Earth Surface Dynamics Discussions

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Comment on esurf-2021-1

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Referee 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-RC4, 2021

First, there is no conflict of interest: My work and the author's work are categorically different and furthermore address different spatial and temporal domains. My work is theoretical with the development of an analytical model of glacier erosion rates at the basin scale, while the author's work addresses glacier erosion at smaller spatial scales utilizing a heuristic approach to define a glacial erosion law for numerical implementation, as is standard for numerical approaches.

Next, please let me express my regret for the tone of my earlier comments without elucidating clear points for the author to address. Since the work makes assumptions in direct conflict with current theories of glacier dynamics, I will not address the computational aspects of the work as the premises on which the model is built are problematic and in this reviewer's opinion unrealistic rending the erosion law in equation 19 open to sever question. Restating the main issues:

- The author has not cited nor sufficiently discussed existing literature: This is an issue as the proposed scientific contribution this work cannot be understood except but subject matter experts.
- The theoretical underpinnings, the glacier dynamics, in several key place are incorrect in section two and three rendering the hypothesized glacier erosion law, the equation 19, the critical key equation of the numerical model, open to question.
- One of the most concerning issue in terms are some of the scientific conclusions of the paper. Most notably in 225: "These findings support the idea that erosion by meltwater **must** play an important role, at least in the lower part of glaciers where the flux of water is much higher than the ice flux." This statement cannot be justified by the a numerical model regardless of soundness of the theoretical underpinnings. While the contributions of numerical simulations to the research and progress of understanding glacier erosion cannot be overstated, drawing such definitive conclusions about mechanisms of glacier erosion is out of reach for this type of approach.
- The paper is not written to address the glacial community which I presume is a key target audience for the work.

Based on these issues I cannot recommend publication of the work as in my opinion the prosed erosion law is unjustified calling into question the numerical model and its results.

Focused Comments for Section 1:

1 -5: “In contrast to fluvial erosion, however, glacial erosion has not been extensively considered in modeling large-scale landform evolution”

Here is a list of reference the author might consult:

Egholm, D. L., et al. "On the importance of higher order ice dynamics for glacial landscape evolution." Geomorphology 141 (2012): 67-80.

Harbor, J., 1989. Early Discoverers XXXVI: W J McGee on glacial erosion laws and the development of glacial valleys. Journal of Glaciology 35, 419–425.

Harbor, J., Hallet, B., Raymond, C. A numerical model of landform development by glacial erosion. Nature 333, 347–349 (1988).

Harbor, J. Numerical modeling of the development of U-shaped valleys by glacial erosion. GSA Bulletin 104, 1364–1375 (1992).

Herman, F., Beaud, F., Champagnac, J.D., Lemieux, J-M., Sternai, P. Glacial hydrology and erosion patterns: A mechanism for carving glacial valleys. Earth and Planetary Science Letters, 310, 498–508 (2011).

MacGregor, K.R., Anderson, R.S., Anderson, S.P., Waddington, E.D. Numerical simulations of glacial–valley longitudinal profile evolution. Geology 28, 1031–1034 (2000). Oerlemans, J. Numerical experiments of large-scale glacial erosion. Zeitschrift fuer Gletscherkunde und Glazialgeologie 20, 107–126 (1984)

Oerlemans, J. Numerical experiments of large-scale glacial erosion. Zeitschrift fuer Gletscherkunde und Glazialgeologie 20, 107–126 (1984).

Tomkin, J.H. Numerically simulating alpine landscapes: The geomorphologic consequences of incorporating glacial erosion in surface process models. Geomorphology 103, 180-188 (2009).

Ugelvig, S.V., Egholm, D.L., Iverson, N.R. Glacial landscape evolution by subglacial quarrying: A multiscale computational approach. J. Geo. Res. E. Sur. 121, 2042-2068 (2016).

Ugelvig, S. V., et al. "Overdeepening development in a glacial landscape evolution model with quarrying." *AGU Fall Meeting Abstracts*. Vol. 2013. 2013.

35-40: “A comparable representation of glacial erosion where the erosion rate can be directly computed from properties of the topography is not yet available.”

