Geophysical Research Abstracts
Vol. 16, EGU2014-4134, 2014
EGU General Assembly 2014

Enhancing the characterization of bedload transport in rivers using the analogy between the Hertz contact theory and plate hydrophone measurements

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Vibration measurements performed with plate or pipe geophone/hydrophone systems are of growing interest for bedload transport monitoring since they allow performing high temporal resolution and continuous records. Our set-up is constituted by a piezoelectric hydrophone acting as a "sediment vibration sensor" in contact with a steel plate located on the streambed. With such an apparatus, the signal processing is generally reduced to power spectral analysis or impact counting.

However, a large amount of useful information is contained in the waveform of the impact signal, which conveys the force and the contact time that the bedload imposes on the plate. The wave amplitude is not well constrained because it varies a lot with changing impact location and velocity. The wave frequency is a more relevant parameter, less sensitive to these variables. According to the Hertz contact theory the frequency of the first signal arrival (flexural wave) is directly proportional to the bed-material grain size. Then, an appropriate analysis of the frequency attributes (central frequency, modulation) is needed to estimate the size of bedload particles. In this way, we have developed a complete processing algorithm based on a high dimensional decomposition method (chirplet transform) to get an accurate estimation of the first arrival frequency content.

Results on summer flood events in a lowland river show that impacts are well separated by their central frequency and that most of transport occurs during larger peak flows. The portion of coarser sediment which is characterized by low frequencies is preferentially transported during the rising limb whereas the finer sand fraction identified by higher frequencies is transported during both rising and falling limb. Such a processing offers the opportunity to better understand the bedload signature of vibration measurements and is promising in view of quantifying processes of bedload transport and deposition. This final objective of quantification is an ongoing research by performing a flume experiment with various impact velocity and granulometry (collaboration with the Hydrology Department of Trier University).