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Temporal variability of the bed load transport efficiency in two glacier-fed mountain streams

Johannes Kammerlander (1,3), Johannes Schöber (2), and Stefan Achleitner (3)

(1) Austrian Research Centre for Forests, Department of Natural Hazards, Rennweg 1, 6020 Innsbruck, Austria (j.kammerlander@gmx.at), (2) TIWAG Tiroler Wasserkraft AG, Innsbruck, Austria (johannes.schoeber@tiwag.at), (3) Unit of Hydraulic Engineering, University of Innsbruck, Technikerstrasse 13, 6020 Innsbruck, Austria (stefan.achleitner@uibk.ac.at)

The Pitzbach and the Oberbergbach are two steep mountain streams with partly glaciated catch-ments and located in the Central Alps of North Tyrol (Austria). At both streams, continuous measurements at water intakes and attached desilters provide time series of water discharge Q and bed load transport rate Q_b. The used data sets has a resolution of 15 min and have a span of ten to twelve years. These data are used to analyze the relation between the discharge (trigger) and bed load transport rate (response) at multiple time scales.

Taking the entire data set of each stream, Q_b is significantly correlated with Q, but the $Q - Q_b$ relation reveals two break points reflecting different transport modes. The first breakpoint appears at a very low transport rate and it is associated with the shift from the marginal transport of sand (phase 0) to significant (but still low) transport of sand and gravel (phase 1). This shift is accompanied by an increase of the gradient in the log-log plot. Beyond the second breakpoint, the gradient of the log-scaled $Q - Q_b$ relation decreases again. It is associated with the shift from travelling bed load and the initial mobilization of coarse sediment from the bed surface (phase 2).

Anyway, the scatter range of the $Q - Q_b$ relation is large and extends over four orders of magnitude. The variability of bed load transport rate at a certain discharge level seems log-normal distributed and the standard deviation of log-transformed bed load transport rate is constant for low flows, but decreases at high flows. Additionally, the $Q - Q_b$ relation differs with time. The temporal variability of the $Q - Q_b$ relation is investigated by fitting power functions (rating curves) to yearly and monthly segregated $Q - Q_b$ pairs that are associated to phase 1 transport. The rating curves significantly differ between most of the years and the data even show seasonal differences. At the Oberbergbach the transport efficiency is low at the beginning and increases during the summer half year. This seasonal increase is attributed to the shift from snowmelt-dominated runoff in early summer towards glacier melt in late summer. It is probably accompanied with the increased mobilization of highly abundant and mobile sediment at the glacier forefield. In contrast, a seasonal decrease of transport efficiency is present at the Pitzbach. This is rather surprising since both streams show similar characteristics regarding the catchment size and glaciation. A possible reason for this opposite trend is the bed load supply from the ephemeral tributaries into the main channel during the snow-melt season. While the sediment connectivity between the tributary channels and main channel is weak at the Oberbergbach, it is much more pronounced at the Pitzbach. Thus, the large scatter of the $Q - Q_b$ relations of both streams is attributed to temporally variable sediment supply conditions that result from the contribution of different sediment sources.