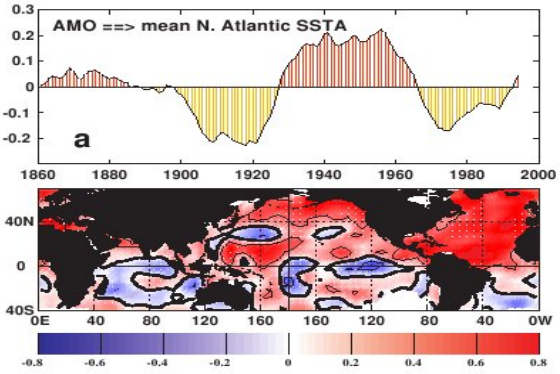
Earth Gauge
A National Environmental Education Foundation Program

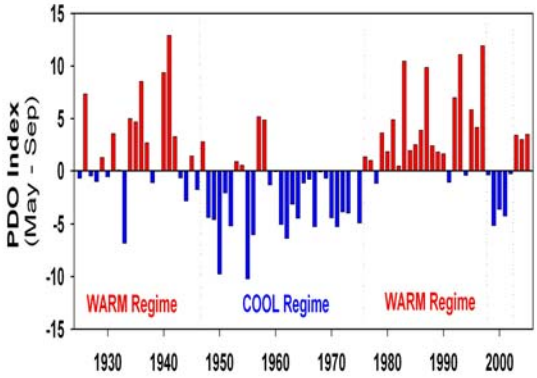
Drought and Climate Change

Many Americans will associate 2007 with drought. At one point, 60 percent of the U.S. was either abnormally dry or in a drought condition.[i] Here, read about two fundamental causes of drought: regional ocean temperature cycles and "unidirectional climate trends," such as rises in global temperature and carbon dioxide concentrations.

OCEANIC INFLUENCES ON DROUGHT

The **Atlantic Multidecadal Oscillation (AMO)** and the **Pacific Decadal Oscillation (PDO)** are two cycles where temperatures in the oceans alternate between warm (positive) and cool (negative) phases. The temperatures in most of the Atlantic between the Equator and Greenland change in unison over the AMO's 65-year period. The phases of the 50-year PDO cycle are characterized by the northeast Pacific's sea surface temperatures (SST's). When the northeast Pacific is cool (negative phase), the northwest Pacific is actually much warmer than average and vice-versa.[ii] The phases of both the AMO and PDO are "predominately though not uniformly warm or cool." In other words, the graphs below show multidecadal trends subject to seasonal and interannual variation.[iii]





(Images courtesy of NOAA)

The United States' most severe droughts occur when positive AMO phases coincide with negative PDO phases, such as the drought of the 1950's, which was most severe in the Southwest. Interactions between the PDO, AMO, and Northern Hemisphere temperature explain 74 percent of the drought frequency data for the Continental U.S.[iv] Several case studies illustrate this:

- ***The Dust Bowl:*** At one point during the 1930's, drought conditions covered almost the entire Continental U.S.; the southern Great Plains were most heavily impacted. The PDO was in a warm phase during the 1930's, yet SST's outside of the northeast Pacific were abnormally cool, particularly in the tropical Pacific. These cool tropical SST's led to a strengthening of the summertime high-pressure system that sits over the Great Plains, which drove summertime rainfall out of the Great Plains Region. Warm Atlantic SST's during the 1930's reinforced the drought by creating high-altitude, high-pressure zones near the Equator. These zones caused the Bermuda high pressure zone to shift to the east, which suppressed the summer and fall winds that bring moisture to the Central U.S. from the Gulf of Mexico. Over the past 400 years, similar droughts have occurred in the Continental U.S. once or twice per century.[v]
- ***Western U.S. Wildfires:*** A warm AMO corresponds to drier conditions throughout the United States, and drier and warmer conditions in the Western United States. Tree ring records that go back almost 500 years show that the Western Region consistently experiences more wildfires during warm phases of the cycle.[vi]
- ***Regional Rainfall Patterns:*** The Mississippi River Basin has ten percent more water flowing through it when the AMO is at its warm extreme than when the AMO is at its cool extreme.[vii] The Lake Okeechobee watershed follows a similar pattern, but the difference in rainfall between the two extremes is 40 percent.[viii]
- ***The Colorado Plateau:*** During the 20th Century, the Colorado Plateau experienced three distinct precipitation episodes. From 1905-1941 the Plateau was wet; from 1942-1977 it was dry; and from the late 1970's until about 1999 it was wet. These periods roughly correspond to the PDO going from warm, to cool, to warm.[ix]