It is essential discuss the scales, both temporal and spatial, on which erosion rates are being considered. Though not explicitly discuss in the introduction, it can be implied from context that the spatial scales considered are smaller than the scale of the glacial landforms which is sub basin scale.

Alley, R. B., K. M. Cuffey, and L. K. Zoet. "Glacial erosion: status and outlook." Annals of Glaciology 60.80 (2019): 1-13.

Alley, R. B., et al. "Stabilizing feedbacks in glacier-bed erosion." Nature 424.6950 (2003): 758-760.

Andrews J.T. Glacier power, mass balances, velocities and erosion potential. Zeitschrift fur Geomorphologie 13, 1-17 (1972).

oulton, Geoffrey S. "Processes and patterns of glacial erosion." Glacial geomorphology. Springer, Dordrecht, 1982. 41-87.

Boulton, G. S. "Theory of glacial erosion, transport and deposition as a consequence of subglacial sediment deformation." Journal of Glaciology 42.140 (1996): 43-62.

Cook, Simon J., et al. "The empirical basis for modelling glacial erosion rates." Nature communications 11.1 (2020):

Delmas, M., Calvet, M., Gunnell, Y. Variability of quaternary glacial erosion rates— a global perspective with special reference to the Eastern Pyrenees. Quat. Sci. Rev. 28, 484–498 (2009).

Hall, Adrian M., et al. "Glacial ripping: geomorphological evidence from Sweden for a new process of glacial erosion." Geografiska Annaler: Series A, Physical Geography (2020): 1-21.

Hallet, B. Glacial abrasion and sliding: their dependence on the debris concentration in basal ice. Annals of Glaciology 2, 23-28 (1981).

Hallet, B. Glacial quarrying: A simple theoretical model. Annals of Glaciology 22, 1–8 (1996).

Iverson, N.R. A theory of glacial quarrying for landscape evolution models. Geology 40, 679–682 (2012).

Menzies, J., Jaap JM van der Meer, and W. W. Shilts. "Subglacial processes and sediments." Past glacial environments. Elsevier, 2018. 105-158.

Steinemann, Olivia, et al. "Quantifying glacial erosion on a limestone bed and the relevance for landscape development in the Alps." Earth Surface Processes and Landforms 45.6 (2020): 1401-1417

Ugelvig, S. V., et al. "Glacial erosion driven by variations in meltwater drainage." Journal of Geophysical Research: Earth Surface 123.11 (2018): 2863-2877.

Equation 4 is incorrect: See chapter 7, eq's 7.6, 7.10, 7.17, **8.35**, 8.36, 8.65 and sections 8.1, 8.4, 8.5 and 8.6 in Cuffey, Kurt M., and William Stanley Bryce Paterson. The physics of glaciers. Academic Press, 2010. Sliding velocity cannot be reduced to ice thickness and slope under any approximation. As Cuffey and Patterson in discussion the Shallow Ice Approximation say in chapter 8, "The rate of basal slip must be specified directly or through a relation to bed stress such as Eq. 8.25"

Equation 6: Yes erosion laws of this form are typically implemented, however there are many other forms that have been used within numerical simulation.

50: This section requires substantially further discussion and justification. Ice thickness is not a diffusion process. See section 8.5.5 and equation 8.65 , 8.70, 8.77, 8.78 and 8.79 in Cuffey and Patterson. In the Shallow Ice Approximation ice flux q~h not the partial derivative of h wrt to x. There is a divergence relationship, first order partial derivatives, but diffusion is second order in the spatial partial derivatives. Without substantial justification, ice thickness cannot be treated as diffusion with strong diffusivity.

Section 2:

Again equation 4 is unfounded so that section 2 begins with a false premise. This problem then follows through into equations 8, 9, and the key equation 14 rendering it unfounded.

70-80: This section requires further explanation.

100: The authors treatment of catchment size, precipitation, and discharge may have a clear rationale for fluvial systems, but it is not clear why this would apply to glacial system except perhaps at the terminus. The author needs a detail justification.

Equation 19: Taken as a whole, the validity of the proposed erosion law is questionable.