EL NIÑO/SOUTHERN OSCILLATION SIGNALS IN THE LONG TERM CLIMATE RECORD OF DONNER SUMMIT, CALIFORNIA

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ABSTRACT

The latest El Niño event has prompted questions about the predictability of North American weather based on the relative strength of the Southern Oscillation Index (SOI). The annual precipitation, snowfall, and air temperature data from an area near Donner Pass, California have been analyzed in comparison with the SOI from the equatorial Pacific Ocean. There was found to be a positive correlation between decreasing SOI values and increasing annual precipitation; a positive correlation between increasing SOI values and increasing annual snowfall; and a positive correlation between increasing SOI values and increasing average annual air temperature. All these correlations, however, are weak. 64% of the wettest years on record occurred with a low SOI, and 52% of the driest years on record occurred with a high SOI. Data was available from 1900 through 1997 excluding 1907, 1908, 1914, 1915, and 1932.

INTRODUCTION

Global circulation cells are a consequence of unequal absorption of solar radiation at various latitudes. Pressure differences result, driving surface and upper level winds. Under "normal" conditions, the Walker Cell circulation of the equatorial Pacific is maintained by trade winds driving from east to west at the surface and west to east aloft. As Pacific surface waters are blown westward, they are replaced by cold waters upwelling off the west coast of South America. During abnormal conditions, as pressure gradients shift, this circulation of the Walker Cell breaks down, promoting westerly surface winds and the piling up of warm waters against the west coast of South America. This increase in eastern equatorial Pacific ocean temperatures is referred to as an El Niño event.

The Pacific Ocean at the equator is the greatest stretch of east/west oriented open ocean on the planet. Consequently, the interaction here between the ocean and atmosphere is thought to have substantial influence on the global climate. During the 1920s, Gilbert Walker (after whom the Walker Cell is named) discovered a strong and inverse relationship between surface pressure at Darwin, Australia and the island of Tahiti. High pressure at one site almost always meant low pressure at the other. Every few years this pressure difference would reverse itself. This is what has been coined the Southern Oscillation. The Southern Oscillation and El Niño are closely related, but may occur independently. An index of the relative strength of any one El Niño/Southern Oscillation event has been developed. This index includes variables of surface pressure and departures from average equatorial Pacific sea surface temperatures. During a high index, pressure is greater on the east side of the Pacific, driving the easterly trade winds; conversely, weakening easterly surface winds are indicative of a low index, allowing the warmer western waters (at slightly higher sea levels) to flow east. A low Southern Oscillation Index (SOI) is usually accompanied by El Niño conditions. Because the interaction of the ocean and atmosphere is very complex, each El Niño/Southern Oscillation event is different and sometimes difficult to categorize. Though these ocean/atmospheric connections often defy attempts at classification, the Southern Oscillation Index remains a good gauge of the relative strength of an El Niño event.

The El Niño event of 1997 has gained great notoriety with the media, the public, and the scientific community. In the United States, the media have ascribed most everything from tornado activity to an increase in dog bites to the warm waters off South America. Weather phenomena are readily labeled with tag lines such as: *"moist El Niño air flows"* or *"El Niño-generated storms"*. Bold two- and three-month weather forecasts have been issued on the premise of the El Niño event persisting. There is deliberation within the scientific ranks as to what role a strong El Niño plays on the global weather stage. It is generally agreed upon that a strong El Niño event significantly alters winds at the jet stream level thereby shifting the position of large ridges of high and low pressure. The influence an El Niño event has on seasonal weather at specific areas -- especially at latitudes far north or south of the equator -- is not largely understood.

ANALYSIS/RESULTS

Southern Oscillation Index data for the years 1900 through 1997 (excluding 1907, 1908, 1914, 1915, and 1932) were obtained from the NOAA Climate Analysis Center and Scripps Institution of Oceanography in southern California. The SOI values have been tabulated for seasonal three-month periods: December, January, February; March, April, May; June, July, August; and September, October, November. Annual SOIs were

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obtained by averaging the four seasonal values. These data were compared with data on annual precipitation, snowfall, and average air temperature from Donner Summit, California (39°19'N, 120°22'W, 2100 m). The Donner Summit data are complete throughout 1900 - 1997. The Donner Summit data were chosen because of the length of record, completeness of record, and high variability in annual precipitation (480 - 2852 mm, average 1343 mm). Figure 1 is a plot of the SOI values along with notations of selected annual precipitation during extreme SOIs.

