Rapide destruction du signal lié à l'export sédimentaire des chenaux sous-glaciaires par les marges proglaciaires en tresse

Rapid shredding of the subglacial sediment export signal by proglacial forefields

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1. Introduction

Alpine glaciers have been retreating at increasing rates in the last decades due to climate warming. As a consequence, large amounts of suspended- and bed-load sediment are released in proglacial environments, such as proglacial forefields. These regions are among the most unstable geomorphic systems of the Earth because they rapidly respond to changing discharge and sediment conditions. Given this, it has been argued that their intense morphodynamic activity, being a complex and non-linear process, is able to "shred" the sediment transport signal itself, and especially that related to subglacial sediment export [1, 2].

To date, our knowledge on subglacial sediment export by subglacial streams is essentially dominated by suspended sediment dynamics recorded in front of shrinking glaciers because of the limitations in measuring bedload transport. This latter is usually monitored far downstream from glacier termini by permanent stations (e.g. water intakes; [3, 5]) leaving major uncertainties in the absolute amounts and temporal patterns of transport in both glacial and proglacial environments, as well as the relative importance compared to suspended sediment in case of morphodynamic filtering. Recent developments in in environmental seismology, the discipline that uses ambient noise to detect and to measure geomorphic processes, opened new opportunities in this sense because it allows to study fluvial processes that are rare and difficult to measure, such as bedload transport dynamics in close proximity to glacier termini [6].

This work focuses on investigating the extent to which a proglacial morphodynamic is able to filter subglacial sediment export. Our aim is to investigate the evolution of the both suspended sediment (Qs) and bedload (Qb) subglacial export signals within the proglacial forefield to quantify the extent and the timescale over which proglacial morphodynamics filter them. At present, there are no studies combining continuous measurements of both suspended- and bed-loads in such environments.

2. Methodology and methods

The study is carried out in the Glacier d'Otemma proglacial forefield (southern-western Swiss Alps, Valais) over two entire melt seasons (June-September 2020 and 2021) experiencing different climatic conditions. We installed two gauging stations equipped with turbidity probes, water pressure sensors and geophones close to the glacier terminus (GS1) and at the forefield outlet (GS2) in order to be able to detect how the subglacial sediment export signals related to the two type of transport evolve in space (ca. 900 m apart; Figure 1). On one hand, suspended transport was recorded using conventional turbidity-suspended sediment concentration relationship, while on the other hand bedload transport was monitored seismically inverting the collected seismic data using a pre-assemble physical inversion method called Fluvial Model Inversion (FMI, [7]) calibrated combining active tests and statistical approaches. Both continuous suspended- and bedload records (Figure 2a) where then post-processed using signal post-processing techniques (Jerolmack and Paola, 2010) to identify which transport type is most prone to morphodynamic filtering and the timescale over which it operates.

