High-resolution monitoring of bedload transport rates accelerometers vs image processing

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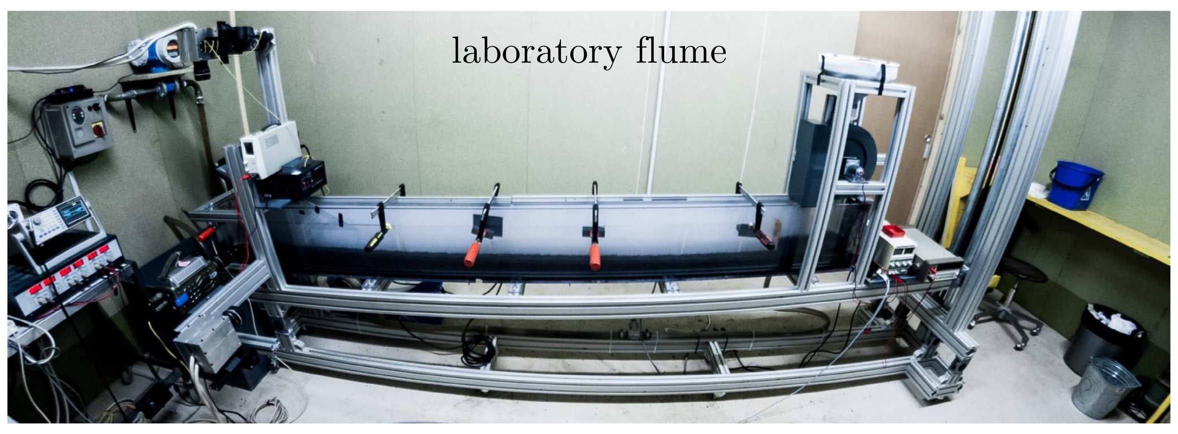
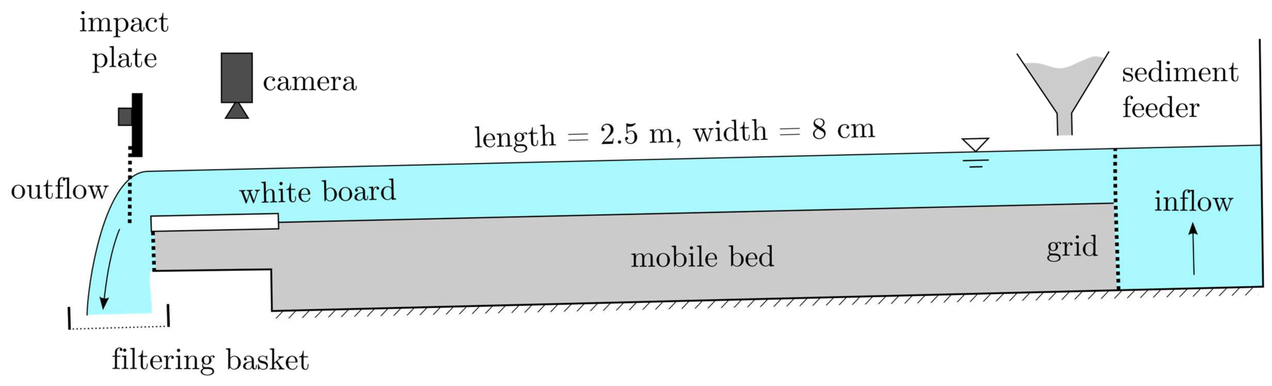
MOTIVATION

The intermittent nature of bedload transport at low flow rates is an important issue for the development and the validation of bedload transport equations. High-resolution records over long periods of time is a fundamental need for researchers. Indirect measurement methods have raised an increasing interest during the last two decades. In this study, we calibrate two technologies: impact plates and image processing.