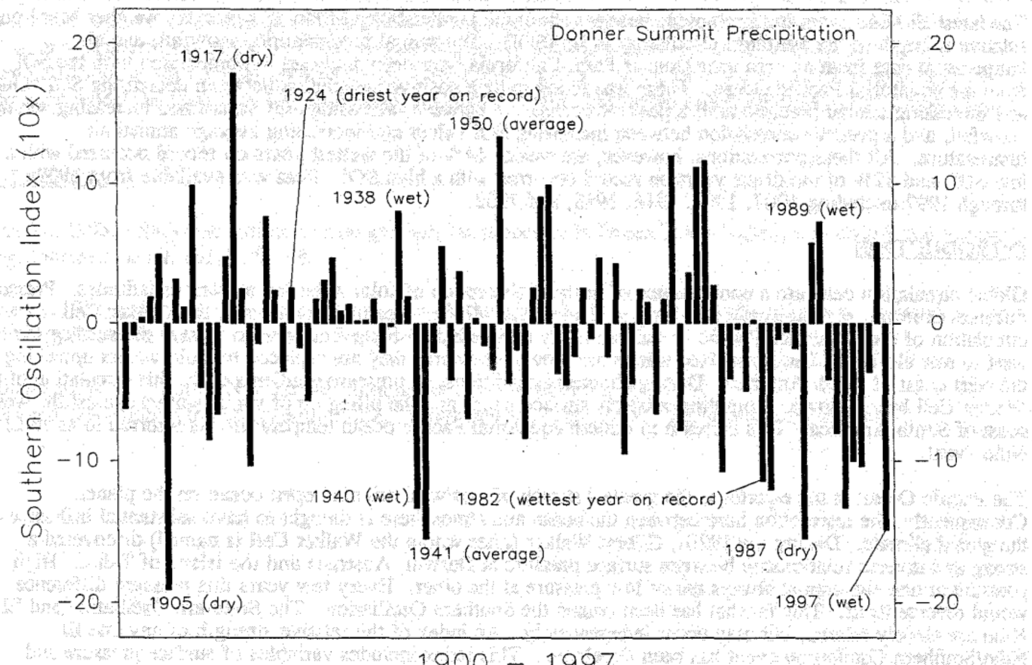

Figure 1. Historic Southern Oscillation Index values and selected notations of Donner Summit annual precipitation, 1900 - 1997.

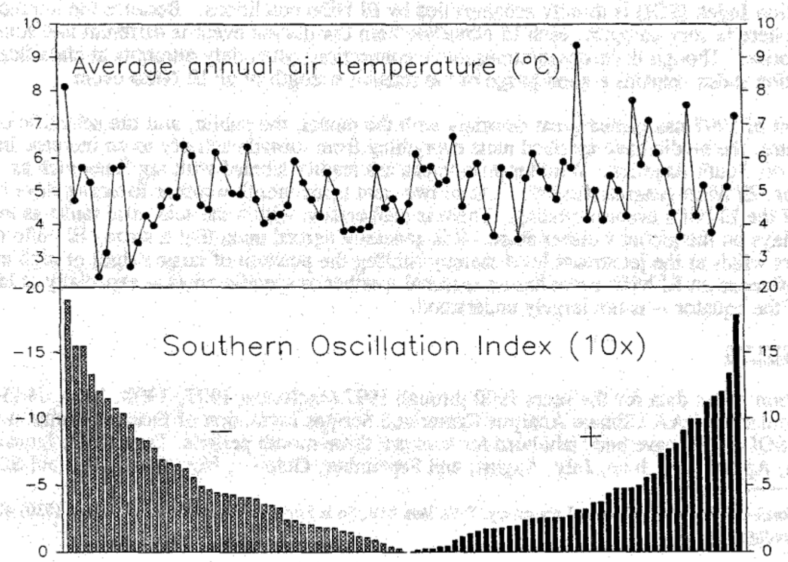

Figure 2. Southern Oscillation Index values, plotted lowest to highest, and coincident Donner Summit average annual air temperature, 1900 - 1990.

Annual precipitation is measured from October 1 to September 30. (Based on the standard deviation of the data, 497 mm, seasonal precipitation was classified into one of three groups: wet, average, or dry.) It can be noted from Figure 1 that a strongly negative or strongly positive SOI is not necessarily indicative of a wetter-than-average or drier-than-average season. 1905, 1941, and 1987 were all dry or average years during periods of strongly negative SOIs. But of the 25 wettest years on record, 16 (64%) occurred during a negative SOI event. Conversely, 1938, 1950, and 1989 were all average or wet years during strongly positive SOIs; and of the 33 driest years on record, 17 (52%) occurred during positive SOI events. It should be noted that the wettest year on record (1982) occurred during a negative SOI, and the driest year on record (1924) occurred during a positive SOI.

