Review of Paster et al.: "Channel evolution processes in a diamictic glacier foreland. Implications on downstream sediment supply: case study Pasterze / Austria"

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In their manuscript, Paster et al. investigate the channel evolution of a proglacial stream draining the Pasterze glacier in the Austrian Alps between 2015 and 2018. Using a combination of field surveying, remote sensing imagery and hydrodynamic modelling, the authors investigate the recent and future evolution of the sediment transport along the ~850 m long river reach. Relying on predicted runoff until 2050, the authors model the future transport capacity of the river and compare this to field and remote sensing derived measurements of grain size distributions. From their analysis, the authors conclude that the continuous erosion of finer sediments leaves very coarse grain sizes in the channel, armouring the bed and ultimately stabilizing the proglacial river system.

The manuscript is well written and addresses a topic that is potentially interesting for a broad range of readership. Before acceptable for publication in Hydrology and Earth System Sciences, however, the authors need to address a number of general and specific issues that I outlined in detail below.

General comments

A) Introduction: While the introduction is generally well written, it would certainly benefit from a stronger focus on the research gap that the authors want to address in their study. In my view, the aims should be better linked to the scientific context presented in the introduction. This is also true for the relevance and importance of the study. The authors are addressing the fundamentally important topic of how sediment dynamics might change in a changing climate. This should be stressed more explicitly, especially in a setting where the Margaritzenstausee reservoir is located only a kilometre downstream of the study site. Managing the sediment influx of reservoirs is a big issue that calls for studies that enhance our understanding of proglacial sediment dynamics.

B) Sediment sampling: Applying two different methods, line-by-number sampling in the accessible river sections and manually measuring grains in orthomosaics in the inaccessible canyon, respectively, makes comparability of the data generated an issue. It remains unclear why the authors did not construct partial grain size distributions from the same method in the entire study area. Given the inaccessibility of the canyon, visually measuring grains in orthomosaics would be suited for this and assure comparability. Another way forward would be to construct partial grain size distributions from both methods for some of the sampling points to assess the difference between methods and quantify a potential bias towards larger grain sizes introduced by measuring clasts in the orthomosaics. The authors should explicitly address the uncertainties introduced by the application of two different methods in their manuscript. The studies cited in L144-145 would suggest a shift towards larger grain sizes. Moreover, the description of the photogrammetrical sampling would benefit from a more detailed description. A final point to consider would be to make use of the automated extraction of grain size distributions from images (photo sieving) that also has been applied to entire reaches (Purinton and Bookhagen 2019). This would allow the authors to construct a more complete data set on grain size distributions by increasing their sampling size (only ten locations so far).

C) Evolution of the river reach: Despite the interesting data set the authors present and analyse in the present manuscript, some interpretations in the manuscript are not fully backed by the data and some discussion points do not cover all relevant aspects. Multiple studies (also cited in the manuscript) show proglacial areas to be highly dynamic systems, where changes can happen within single events. Here the authors use an orthophoto from 2015 (from the federal government) and a UAV derived orthoimage from 2018 to investigate the channel dynamics. But this data set does not allow insight with higher temporal resolution, e.g. the interpretation that the bed is actually stabilizing. Here, the authors should make use of additional data sets that might allow a detailed quantification of the short-term dynamics. Furthermore, the interpretation that glacifluvial erosion in the channel leads to bed armouring and ultimately to a stabilized channel is based on the assumption that a) the channel does not migrate laterally or completely changes course and b) that sediment delivery to the channel reach does not change dramatically. Below I added comments in this respect to specific locations.

Specific comments

- L14: analyses instead of analysis
- L32: “steadily increasing spatial boundary”? Does this refer to the proglacial area that increases due to glacial recession? Consider rephrasing
- L36-39: consider splitting in two sentences
- L40: maybe: be described as a sediment cascade?
- L55-56: River bed incision into glacifluvial sediment and the formation of an armour layer is portrayed here as inevitable. While this might be true on the long run (when the catchment is devoid of transportable sediment), lateral migration, sediment delivery from valley flanks and a complete sift of the channel can happen in highly dynamic proglacial environments.
- L59: is able to transport sediments
- L65-66: For catchments with smaller glaciers, this peak-water effect has probably already been crossed, whereas for larger glaciers, this still lies in the future.
- L66-68: the second part of this sentence is not clear, please rephrase
- L69: repetition of L44-45
- L79-86: I think it would be important to mention that the reservoir Margaritzenstausee is located directly downstream. This increases the relevance of the study, as sediment management is an important topic for the reservoir.
- L91: Please explain the abbreviations here and elaborate how these values have been calculated. Was the length measured as Euclidean distance between start and end point of the segments, or along the channel? This also applies for the calculation of channel slope that can be derived from digital topographic data in multiple ways.
- L97-99: explain abbreviation “LbN” in the figure caption and provide details on the coordinate reference system used in the figure.
- L105-106: Glacifluvial processes are an important process for paraglacial adjustment, I am unsure why paraglacial reworking is contrasted here with glacifluvial processes?
- L124: Indicate which version of Agisoft Photoscan (Metashape since some years) was used for processing
- L125: add reference
- L134-135: Here it is unclear what the 478231187 points refers to? Usually, a DEM is a 2D raster with a certain pixel size. Please add details on the ground resolution of the DEM and Orthomosaic here
- L140-141: incomplete sentence
- L143: partial grain size distributions

