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Scientists look to ocean for clues about drought

by Melanie Lenart

The landlocked Southwest does not escape the ocean's reach. Although scientists continue to untangle how these sea changes affect southwestern climate, what they've learned so far is chilling. Both the Pacific and Atlantic Oceans appear aligned to favor long-term drought in the Southwest.

These are the major oceanic fluctuations that appear to influence regional climate:

- The El Niño Southern Oscillation (ENSO), centered in the tropical Pacific. While "El Niño" (and its opposite, La Niña) relates to changes in sea surface temperatures, the "Southern Oscillation" refers to the associated patterns of atmospheric pressure over the tropical Pacific.

- The Pacific Decadal Oscillation (PDO), identified by changes in sea surface temperatures further north in the Pacific Ocean.

- The Atlantic Multidecadal Oscillation (AMO), identified by changes in sea surface temperatures averaged over the North Atlantic from the equator to 70º North.

If ENSO is the poster child of oceanic influences on climate, the AMO and PDO are the new kids on the block. Scientists began only in the mid-1990s to document the relation between North American climate and the long-term Atlantic changes captured by the AMO. They are still hammering out a consensus on its features, its climatic effects, and whether it even exists as an identifiable physical process. Similarly, researchers are still trying to pinpoint the reasons for PDO fluctuations and the scale of its reach.

The index researchers use to detect the AMO is actually a 10-year running mean of North Atlantic sea surface temperature, and its climatic effects do not show up in year-to-year analyses. They only emerge when climatic data are lumped together into decades, a process known as smoothing because it reduces year-to-year spikes.

But the correlation between long-term drought in the continental United States and the AMO warm phase appear real enough in both the instrumental record and longer records based on tree rings and other proxies, noted Julio Betancourt, one of the scientists at the forefront of this research. Betancourt is a researcher at the U.S. Geological Survey's Desert Laboratory in Tucson.

"If the North Atlantic warms, then you're nailing summer precipitation across much of the continent. Drought in May and June, the peak months of precipitation in the Plains and Front Range, can be followed by a weak monsoon season across the Southwest in July and August," Betancourt explained.

Unlike the AMO, the Pacific Decadal Oscillation does show up in tests for annual effects on climate, although it's still unclear whether the PDO rates as its own phenomenon or merely serves as a memory bank of dominant ENSO patterns. The "cool" phase of the PDO is associated with low precipitation in the Southwest, especially during the winter—much like an extended La Niña event.

But while ENSO typically switches from El Niño to La Niña conditions and back again within three to seven years, the PDO and AMO take more like three to seven decades to go full circle.

When a "cool" PDO phase lines up with a "warm" AMO phase—as it did in from 1998 to mid-2002—the result can be year-round, persistent drought in the Southwest, Betancourt said (see Figure 1).

This "double-whammy" effect also helps explain how things got so dry during the 1950s drought, Betancourt indicated. The proportion of Southwest area besieged by drought neared 100 percent (see Figure 1) before the welcome relief carried in by a strong El Niño event in 1957–58. For this analysis, the Southwest includes Arizona, Colorado, New Mexico, Utah, and parts of Texas and southern Oklahoma.

The AMO moved into a warm phase in 1995, just before precipitation in Arizona and New Mexico began to falter. The PDO switched into a "cool" phase in the summer of 1998.

On a positive note, the PDO has switched back into gray territory, for the moment at least. In August 2002, values switched from negative to positive, according to an index posted on the National Oceanic and Atmospheric Administration website.

Positive PDO values can mean good news, heralding a Southwest-friendly "warm" phase, when maintained for the better part of a decade or so. But

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Drought clues, continued

Betancourt doesn't believe the Southwest will be released from the current drought's stranglehold quite so easily. One phase of the PDO typically lasts about 20 or 30 years, while one phase of the AMO usually lasts about 30 or 40 years.

Still, the research to identify the mechanisms behind the oscillations—and therefore improve the chances of using these indices for long-term climate forecasting—remains in the early stages.