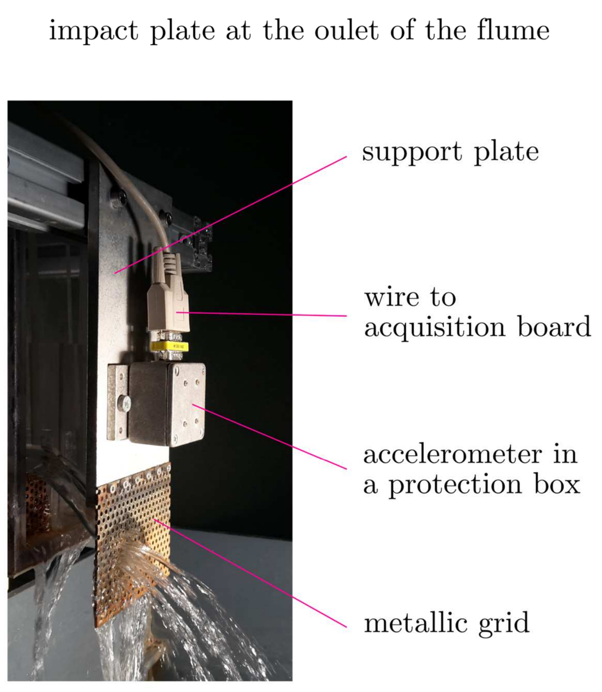


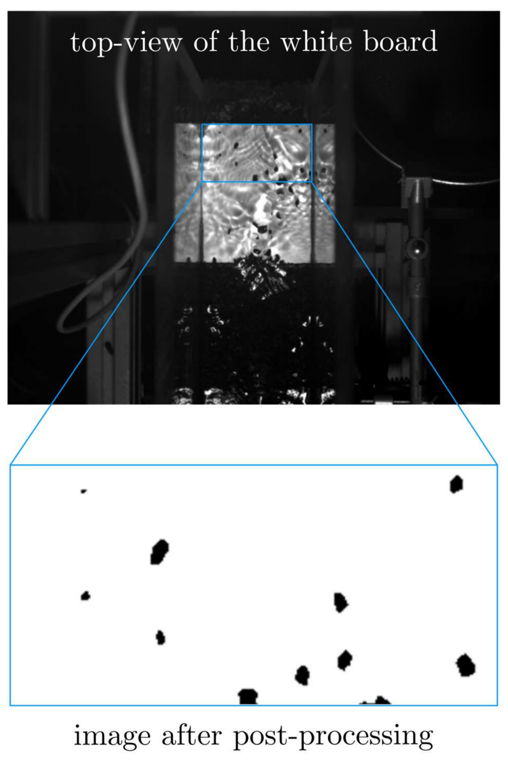
EXPERIMENTAL SETUP

- 2.5-m-long 8-cm-wide tilting flume
- sediment feeder upstream
- constant flow during each run
- q = 5-10 L/s, slope = 2-5°
- sediments weighted every 30 s
- bedload discharge continuously monitored at the outlet (impact plate and camera)
- 3 runs of 10 min with glass beads
  - d = 4 mm
- 3 runs of 20 min with gravel
  - d_{50} = 6 mm, σ_d = 1.2 mm

IMPACT PLATE

An accelerometer fixed on a perforated metallic plate is mounted vertically at the flume outlet.
Vibrations due to impacting grains are recorded with at 10'000 Hz. A 4000 Hz high-pass filter is then applied to the signal.
The number of peaks in the signal ($N_{part,acc}$) indicates the number of impacting grains. The number of oscillation larger than 10 mV (N_{imp}) is related to the bedload transport rate.





CAMERA

A camera takes top-view images (at 50 fps) of the grains moving over a white board placed horizontally at the flume outlet.
The number of grains ($N_{part,vid}$), their size and their velocities are computed using a particle tracking algorithm during post-treatment
The ratio of black pixels (representing the grains) to white pixels (activity) is computed in real time. It is related to the bedload transport rate.

