Evaluation of hydrologic indices for forecasting Western U.S. seasonal water supply

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PACLIM Climate Variability of the Eastern North Pacific and Western North America

ABSTRACT

Forecasting seasonal runoff is an important challenge in the Western U.S. because the timing and volume of summer (dry season) streamflows play a critical role in managing water supply and delivery systems. Beginning in mid-December of each year, observations of the snow pack throughout the west begin to provide invaluable information on the amount of runoff expected in late spring and summer. The skill of such water supply forecasts also benefits, in some locations, from the consideration of synoptic climate indices – e.g., using sea surface temperature anomalies to characterize ENSO or PDO state, which have been shown to have predictable teleconnections to land surface hydrology months in advance. These two sources of forecast information complement each other, with climate/SST state information providing predictability at long lead times (3-9 months), and observed snow and other moisture states of local catchments providing skill at shorter lead times (1-4 months). However, since similar SST anomalies can produce widely different future hydrology outcomes, information at intermediate lead times describing how a particular teleconnection or climate pattern is evolving on a macro-scale level (especially regarding precipitation anomalies) may provide additional insight into future spring and summer runoff. In this study, we explore the use of a long-term land surface hydrology data set to define hydrologic indices with potential predictive value, and to assess where these might enhance predictability already achievable using local observations and climate indices. We find one candidate index with potential value in the Pacific Northwest, but little improvements in the southwestern U.S. relative to existing climate and observation-based indices.

BACKGROUND and STUDY RATIONALE

Currently two sources of hydrologic predictability are commonly used in monthly to seasonal streamflow forecasts: remote (ocean temperature- or SST-based) and local (observation-based).

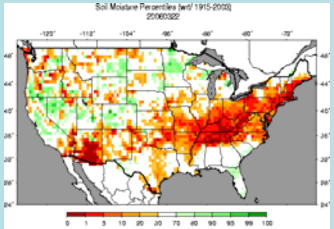
1) **Remote SST- based indices** exhibit predictive skill for hydrology in the Western United States, and the predictability of the SST indices themselves is relatively high. Uncertainty in the manifestation of any SST anomaly event (e.g., El Nino), however, creates uncertainty in the event's future hydrologic impacts. Since these indices describe drivers of large-scale climate patterns, their value is generally highest at longer lead times up to 9 months.

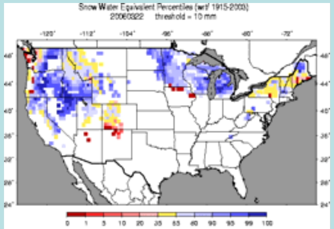
2) **Local ground-based, point observations** of snow water equivalent and accumulated water year precipitation are the central predictors in operational long lead forecasting of summer streamflow. These predictors are local to the streams they are used to predict. They have little accuracy in the first few months of the water year, hence official water supply forecasts (produced by the NRCS NWCC and NWS RFCs) are not released until mid-December and January 1. These indices have their peak predictive value late in the runoff season in April and May.

A **third category** of predictive information that may be useful for summer runoff prediction can be termed a synopic scale hydrologic index.

Recent work (Wood and Lettenmaier, 2006) provides a real-time estimation of the evolution of continental-scale patterns of land surface moisture. The information is derived from snow water equivalent and soil moisture as simulated by a water and energy balance model that is driven by real-time ground observations of temperature and precipitation. Predictors derived from this dataset appear to show potential for providing seasonal forecast information at lead times between those that are optimal for the remote SST- and local ground-based data sources.

soil moisture and SWE simulations, 1915-present, updated daily





DEVELOPING CANDIDATE LAND-SURFACE PREDICTORS

The exploration for a suitable land-based index requires certain characteristics:

- Objective characterization – reproducible by others
- Capture large-scale evolution of integrated climate effects on the land surface
- High correlation with streamflow or other hydrologic characteristics

1. Exploratory Data Analysis

Using the archive of retrospective forecasts of snow water equivalent (SWE) and soil moisture (SM) over the Continental U.S., we performed a principal components (PC) analysis was on the total (SWE+SM) surface moisture anomalies for each month to identify regions of coherent variability. The figures **below** show typical PC loadings, with variability explained in the bottom left corner.

