Communicating hydrologic verification information for operational forecasting and real-time decision making in the U.S. National Weather Service

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INTRODUCTION

In the U.S. National Oceanic and Atmospheric Administration (NOAA)'s National Weather Service (NWS), the River Forecast Centers (RFCs) produce hydrologic forecasts across time scales ranging from hours to months to support a wide variety of applications, such as public safety during flooding and economic well-being for large-scale water management. These include both single-valued forecasts and probabilistic forecasts, which are based on ensemble techniques. Forecast verification is essential to monitor forecast quality over time, analyze the different sources of uncertainty and skill across the entire river forecasting process, and to compare the quality of forecasts from different methodologies, in order to improve future forecasts. Several verification applications are currently used for verifying both forcing inputs and hydrologic outputs from the NWS river forecasting system (*Fig. 1*). Such verification is only useful if the information assists with decisions about the forecast or forecasting system being verified. Thus, the NWS developers and forecasters are working together with users to develop meaningful verification products, in order to help the forecasters and external users in their decision making. This requires a combination of diagnostic verification, which aims to improve forecasting techniques by identifying biases in past forecasts, and real-time verification information, which aims to identify biases in a current (real-time) forecast using historical analogs to the real-time forecast, as described below.

REAL-TIME VERIFICATION

Real-time verification aims to help forecasters make decisions in real-time by providing verification information for a real-time forecast. There are several components: querying analogs (i.e. past forecasts that are analogous to the current forecast); displaying summary verification statistics of past forecasts from similar conditions; checking for anomalies in the forecasts; and performing bias-correction. Queries for analogs, either for single-valued or probabilistic forecast, are based on multiple attributes of the current forecast (e.g. forecast value, ensemble mean/spread, probability for a given threshold) and other variables (e.g. observation at forecast issuance) relative to antecedent conditions, synoptic conditions; and they could include spatial queries (e.g. basin condition within a given radius of the forecast point). *Fig. 2* shows an example for a potential flood forecast for the Russian River at Guerneville, California. Using a 6-year single-valued forecast archive, historic analogs were selected whose forecast values at lead hour 6 were within an interval [current 6-hr forecast value ± 20%] and the forecast peak occurred within the next 48 hours. These analogs show a tendency to overforecast. Given what happened (which would not be known in real-time), forecasters would have improved their forecast by correcting the biases shown in the analogs and thus not issuing a flood warning. *Fig. 3* gives another example of a web-based functionality for an interactive selection of analogs relative to snow water equivalent forecasts.

To remove forecast biases for real-time forecast, a non-parametric bias-correction technique has been developed using indicator cokriging (ICK) (Brown and Seo, 2009). The ICK technique uses past forecasts and observations to estimate the (unbiased) distribution of observations given the current forecast. The regression coefficients are estimated by solving the ICK system, which minimizes the Continuous Ranked Probability Score (CRPS). An example of the ICK performance is given in *Fig. 4* for precipitation ensembles from the Global Ensemble Forecasting System (GEFS) of the National Centers for Environmental Prediction (NCEP). These results were obtained from the Juniata River at Huntingdon, Pennsylvania, using 12-hourly GEFS forecasts from 2000-2005 in a cross-validation framework. *Fig. 4* shows the positive skill in terms of the CRPS of the bias-corrected probability forecast over the uncorrected ensemble forecast for all lead times.

WEB-BASED VERIFICATION FOR WATER SUPPLY FORECASTS

For the NWS seasonal water supply forecasts, new verification tools have been developed via a web interface (**www.nwrfc.noaa.gov/westernwater)** to enable users to generate customizable dataset and verification plots for a variety of verification metrics (e.g., skill scores, categorical statistics relative to user-defined thresholds). Such tools provide insights into the strengths and weaknesses of the NWS water supply forecast techniques and can help users to assess potential forecast errors in the real-time forecasts to minimize their risk.

When long term forecast skill relative to climatology is plotted on a spatial map (*Fig. 5*), forecast points with problems are easily identified. Tools to produce such maps for a variety of verification scores and with animation by lead time or forecast period (e.g. months, seasons) are being developed for all types of NWS river forecasts and will be included in the NOAA's Community Hydrologic Prediction System (CHPS) verification service.