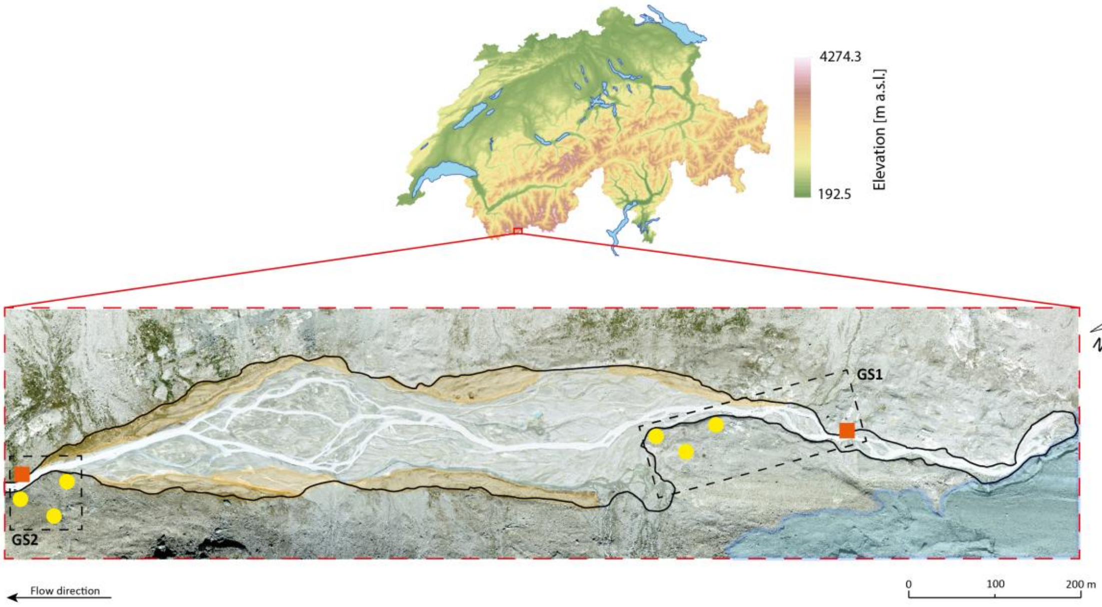

Figure 1: Glacier d'Otemma proglacial forefield and location of the gauging stations GS1 and GS2. Orange squares refer to turbidity probes and water pressure sensors, while yellow circles to geophones. Blue shaded regions highlight both bare- and debris covered-ice and orange areas to terrace systems.

3. Results and conclusions

Results show that the signal of subglacial bedload export, unlike suspended load export, is rapidly shredded by proglacial stream morphodynamics, which we show is due to a particle-size dependent autogenic sorting of sediment transport at both sub-daily and seasonal time-scales (figure 2b). Given this, over very short distance the signal of subglacial bedload sediment export is lost and replaced by a signal dominated by morphodynamic reworking of the proglacial braidplain. The suspended signal is less impeded but significant floodplain storage and release of suspended sediment was observed. These results question the reliability of current inferences of glacial erosion rates from sediment transport rates often measured some way downstream of glacier margins [8, 9].

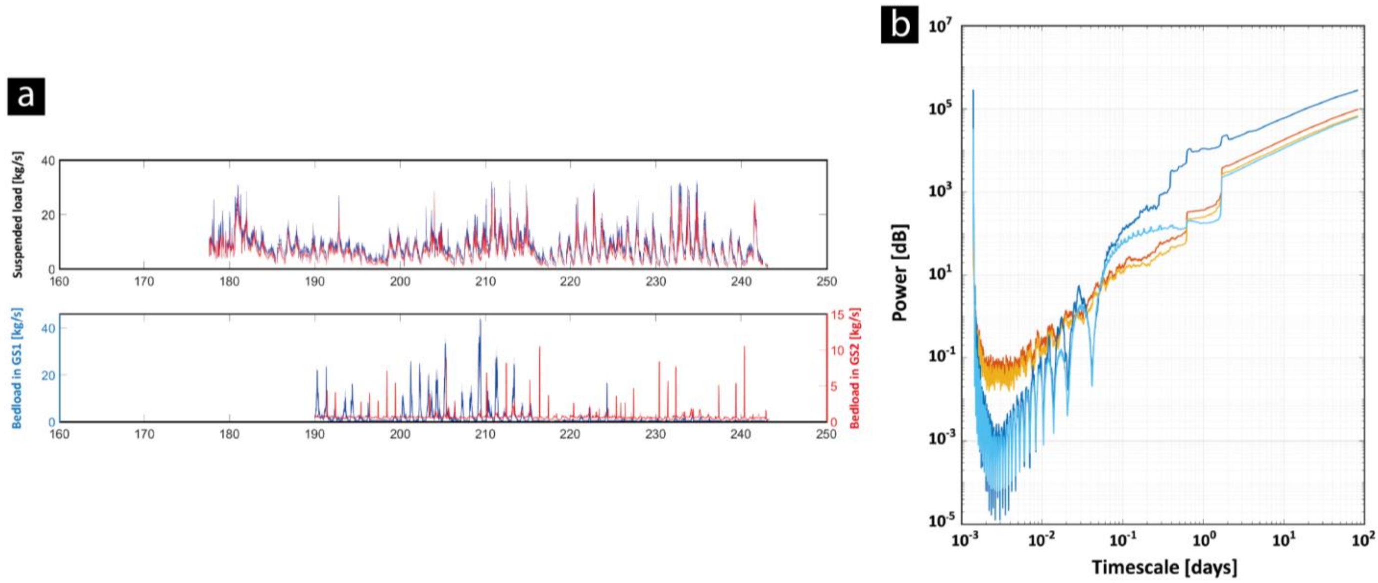

Figure 2: (a) Continuous suspended sediment (Qs) and bedload (Qb) transport for the 2020 melt season in GS1 (blue line) and GS2 (red line). (b) Power spectra of instantaneous suspended sediment (orange line) an bedload (blue line) in GS1 (dark) and GS2 (light).

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