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A non-parametric postprocessor for bias-correcting multi-model ensemble forecasts of hydrometeorological and hydrologic variables

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Operational forecasts of hydrometeorological and hydrologic variables often contain large uncertainties, for which ensemble techniques are increasingly used. However, the utility of ensemble forecasts depends on the unbiasedness of the forecast probabilities. We describe a technique for quantifying and removing biases from ensemble forecasts of hydrometeorological and hydrologic variables, intended for use in operational forecasting. The technique makes no a priori assumptions about the distributional form of the variables, which is often unknown or difficult to model parametrically. The aim is to estimate the conditional cumulative distribution function (ccdf) of the observed variable given a (possibly biased) real-time ensemble forecast from one or several forecasting systems (multi-model ensembles). The technique is based on Bayesian optimal linear estimation of indicator variables, and is analogous to indicator cokriging (ICK) in geostatistics. By developing linear estimators for the conditional expectation of the observed variable at many thresholds, ICK provides a discrete approximation of the full ccdf. Since ICK minimizes the conditional error variance of the indicator expectation at each threshold, it effectively minimizes the Continuous Ranked Probability Score (CRPS) when infinitely many thresholds are employed. However, the ensemble members used as predictors in ICK, and other bias-correction techniques, are often highly cross-correlated, both within and between models. Thus, we propose an orthogonal transform of the predictors used in ICK, which is analogous to using their principal components in the linear system of equations. This leads to a well-posed problem in which a minimum number of predictors are used to provide maximum information content in terms of the total variance explained. The technique is used to bias-correct precipitation ensemble forecasts from the NCEP Global Ensemble Forecast System (GEFS), for which independent validation results are presented. Extension to multimodel ensembles from the NCEP GFS and Short Range Ensemble Forecast (SREF) systems is also proposed.