Earth Surface Dynamics Discussions

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Comment on esurf-2021-1

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Community comment on "Modeling glacial and fluvial landform evolution at large scales using a stream-power approach" by Stefan Hergarten, Earth Surf. Dynam. Discuss., https://doi.org/10.5194/esurf-2021-1-CC1, 2021

Comment on: A stream-power law for glacial erosion and its implementation in large-scale landform-evolution models, by Stefan Hergarten.

I was not formally asked to review this paper, but I believe my expertise can be useful to improve the manuscript. In that sense, I will focus on very general comments and I am not proposing a detailed review.

The main focus of the study is to develop a landform evolution model that can be solved more readily with less computational power than the current existing models. This would, indeed, be a very useful contribution to glacial geomorphology, especially as the author are making their code open source. To do so, the author derive a stream power law for glacial erosion, including a parametrization of bedrock erosion and sediment transport by subglacial water flow.

My main concern regarding the study is that the author provides little to no explanations for the simplifications they propose, and in many cases, these simplifications are contradictory to the current understanding of these erosion and transport mechanisms. Throughout the paper, there are very few explanations of the current state of knowledge of the physical processes involved in glacial erosion and sediment transport. Most of the papers cited are numerical models that already make significant assumptions. For example, in Section 2, l. 63-64, the derivation of the glacial stream power starts with the statement “If we consider a rectangular cross section […]”. Yet, we know glacial valleys are not rectangular and there is no explanation of that simplification.

Another point of concern is the recurring citation of Prasicek et al. (2020) to justify numerous simplifications. In the Prasicek et al. (2020) study, the goal is to assess timescales of respective processes: glacial erosion, climate and tectonic; not to reproduce landforms. The assumptions Prasicek et al. (2020) are making to assess the relative effectiveness of processes over time, become inadequate when applied to a model that aims at reproducing landforms themselves.

To be more specific, I believe the following reasonings are problematic:

- While reading the paper, I was left with the feeling that because there is a stream power erosion law for rivers there should be one for glaciers. In river systems the shear stress can be approximated with discharge, which in turn can be approximated with catchment area and precipitation. Futhermore, observations by Hack (1957) support a simple scaling. For glacier erosion, however, not only do erosion and transport mechanisms remain unclear in general, but there is no large-scale field observations that support such scaling. The paper cited to support such scaling (Bahr, 1997) refers to glaciers themselves, not glacial landscapes, and is therefore not applicable to glacier erosion. In term of the specifics of glacial erosion, even assuming a simple relationship between erosion and sliding velocity to a power, this power is likely >1 (Herman et al., 2015; Koppes et al., 2015). Sliding velocity is intricately linked to basal shear stress and basal water pressure (e.g. Beaud et al., 2014; Ugelvig et al., 2018). Therefore, a thorough explanation is necessary to simplify our current state-of-the-art understanding of the physical processes of glacial erosion into a simple stream power-type law.

- Using a shallow ice approximation has be shown to not work very well on steep landscapes (Egholm et al., 2011). These simplifications and their implications for landscape evolution results should be explained.
- Model of glacio-fluvial incision (l. 229-232): "*While Beaud et al. (2016) developed a more elaborate model for the incision 230 by meltwater within narrow channels, the meltwater component should preferably not introduce a level of complexity much beyond the simple models of fluvial and glacial erosion used here. So let us assume that erosion by meltwater can be described by the same formalism as fluvial erosion.*" That statement is in opposition to the results presented in the Beaud et al. (2016) study. Since that model is the only to date to describe such mechanism, dismissing the results or making different assumptions should be substantiated.
- Finally, the authors are omitting the vast majority of the glacial landform evolution literature together with the literature explaining the physical underpinning of glacial erosion and sediment transport. In the references at the end of my comment, I propose a non-exhaustive list of papers that should be cited and the finding of which should be included in the current study.

In summary, in its current form, I do not believe that the current study makes a convincing point that a stream power glacial erosion rule can, or should be used. If the goal of the paper is to reproduce landforms, the author should include and discuss extensively the existing literature and justify their simplifications. If the goal is to produce a model that can be used to test interplay between erosion, climate and tectonic, similarly to Prasicek et al. (2020), that should also be clarified. In any case, I believe, the assumptions should be discussed in light of the existing literature.

I hope you find my comments constructive and am available to answer further questions if necessary (flavien.beaud@ubc.ca).

Best,

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