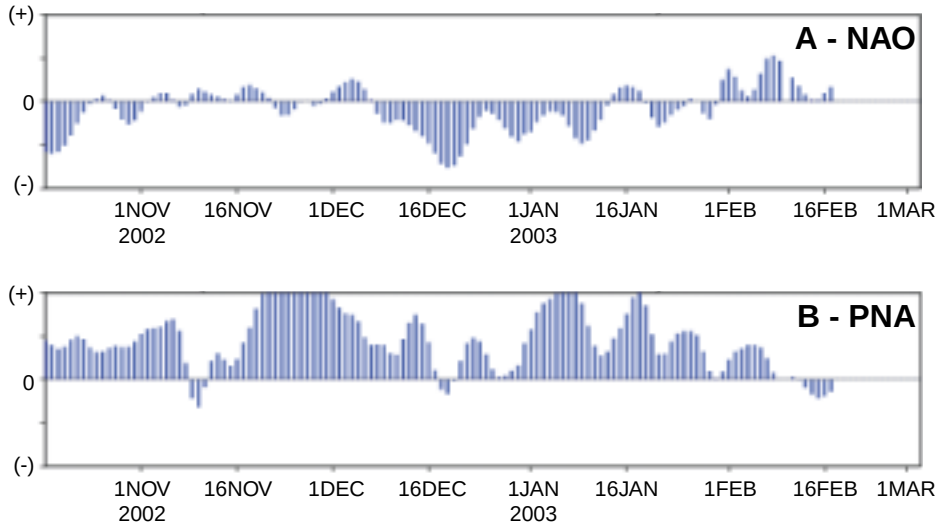

Figure 3. (a) NAO index and (b) PNA index for November 2002 through February 2003. Note the extended period of predominantly negative NAO and positive PNA between mid-December and early February, which coincided with an extended dry spell in the southwestern United States. Source: Climate Diagnostics Center.