Particle Image Velocimetry Analysis for the Assessment of Bedload Sampling Using Helley-Smith

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Abstract

Excess sediment is one of the main agents of water pollution, affects the aquatic ecosystem and causes siltation problems in reservoirs and rivers. Bottom sediments are coarse and easily deposited, being the major responsible for morphological alterations in rivers. Therefore, is important to estimate the amount of sediment transported in other to establish mitigation strategies and recovery of affected areas. There are several methodologies for estimating bedload transport: equations, numerical modeling, direct physical sampling, and indirect method measuring dune tracking. Most studies measure bedload transport using the equipment Helley-Smith, generally taken as reference value for other methods. However, Helley-Smith causes changes in the flow field, often resulting in overestimates in sand bed rivers. Those overestimates were not yet described and quantified in detail. This article tries to solve this gap by observing the Helley-Smith sampler at the time of sampling. For this, we used a video camera recording processed by Particle Image Velocimetry (PIV) technique to qualitatively evaluate changes that the intrusive sampler causes in the displacement of bottom sediments in a sand bed river. When the sampler was properly allocated to the bottom, PIV resulting velocity maps of bedload particle transport identified the acceleration of the bottom particles as they approached the mouth of the sampler. We also noticed areas of convergence and vorticity of the sediments towards the sampler's mouth, which may overestimate sampling. When the sampler's mouth was disconnected from the bed due to the morphology of the bottom, we find regions of divergence in the displacement of the sediments creating unrealistic results for bedload transport analysis. In addition, the presence of organic matter can be underestimated, which causes difficulties in analyzing the quality of the collections because it is not possible to guarantee an equity in the positioning of the equipment at the bottom of the channel. We thus recommend complementation Helley-Smith measurements with surrogate methods, for example such as using ADCPs or optical methods, as the one described here.

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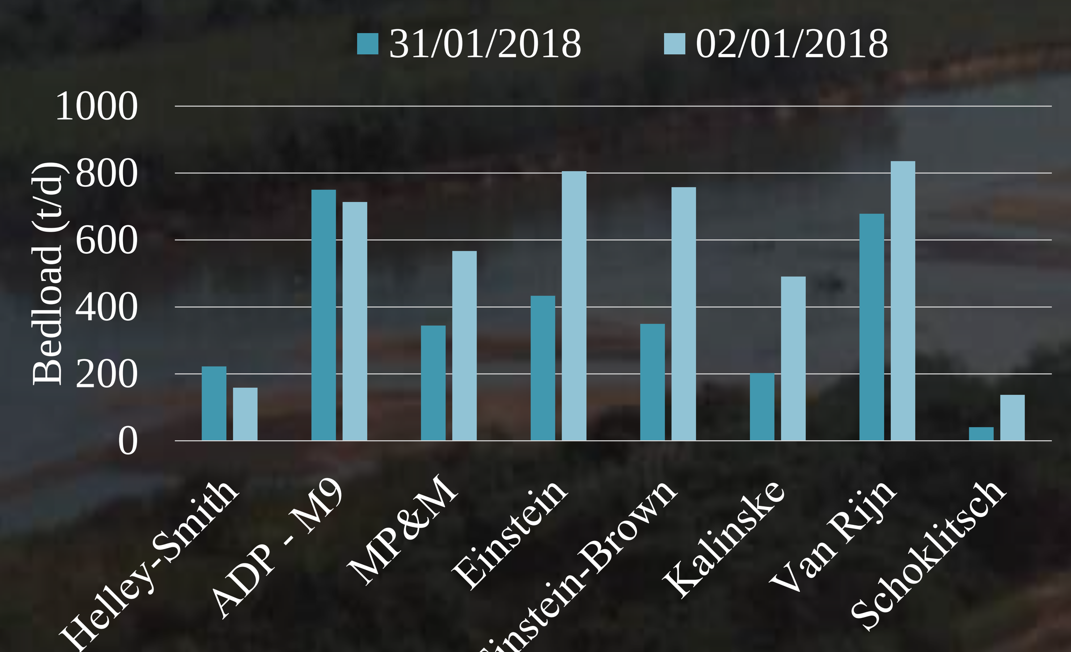
Motivation

Bottom sediments are coarse and easily deposited, being the major responsible for morphological and ecosystemic alterations in rivers. Therefore, is important to estimate the amount of sediment transported in other to establish mitigation strategies and recovery of affected areas. There are several methodologies for estimating bedload transport: equations, numerical modeling, direct physical sampling, and indirect method measuring by ADCP's. Most studies measure bedload transport using the equipment Helley-Smith, generally taken as reference value for other methods.

