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Streamflow Prediction Based on El Niño, La Niña and Atmospheric Circulation

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TECHNICAL COMPLETION REPORT

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ABSTRACT

The relationship between the El Niño/Southern Oscillation (ENSO) and unimpaired streamflow over the contiguous United States was studied. The ENSO is a warm event in the tropical Pacific Ocean and is considered a significant perturbation of the general atmospheric circulation. El Niño events have been observed and recorded since 1726. They occur approximately once every 4 years; however, the time interval between successive events varies from 2 to 10 years.

ENSO-related events have important consequences for U.S. atmospheric and weather patterns, but the nature of these consequences depends on the type of El Niño. In 1941 and 1983, the major ENSOs of this century, heavy rains were experienced in the West and Southwest and the Colorado River basin. However, most ENSO episodes produce dry conditions in these regions (e.g., that of 1986-1987).

In these studies there was an identification of regions of land that appear to have strong and consistent ENSO-related streamflow signals. Coherent and significant streamflow responses to ENSO forcing are found in four regions of the United States: the gulf of Mexico, the Northeast, the North Central, and the Pacific Northwest.

Streamflows in the Pacific Southwest of the U.S. in relation to the tropical Type 1 El Niño-Southern Oscillation and La Niña events were specifically studied. The Pacific Southwest streamflow responses to the Type 1 ENSO thermal forcing are characterized by a wet December-July season in the subsequent year of the event. Similarly, a dry February-July season is detected as a period at which the La Niña-streamflow relationship is strong and spatially coherent.

Once an ENSO event sets in, a long-range forecasting utility may be available for these regions. The results of this analysis, which are consistent with previous studies on precipitation and temperature, demonstrate the mid-latitude hydrologic response to the tropical ENSO phenomena.

TECHNICAL COMPLETION REPORT

PROJECT NUMBER: W-787

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TITLE: Streamflow Prediction Based on El Niño, La Niña and Atmospheric
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INVESTIGATOR: John A. Dracup, UCLA

KEY WORDS: Streamflow, Climate, Global Climate Change, El Niño, La Niña,
Southern Oscillation, ENSO

PROBLEM AND RESEARCH OBJECTIVES:

The research problem under study here was whether regional streamflows could be identified and potentially predicted based on the impact of El Niño, La Niña and the Southern Oscillation. The El Niño/Southern Oscillation is commonly designated as ENSO events. Researchers have determined that these ENSO events have significant world wide impacts on such events as precipitation, temperatures, floods, droughts and wildfires.

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recorded since 1726. They occur approximately once every 4 years; however, the time interval between successive events varies from 2 to 10 years.

The research objective was to identify regions of land that appear to have a coherent and consistent ENSO-related signal. The identification of these regions and the predictions of the onset of an ENSO event could then lead to the prediction of climatic anomalies.

METHODOLOGY:

In this research project, streamflows were analyzed by using an empirical methodology. These methods were first developed by researchers in the atmospheric science community to study the influence of ENSO on global precipitation and temperature. We have adopted these methods with some changes and additions to explore the ENSO-streamflow relationships over the contiguous United States.

The analysis starts with a transformation of original records into percentiles based on a lognormal distribution. A 24-month percentile composite based on nine ENSO events that occur from 1948-1988 is then established for each station. The first harmonic extracted from the composite is assumed to be the ENSO-related signal appearing in streamflow anomalies. The vectorial display of these harmonic over a map of the U.S. provides the areal extents of the ENSO influence on streamflow. Regions of coherent response are identified and then aggregate composites are formed for each of these regions. The aggregate composite is used to identify a season of strong and consistent response to ENSO. This season is then used to form an Index Time Series (ITS) for every year in the time series. The ITS is used to assess the temporal

consistency of the signal. This same analysis was also used to study the influence of La Niña and Type I ENSO events on U.S. streamflow.

Additional analysis was performed to assigned assess the statistical significance of the El Niño or La Niña streamflow anomaly. The probability of random occurrence of the wet(dry) season in the aggregate composite was tested using the hypergeometric model. A cumulative probability computed from the hypergeometric distribution gives an occurrence significance level of the relationship between the streamflow anomaly and El Niño (La Niña). Lastly, it was of interest to determine whether there is a significant difference in the magnitude of seasonal streamflow (averaged over the December-July season) between the years associated with Type I ENSO and La Niña events. A rank-sum test know as the Mann-Whitney U, alternative to the *t*-test, is used to infer whether the two independently drawn sample come from the same population.

PRINCIPAL FINDINGS AND SIGNIFICANCE:

Several areas of the U.S. have been identified as having a statistically significant response ocean-atmospheric conditions in the tropical Pacific. The results are summarized for the three separate analyses of El Niño, La Niña, and Type I ENSO events.

Coherent and significant streamflow responses to hypothesized El Niño forcing are found in four regions of the United States: wet conditions in the Gulf of Mexico and North Central; and dry conditions in the Northeast and Pacific Northwest. These results are consistent with previous studies on precipitation and temperature; moreover, the streamflow response presents are

reasonable alternative as a hydroclimatic surface parameter in order to find large-scale circulation signals.

Within each region identified above, specific timing and sign of streamflow anomalies associated with La Niña events were documented. Two general conclusions were confirmed regarding the sign reversal of the streamflow anomaly during El Niño and La Niña events, and the biennial tendency associated with the Southern Oscillation. These relationships between U.S. streamflow conditions and the extreme phases of the SO were found to be statistically significant, especially for the extreme streamflow conditions. The NC and PNW regions had the strongest relationships between seasonal streamflow and El Niño/La Niña events. In general, the response of streamflow to either extreme of the SO within each region appears during the second half of the event year or during the subsequent year.

Streamflows in the Pacific Southwest of the United States during tropical Type I ENSO conditions are characterized by a wet December-July season in the subsequent year of the event. The hypothesized tropical influences have also been characterized as an enhancement (suppression) of the annual cycle during the subsequent year that follows the Type I ENSO (La Niña) phenomena. This suggests that the seasonal Southern Oscillation Index (SOI) could be a useful predictor for streamflow six to twelve months in advance.

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PROFESSIONAL PRESENTATIONS:

Kahya, E., and J.A. Dracup, 1992: The Relationship Between ENSO Events and California Streamflows. *Presented at the American Geophysical Union Fall Union*, San Francisco, CA., Dec. 8th.

M.S. THESES:

Kelly, Jonathan	1993	Civil Engineering	M.S.	Private Sector
Piechota, Thomas	1993	Civil Engineering	M.S.	Public Sector-Univ.

Ph.D. DISSERTATIONS:

Freeman, Frederick	1994	Civil Engineering	Ph.D.	Public Sector-Fed.
Kahya, Ercan	1993	Civil Engineering	Ph.D.	Public Sector-Fed.