Forecast Technology Integration for Water Resources Management

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Project Objective

A primary objective of the GEWEX America Prediction Project (GAPP) is to interpret and facilitate transfer of the results of improved seasonal predictions to users for the optimal management of water resources. This project seeks to (1) develop verification methodologies for ensemble streamflow predictions that are relevant to water resource management decisions, (2) demonstrate risk-based decision-making techniques using ensemble streamflow predictions, and (3) integrate these within the tools used by operational agencies to enhance their systems for forecast verification and reservoir operations. This work is being accomplished through a detailed case study involving the application of ensemble streamflow predictions from the Des Moines River Advanced Hydrologic Prediction System (AHPS) for making storage allocation decisions at Saylorville Reservoir.

Progress Report

To facilitate the integration of forecast technologies in an operational setting, a research-quality forecast verification data set is being developed from the operational AHPS system for the Des Moines River basin. This data set is being assembled in collaboration with John Schaake and others at the NWS/HL, as part of their research contribution to GAPP. The verification data set consists of ensemble streamflow forecasts over a 42-year period at multiple sites throughout the basin. The data set contains traces at a 6-hour time step, prepared at weekly forecast intervals, with a one-year forecast horizon. In contrast, operational Des Moines AHPS products are prepared at monthly forecast intervals, with a 90-day forecast horizon. We anticipate that the data set will be useful to many investigators for assessing the quality and value of medium-range (days to weeks) to long-range (monthly to seasonal) streamflow forecasts for water resources operations.

Verification of probabilistic forecasts is an essential first step for operational use of forecasts in decision-making. However, most verification approaches provide limited information on the quality of streamflow forecasts. An important contribution of our research has been to develop distributions-oriented (DO) techniques for verification of probabilistic streamflow forecasts. Simplified expressions have been derived for traditional DO forecast quality measures [Bradley et al. 2003a]. Most of the forecast quality measures can be estimated analytically using sample moments of forecasts and observations from a verification data sample. Other measures require a statistical modeling approach for estimation. Unlike the traditional DO approach, which assumes forecasts and observations are discrete variables [Murphy 1997], the simplified expressions also apply to continuous forecasts, like those produced by ensemble forecasting systems. Results from Monte Carlo experiments show that the statistical modeling approach can significantly improve estimates of these measures in many situations. The improvement is achieved mostly by reducing the bias of forecast quality estimates, and for very small sample sizes, by slightly reducing the sampling variability. The statistical modeling techniques are most useful when the verification data sample is small (a few hundred forecast-observation pairs or less), and for verification of rare events, where the sampling variability of forecast quality measures is inherently large.

These new DO techniques have then been used as the basis for assessing ensemble predictions interpreted as a probability distribution forecast. First, a flow threshold is used to transform the ensemble forecast into a probability forecast for a discrete event. For each threshold, the DO methods are used to estimate forecast quality measures for the verification data set. The results are then summarized for different thresholds chosen to cover the range of possible flow outcomes. To aid in the comparison for different thresholds, relative measures are used to assess forecast quality. An application with experimental forecasts for the Des Moines River basin illustrates the insights gained from this verification approach [Bradley et al. 2003b]. First, the skill of ensemble forecasts varies over the range of flow outcomes, with high skill for intermediate flows, and low skill for flow extremes (high and low) (see Figure 1). Forecasts were compared for two scenarios. One weights each ensemble trace equally; the other uses a climate forecast to selectively weight traces. The verification results showed that climate weighting improves the skill of the ensemble forecast for intermediate flows. Significantly though, the forecasts for low and high flow extremes were not improved over equal weighting. This kind of information can be extremely important for water managers, since extreme events are often the most significant for decision-making.