- Comparation bedload transport estimation with different methodologies;



- We observed a large difference result between Helley-Smith to other methodologies for estimation bedload transport. Can we take Helley-Smith sampler as reference value?

Objective

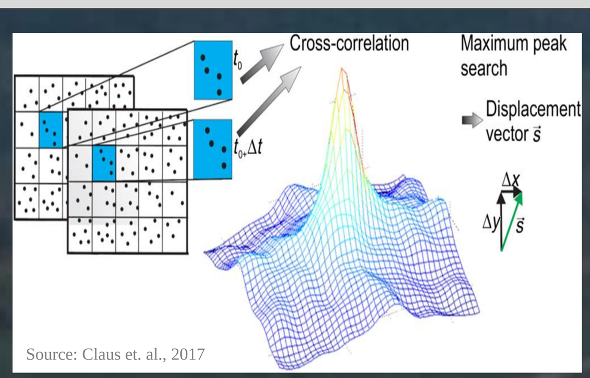
Use Particle Image Velocimetry (PIV) technique to qualitatively evaluate changes that the intrusive sampler causes in the displacement of bottom sediments in a sand bed river.

Helley-Smith

Image of equipment for sampling of bed sediments and, adaptation for filming at the time of collection. In addition to the camera it was adapted lighting to make the image more homogeneous, favoring the accuracy of the particle displacement pattern recognition algorithm.

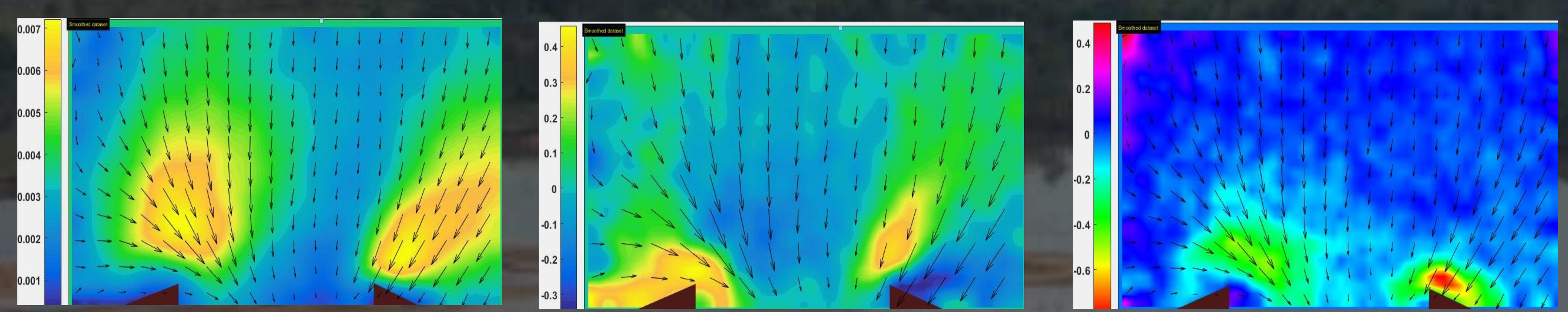
Method

- Processing video recording by PIVlab software (Thielicke, 2014);
- Identification of particle displacement patterns by cross-correlation;
- First step – Sampling and video recording performed with handheld Helley-Smith, and processed used for 7.5;
- Second step – Sampling and video recording realized without sampler, and Helley-Smith too (handheld / 65 lbs).