- L151-153: Please, can the authors add more detail on the data set and method by Schöner et al. (2013)? As this is a crucial input for the study, the readers will want to understand how the Glacier Runoff Evolution Model (GREM) works. Also, please add more detail to the reference Schöner et al. (2013) as cited in the manuscript. Searching for this reference I can only find a presentation on the EURAS-CLIMPACT project that does not contain any detail on the GREM.
- L152: GREM?
- L153-154: It there a reason why the high-resolution digital elevation model derived from UAV imagery cannot be used for a roughness determination here?
- L167-169: Might this data be subject to underestimation/overestimation as the clasts are not lying flat on the ground with their b-axis visible?
- L193-195: this is a decrease by factor two, but not by two orders of magnitude
- L199: what are “big roughness elements”?
- L204-206: Delete “so-called” as knickpoint (or knickzone) is a standard geomorphic term. Maybe add a small explanation here: […] knickpoint, a pronounced convexity in the longitudinal channel profile, […]
- L220-221: But as Fig. 5 shows, the channel has moved considerably in the three years between 2015 and 2018. Except for a few meters, the entire channel shifted considerably, in some locations more than ~50m. I agree that this dynamics are to be expected, as the channel is actively incising. If the authors really want to show that channel migration is lower in 2018 than in 2015 (which again can be expected), they need to show this by data. The automated imagery might help to quantify channel mobility over time.
- L221-222: As this area is highly dynamic, I am not sure whether these changes can be attributed to upstream controls. The collapsing front of the debris-covered glacier changes takes away the lateral confinement in this area and the channel can turn to a steeper course and incise (see August 2016 and August 2017 in Fig. 5a).
- L222-224: Also here, I am not convinced that the data presented support this claim. The authors use the 2015 orthophoto and the 2018 UAV derived data here. From these two points in time, lateral changes in the channel can only be quantified for the entire three years long interval. The lateral confinement by “debris-covered dead ice landforms” towards the south is crucial in this setting. It can be anticipated that in a few years from now, the channel will not be active anymore, but will have shifted towards the centre of the valley. This can already be seen in satellite imagery from the summer of 2022 (see Figs. R1 and R2 below).
- Figure 5b: It is hard to tell the difference between the lines indicating the start and end of the study area and the beginning of the canyon. Maybe colorize? Also in the legend, label should be “start of canyon” or “beginning of canyon”
- L231-232: Again, this is a bold claim relying on only two points in time. In my view, this would require a thorough quantification of channel dynamics with high temporal resolution.
- L233-235: The knickpoint is located in a conspicuous position at the left lateral margin of the valley. From the picture in Fig. 6 one gets the impression that bedrock is exposed in this specific situation. This would strongly limit the mobility of the knickpoint and limit its potential for headward erosion. Can the authors give more detail on the specific setting of the knickpoint?
- L235: This is the first time since the abstract (L15) that river bathymetry is mentioned. Please elaborate in the introduction, methods, and results section how and why river bathymetry was measured and what this adds to the study.
- L237-239: While there might be a tendency of river channels to be more stable in greater distance from the glacier terminus, other factors, most importantly channel slope, are playing a crucial role as well.

