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High-quality probabilistic predictions for existing hydrological models with common objective functions

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Probabilistic predictions describe the uncertainty in modelled streamflow, which is a critical input for many environmental modelling applications. A residual error model typically produces the probabilistic predictions in tandem with a hydrological model that predicts the deterministic streamflow. However, many objective functions that are commonly used to calibrate the parameters of the hydrological model make (implicit) assumptions about the errors that do not match the properties (e.g. of heteroscedasticity and skewness) of those errors. The consequence of these assumptions is often low-quality probabilistic predictions of errors, which reduces the practical utility of probabilistic modelling. Our study has two aims:

1. Evaluate the impact of objective function inconsistency on the quality of probabilistic predictions;

2. To demonstrate how a simple enhancement to a residual error model can rectify the issues identified with inconsistent objective functions in Aim 1, and thereby improve probabilistic predictions in a wide range of scenarios.

Our findings show that the enhanced error model enables high-quality probabilistic predictions to be obtained for a range of catchments and objective functions, without requiring any changes to the hydrological modelling or calibration process. This advance has practical benefits that are aimed at increasing the uptake of probabilistic predictions in real-world applications, in that the methods are applicable to existing hydrological models that are already calibrated, simple to implement, easy to use and fast. Finally, these methods are available as an open-source R-shiny application and an R-package function.