Regression analyses of the SOI values against Donner Summit annual snowfall and average annual air temperature were performed. Correlations exist, but are statistically insignificant. As the SOI increases, both snowfall amounts and average annual air temperature were found to increase (r^2 = .023 and .021, respectively). For this analysis, air temperature data from 1900 through 1990 were used. Figure 2 is a diagram of two coincident plots: the Southern Oscillation Index values plotted lowest to highest, and the corresponding average annual air temperature plotted above. 58% (15 of 26) of the coolest years occurred during low SOI events; and 63% (15 of 24) of the warmest years occurred during high SOIs. The warmest year on record (1906, average precipitation) happened during a high SOI event, and the coolest year on record (1983, wet) corresponded to a low SOI event. It was found that 46% (12 of 26) of the snowiest winters on record occurred during negative SOIs, and 50% (16 of 32) of the least snowiest winters occurred during years with positive SOIs. (The measurement of snowfall "depth" is frequency dependent, and is not necessarily a representative gauge of a winter. Precipitation is the more qualitative value.) Figure 3 shows five regression plots of seasonal and annual SOI values graphed against annual precipitation. All correlations are weak. The strongest correlation is with the

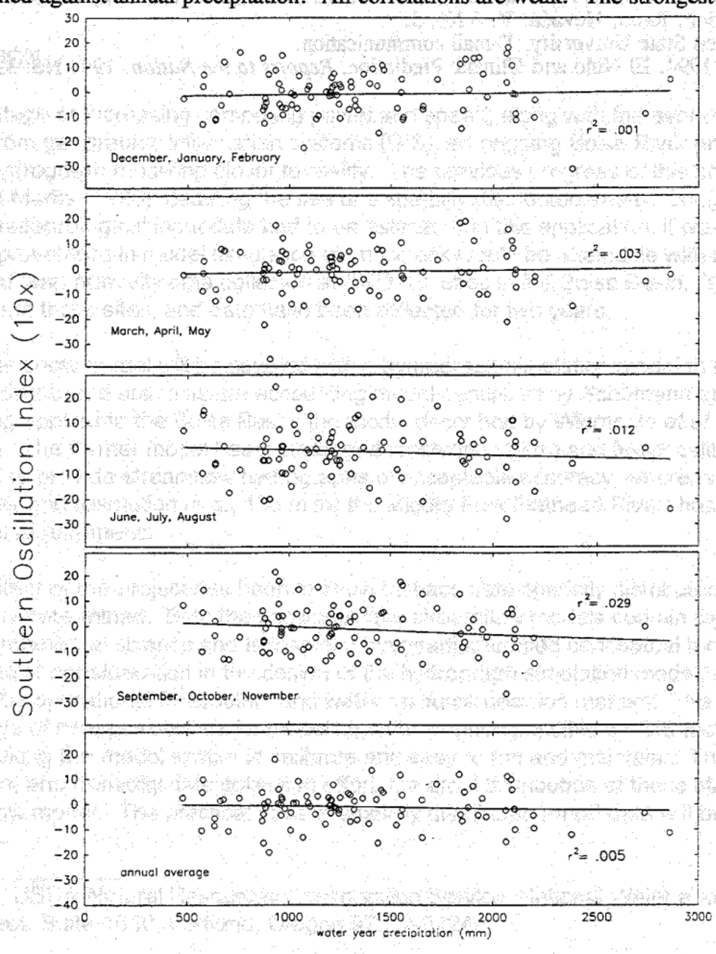

Figure 3. Regression analyses of seasonal and annual Southern Oscillation Index values and annual Donner Summit precipitation, 1900 - 1997.

autumn SOI values (r^2 = .029). For the yearly SOI values, Donner Summit precipitation was found to increase as SOI values decreased (r^2 = .005).

CONCLUSIONS

Slightly more than half of the wettest years on record occurred during times of negative SOI events; and slightly more than half of the driest years on record occurred during positive SOIs. This distribution also approximates the frequency of the cooler and warmer years relative to negative and positive SOIs. Average annual air temperature on Donner Summit is dependent on annual precipitation and its seasonal distribution (generally the wetter the year the cooler the year). It was found that annual precipitation tends to increase and air temperature decrease during low SOI events, but again, the correlations are weak. The wettest year on record, 1982, occurred during a negative SOI; the driest year on record, 1924, occurred during a positive SOI.

Other preliminary analyses have suggested that during El Niño/low SOI events, the northwestern United States tend to receive warm, dry winters, while the southwestern U.S. tends toward wetter winters. To date, the evidence of strong SOI signals in between these two regions is unclear. The analysis of the Donner Summit climate data supports this spongy conclusion. Correlations between the SOI and air temperature, snowfall, and precipitation on Donner Summit are statistically insignificant.

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