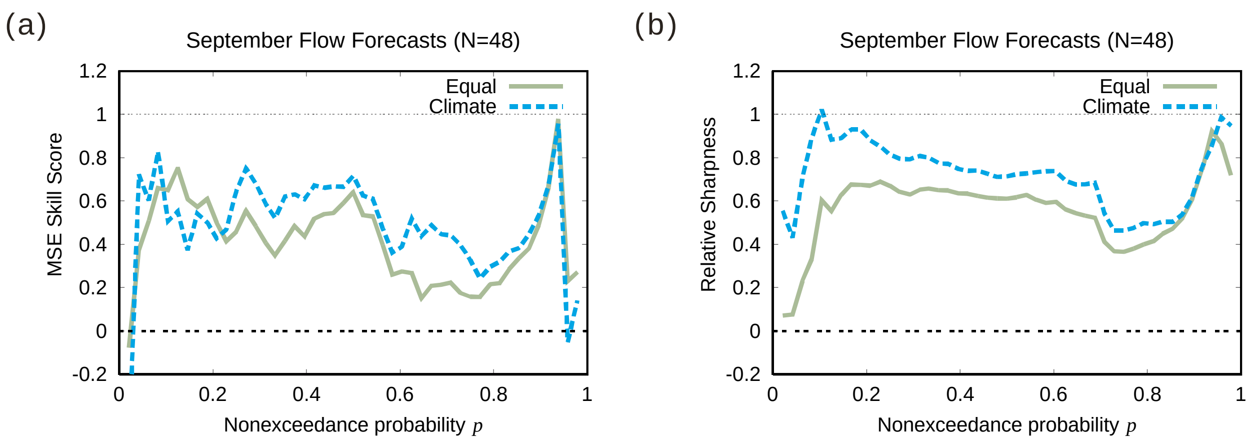

Figure 1: Forecast quality for experimental Des Moines River forecasts of September flow volumes: (a) MSE skill score and (b) relative sharpness. The estimated forecast quality measure are computed for specific flow thresholds, which are indexed by their (climatological) nonexceedance probability. Therefore, low probabilities correspond to low flows, whereas high probabilities correspond to high flow. The measures describe the quality of the probabilistic forecasts for the given thresholds. Note that the spike in skill indicated for a probability *p* of 0.938 is an artifact of the small sample sizes (only 3 events above the threshold in 48 years).

By examining aspects of forecast quality over the range of possible flow outcomes, the DO approaches we have developed have facilitated a diagnostic evaluation of the Des Moines AHPS verification data set. Our preliminary evaluation for a single site in the Raccoon River basin has demonstrated the following. First, as was the case with the experimental forecasts, forecast quality depends on the flow threshold. Of the existing AHPS products, the weekly flow volume forecasts have the best forecast quality. Forecasts for lower flows tend to have more skill and higher discrimination than those for higher flows. Forecast quality for weekly flows decreases rapidly with lead time for high flows, but more slowly for low flows (see Figure 2). More frequent operational updates (weekly rather than monthly) would improve their value in water resources management. In constrast, forecast of the 90-day maximum flows have very little skill for the Des Moines River basin. Still, this product may still have skill in other regions, where high flows are more strongly related to snow pack or large-scale climate anomalies. Forecasts of minimum flows over the 90-day period are not produced operationally by AHPS. However, the forecasts have high quality and potential value. Skill “droughts” occur at various times for weekly flows and 90-day minimum flows. Poor reliability (conditional bias) is responsible for the loss of skill. For instance, biases and conditional biases from summer to early fall reduce forecast skill (see Figure 2). Bias-correction applied to ensembles would improve the forecast quality during this season.

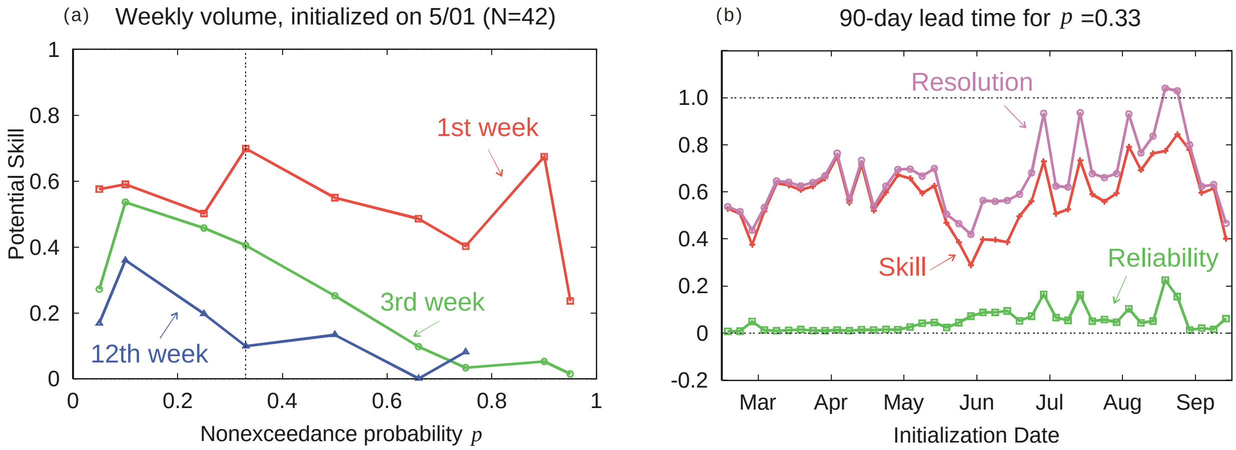

Figure 2: Forecast quality for Raccoon River forecasts from the Des Moines AHPS: (a) potential skill of forecasts issued on May 1 at various lead times; (b) forecast skill, resolution, and reliability of probability forecasts for the 0.33 weekly flow volume threshold. Note that the skill is equivalent to the forecast resolution minus the measure of reliability (conditional bias).

Statement of Work

Our efforts during the third year of this project will focus on (1) final evaluation of the operational verification data set for the Des Moines River basin, and (2) the real-time integration of ensemble forecasts for the Des Moines from the North-Central River Forecast Center (NCRFC) in decision-making. The Des Moines verification data sets allow us to investigate of bias-correction methods for ensemble streamflow forecasts for use in operational decision-making. This research will investigate bias-correction for daily flow volumes, which needs to be applied to traces used for reservoir operations. Corrected traces will then be applied to two decision problems. One deals with risked-based drought planning based on 90-minimum low flow forecasts. The other uses entire traces to make risked-based storage reallocation decisions for the Saylorville Reservoir. The two examples provide a template for using AHPS products in water resources decision-making.

References

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