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18,000 displacement vectors and 44 positions surveys of RFID tracers show a normal diffusion of the bedload in a proglacial stream (Bossons glacier, France)

Hervé Guillon (1,2), Jean-Louis Mugnier (1,2), Jean-François Buoncristiani (3,4)

(1) Université de Savoie, ISTerre, Le Bourget du Lac, France, (2) CNRS, ISTerre, Le Bourget du Lac, France, (3) Université de Bourgogne, Biogéosciences, Dijon, France, (4) CNRS, Biogéosciences, Dijon, France

Bedload transport is a stochastic process during which each particle hops for a random length then rests for a random duration. In recent years, this probabilistic approach was investigated by theoretical models, numerical simulations and laboratory experiments. These experiments are generally carried out on short time scales with sand, but underline the diffusive behaviour of the bedload. Conversely, marked pebbles in natural streams have mainly be used to infer about transport processes and transport time of the bedload. In this study, the stochastic characteristics of bedload transport are inferred from the radio-frequency identification (RFID) of pebbles. In particular, we provide insights for answering the following question : is the bedload transport sub-diffusive, normally diffusive or super-diffusive at the long time scale (i.e. global range)? Experiments designed to investigate the phenomenology of bedload transport have been carried out in the proglacial area of Bossons glacier. This 350 m long alluvial plain exhibits daily flood from the glacial system and is still redistributing material from catastrophic events pre-dating our investigations. From 2011 to 2014, the position of the $\sim$ 1000 RFID tracers have been measured by a mobile antenna and a differential GPS during 44 surveys providing $\sim$ 2500 tracer positions. Additionnaly, in 2014, 650 new tracers were seeded upstream from a static RFID antenna located at the outlet of the study area. For the 1 to 32 cm fraction surveyed, both mobile and static antenna results show no evidence for a significant export outside of the surveyed zone. Initial data have been maximized by using each possible campaign pairs leading to $\sim$700 campaign pairs and more than 18,000 displacement vectors. To our knowledge, this is one of the most extensive dataset of tracers positions measured in a natural stream using the RFID methodology. Using 152 campaigns pairs with at least 20 retrieved tracers,r standard probability distributions were tested against the observed travel distances. Regardless of the time scale, heavy- and light-tailed distributions provide a convincing statistical description of measured data. No single distribution is significantly better than the others. Conversely, the distribution of tracers positions in the system and its time evolution is best described by the normal distribution. Its standard deviation scales with time as $\sigma \propto t^{0.45\pm0.12}$ which suggests a nearly normal diffusive behaviour. The measured virtual velocities and a simple probabilistic model using the time evolution of the mean (i.e. drift) and standard deviation (i.e diffusion) show that the mean bedload transfer time is greater than 5 years. RFID tracers appear as a promising tool to investigate stochastic characteristics of bedload transport.