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A Monte Carlo approach to determine the sensitivity of bedform analysis methods

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There is a strong interaction between the appearance and dimensions of bedforms in rivers and the prevailing hydraulic and morphological conditions. The availability and mobility of sediments, in response to hydraulic variables like flow depth and velocity, determine the bedform characteristics. Vice versa, bedforms have a strong impact on the hydraulic conditions by exerting a flow resistance. Further on, with a thorough knowledge of the dimensions and migration velocities, predictions about sediment transport rates can be made.

Bedform geometries can be derived from multibeam echo sounding data. There are methods to discriminate several layers of superimposed bedforms and to identify the individual geometric attributes (length, height and shape). The calculated results, however, strongly depend on the setting of various input parameters. For choosing the values for these parameters there are mostly no theoretically sound criteria and the process itself is also strongly influenced by the individual experience of the researcher. If repeated several times by several researchers the analysis of the same data set would ultimately lead to different results. Only by means of a structured and traceable approach the level of inherent subjectivity and uncertainties can be reduced.

For the processing of multibeam echo sounding data we combined the existing software tools Bedforms ATM (Gutierrez et al., 2018) and RHENO BT (Frings et al., 2012) using an R-script. The concept of Bedforms ATM is based on a wavelet analysis in order to detect predominant bedform lengths. Applying this tool provides the rationale for deciding on the respective window sizes, which is a required input parameter for RHENO BT. The latter one is used to identify individual bedform geometries from longitudinal bedform profiles.

For estimating the sensitivity of all relevant input parameters to Bedforms ATM and Rheno BT an algorithm was developed in which a Monte Carlo-like simulation is performed. Assuming an individually chosen distribution function, random values are generated for each parameter. Multiple repetitions of the calculation with varying input parameters reveal the possible range of results. The algorithm has been tested on longitudinal profiles of Parana River in Argentina (Parsons et al., 2005) and an own data set of River Oder in Germany. The two case studies cover different ranges of bedform geometries, long and high bedforms characterize the morphology of the Parana River in contrast to much smaller and lower bedforms in the River Oder.

In the simulations carried out several input parameters turned out to be very sensitive. In some cases it can be shown that even slight variations lead to an increase in calculated mean bedform height of about 30 %. Further on, the type of statistical evaluation determines the robustness of the results. These uncertainties underline the need for comprehensive analyses before further processing in order to choose a reliable setting of input parameters and a suitable evaluation method.