The **El Niño Southern Oscillation Cycle (ENSO)** is a three- to seven-year cycle in the tropical Pacific where warm and cool sea surface temperatures "see-saw" back and forth between Indonesia and South America. During the El Niño phase of the cycle, the Southwest and Southeast United States generally experience above average precipitation, whereas the Northwest and Northeast generally experience below average precipitation. During the La Niña phase, essentially the opposite occurs. El Niño's effect on rainfall is most pronounced during the winter months, when there is the strongest contrast between sea surface and atmospheric temperatures.[x]

ENSO's influences interact with those of the AMO and PDO. For example, in the Columbia River, stream flow is on average 12 percent lower during El Niño events than it is when ENSO is in its neutral phase. Warm PDO phases also correspond to reduced precipitation in the Pacific Northwest, and the Columbia's stream flow is nine percent below average during warm regimes. When the El Niño and positive PDO phases align, stream flow is 17 percent below average.[xi] Also, while a warm AMO means more wildfires in the whole Western U.S., specific areas within the West are more prone to burning depending on ENSO's phase.[xii]

(The photograph on the far left is a picture of the Yuma Desert (Arizona) during the El Niño phase, and the photograph to its right is the same spot during the La Niña phase. Recall that El Nino brings above average precipitation to the Southwest. Photos courtesy of USGS)

UNIDIRECTIONAL CLIMATE TRENDS

A warmer atmosphere results in an "amplification" of the water cycle. Some areas of the World are net importers of rainfall (tropical rainforests), while some are net exporters (oceans around the tropics). The "amplification" of the cycle means that dry regions become drier, and wet regions become wetter.[xiii] Some other recent observed trends that have not been linked to regional ocean temperature oscillations include:

- Since the mid-1970's, the percentage of Earth's land area that is considered "very dry" has risen from 12 to 30 percent.[xiv]
- While rainfall in the Southwest was not any lower during the latest (turn of the millennia) drought than it was during the 1950's, temperatures in the Region were higher, as were the mortality rates of the tallest trees in the Southwest, such as Ponderosa and Pinyon Pines. The moisture stress that high temperatures put on the trees weakened them and made them susceptible to bark beetle infestations.[xv]
- The area that is classified as "tropical" (or the area close to the Equator that is hot and humid) has been expanding and the "tropical belt" is now between two and 4.5 degrees wider than it was in the 1970's. This also means that dry areas on the tropic's edges have moved towards the poles. This expansion has been linked to recent droughts in southern Australia and the Mediterranean.[xvi]
- Over the last fifty years in the U.S., the average lengths of both wet and dry spells have grown by over a week and extreme rainfall events have become more common. The longer soil goes without moisture, the harder it is for water to infiltrate the soil when rains do come. These trends make both droughts and floods more likely.

Carbon dioxide (CO_2) levels have risen from 280 parts per million (ppm) during in the 18th Century to over 380 ppm today. Higher CO_2 levels prompt plants to close their stomata, the tiny openings on leaves that regulate how much gas goes into and out of a plant. When plants close their stomata, less water goes from the soil, through the plant and into the atmosphere, and more water stays in the soil and ultimately drains into streams, rivers, and groundwater. During the last forty years in North America, the amount of water that each square meter of land contributes to annual runoff has grown by over a liter. This trend may partially counteract the general trend of rivers and groundwater supplies drying due to increased evaporation from warmer temperatures.[xvii]

