On the use of the chirplet atomic decomposition for characterizing and classifying bedload signals recorded with hydrophones

Barrière, J.[1,2], Oth, A.[2], Schenkluhn, R.[3], Krein, A.[3]

[1] National Museum of Natural History (Mnhn), 19, Rue Josy Welter, L-7256 Walferdange, Grand Duchy of Luxembourg, e-mail: julien.barriere@ecgs.lu

[2] European Center for Geodynamics and Seismology, 19, Rue Josy Welter, L-7256 Walferdange, Grand Duchy of Luxembourg, e-mail: adrien.oth@ecgs.lu

[3] Public Research Centre - Gabriel Lippmann, Department of Environment and Agro-Biotechnologies, 41, Rue du Brill, L-4422 Belvaux, Grand Duchy of Luxembourg, e-mail: krein@lippmann.lu

Hydroacoustic measurements are of growing interest for bedload transport monitoring since this indirect technique allows performing high temporal resolution and continuous records contrary to sediments trap data analysis. We aim to test in our project the reliability of such measurements to describe the bedload transport of typical small lowland rivers. 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. In previous similar studies, the signal processing is generally reduced to power spectral analysis to derive a quantitative relationship with the total mass of the transported materials. In view of the high signal to noise ratio of the recorded signals, we intend to improve the processing procedure in order to derive more information on time-varying bedload properties.

The waveform of the first signal arrival (flexural wave) is directly proportional to the force and the contact time that the bedload imposes on the plate. According to the Hertz contact theory, grain size and mass could be estimated from acoustic measurements. However, recorded signals after impacts exhibit complex waveforms due to boundary reflections. To identify and characterize the first arrival, we use a high-dimensional signal decomposition method based on the chirplet transform. This algorithm provides an optimal reconstruction of the selected waveform in terms of chirp atom characterized by 7 parameters (generalization of 2-D information obtained by wavelet transform in the time/frequency plane).

Afterwards, we performed a hierarchical clustering of reconstructed waveforms and obtain a classification of saltating bedload signals. From the results of two experiments (one artificial and one natural flood event), we observe that this classification is mainly controlled by the central frequency. The frequency of the extracted atom is a key parameter, since it is related to the grain size/mass distribution of transported bedload sediments (high frequencies correspond to small grain size and vice versa). We currently perform a new experiment combining hydroacoustic, seismic (broadband seismometers recording ambient noise) and sediment trap data to assess the expected relationship between such classification and the moving bed materials properties.