Fig.5: Map of RMSE Skill Score relative to climatology

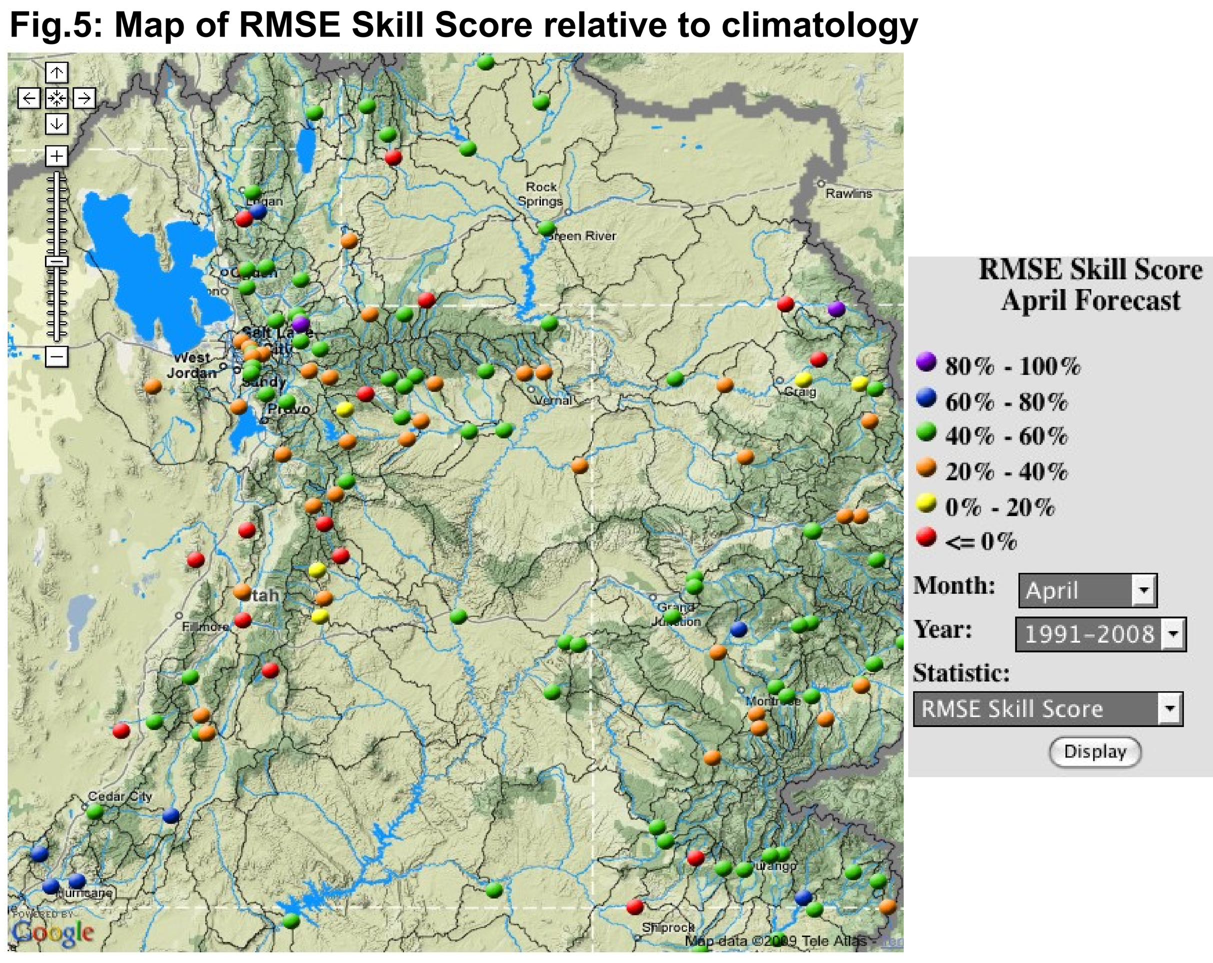
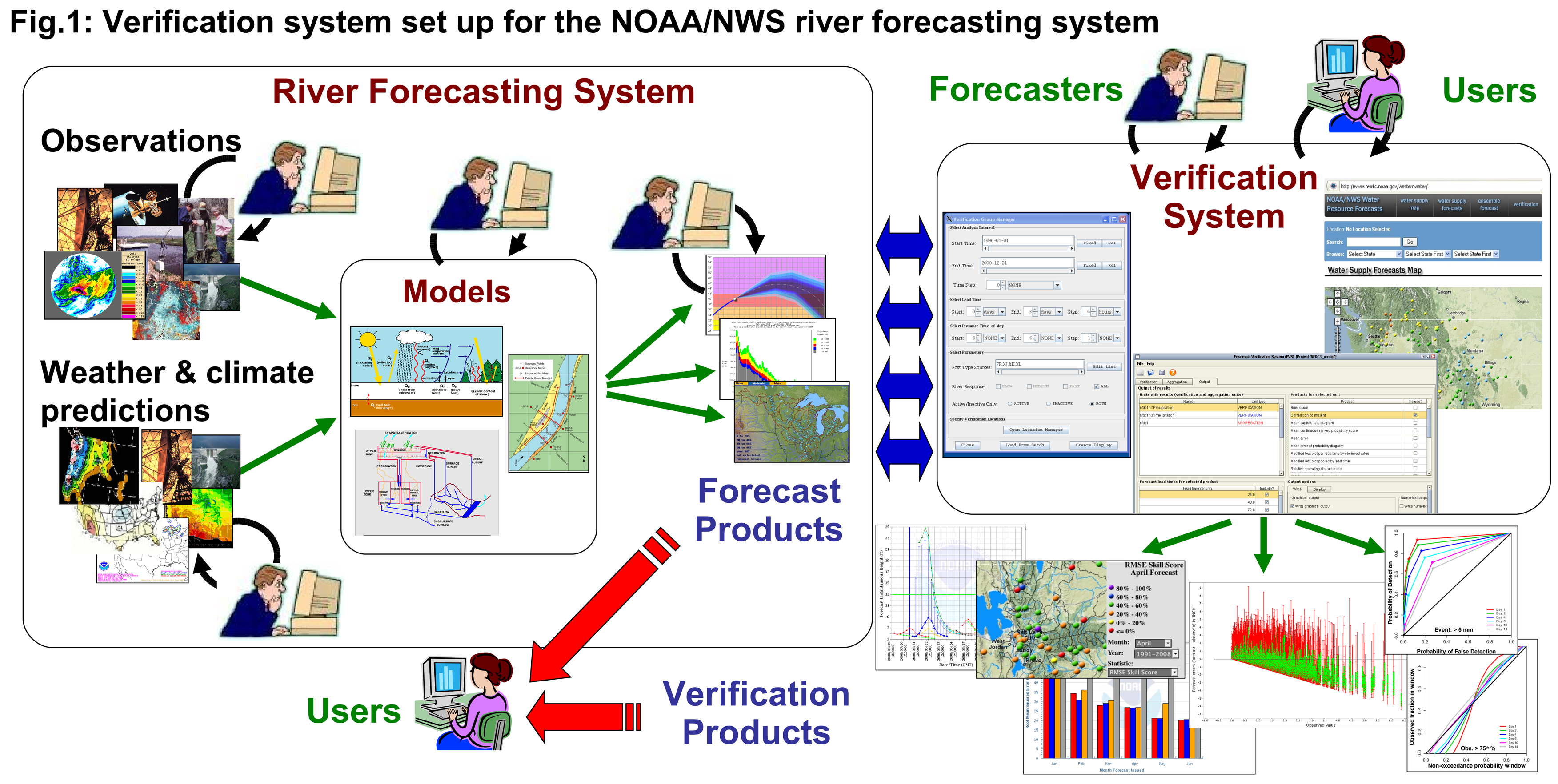