[i] *Borenstein, Seth. "2007's weather extremes: 263 all-time high temps broken in U.S., Europe's heat waves." The Associated Press, 11 December 2007.*

[ii] *United States. National Oceanic and Atmospheric Administration. "Climate Science: Investigating Climatic and Environmental Decadal Processes." Accessed Online 17 December 3007 < http://www.ngdc.noaa.gov/paleo/ctl/clisci100.html>*

[iii] *United States Geologic Survey. "Climatic Fluctuations, Drought, and Flow in the Colorado River Basin." Fact Sheet 2004-3062, version 2. August 2004.*

[iv] *McCabe, G.J et al. 2004, Pacific and Atlantic Ocean influences on multidecadal drought frequency in the United States: Proceedings of the National Academy of Sciences USA, v. 101, p. 4136-4141.*

[v] *Schubert, S.D. et al. "On the Cause of the 1930's Dust Bowl." Science, 303 (2004) 1855-1859 and Woodhouse, C.A. and Overpeck, J.T. "2000 Years of Drought Variability in the Central United States." Bulletin of the American Meteorological Society, 79 (1998) 2693-2714 and Schubert, S.D. et al. 2004: "Causes of Long-Term Drought in the U.S. Great Plains." 17, 485–503.*

[vi] *Kitzberger, T et al. "Contingent Pacific-Atlantic Ocean influence on multicentury wildfire synchrony over western North America." Proceedings of the National Academy of Sciences: January 9, 2007, vol. 104, no. 2. pps 543-548.*

[vii] *Enfield, D.B. et al. "The Atlantic multidecadal oscillation and its relation to rainfall and river flows in the Continental U.S." Geophysical Research Letters, vol. 28, (2001) 2077-2080.*

[viii] *ibid*

[ix] *United States Geologic Survey. "Precipitation History of the Colorado Plateau Region, 1900-2000." Fact Sheet 119-02. 2002.*

[x] *Kousky, V.E. "The El Niño Southern Oscillation Cycle." Cooperative Program for Operational Meteorology, Education and Training: University Corporation for Atmospheric Research (2003). Accessed Online 17 December 2007 <http://www.meted.ucar.edu/climate/enso/>*

[xi] *Gedalof, Ze'ev et al. 2004. "Columbia River Flow and Drought Since 1750." Journal of the American Water Resources Association. December: 1579-1592.*

[xii] *Kitzberger, T et al. "Contingent Pacific-Atlantic Ocean influence on multicentury wildfire synchrony over western North America." Proceedings of the National Academy of Sciences: January 9, 2007, vol. 104, no. 2. pps 543-548.*

[xiii] *Soden, B., Wentz, F.J., Santer, B.D. and Zwiers F. "Climatically-Induced Increases in Water Vapor and Precipitation: Causation and Implications. " United States Senate, Washington, D.C. 29 October 2007. Accessed Online 17 December 2007 <http://www.ametsoc.org/atmospolicy/ESSSarchiveclimatechange.html>*

[xiv] *Dai, Aiguo et al. "A Global Dataset of Palmer Drought Severity Index for 1870-2002: Relationship with Soil Moisture and Effects of Surface Warming." Journal of Hydrometeorology. Volume 5 (2004) 1117-1130.*

[xv] *Breshears, D.D. et al. "Regional vegetation die-off in response to global-change-type drought." Proceeding of the National Academy of Sciences, vol. 102, no. 42 (2005) 15144-15148.*

[xvi] *Seidel, D.J., Q, Fu, W.J. Randel and T.J. Reichler, Widening of the tropical belt in a changing climate. Nature Geoscience, doi:10.1038/ngeo.2007.38 (published online: 2 December 2007)*

[xvii] *Gedney, N et al. "Detection of a direct carbon dioxide effect in continental river runoff records." Nature: Volume 439, 835 (2006) and Betts, RA et al. "Projected increase in continental runoff due to plant responses to increasing carbon dioxide." Nature: Volume 448, 1037 (2007).*