# Uncovering North American Temperature and Precipitation Patterns Associated with the Southern Oscillation

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ABSTRACT: The extreme phases of the Southern Oscillation (SO) have been linked to fairly persistent classes of circulation anomalies over the North Pacific and parts of North America. It has been more difficult to uncover correspondingly consistent patterns of surface temperature and precipitation over much of the continent. The few regions that appear to have consistent SO-related patterns of temperature and precipitation anomalies are identified and discussed. Also discussed are regions that appear to have strong SO-related surface anomalies whose sign varies from episode to episode.

## INTRODUCTION

The Southern Oscillation is the best documented and understood mode of interannual climate variability. While much remains to be learned about the evolution of individual warm SO episodes, research over the past two decades (e.g., Bjerknes, 1969; Rasmusson and Carpenter, 1982) has provided a fairly clear picture of the mean features associated with the warm extreme of the SO. Horel and Wallace (1981), through a spatial correlation analysis of geopotential height data, demonstrated that teleconnection patterns link the equatorial tropics with mid-latitude circulation anomalies over North America. These diagnostic studies were further bolstered by theoretical work, e.g., Opsteegh and Van den Dool (1980), which helped to explain the statistical teleconnection patterns in terms of Rossby wave propagation on a sphere.

We now envision the SO as a slowly evolving state of the climate system, which is manifested most clearly in the Pacific Ocean but includes the global atmosphere and may involve the other ocean basins as well. While the warm phase of the SO (also called the ENSO phase after El Niño/Southern Oscillation) has been studied extensively over the past decade, the appearance of extremely cold equatorial waters associated with an enhanced trade wind circulation early in 1988 has spurred renewed interest in the cold extreme of the SO. This phase of the SO has also been identified with high values of the Tahiti-Darwin SO index (Ropelewski and Jones, 1987), stronger than normal easterly trades across the Pacific, and strong 200 mb westerly wind anomalies over the equator (Ropelewski and Halpert, 1989). Since the SO tends to evolve slowly through both its extremes, the identification and tracking of SO has a promising potential for long-range (monthly, seasonal) prediction.

## REGIONS WITH TYPICAL ANOMALY PATTERNS

Typical anomaly patterns of surface temperature and precipitation associated with the extremes of the SO have been identified (Ropelewski and Halpert, 1986, 1987, 1989). These studies indicate that consistent North American SO-related precipitation and temperature patterns are confined to the far northwestern reaches of the continent and to the southeastern Gulf regions (Figure 1).

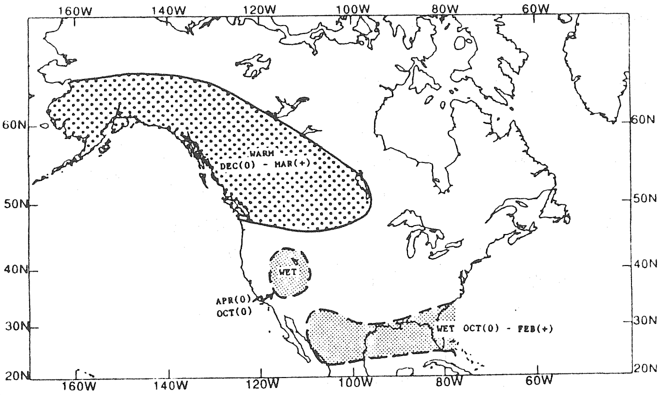

Figure 1. Schematic of areas with consistent SO-related precipitation and temperature anomalies. The anomalies are illustrated for the ENSO (warm phase of the oscillation). These anomalies have the opposite sign in association with the cold, high index, phase. The Great Basin shows a warm phase signal only. The Gulf/Mexico area also tends to be cool in ENSO episodes.

During the warm, or ENSO, phase of the oscillation, the northwestern sections of North America tend to exhibit positive temperature anomalies, while the southeastern region tends to be cooler than normal. The reverse-sign anomaly pattern tends to occur during the cold, or high index, phase of the SO (Table 1). The southeastern areas of North America, especially those adjacent to the Gulf of Mexico, tend to experience more than normal precipitation during the winter half of the year (October to March) during the ENSO phase of the oscillation and drier than normal conditions during the high index phase. There is also a tendency for the Great Basin to experience above normal precipitation over the April to October "season" during warm episode years. However, there appears to be no corresponding relationship

In J.L. Betancourt and A.M. MacKay, editors, 1990. Proceedings of the Sixth Annual Pacific Climate (PACLIM) Workshop, March 5-8, 1989: California Department of Water Resources, Interagency Ecological Studies Program Technical Report 23.

between Great Basin precipitation and the SO during the cold phase of the oscillation.

## DISCUSSION OF OTHER REGIONS

While we could not find any **consistent** SO-temperature or SO-precipitation relationships for other regions of North America, this does not necessarily imply that the SO has no influence over monthly and seasonal climate anomalies in other regions. In fact, historical evidence suggests that the warm phase of the SO may be associated with precipitation anomalies of either extreme in the Pacific northwestern sections of the United States. Thus we are presented with the apparent paradox that in Oregon and Washington the ENSO phase can be linked with the **dry** winter conditions for 1951, 1965, 1972, 1976, 1986/7 and with the **wet** conditions of 1953, 1957, 1969, and 1982 (Karl and Knight, 1985). Likewise, the cold phase of the SO appears to be associated with anomalies of either sign.

To further complicate the issue, areas of precipitation anomalies very often, but not always, include Northern California. This suggests that SO-related precipitation patterns over the Pacific Northwest depend strongly on the detailed evolution of the individual ENSO and high index episodes. Thus, for the northwestern states, predictions (or even observations) of the initiation of ENSO episodes or of high index episodes are not very useful for predicting precipitation anomalies.

A further examination of monthly SO-precipitation patterns indicates that anomalies tend to be reasonably persistent within episodes; i.e., it appears that once a precipitation anomaly (and presumably a corresponding circulation anomaly) is initiated in conjunction with a particular SO episode, these anomalies tend to persist throughout the northwest's rainy season.

Table 1. Number of positive/negative anomalies associated with ENSO and high index phase of the Southern Oscillation. *(After Ropelewski and Halpert, 1986, 1989.)*

| | **Precipitation** | | | |
|---|---|---|---|---|
| | ENSO | | High Index | |
| Region | Wet | Dry | Wet | Dry |
| Gulf/Mexico [Oct(0)-Mar(+)] | 18 | 4 | 3 | 16 |
| Great Basin [Apr(0)-Oct(0)] | 9 | 2 | 4 | 4 |

| | **Temperature** | | | |
|---|---|---|---|---|
| | ENSO | | High Index | |
| Region | Warm | Cold | Warm | Cold |
| NW North America [Dec(0)-Mar(+)] | 18 | 4 | 5 | 14 |
| SE United States [Oct(0)-Mar(0)] | 5 | 20 | 10 | 8 |

Numerical modeling is another arena that may provide some help in understanding and predicting precipitation anomalies associated with the SO. A promising example of this approach is the numerical simulation presented by Trenberth et al. (1988) to explain the spring and summer drought of 1988.

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