- L241-242: If this knickpoint is produced by underlying bedrock, knickpoint migration will be very slow.
- L244: “non-fluvial sediment”? In extreme cases, steep rivers can transport large blocks… I guess the authors want to make the claim that these sediments are glacially deposited and remain in position, while the finer clasts are eroded and transported by the river?
- L247: before, the formation of the canyon has been described as glacifluvial, why are the authors using the term “post-glacial” here?
- L250-261: But this stabilization “from a hydraulic point of view” (L252) or the establishment of “an erosion-resistant pavement layer” will only happen under the assumption that the channel will not migrate laterally, or even shift to a new course. Baewert and Morche (2014) show that in a proglacial environment of the Gepatschferner the channel completely shifted to a new course following one extreme precipitation event. Proglacial areas are highly dynamic, and this is especially true for their upper margin where melting dead ice constantly reshapes the topography of the valley floor.
- L257-261, L263-265, Figure 6: It is not clear to me how the authors a) define and b) predict these “erosional breakpoints”? Are these “erosional breakpoints” not identical to the locations where partial grain size distributions were constructed from UAV derived imagery? If so, how can breakpoints (i.e. locations where something changes in my understanding) be defined based on six sample locations?
- L273-275: inevitable? I don’t think this claim is justified, as I outlined before. Again, Baewert and Morche (2014) show an alteration from single thread to braided and back to single thread over a couple of years in a similar setting.
- L300-316: Also in this section the authors should attribute the various other possibilities of how the channel surveyed here might evolve in future.
- L318-337: Given all the concerns raised above, I would recommend the authors to formulate the conclusions much more cautiously here. While proglacial rivers might have a general tendency to stabilize due to bed armouring and the ultimate formation of a pavement layer, a lot of disturbances will distort this trajectory in a highly dynamic environment. Their survey of a single proglacial river section over the course of three years does not justify very general claims on the evolution of proglacial rivers.

References:

- Purinton, B. and Bookhagen, B.: Introducing *PebbleCounts*: a grain-sizing tool for photo surveys of dynamic gravel-bed rivers, Earth Surf. Dynam., 7, 859–877, https://doi.org/10.5194/esurf-7-859-2019, 2019.

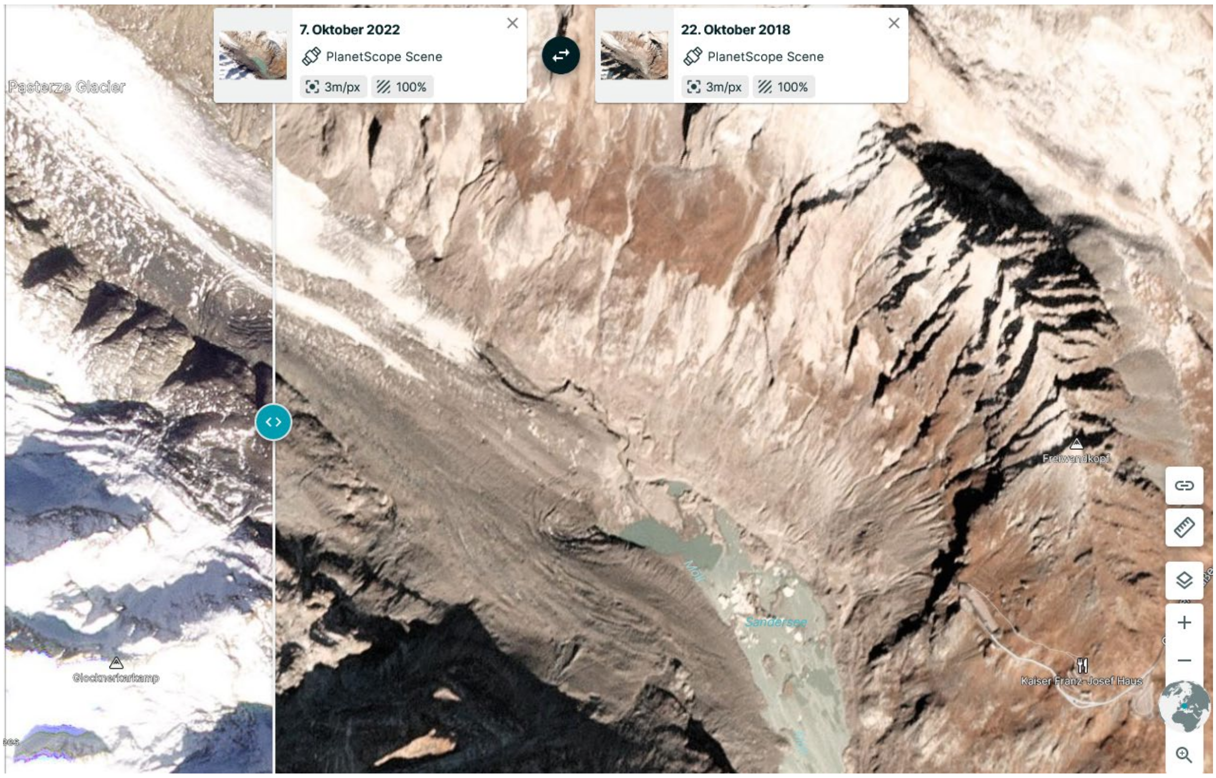

Fig. R1 – Planet satellite image of the study area (2018-10-22). This is the situation as described in the manuscript. www.planet.com

Fig. R2 – Planet satellite image of the study area (2022-10-07). Note the formation of an incipient channel in towards the southwest of the old canyon. Future melting of dead ice will likely allow water flow in the center of the valley. Also note how the meander in the lower part of the channel changed its course. www.planet.com