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# Uncertainty in modeling fine sediment transport and morphodynamics

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**Abstract**

Numerical simulation models in earth sciences are typically setup and applied to evaluate large-scale or complex physical processes. These models are calibrated by manipulating a number of independent variables to obtain a match between the observed and simulated distributions of output variables (e.g. Oreskes et al., 1994). The number of independent variables increases with increasing model complexity. Complex numerical models may even be underdetermined or overparameterised in such a way that there is no single mathematical solution to the problem (Beven, 2006). In addition model input parameters may be stochastic by nature (with unknown distribution) so that model outcomes are uncertain as well.

Data are needed as model input parameters, but also to validate model outcomes. More complex models need more and higher quality data that are often not available. Limited data availability raises questions on the uncertainty related to the outcome of complex numerical models (Murray et al. 2016). There may be not enough data (in time and space) to adequately describe independent model input parameters or to validate model outcomes. There may be only a particular type of data available (for example suspended sediment concentration) whereas the model outcome focuses on bed level changes. On the other land, complex models are based on physical principles and processes giving the models an inherent value. The models may capture enough physics to give trustworthy outcomes even under conditions of a certain level of model input uncertainty. These considerations raise questions on the level of validation required to have trustworthy model predictions and on how complex model uncertainty should be assessed. How relevant are the available data (e.g. SSC) for the model purpose (e.g. morphological predictions) and how accurate does this calibration need to be? What level of process complexity is required to adequately predict sediment transport patterns?

This work aims at assessing uncertainty levels of model outcome based on observations in the water column (e.g. suspended sediment concentration, most commonly applied for supply-limited fine sediment transport studies) and morphodynamic changes (more common in erosion-rate limited sand transport studies). Establishing model uncertainty requires (1) a metric that quantifies how the model performs (model accuracy), and (2) a methodology to capture the uncertainty range. The accuracy of a model can be quantified in various ways. A fine sediment transport model with only minor morphological changes but with large suspended sediment transport rates is typically evaluated by comparing measured and modeled SSC. A range of statistical techniques are commonly used to assess the skill of water quality models. The most commonly used metric in determining the accuracy of morphodynamic area models is the Brier Skill Score (Sutherland et al., 2004), using a normalized mean-square-error (MSE) to measure the proportion of improvement in accuracy of a prediction over a reference model prediction (Bosboom et al. (2014) or van der Wegen and Jaffe (2013)). In all these studies, the main criterion to evaluate model accuracy is bed level change. In fine sediment transport studies, model accuracy may be better determined through SSC calibration (van Maren and Cronin, in review).

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The sensitivity of model outcome to uncertainty in model input parameters can be identified through stochastic or probabilistic approaches. This has become common practice in hydrological models, and is now used more and more in one- or two-dimensional morphological models. The basis of stochastic modeling is that a certain likelihood distribution is assumed for the independent variables, of which the effect is evaluated through Monte Carlo simulations. Applying such methodologies to complex three-dimensional modeling of fine sediment transport is often only limitedly feasible because of (1) the required computational time and (2) unknowns in model input (the required erosion parameters and sediment settling parameters are difficult to measure in actual field conditions). An alternative is to apply the concept of equifinality (Beven, 2006) to quantify the uncertainty in fine sediment transport predictions (van Maren and Cronin, in review).

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