Irregularity of bedform dimensions

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Abstract

Measured bed elevation profiles show that bedforms are far from regular. Even under controlled steady flow conditions in laboratory flumes bedforms are irregular in size, shape and spacing. Here we present a new Bedform Tracking Tool to determine the (stochastics of) bedform characteristics in an objective manner. This tool helps us in developing a model for variability in bedform dimensions.

Form drag, i.e. the flow resistance that is attributed to the presence of bedforms, depends on bedform dimensions. We expect that by taking into account the variability in bedform dimensions the prediction of form drag will be improved. Present research focuses on the effects of variability in bedform dimensions upon form drag.

A new Bedform Tracking Tool

There exist several methods to determine bedform dimensions from measured bed elevation profiles. For instance, you can:

- Select crests and troughs manually;
- Find the zero upcrossings and zero downcrossings;
- Find local extremes and select bedform heights and bedform lengths by introducing threshold values.

Furthermore, other choices have to be made, e.g.:

- How to determine the trend line?
- Use a filter to eliminate smaller scale ripples and/or larger scale alternating bars? If yes, what kind of filter?
- Use threshold values for the bedform length and bedform height?
- How are, for instance, bedform length and bedform height defined?

The method and choices influence the stochastics of bedform dimensions significantly. To compare various data sets, we developed a generically applicable Bedform Tracking Tool (BTT) that determines the (stochastics of) bedform dimensions (1) as objectively as possible, and (2) for all data sets in the same way (Van der Mark and Blom, in press).

The BTT first deletes outliers from the data and then determines a trend line. The user can choose for applying a straight trend line (Fig. 1) or a Moving Average trend line (Fig. 2). Next, zero upcrossings and downcrossings are determined. A crest is defined as the maximum value between a zero upcrossing and the subsequent zero downcrossing. A trough is defined as the minimum value between a zero downcrossing and the subsequent zero upcrossing (Fig. 3). Bedform characteristics such as bedform length are determined from the crest elevations and trough elevations.

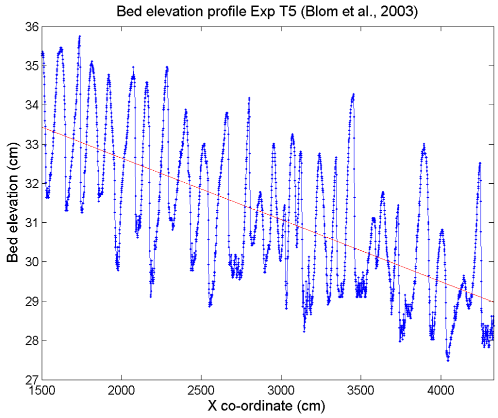

Figure 1. Determination of a straight trend line (red line). Data represent bed elevations in a flume experiment.

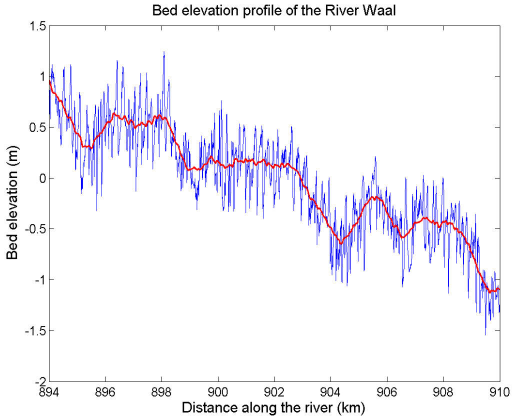

Figure 2. Determination of a Moving Average trend line (red line). Data represent bed elevations in the Waal branch of the River Rhine.

Analysing the variability in bedform dimensions

55 laboratory experiments (Driegen, 1986; Klaassen, 1990; Blom et al., 2003) have been analysed to study the irregularity of geometric properties of bedforms. For each experiment, Fig. 4 shows the standard deviation of bedform height against mean bedform height, and Fig. 5 shows standard deviation of bedform length

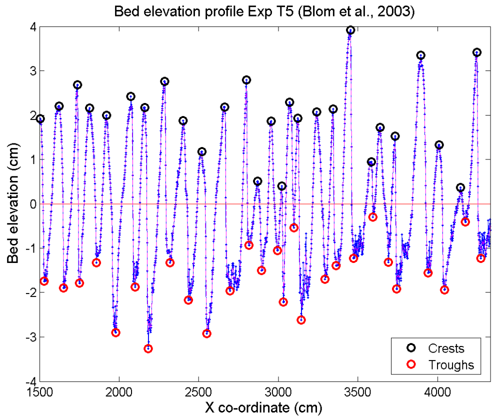

Figure 3. Crests and troughs determined using the Bedform Tracking Tool.