Fig.1: Verification system set up for the NOAA/NWS river forecasting system



The current NWS verification system consists of different applications (e.g. the Interactive Verification Program for single-valued forecasts, the Ensemble Verification System (EVS, Brown *et al*., 2008 and 2009) for ensemble forecasts, and the verification component of the Western Region Water Supply website), which will be merged into a unified verification service for the NOAA's Community Hydrologic Prediction System (CHPS) based on a service-oriented architecture.

Fig.2: Analog display for a potential flood forecast

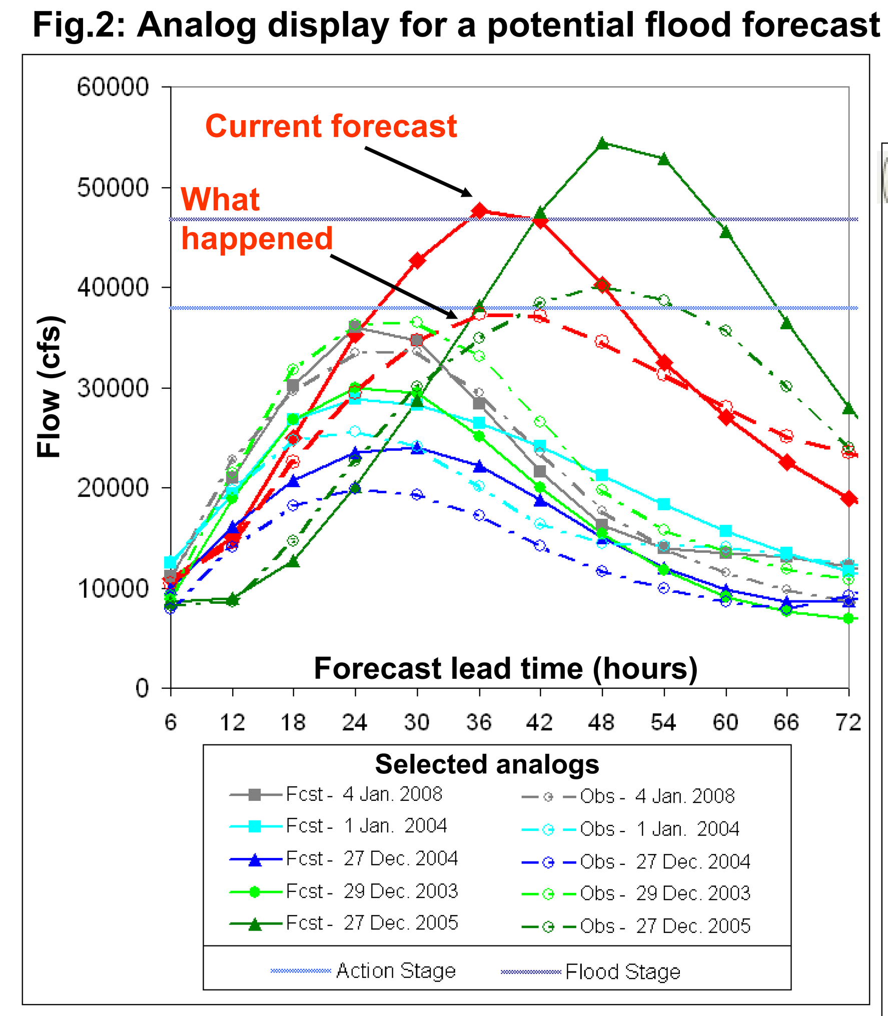


Fig.3: Web-based analog functionality

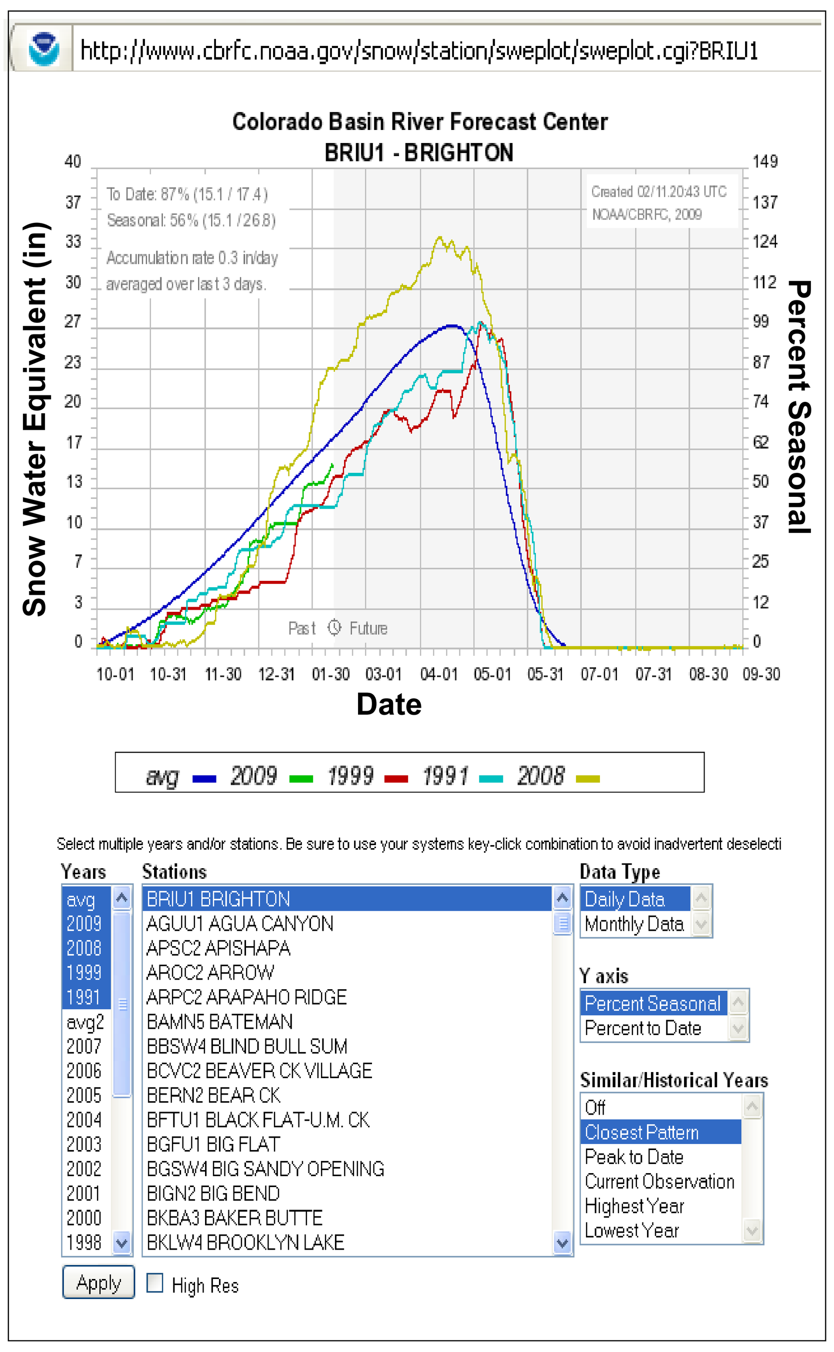
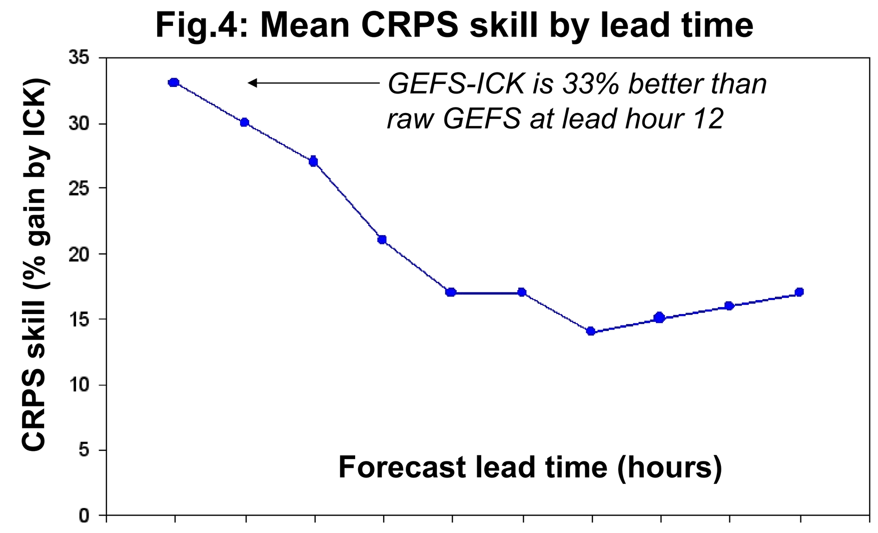


Fig.4: Mean CRPS skill by lead time



CONCLUSIONS

Functionalities for real-time verification are being developed to aid forecasters make decision in real-time based on historic analogs to the current forecast, summary diagnostic verification statistics of past forecasts from similar conditions, (non-parametric) bias-correction, and to provide users with real-time access to customizable datasets and verification statistics. Real-time verification shows promising results, although the selection of analogs constitutes a great challenge (especially for extreme events). A key source of skill