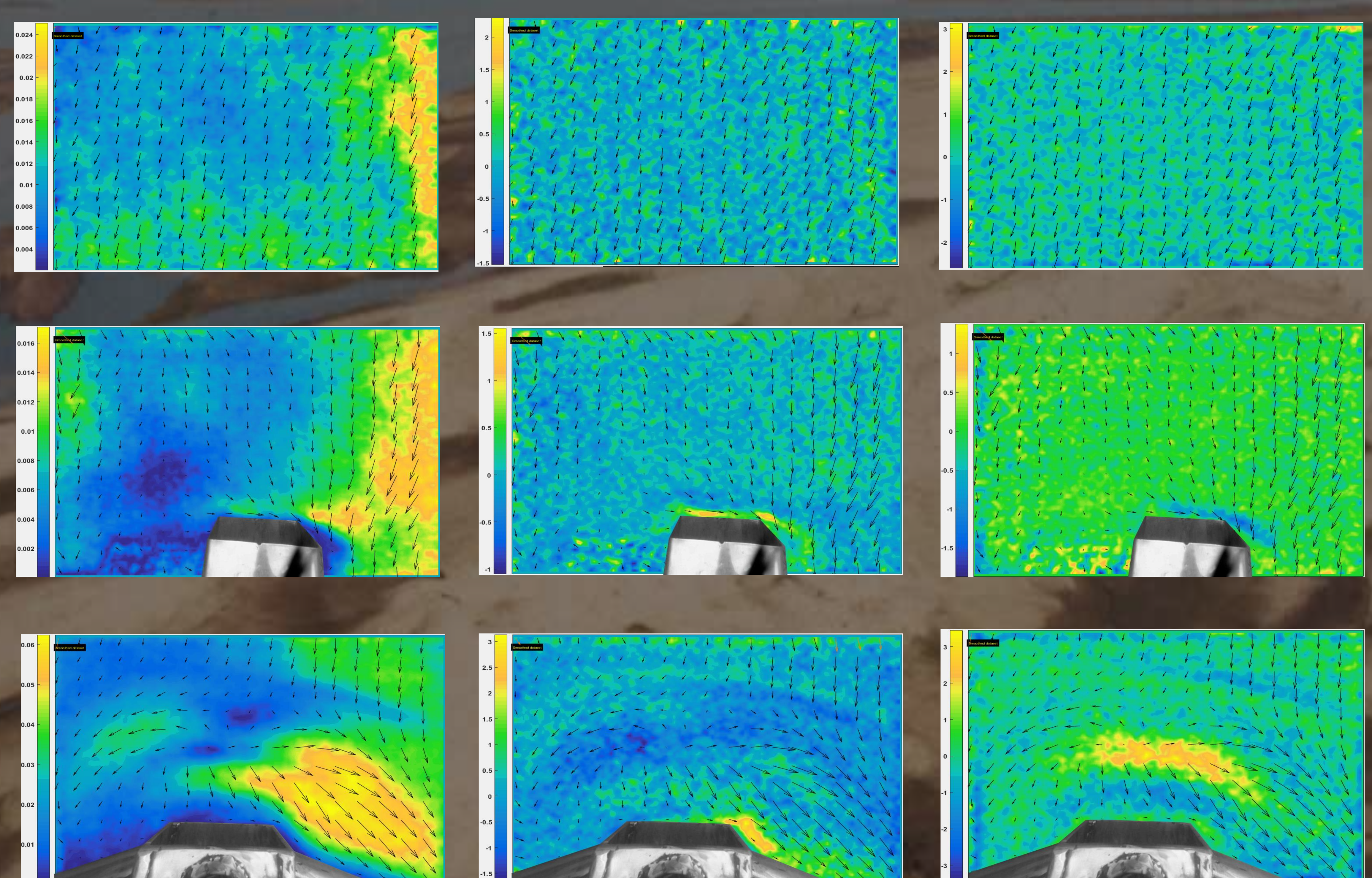


Results

FIRST STEP



SECOND STEP



VELOCITY MAGNITUDE (m/s) VORTICITY (1/s) DIVERGENCE (1/s)

In the first experiment we noticed that there is an increase in sediment displacement velocity when approaching the mouth of the sampler, we also observe regions of convergence, vorticity and divergences.

In the second experiment we evaluated the background transport without the intrusion of equipment and with two Helley-Smith of different dimensions. We observed that in natural conditions the field of velocity, vorticity and divergence remain homogeneous and with the vector field practically unchanged, as well as with the handheld Helley-Smith. Helley-Smith with larger dimensions presented high disturbances in the natural sediment displacement behavior.

Discussion

When the sampler was properly allocated to the bottom, PIV resulting velocity maps of bedload particle transport identified the acceleration of the bottom particles as they approached the mouth of the sampler. We also noticed areas of convergence and vorticity of the sediments towards the sampler's mouth, which may overestimate sampling. When the sampler's mouth was disconnected from the bed due to the morphology of the bottom, we find regions of divergence in the displacement of the sediments creating unrealistic results for bedload transport analysis.

In addition, the presence of organic matter can be underestimated, which causes difficulties in analyzing the quality of the collections because it is not possible to guarantee an equity in the positioning of the equipment at the bottom of the channel.

Conclusions

Using Helley-Smith for sampling in sand bed rivers can generate unrealistic, underestimated or overestimated results.

We thus recommend complementation Helley-Smith measurements with surrogate methods, for example such as using ADCPs or optical methods, as the one described here.

Future Directions

We need to evaluate Helley-Smith under controlled conditions and to investigate the agreement of using DPIV techniques to study the displacement behavior of the bottom sediments. Additionally perform the calibration of the Helley-Smith for sampling in sand bed rivers.

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