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Establishing time series of flux and grain size of suspended sand in rivers using an acoustic method

Jessica Laible[1], Benoît Camenen[1], Jérôme Le Coz[1], Guillaume Dramais[1], Francois Lauters[2], and Gilles Pierrefeu[3]
[1]INRAE, River hydraulics, France (jessica.laible@inrae.fr)
[2]EDF, France (francois.lauters@edf.fr)
[3]CNR, France (g.pierrefeu@cnr.tm.fr)

Measuring the concentration and grain size of suspended sand in rivers continuously remains a scientific challenge due to its pronounced spatio-temporal variability. Vertical and lateral gradients within a river cross-section require spatially-distributed water sampling at multiple verticals and depths. However, this classical approach is time-consuming and offers limited temporal resolution. Sampling is particularly difficult in presence of a bimodal suspension composed of fine sediment and a sand fraction, notably if the fine/sand ratio varies with time. The aim of this study is to establish time series of sand concentration and grain size by improving temporal resolution using an acoustic multi-frequency method based on acoustic attenuation and backscatter to measure the suspension indirectly. Experiences of Moore et al. (2012) and Topping & Wright (2016) with Horizontal Acoustic Doppler Current Profilers (HADCPs) show that dual-frequency inversion can separate the fine sediment fraction dominating acoustic attenuation from the sand fraction dominating acoustic backscatter. Concentration and grain size of suspended sediment, both the fine and sand fraction, can be quantified by signal inversion after correction for transmission losses.

Applying existing dual-frequency, semi-empirical methods in a typical Piedmont river (River Isère, France) remains a challenge due to the high concentrations and a broad bimodal distribution. Two monostatic HADCPs of 400 and 1000 kHz were installed at a hydrometric station of the Isère at Grenoble Campus where discharge and turbidity have been recorded for more than 20 years. Using frequent isokinetic water samples obtained with US P-72 and US P-06 samplers close to the ensonified volume, a relation between acoustic signal and the sediment concentration and grain size can be determined. Simultaneously, total sand flux and grain size distribution are calculated performing solid gaugings using Delft bottle samples and ADCP measurements in the entire cross-section. The method using index concentration and grain size in the HADCP measurement area is then used to evaluate the total sand flux and average grain size time-series in the cross-section.

First results show good correlations between the fine sediment concentration and the sediment attenuation for both frequencies. Specific extreme events (e.g. debris flows, dam flushes or spring floods) show distinct signatures in acoustic attenuation, backscatter and ratio between the two frequencies. During a debris flow (concentration up to 5.3 g/l), attenuation reached 1.6 and 3 dB/m for 400 respectively 1000 kHz, but no peak in backscatter intensity, whereas a spring flood (up to 4 g/l with at least 50 % sand) caused major peaks in attenuation and backscatter. Pronounced hysteresis during the events and time-varying ratio between attenuation due to sediments measured by 400 and 1000 kHz indicate suggest that the grain size distribution may vary. Relating sand concentration from physical samples with beam-averaged backscatter may elucidate changes in grain size more precisely. Existing heterogeneities of concentration and grain size along the acoustic beam contradict the homogeneous distribution supposed by the method and require local analysis based on local concentration and grain size characteristics.