and uncertainty in hydrologic forecasts originates from the atmospheric forcing. Verification must, therefore, be applied to all stages of the forecasting process, from weather and climate to water. Collaborative research work is under way with universities (e.g., University of Iowa, University of California, Irvine, Iowa State) and NCEP, as well as scientists involved in the verification testbed of the Hydrologic Ensemble Prediction Experiment (HEPEX) (http://hydis8.eng.uci.edu/hepex/testbeds/Verification.htm). Such collaboration between the meteorological and hydrologic communities will help to ensure commonality of verification products and practices, thus facilitating the communication of forecast information to all users.

REFERENCES

Brown J.D., J. Demargne, D.-J. Seo, and Y. Liu, 2009: The Ensemble Verification System (EVS): a software tool for verifying ensemble forecasts of hydrometeorological and hydrologic variables at discrete locations. Submitted to *Environmental Modelling and Software.*

Brown J.D., J. Demargne, L. Wu, and D.-J. Seo, 2008: *Ensemble Verification System Version 1 - User's Manual,* http://www.nws.noaa.gov/oh/rfcdev/docs/EVS_MANUAL_V1.0.pdf.

Brown, J.D. and D.-J. Seo, 2009: A non-parametric post-processor for ensemble forecasts of hydrometeorologic and hydrologic variables. Submitted to *Journal of Hydrometeorology.*