"On a decadal basis, it comes up very clear. But the AMO and PDO oscillations are so long. We don't know what the mechanisms are that make them shift," noted U.S. Geological Survey researcher Gregory McCabe, who is an author with Betancourt and others on an upcoming paper describing how AMO and PDO patterns relate to long-term drought frequency in the United States.

McCabe believes researchers eventually will discover a physical reason behind the oceanic oscillations. On the other hand, those who see the PDO as a long-term expression of ENSO variability rather than a physical process in its own right include Michael Dettinger, a U.S. Geological Survey researcher and co-author with McCabe on a 1999 article that related ENSO to the PDO.

When heat is concentrated in the tropical Pacific, as during an El Niño event, a side effect is a cooling of the northern Pacific, Dettinger explained. The situation generally reverses during a La Niña event. The PDO phase reflects whichever ENSO phase has been most dominant when measured over decades instead of year to year, he suspects.

"The North Pacific is like a huge flywheel that takes a long time to spin up and get going in that direction," he added. "But once it gets going, it takes a long time to wind down."

Of the two long-term oscillations, the PDO has the advantage of having an identifiable relation to Southwest climate. Dettinger believes the climatic effects hold regardless of whether the PDO is a separate process from ENSO.

"The Southwest and western North America get most of our weather from the winds and storms and jet streams that come across the North Pacific to reach North America," he said. "What that means is that even if the PDO were solely driven by the ENSO process, the shape that those processes give to the North Pacific is the most immediate source of our weather."

The naming of PDO phases follows ENSO conventions, with a "cool" event referring to relatively cool sea surface temperatures extending from