PC 1 loadings for SWE+SM in Jan, Mar, May

PC 2 loadings for SWE+SM in Jan, Mar, May

Unsurprisingly, the regions of first two PC loadings capture essential spatial components of land surface moisture variability:

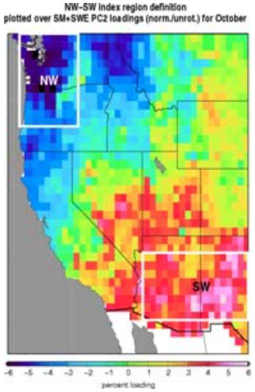
PC-1: Overall regional moisture variability

PC-2: A North-South (N-S) dipole, a common expression of western U.S. climate anomalies

2. Predictor Development

With the goal of forecasting summer streamflow in major western U.S. rivers, we are evaluating two types of predictors for use in a regression framework by calculating their correlation with summer river flow:

- ❑ PC1 and PC2
- ❑ reduced-area indices based on spatial averages of moisture in regions selected to target the areas of high loading in the PCs. One such region selection is shown **at right**.



In an example of the latter, the time series of NW moisture and SW moisture were each normalized to the range 0-1, and combined in several ways, such as:

NS-diff = NW – SW

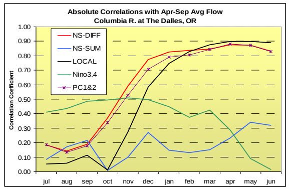
NS-sum = NW + SW

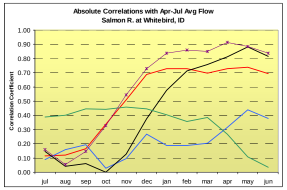
We compared these against predictors provided by:

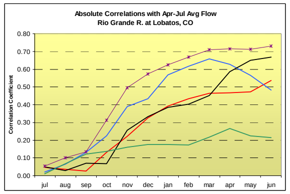
- ❑ Local drainage-basin averaged SWE+SM
- ❑ The Nino3.4 time series

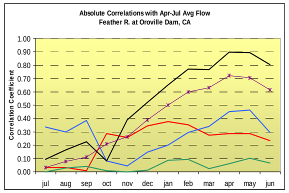
PRELIMINARY EVALUATION RESULTS

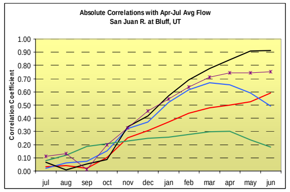
The plots below show the absolute correlations of summer runoff for the synoptic-scale hydrologic predictors and the baseline predictors. (Note that the correlation values are valid for the end of each month.)

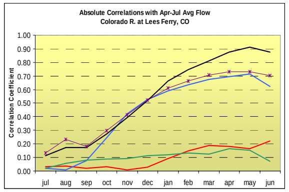












DISCUSSION and CONCLUSIONS

The use of predictors based on synoptic scale hydrologic conditions may offer a slight increase in predictability of summer streamflow in the west at for late fall forecasts, relative to either SST-based indices or local estimates of moisture. Land surface moisture state assessments integrate climate effects over time, hence incorporate anomalies from the previous seasons as well as recent climate effects.

- ❑ Among the indices, NS-diff offered the greatest increase over local predictors in fall correlations with summer flow in the PNW, while the NS-sum appeared more predictive in the SW.
- ❑ The regression forecast correlations based on PCs 1 and 2 generally equal or exceed the correlation of the regionally-based index approach.
- ❑ In some locations, such as the upper Colorado R. and Feather R., the local predictors were most highly correlated with summer runoff.
- ❑ In most locations, PC1 and PC2 provide information comparable in predictive value to "perfect" knowledge of local SWE and SM state.

The PC-based regression requires more sophistication to implement than would a regional index approach for forecasting, hence there may be a slight tradeoff between ease of use and forecast benefit.

REFERENCES

Wood, A.W. and D.P. Lettenmaier, 2006, A testbed for new seasonal hydrologic forecasting approaches in the western U.S., Bulletin of the American Meteorological Society (in review).

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