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Can streamflow data provide more certain TSS predictions?

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Total suspended solids (TSS) is commonly accepted as a proxy of water quality due to recognised impacts on receiving waters (physical, biological, ecological and ecotoxic). Therefore, the accurate prediction of TSS loads and concentrations is important to assess the risk of hazardous conditions in a stream, e.g. due to land-use changes or pollution management strategies.

Unfortunately, TSS predictions are rather uncertain. First, erosion and sediment wash-off is a complex interplay of many processes, which are not well identifiable. Second, monitoring TSS is challenging. Thus, calibration data for TSS models are often inaccurate and relatively short and do not cover the whole variability of TSS in a stream. Consequently, although TSS models can reproduce observed events, their capacity to predict unobserved events is usually very low. Third, when the focus is on TSS concentrations, streamflow predictions are needed. This requires a hydrological model, which introduces additional uncertainty. Interestingly, this uncertainty is often overlooked.

A common approach to model TSS concentrations relies on a physically-based sediment build-up/wash-off model (BWM), which has an integrated hydrological component with precipitation as an input. Because streamflow is here an intermediate state, streamflow data are not directly required for TSS calibration. However, it remains unexplored how better i.e. more frequent or more accurate streamflow observations improve TSS predictions.

In this work we therefore investigate the value of using streamflow data to better calibrate TSS models. Specifically, we use two methods. First, we calibrate a TSS model, which considers streamflow as an internal state, only on observed TSS concentrations. Second, we use additional streamflow observations. To reliably calibrate the model, we adopt a *multi-objective Bayesian calibration* approach, which considers input errors, model structure deficits and observation errors as a sum of *independent random noise* and *autocorrelated error process (bias)* (Reichert and Schuwirth, 2012). This seems very promising, because the first term accounts for stochasticity, such as measurement error of TSS concentrations and random effects in sediment production, whereas the second captures the remaining inability to reproduce observed patterns. In addition, we also assess the predictive capability of the models, analyse how the additional information of the streamflow data influence different properties of both error terms and their contribution to the total predictive uncertainty.

We illustrate the approach on a small catchment in Warsaw, Poland, where we monitored precipitation, TSS concentrations, water levels and velocities during a dedicated field campaign. To these data, we calibrated a hydrological model (HyMod) and a conceptual BWM for TSS concentrations.

Our results show that i) using additionally streamflow data to calibrate the TSS model substantially improves TSS predictions (assessed by data coverage and uncertainty band sharpness), and ii) most of the prediction uncertainty is due to systematic errors and not random noises. Furthermore, by formally describing systematic errors we are able to provide more reliable uncertainty estimates than before. These findings are relevant for investigating the frequency of exceeding hazardous thresholds for TSS concentrations in receiving waters.

References:

P. Reichert and N. Schuwirth. 2012. Linking statistical bias description to multiobjective model calibration. Water Resources Research, 48, W09543.