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Improving hydrological forecasts through temporal hierarchal reconciliation

Mohammad Sina Jahangir and John Quilty

Department of Civil and Environmental Engineering, University of Waterloo, Waterloo, Canada (msjahang@uwaterloo.ca)

Hydrological forecasts at different horizons are often made using different models. These forecasts are usually temporally inconsistent (e.g., monthly forecasts may not sum to yearly forecasts), which may lead to misaligned or conflicting decisions. Temporal hierarchal reconciliation (or simply, hierarchical reconciliation) methods can be used for obtaining consistent forecasts at different horizons. However, their effectiveness in the field of hydrology has not yet been investigated. Thus, this research assesses hierarchal reconciliation for precipitation forecasting due to its high importance in hydrological applications (e.g., reservoir operations, irrigation, drought and flood forecasting). Original precipitation forecasts (ORF) were produced using three different models, including 'automatic' Exponential Time-Series Smoothing (ETS), Artificial Neural Networks (ANN), and Seasonal Auto-Regressive Integrated Moving Average (SARIMA). The forecasts were produced at six timescales, namely, monthly, 2-monthly, quarterly, 4-monthly, bi-annual, and annual, for 84 basins selected from the Canadian model parameter experiment (CANOPEX) dataset. Hierarchical reconciliation methods including Hierarchical Least Squares (HLS), Weighted Least Squares (WLS), and Ordinary Least Squares (OLS) along with the Bottom-Up (BU) method were applied to obtain consistent forecasts at all timescales.

Generally, ETS and ANN showed the best and worst performance, respectively, according to a wide range of performance metrics (root mean square error (RMSE), normalized RMSE (nRMSE), mean absolute error (MAE), normalized MAE (nMAE), and Nash-Sutcliffe Efficiency index (NSE)). The results indicated that hierarchal reconciliation has a dissimilar impact on the ORFs' accuracy in different basins and timescales, improving the RMSE in some cases while decreasing it in others. Also, it was highlighted that for different forecast models, hierarchical reconciliation methods showed different levels of performance. According to the RMSE and MAE, the BU method outperformed the hierarchical methods for ETS forecasts, while for ANN and SARIMA forecasts, HLS and OLS improved the forecasts more substantially, respectively. The sensitivity of ORF to hierarchical reconciliation was assessed using the RMSE. It was shown that both accurate and inaccurate ORF could be improved through hierarchical reconciliation; in particular, the effectiveness of hierarchical reconciliation appears to be more dependent on the ORF accuracy than it is on the type of hierarchical reconciliation method.

While in the present work, the effectiveness of hierarchical reconciliation for hydrological forecasting was assessed via data-driven models, the methodology can easily be extended to

process-based or hybrid (process-based data-driven) models. Further, since hydrological forecasts at different timescales may have different levels of importance to water resources managers and/or policymakers, hierarchical reconciliation can be used to weight the different timescales according to the user's preference/desired goals.