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Systematic evaluation of autoregressive error models as post-processors for a probabilistic streamflow forecast system

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A post-processor that accounts for the hydrologic uncertainty in a probabilistic streamflow forecast system is necessary to account for the uncertainty introduced by the hydrological model. In this study different variants of an autoregressive error model that can be used as a post-processor for short to medium range streamflow forecasts, are evaluated. The deterministic HBV model is used to form the basis for the streamflow forecast. The general structure of the error models then used as post-processor is a first order autoregressive model of the form $d_t = \alpha d_{t-1} + \sigma\varepsilon_t$ where d_t is the model error (observed minus simulated streamflow) at time t, α and σ are the parameters of the error model, and ε_t is the residual error described through a probability distribution.

The following aspects are investigated: (1) Use of constant parameters α and σ versus the use of state dependent parameters. The state dependent parameters vary depending on the states of temperature, precipitation, snow water equivalent and simulated streamflow. (2) Use of a Standard Normal distribution for ε_t versus use of an empirical distribution function constituted through the normalized residuals of the error model in the calibration period. (3) Comparison of two different transformations, i.e. logarithmic versus square root, that are applied to the streamflow data before the error model is applied. The reason for applying a transformation is to make the residuals of the error model homoscedastic over the range of streamflow values of different magnitudes.
Through combination of these three characteristics, eight variants of the autoregressive post-processor are generated. These are calibrated and validated in 55 catchments throughout Norway. The discrete ranked probability score with 99 flow percentiles as standardized thresholds is used for evaluation. In addition, a non-parametric bootstrap is used to construct confidence intervals and evaluate the significance of the results.

The main findings of the study are: (1) Error models with state dependent parameters perform significantly better than corresponding models with constant parameters. (2) Error models using empirical distribution functions perform significantly better than corresponding models using a Standard Normal distribution. (3) For error models with constant parameters, those with logarithmic transformation perform significantly better than those with square root transformation. However, for models with state dependent parameters, this significance disappears and there is no difference in the performance of the logarithmic versus the square root transformation. The explanation is found in the flexibility that is introduced with the state dependent parameters which can account for and alleviate the more non-homoscedastic behaviour that is found for the square root transformation.
The findings are derived from the application of the error models to Norwegian catchments and with the HBV model as the deterministic rainfall runoff model. However, it is anticipated that similar findings can be made in other regions and with other rainfall runoff models. Thus, the findings provide guidelines on how to construct autoregressive error models as post-processors in probabilistic streamflow forecast systems. In addition, the study gives an example on the application of bootstrap to test the significance of differences of the forecast evaluation measures for continuous probabilistic forecasts.