RELATIONSHIP BETWEEN ATMOSPHERIC CIRCULATION AND SNOWPACK IN THE WESTERN UNITED STATES

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RESEARCH OBJECTIVES

Snow anomalies in the western United States (WUS) have been widely investigated by many researchers because of their significant impact on water availability. This previous research indicated that the ocean has a dominant effect on snow variation in the WUS and contributes to more than 60% of the variance in snow anomalies. This study investigates those findings, focusing on the snow variations in the WUS resulting from anomalous atmospheric circulation, attributed to both atmospheric internal variability and tropical Pacific sea surface temperature (SST) forcing.

APPROACH

In this study, the observed Snow Water Equivalent (SWE) data in the WUS was obtained from snow course data collected manually by the U.S. Department of Agriculture (USDA) cooperative snow survey program and the California Department of Water Resources. The April 1 SWE maximum for 1950–1997 is the focus of this analysis. The observed tropical Pacific SST was averaged for December to February (DJF) to identify winter season El Niño-Southern Oscillation (ENSO) events. When the average SST is above 1°C, below -1°C, or between -1°C and 1°C, the ENSO event is defined as “warm,” “cold,” or “neutral,” respectively. For 1950–1997, there are 8 warm, 6 cold, and 33 neutral winters. The Pacific/North American (PNA) index indicates the 500 mb geopotential height anomalies. PNA indices for DJF are averaged to identify winter PNA patterns. When the DJF-average PNA index is above 0.5, the corresponding atmospheric pattern is defined as the “positive PNA pattern”; when it is below -0.5, the atmospheric pattern is defined as the “negative PNA pattern.” There are 9 positive and 6 negative PNA patterns for the 33 neutral winters.

ACCOMPLISHMENTS

Table 1 provides the quantitative comparison of SWE, temperature, and precipitation anomalies during the ENSO episodes and under the PNA circulation patterns, which represent the ocean and atmospheric internal variability influences, respectively. The numbers for the SWE anomaly in Table 1 are the averages of those SWEs passing the 95% significance test in the northwest and southwest, and the numbers for temperature and precipitation anomalies are the averages over the corresponding snow-course stations in the same regions. Table 1 shows that the warm ENSO generates a significant positive SWE anomaly in the southwest (55.2 mm), but has a weaker impact on the northwest SWE (-3.7 mm). The cold ENSO produces a strong positive SWE anomaly in the northwest (117.8 mm), but has a mild effect on the southwest SWE (-21.5 mm). Under the positive PNA pattern without oceanic forcing, the entire WUS has negative SWE anomalies (-80.2 mm in the northwest and -71.2 mm in the southwest), while under the negative PNA pattern, the WUS has positive SWE anomalies (73.1 mm in the northwest and 88.8 mm in the southwest). Table 1 also indicates that the positive SWE anomaly results from the stronger precipitation and colder temperature, whereas the negative SWE anomaly is caused by weaker precipitation and warmer temperature. The empirical orthagonal function (EOF) analysis further shows that the PNA patterns contribute to 39% of the total SWE variance, and the ENSO episodes account for only 18%, indicating that the atmospheric internal variability has a dominant impact on the SWE variations in the WUS.

Regions / Events	Northwest			Southwest		
	SWE(mm)	P(mm)	T(°C)	SWE(mm)	P(mm)	T(°C)
Warm ENSO	-21.5	-11.0	0.62	55.2	32.7	-0.14
Cold ENSO	117.8	44.7	-0.81	-3.7	-3.1	-0.28
Positive PNA	-80.2	-22.6	0.77	-71.2	-27.2	0.68
Negative PNA	73.1	20.5	-1.08	88.8	26.6	-0.56

Table 1. SWE, temperature, and precipitation anomalies averaged over the snow course stations, where the SWEs pass the 95% Student's *t* test (P is precipitation and T is temperature)

SIGNIFICANCE OF FINDINGS

Our study shows that the oceanic impact on WUS snow is likely overestimated, and that atmospheric internal variability also plays an important role in WUS snow volume. This study provides significant insight into forecasts of winter and spring snow mass in the WUS, where snow is the major water resource.

RELATED PUBLICATIONS

Jin, J., N.L. Miller, S. Sorooshian, and X. Gao, Relationship between atmospheric circulation and snowpack in the western United States. Hydrological Processes (in press), 2005. Berkeley Lab Report LBNL-55404.

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