Drought Determinants for the Colorado River Basin

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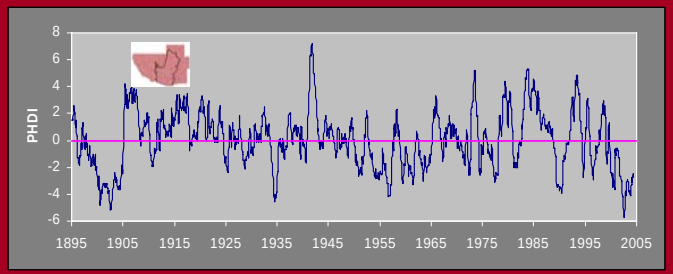
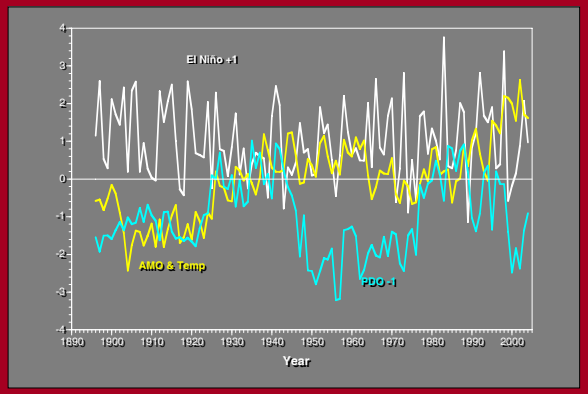
Introduction

Ongoing drought in the Colorado River Basin, unprecedented urban growth in the watershed, and 2 × CO_2 numerical model simulations showing higher temperatures and lower precipitation totals in the future have all combined to heighten interest in drought in this region. We use principal components analysis to independently assess the influence of various teleconnections on Basin-wide and sub-regional winter season Palmer Hydrological Drought Index (PHDI) variations in the Basin. The approach should isolate the relative importance of each teleconnection and established the accuracy of resultant seasonal drought predictive equations. The research should be useful in reducing uncertainty in the climate controls of drought in the Colorado River Basin.



Drought Data

We selected the popular Palmer Hydrological Drought Index (PHDI) as the primary measure of drought in the Basin. The PHDI accounts not only for precipitation totals, but also for temperature, evapotranspiration, soil runoff, and soil recharge. The index varies roughly between -6.0 and +6.0; values near zero indicate normal conditions for a region, values less than –2 indicate moderate drought, values less than –3 indicate severe drought, and values less than –4 indicate extreme drought. Oppositely, values greater than +2 indicate moderately wet conditions, those above +3 represent very wet conditions, and PHDI values above +4 are for extremely wet conditions. The monthly data extend from 1895 to present for the 23 climate divisions in the Basin (see above figure).



Teleconnection Data

In order to explain temporal variance in the PHDI data, we selected teleconnections that others have identified as important in controlling climate in the Southwest. These included two measures of El Niño – Southern Oscillation (ENSO), the Pacific Decadal Oscillation (PDO), the Atlantic Multidecadal Oscillation (AMO), the North Pacific Index (NPI), and the monthly northern hemispheric and global temperature anomalies. All of these monthly data were assembled from 1895 to present. Others scientists have shown that the Colorado River system's water supply is almost entirely dependent upon winter precipitation, and therefore, the analyses conducted in this investigation are limited to November through April.

We used principal components analyses, with varimax rotation, to transform the teleconnection indices onto independent, orthogonal axes. The first component is highly related to ENSO variables and is labeled the El Niño factor. The second component is dominated by global and hemisphere temperature and the AMO, and the third vector is completely dominated by PDO. The three components explain over 72% of the variance in the teleconnection data. The component scores, shown above, reveal the time series for the three factors that should have some control on drought in the study area..

Basin and Sub-Basin Results

Component scores for these three independent eigenvectors were used as predictors in a multiple regression analysis with Basin-wide PHDI as the dependent variable. The resultant equation shows that all three components explain a significant ($r<0.03$) amount of variance in PHDI values with a multiple R value of 0.44, R^2 of 0.19, and adjusted R^2 of 0.17. The standardized regression coefficients are 0.34 for the PDO vector, 0.21 for the El Niño vector, and -0.19 for the AMO-planetary temperature vector. The PDO vector explains 11% of the variance in PHDI for the Basin as a whole, while the El Niño and AMO-planetary temperature vectors explained 4% each; 81% of the variance in winter season PHDI remains unexplained.

We repeated these analyses for the upper and lower portions of the Basin and found that the results above were essentially the same for the lower portions of the Basin. However, in the upper Basin, the AMO was the only significant predictor of drought.

Conclusions

Three fundamental conclusions come from our work:

1) ENSO, PDO, AMO, and hemispheric and global temperatures control only 19% of the variance in winter-season drought in the Colorado River Basin. Drought tends to occur when PDO and ENSO are in their cool phases (i.e., La Niño periods) and when AMO and hemispheric and global temperatures are in their warm phases. PDO dominates the explained variance levels.

2) The PHDI values in the upper portion of the Basin are out-of-synch with the Basin as a whole, and largely unrelated to the teleconnection patterns.

3) These results did not change even when smoothed versions of the multidecadal teleconnections were used.

Acknowledgment

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