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Low flow forecasting with a lead time of 14 days for navigation and energy supply in the Rhine River

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Low flow forecasting, days or even months in advance, is particularly important to the efficient operation of power plants and freight shipment. This study presents a low flow forecasting model with a lead time of 14 days for the Rhine River. The forecasts inherit uncertainty sources mainly because of model parameterization. Therefore, a systematic uncertainty analysis is applied to indicate the major uncertainty sources in the results. Firstly, the Rhine basin is divided into 7 major sub-basins. Each sub-basin is modeled separately with a data-driven model and the output discharges are routed to Lobith after German-Dutch border with another data-driven model. Five pre-selected low flow indicators (basin averaged precipitation, basin averaged potential evapotranspiration; basin averaged fresh snow depths, basin averaged groundwater levels and major lake levels in the sub-basins) are used as inputs to the models. The basin discretization and the selection of indicators are based on a literature study and seasonality analysis of the discharge time series from 108 sub-basins. The correlations between indicator and low flows with varying temporal resolution and varying lags between indicator and low flows were used to identify appropriate temporal scales of the model inputs. We assume that a suitable model structure for the Rhine basin has been determined; that is, the sub-system boundaries have been specified, the important state variables and input and output fluxes to be included have been identified and selected for each sub-basin. The results in this study show that the data-driven models used for each sub-basin are capable of representing the essential characteristics of the system based on lagged and temporally averaged low flow indicators and are forecasting low flows adequately. In addition to the forecast results, the uncertainties due to specific model parameters in the calibrated data-driven model corresponding to key processes are also given.