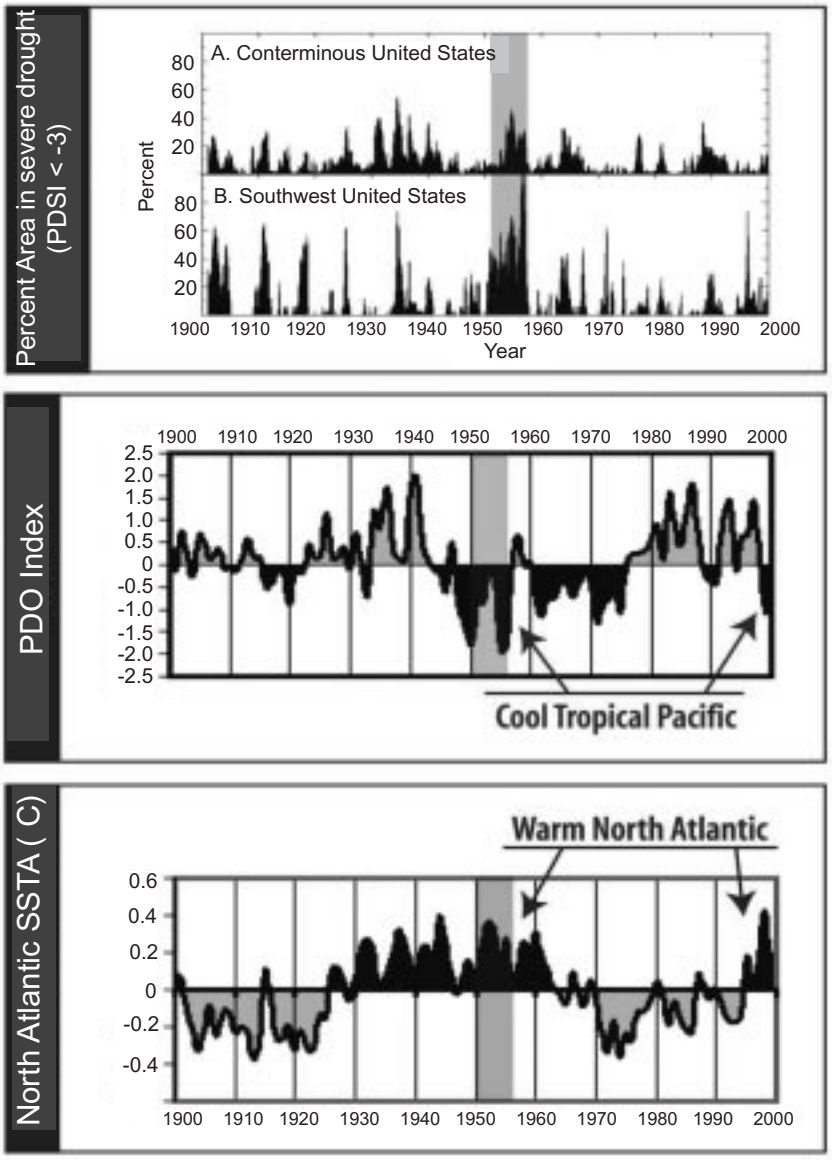

Figure 1. Opposing shifts in tropical Pacific and North Atlantic Ocean temperatures may foretell persistence of disastrous, multiyear droughts across the North American continent. During most of the 1950s, drought conditions characterized the Southwest (top), which in this analysis includes Arizona, New Mexico, Utah, Colorado and parts of Texas and Oklahoma. The gray shading shows the same time frame in all figures, including those of two indices that appear linked to long-term drought in the Southwest, the PDO (middle) and AMO (bottom). The indices returned to their 1950s pattern in 1999, which some see as an ominous sign that long-term drought may be in store. All figures provided by Julio Betancourt.

the tropical Pacific along the western U.S. coast, and relatively warm sea surface temperatures across the majority of the North Pacific. So, despite the nomenclature, the Southwest suffers a lack of precipitation when warm sea surface temperatures dominate (on a decadal scale) in the northern waters of both ocean basins.

In contrast, the relatively cool sea surface temperatures that occur in the northwestern Pacific during a "warm" event displace the jet stream southward, generally to the advantage of Arizona and New Mexico. In addition, the associated warm tongue of water along the West Coast, which comes up from the tropics, supplies moisture for storms.

"The Pacific has really ruled our thinking for the last few decades," Betancourt said. It's more difficult for scientists to accept the idea of an Atlantic influence on Southwest climate because prevailing winds in the mid-latitudes come from the west and southwest, rather than the east, he added. But he believes the strong correlations he and others are finding between AMO patterns and decadal drought will prove convincing in the end.

David Enfield, an oceanographer with the National Oceanic and Atmospheric Administration and one of the first researchers to examine the climatic effects of the AMO, suspects the Atlantic changes influence climate by changing the steering pattern for weather over the continent at 500 millibars (at about 16,000 feet on average). As he and colleagues reported in a 2001 article, the AMO warm phase is associated, for the southern portion of the continent, with a higher than usual atmospheric ridge over the West Coast and increasingly lower pressure in an eastward direction.

Enfield has also found correlations between the AMO and ENSO patterns. In fact, all three oceanic fluctuations appear to influence each other to varying degrees in ways that are difficult to isolate in time and space.

Related Reading

Newsletter articles

"PDO: Where will the footprints lead?" END InSight newsletter story available at http://www.ispe.arizona.edu/climas/forecasts/articles/PDO_Oct2002.pdf

"Predicting El Niño," END InSight newsletter story available at http://www.ispe.arizona.edu/climas/forecasts/articles/predictelnino_Dec2002.pdf

"Southwest drought regimes might worsen with climate change," Southwest Climate Outlook newsletter story available at http://www.ispe.arizona.edu/climas/forecasts/articles/climatechange_Dec2003.pdf

Websites

National Oceanic and Atmospheric Administration website to access indices for ENSO, PDO, and AMO, among others: http://www.cdc.noaa.gov/ClimateIndices/

Journal articles

Delworth T. L., and M. E. Mann. 2000. Observed and simulated multidecadal variability in the Northern Hemisphere. *Climate Dynamics* 16:661–676.