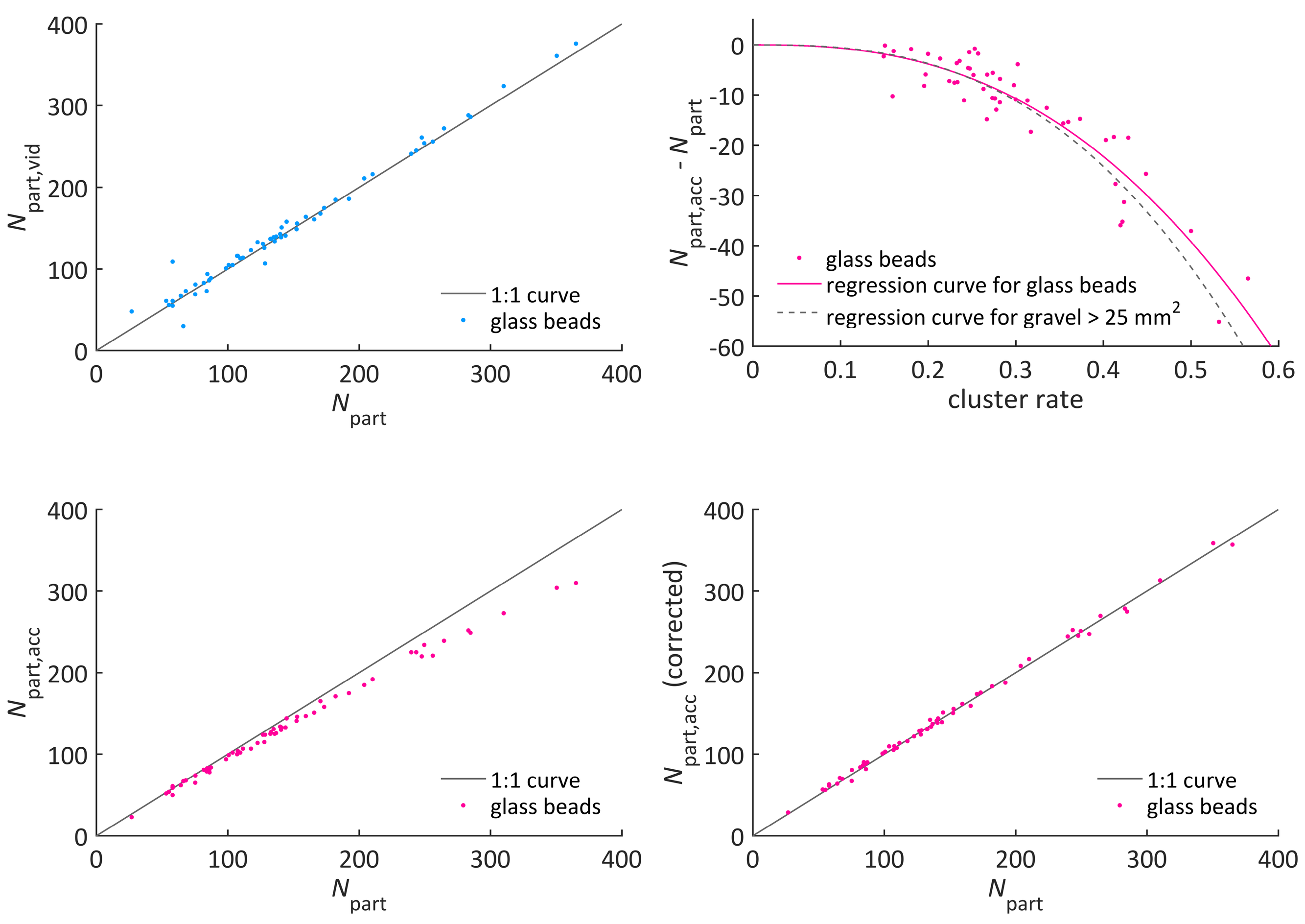
NUMBER OF GRAINS

Low bedload transport rates (gravel):

- N_{part} < 30 grains/30-sec
- standard error < 4 grains/30-sec

High bedload transport rates:

- N_{part} underestimated by the accelerometer
- the accelerometer saturates
- standards errors are larger for gravel than for glass beads

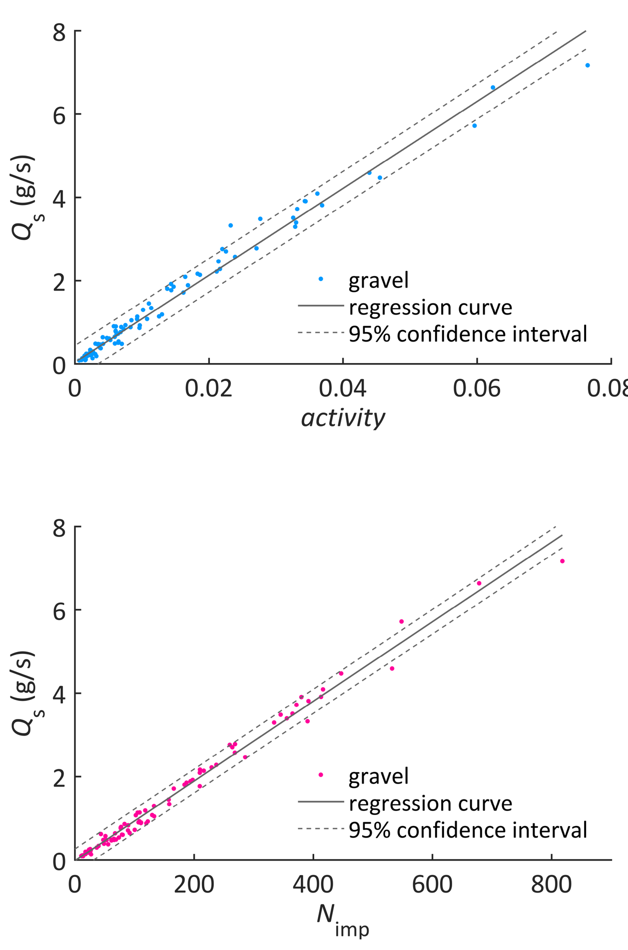


SATURATION

Saturation is due to the arrival of grain clusters. The cluster rate is defined as the fraction of grains whose inter-arrival time is less than 60 ms.
The relation between the residuals and the cluster rate is the same for glass beads and natural gravel if grains smaller than 25 mm² are removed. When $N_{part,acc}$ is corrected, the accelerometer achieves the same level of accuracy at high and low transport rates.

BEDLOAD TRANSPORT RATE

The number of impulses in the signal of the accelerometer N_{imp} and the activity are both linearly correlated with the bedload transport rate.
No saturation effect is observed in the range of values investigated.
The accelerometer is slightly more accurate than the camera.
The standard error are 0.03 g/s and 0.07 g/s for low transport rate, and 0.14 g/s and 0.20 g/s for high transport rates.



OUTCOME

Impact plate	Image processing
Cost-effective ✓	Expensive (price of the camera)
No data storage issue ✓	Large amount of data to store (images) and to treat
Good accuracy, saturation effect can be corrected	Good accuracy ✓
Robust, calibration depends on the device setup ✓	Calibration depends on the camera settings and on ambient luminosity
Particles size and velocity can affect calibration (possible effect on the signal amplitude and frequency)	Calibration is independent from the particle characteristics (direct measurement), size and velocity can be directly computed ✓