

The Association Between Equatorial Sea Surface Temperature Gradients and Upper Klamath Seasonal Streamflow: Trans-Niño Index

by
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Executive Summary

I. Background

Seasonal streamflow volumes in the Upper Klamath Basin, Oregon, USA are of great interest to water resource managers because seasonal water quantity is an important factor affecting the livelihood of fish, growers, tribes, and municipalities in the area. Human effects on the flow regime in the areas downstream of Upper Klamath Lake are high, but they are small on the two primary tributaries that form approximately 50 percent of the total inflow into the lake, the Sprague and Williamson Rivers. This permits an evaluation of climate variability affecting interannual streamflow volumes on these two rivers. The knowledge established with this study permits the development of improved predictive streamflow models that are robust, and thus desirable, for the management of water related resources in the basin.

II. Methods

Hydrologic data for the Sprague and Williamson rivers were analyzed for trends and patterns useful to characterize interannual streamflow variability. Annual runoff ratios, variance ratios, seasonal autocorrelation coefficients, and moving window 25-year average monthly hydrographs were computed for both basins. This evaluation identified the current character of the hydrologic cycle and allowed a comprehensive understanding of the shifts occurring in the basin.

To quantify the basin's response to large-scale climate variability, six climate indices were evaluated for their association with seasonal streamflow and snow water equivalent (SWE) observations within and in the vicinity of Upper Klamath Basin. These climate indices are based on atmospheric conditions or sea surface temperatures and are commonly used to monitor the El Niño and other large-scale variations in climate as well as support hydrologic predictions in the western US. These indices included the well-established Southern Oscillation Index (SOI), the Niño 3.4 sea surface temperature index, the Multivariate El Niño-Southern Oscillation Index (MEI), the Pacific Decadal Oscillation index (PDO), and the Pacific North American index (PNA), as well as a relatively new index, the Trans-Niño Index (TNI). The TNI is the only large-scale climate variable strongly associated with hydrologic variability within the Upper Klamath Basin. This index was updated and revised for use in real-time streamflow prediction models.

November through May principal components based regression models were developed to predict Sprague and Williamson seasonal streamflow. In addition to the conventional variables used (SWE, precipitation, and antecedent streamflow), new variables were identified, which included a groundwater index (Williamson River only), mean areal precipitation, mean areal temperature, and the TNI. Attention was given to the physical meaningfulness of each variable, month-to-month variable consistency, and overall model performance as measured by the standard error.

III. Results

A number of important findings have surfaced regarding the hydrology of Upper Klamath Basin.

- 1) There is a significant difference between the Sprague and Williamson runoff ratios, defined as the annual streamflow divided by the mean areal annual precipitation (obtained from analyzing monthly precipitation grids from PRISM). The Sprague has higher and less variable runoff ratios than the Williamson. This is a direct result of the differences in the geology and hydrology of the two basins and indicates that each basin should be modeled independently.

- 2) Decadal-scale variance and persistence patterns exist. That is, there appear to be cycles of high and low streamflow variability and cycles of high, low, and anti-persistence in annual

streamflows. These patterns are most prevalent in the Sprague streamflow data because the unique geology and groundwater influence in the Williamson smoothes much of the seasonal snowmelt signal as well as introduces lags in streamflow response to climate forcing. These cycles of variability and persistence have significant ramifications in water management.

3) There has been a forward shift in the timing of peak seasonal streamflow for both the Sprague and Williamson rivers since streamflow records began in the 1930s. There has been a pronounced shift from April clearly being the month of peak streamflow volume to March becoming as significant or more significant than April. This finding suggests that the March streamflow volume should be included in the forecast period, with water management decisions being shifted forward accordingly, and that the 1 March forecast is now equally as important as the 1 April forecast.

4) The TNI was identified as being strongly associated with seasonal streamflow and 1 April SWE within and outside of the Upper Klamath Basin. This association with Upper Klamath Basin hydrology is strongest during the current warm phase of the Pacific Decadal Oscillation (PDO) (1978 – present) but does persist to a lesser degree into the previous PDO phase (1945 – 1977). This signal is not only present in the Upper Klamath Basin but also extends to other regions in the western US.

5) Incorporating fall and early winter values of the TNI into Upper Klamath Basin seasonal streamflow prediction models reduces the uncertainty of early season streamflow volume forecasts. Results suggest that the TNI reduces the early season forecast uncertainty observed in the 1 December, 1 January, and 1 February forecasts for both the Sprague and Williamson rivers. An early more accurate streamflow prediction model should provide the USBR with better tools to make earlier decisions regarding water resource management in the basin.

IV. Conclusions

Water management in a challenging basin such as the Upper Klamath can be fostered by better understandings of the hydrology and climatology of the basin as well as the ability to produce more accurate and robust streamflow forecasts and to produce them earlier in the season. This research has produced results useful toward these ends. Together with improved basin-wide range management, crop selection, and land conservation methods, improved forecast tools and local climate understanding may greatly enhance the likelihood of agricultural sustainability in the basin.

V. Recommendations

Study results show that incremental improvements have been achieved by careful evaluation of existing data. Adjustments to the data infrastructure that would help employ these new models in an operational setting are:

1) Groundwater data within the basin would be more useable if it were available in real-time. This would require the installation of an automated measuring station at the Oregon Water Resources Department well #280.

2) A reliable and efficient method to compute mean areal precipitation and temperature needs to be established so that the data are available in real-time.

Recommended adjustments in water management include:

3) Water management rules and guidelines should be developed and operated with full regard for the current hydrologic regime and its decadal-scale cycles.

4) Streamflow forecast models should target the March through September period and be adapted to any gradual or abrupt climate shifts that may affect the model forecast accuracy.