Enfield D. B., A. M. Mestas-Nuñez, and P. J. Trimble. 2001. The Atlantic multidecadal oscillation and its relation to rainfall and river flows in the continental U.S. *Geophysical Research Letters* 28:2077–2080.

Gray S. T., J. L. Betancourt, C. L. Fastie, S. T. Jackson. 2003. Patterns and sources of multidecadal oscillations in drought-sensitive tree-ring records from the central and southern Rocky Mountains. *Geophysical Research Letters* 30:1316–1320.

McCabe G. J., M. D. Dettinger. 1999. Decadal variations in the strength of ENSO teleconnections with precipitation in the western United States. *International Journal of Climatology* 19:1399–1410.

How might climate change affect these fluctuations? At this point, climate models give mixed results even when predicting how global warming might affect ENSO, which is understood and accepted much more than the PDO and AMO. So the jury is out when it comes to predicting the effect of global warming on oceanic fluctuations in general.

"We don't even have the first principles down," noted Dettinger, alluding to the mechanistic principles governing these oceanic oscillations. "So until we get that down, I don't expect to see accurate predictions of what would happen with global warming."

Still, it's interesting to consider that the Intergovernmental Panel on Climate Change generally expects atmospheric warming to be greater in northern latitudes than in the tropics. As noted earlier, relatively warmer sea surface temperatures in the North Atlantic and North Pacific do not bode well for Southwest precipitation.

On the other hand, an increase in El Niño frequency or intensity—which many researchers expect based on their admittedly incomplete understanding of the process—could improve Southwest precipitation patterns both at the annual scale of ENSO events and the decadal scale of the PDO.

Given the uncertainty, Southwest residents would do well to assume the worst when it comes to making preparations for drought, McCabe suggested.

"It seems that we've been living in an anomalously wet period," McCabe said. "If we even go back to normal, are we going to be able to withstand it? It's kind of frightening now, with increased population and water demand. It will be interesting to see how we survive a 1950s-like drought."

Monthly Climate Summary - January 2004

Highlights

Hydrological Drought – Hydrological drought continues in the Southwest.

- All New Mexico reservoirs are at well below-average levels.
- Storage in the major Colorado River reservoirs is still below average.

Precipitation – Water Year precipitation for most of the Southwest is still below average. However, recent precipitation will bring short-term drought relief to Arizona, and more precipitation is forecast for the Southwest during late January 2004. However, snowpack is still quite low for this time of year for much of Arizona and New Mexico.

Temperature – During the past 30 days, temperatures have been above average across the Southwest, with the exception of northern Arizona. During late December, many low temperature records were set in our region.

Climate Forecasts – Seasonal forecasts indicate considerably increased probabilities of above-average temperatures across Arizona and most of New Mexico through the winter and into the early summer months. February-April 2004 precipitation forecasts indicate slightly increased probabilities of below-average precipitation for Arizona and New Mexico.

ENSO – ENSO conditions remain neutral. However, there is a somewhat better than average chance of a weak El Niño episode developing in 2004.

The Bottom Line

Hydrological drought is expected to persist in most of the Southwest through the winter.

- The **most likely scenario** is that above-average temperatures will continue throughout the winter and early spring. Despite recent precipitation in the Southwest, there is no indication that the Southwest will receive drought-ending precipitation during the next several months.
- The **worst case scenario** is that continued neutral ENSO conditions do not bring even average precipitation to the Southwest. This would result in continued soil moisture and reservoir depletion by the beginning of summer 2004. In Arizona, neutral ENSO conditions most often result in below-average precipitation.
- The **best case scenario** is that medium-range forecasts for continued storminess in the Southwest are correct and result in substantially increased mountain snowpack. The probability of La Niña and exceedingly dry conditions developing is low, and that's good news!

The climate products in this packet are available on the web:
http://www.ispe.arizona.edu/climas/forecasts/swoutlook.html