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Bayesian calibration of a 1D hydrodynamic model used as a rating curve in a tidal river: Application to the Lower Seine River, France

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Hydrometric stations may be influenced by the sea tide, disrupting the stage-discharge relation and making it difficult to estimate discharge through a traditional rating curve. Twin-gauge stage-fall-discharge (SFD) rating curves, based on a flow friction equation and stage and water slope measurements, are a possible alternative, but they were found to perform poorly when the tide effect is strong. To capture the complex flow dynamics, including flow reversal, an approach via a 1D hydrodynamic model is proposed.

To set up the model, the cross-sectional geometry, friction coefficient, upstream discharge and downstream water level are required. In hydrodynamic modelling, the friction coefficients are the main calibration parameters and spatial changes of roughness combined with unsteady flow make their manual calibration difficult. Moreover, the understanding and quantification of uncertainties associated with data and model is an important step of the calibration process. Therefore, an automatic calibration of friction coefficients is proposed via Bayesian inference. In terms of numerical tools, the selected 1D hydrodynamic code is Mage, developed by INRAE, solving the 1D Saint-Venant equations for subcritical, transient flows. Likewise, the Bayesian Modeling (BaM) framework (https://github.com/BaM-tools) is used to specify prior information and estimate friction coefficients and their uncertainty, using stage and discharge observations.

The case study is the Lower Seine River in France, because it comes as a simple hydraulic model with a strong tidal effect with gauging campaigns and stage records available. Discharge time series of the Seine at Poses and of the Eure, the only significant tributary, are specified as upstream boundary conditions. The downstream boundary condition is the stage time series of the Seine at Saint-Léonard, reflecting the tidal signal. Calibration data include stage records at different stations and times, and ADCP discharge measurements at Rouen during several tidal cycles.

For all reaches, a lognormal distribution with 95% probability interval [33; 49] is used as a prior for the Strickler coefficient. Bayesian estimation then provides their posterior distributions, represented by a large number of samples generated by means of a Markov Chain Monte Carlo (MCMC) algorithm. These samples can be used to identify optimal "maxpost" coefficients (maximizing the posterior density), but also to quantify and propagate their uncertainty. Thereafter, a propagation is performed to estimate the stage and discharge series of all cross-

sections along with their uncertainty.

This study aims to provide an alternative solution for the continuous monitoring of discharge from stage records and upstream discharges in tidal rivers in order to improve flood forecasting, warning systems and the understanding of tidal-influence on hydrometric stations.