Bedload transport assessment with ADCP in a large gravel bed river

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ABSTRACT

Quantification of bedload transport of rivers is of major interest since this mode of sediment transport plays a crucial role in the morphological changes. Direct measurement of bedload transport in large rivers is, however, challenging, sometimes even not feasible. To overcome this issue, surrogate acoustic techniques have been thoroughly tested to quantify bedload transport, but there are still open questions regarding their use in field circumstances, especially in large rivers. In this paper we introduce the results of an intensive bedload measurement campaign, performed in the gravel bed section of the Danube River in Hungary between 2019-2021. A so called BfG type bedload sampler was employed to measure the sediment transport in a direct manner, moreover, parallel with the sampling, acoustic Doppler current profiler (ADCP) was also used from the mounted on the sampling vessel. The bias of the Bottom Tracking signal from the GPS detected real positions was analyzed and compared with the measured bedload transport rates. Furthermore, video camera footages taken from the bedload sampler provided crucial supporting information about the uncertainties of the direct sampling.

1. Introduction

The bedload transport in rivers, i.e. the movement of coarse particles at the river bed, plays a crucial role in the morphological changes, thus the quantification of the spatial and temporal variation of this process is of major importance in river engineering. Conventional, i.e. direct physical sampling methods have been used for decades and so their application limits are quite well revealed. It is known that their use in large rivers are very cost and time demanding, moreover, the uncertainty in physical samplings can be significant. Furthermore, applying bedload samplers in flood situations can be unsafe and due to the severe flow conditions it might even be unfeasible. Complementary indirect methods are therefore under development which are using acoustic and imagery methods to quantify the bedload transport. For instance, Ramooz and Rennie (2010) tested the Bottom Tracking signal of an ADCP in laboratory circumstances to measure the so called virtual bedload velocity. They introduced strong relationship between the collected bedload and the measured virtual bedload velocity. Latosinski et al. (2017) assessed the ADCP data to estimate bedload transport rate in the Parana River and compared the results with empirical formula. Conevski et al. (2020) tested the influence of different instrument frequencies for the estimation of bedload transport in the sand bed Elbe and Oder rivers in Germany. They compared the results with physical samplings and found acceptable agreement between the virtual bedload velocity and the measured bedload transport rates. In this study, we make an attempt to further decrease the uncertainties for the ADCP based bedload transport estimation with completing the measurements with direct bedload samplings as well as with assessing underwater videos of the river bed.

2. Methods

Intensive measurement campaigns of bedload transport were carried out in the Upper-Hungarian section of the Danube River at rkm 1791, between 2019-2021. The mean flow discharge here is around 2200 m3/s, the river width is ~350 m, the longitudinal slope is around 15 cm/km. The river bed mainly contains gravel of 2-20 mm. The measured flow range was between 1200 and 4300 m3/s, so low and high flows were also analyzed. During one campaign 5 verticals in a cross-section were measured. For sampling the bedload, a BfG-type sampler was employed, lowered from a vessel. In each vertical 15 minutes long samplings were carried out. Parallel with the sampling a 1200 KHz Rio Grande ADCP was continuously measuring fixed to the vessel. A water resistant video camera was mounted on the bedload sampler enabling the recording of the river bed during the samplings. The virtual bedload velocity was calculated following the method introduced by Rennie and Villard (2004), i.e. the differences between the instrument positions detected by an RTK-GPS and the ADCP's Bottom Tracking were processed and divided by the measurement time. This way, a set of measured bedload transport rate and related virtual bedload velocity data pairs was generated.

Fig. 1. BfG-type bedload sampler (left), video footage from the camera fixed to the sampler (right).

3. Results

For the assessment, we only used those measurements where all the three methods, i.e. the physical sampling, the underwater videos and the ADCP surveys, provided adequate information for the same sample. Unsuccessful samplings, non-visible videos or ADCP data with false positions were excluded therefore. The remaining data, ~20 data pairs, were then further analyzed. Based on the videos, we distinguished two transport modes: continuous and discontinuous movement of the sediment grains. The former represents sheetflow kind of motion, whereas the latter rather indicates the incipient motion range. When relating the physically measured bedload transport rate with the ADCP based virtual bedload velocity, it could be shown that the data for the two transport modes can be well separated indeed. On the one hand, when the grains indicated incipient or intermittent motion, the related velocities strongly varied, leading to weak correlation. On the other hand, when the gravel transport was rather continuous, however only for three cases here, the Bottom Tracking better represented the transport rate. Moreover, the gradient of the fitted regression line is significantly higher, indicating much higher rate at the same virtual velocity when the transport is permanent. Further representative data, preferably covering a wider range, is needed to verify the above presented assumptions.

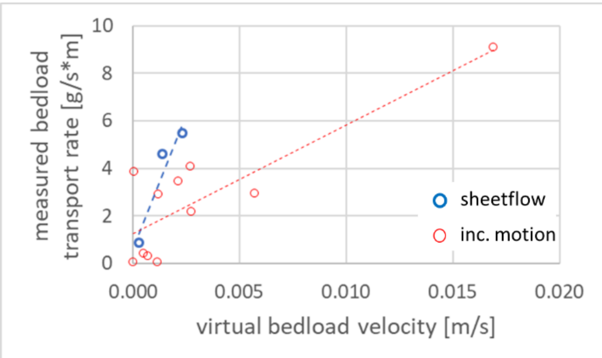

Fig. 2. Virtual bedload velocity against measured bedload transport rate.

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