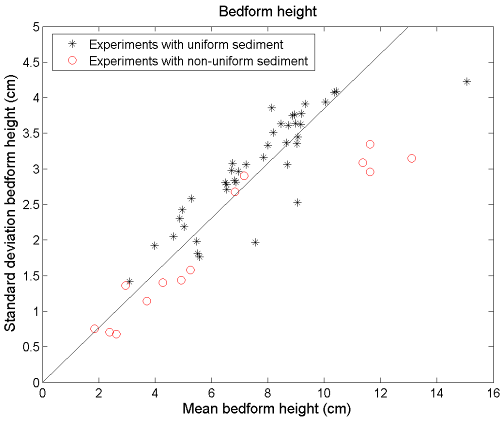

Figure 4. Standard deviation of bedform height versus mean bedform height for 55 laboratory experiments.

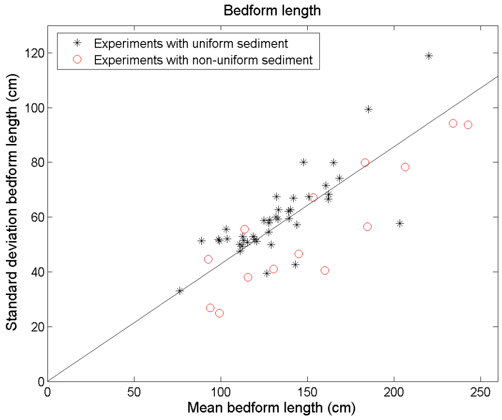

Figure 5. Standard deviation of bedform length versus mean bedform length for 55 laboratory experiments.

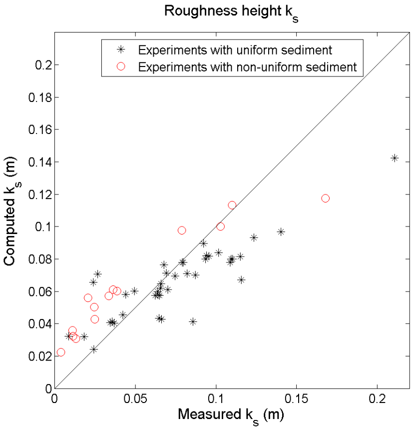

Figure 6. Computed roughness height versus measured roughness height for 55 laboratory experiments.

against mean bedform length. Fig. 4 and 5 show that the standard deviation more or less scales with mean for both bedform height and bedform length. Standard deviations of crest elevation and trough elevation also scale with their mean values. Roughly, the experiments with non-uniform sediment have more regular bedform dimensions than the experiments with uniform sediment. One reason for the non-uniform sediment experiments to be more regular, is the occurrence of a coarse layer underneath migrating bedforms in the case of non-uniform sediment. This layer limits the variability in bedform dimensions (Wilcock and Southard, 1989; Blom et al., 2003).

Comparison of measured versus computed roughness height

For the 55 flume experiments, bed roughness (Chézy) is determined from measured values of the flow velocity, hydraulic radius and water level slope. The Chézy roughness is corrected for sidewall roughness according to Vanoni and Brooks (1957). This Chézy roughness, which incorporates both grain and form roughness, is rewritten into a Nikuradse roughness height k_s with a White – Colebrook type formula (Jansen et al., 1979). We call this the 'measured' k_s. Based on the grain diameter of the bulk sediment (D_{90}), measured bedform height (Δ) and measured bedform steepness (Δ/λ), we determine a 'computed' roughness height k_s (Van Rijn, 1982).

Fig. 6 compares computed roughness height with measured roughness height. Roughly, for lower roughness heights, the computed k_s values are larger than the measured values, while for higher roughness heights, the computed k_s values are smaller than the measured values. Present research focuses on investigating whether prediction of form drag may be improved by taking into account the variability in bedform dimensions.

Conclusions

A generically applicable Bedform Tracking Tool is developed that determines the (stochastics of) bedform dimensions as objectively as possible. For the considered flume experiments, standard deviation of bedform height scales with the mean bedform height. This is also valid for bedform length, crest elevation and trough elevation. Non-uniform sediment gives rise to more regular bedform dimensions than uniform sediment.

Acknowledgements

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