We appreciate this review and the need to improve the description of the model's implementation. As a result, we have addressed the reviewer's comments to the best of our ability and interpretation of the comments.

Below, Dr. Hergarten's comments are in bold and our response is in normal font. Changes to the manuscript text are in italics.

Best regards,
Ian Delaney, on behalf of all authors

1. **Let me start from the sediment balance (Eqs. 7 and 8). If I am not totally wrong, (capital) Qs is still the sediment flux (volume per time). Then the divergence of Qs has a unit of square meters per second, while the other terms in Eq. 7 are meters per second. So the Exner equation is still not written correctly. The term inside the divergence must be flux per unit width, not flux! Then you may approximate it by flux per width. From its physical dimension, your property Qs (line 122) would be m4 per second, which would make no sense at all. So please write the sediment balance correctly**

   We appreciate this comment and have corrected the sediment transport equation. The text now reads:

   The model simulates the evolution of a subglacial till layer, which we define as transportable sediment below the glacier due to glacier erosion and fluvial sediment transport. Fluvial sediment transport, in supply- and transport-limited regimes, mobilizes and deposits sediment, adding or removing material from the till layer (Brinkerhoff et al., 2017; Delaney et al., 2019). Conversely, erosive processes such as abrasion and quarrying add material to the layer, while we do not consider processes such as fluvial abrasion that appear to produce minimal sediment (Beaud et al., 2018). To represent these processes, we implement the Exner Equation (Figure **??***; Exner, 1920a,b; Paola and Voller, 2005), a mass conservation relationship, to solve for the till layer height given the erosive and fluvial conditions.*

$$\underbrace{\frac{\partial H}{\partial t}}_{\text{till evolution}} = - \underbrace{\nabla \cdot Q_s}_{\text{sediment transport}} + \underbrace{\dot{m}_t}_{\text{bedrock erosion}} , \tag{1}$$

   H is till thickness and t is time (Table 1). The first term represents fluvial sediment transport processes, where $\nabla \cdot Q_s$ represents sediment mobilization in either supply- or transport-limited regimes. The second term captures bedrock erosion processes, where $\dot{m}_t$ is a bedrock erosion rate.

   We evaluate the mobilization of sediment in both supply- and transport- limited conditions. Divergence of the sediment flux is evaluated by approximating $\nabla \cdot Q_s$ with $\frac{\nabla \cdot \widetilde{Q_s}}{w}$ and using the mobilization scheme from Delaney et al. (2019)

$$\nabla \cdot \widetilde{Q_s} = \begin{cases} \dfrac{Q_{sc} - Q_s}{l} & \text{if } \frac{Q_{sc}-Q_s}{l} \leq \dot{m}_t w \quad \text{(transport-limited)} \quad (2a) \\ 0 & \text{if } H = H_{lim} \ \ \& \ \ \frac{Q_{sc}-Q_s}{l} \leq 0 \quad (2b) \\ \dfrac{Q_{sc} - Q_s}{l}\, \sigma(H) + \dot{m}_t w \ (1 - \sigma(H)) & \text{otherwise} \quad \text{(supply-limited)} \quad (2c) \end{cases}$$

   Q_{sc} is sediment transport capacity, or the amount of sediment that could be transported under the given hydraulic conditions. l is a characteristic length-scale for sediment mobilization, over which sediment mobilization adjusts to sediment transport conditions. σ is a sigmoidal function of H

In this form, Condition 2a, $\frac{Q_{sc}-Q_s}{l}$, has units $\mathrm{m}^2\,\mathrm{s}^{-1}$ as does Condition 2b and the term $\dot{m}_t w$. As a result, $\nabla \cdot \widetilde{Q_s}$ has units $\mathrm{m}^2\,\mathrm{s}^{-1}$. In turn, when we approximate $\nabla \cdot Q_s$ with $\frac{\nabla \cdot \widetilde{Q_s}}{w}$, the unit of $\nabla \cdot Q_s$ becomes $\mathrm{m}\,\mathrm{s}^{-1}$. Units of $\mathrm{m}\,\mathrm{s}^{-1}$ for $\nabla \cdot Q_s$ make Equation 5 consistent. Here w is a width perpendicular to water flow.

2. **As a second point, the description of the routing scheme and solving the system is weird. From Eq. 16, I guess that you compute the hydraulic potential of each nodes by some kind of weighted mean of the potentials of the receivers and the respective hydraulic gradients. Equation 16, is however, strange because it is just $\phi_0 = \phi_0$+ something, which cannot hold in this form. And what are the hydraulic gradients inside the sum? Are these the gradients from the node to the respective receiver or the hydraulic gradient of the receiver? The latter would be questionable if, e.g., a small channel enters a big channel.**

   We appreciate this comment, especially in light of similar comments by the other reviewer. In turn, this Section 2.3.1 has been rewritten as to address these concerns. The section in its entirety is below. In summary, ϕ_0 is evaluated by summing the hydraulic potential up the glacier from the terminus. In one dimension, this would be evaluated by integrating the hydraulic potential gradient in the Darcy-Weisbach (Equation 1 in the manuscript) up-glacier from the terminus. In two dimensions, we use the routing information from the stack to evaluate this.

3. **Then there is a part (lines 186-195) that I do not understand well.**

   We understand why the reviewer may not understand this well. In Section 2.3.2 below, please find our updated phrasing. We believe that these matters should be clarified in the new presentation.

4. **For the following part (from line 196), I have some idea, but there still seems to be something wrong. Neither the flux of water (Eq. 18) nor the flux of sediment (Eq. 19) can be computed from a sum over the receivers. I guess it is a sum over what is sometimes called donors or donators in the literature.**

   The reviewer is correct in the comment and identified short comings and errors in our description. In evaluating the hydraulic gradient, we are moving up the glacier, so “receivers” from a downstream perspective are used. For the sediment and water discharge, we use the “donor” cells of each cell. We have updated the text to reflect this. Additionally, balances of sediment and changes in till height have been modified to reflect these changes.

Section 2.3.1

We assume that sediment and water moves across the glacier bed following the steepest gradient in hydraulic potential. On glaciers, we define the hydraulic potential at a cell i in the grid, ϕ_i, based upon the elevation of the glacier bed plus the ice thickness, following Shreve (1972).

$$\phi_i = f_f\,\rho_i\,g\,(z_{s,i} - z_{b,i}) + \rho_w\,g\,z_{b,i} \quad , \tag{3}$$

where f_f is the flotation fraction across the glacier, z_s is the glacier surface, and z_b is the glacier bed.

With this information, we use a multi-cell routing scheme (Quinn et al., 1991) to establish flow routing based upon the steepest hydraulic potential in Equation 3 and with a single value of f_f across the glacier bed. We implement this scheme in a similar way as Bovy et al. (2016), but on a regular grid in x and y directions, where fluxes can pass to the four surrounding cells sharing an edge. This routing scheme returns a stack (s_t; Table **??**), which contains information about the order of cells to perform the calculations, along with the number of cells flowing in to a cell

(donors; n_d), number of cells that a cell contributes (receivers; n_r), and the weight of hydraulic potential and water or sediment discharge directed from one cell to another (w_d or w_r).
For the first time step, the hydraulic potential ϕ is evaluated under the condition that $f_f = 1$. After the first time step, we assume that the flotation fraction, will vary in response to changing hydraulic conditions such as diurnal or seasonal water input (e.g., Iken and Bindschadler, 1986). In turn, to establish an average flotation fraction f_f across the glacier bed for Equation 3, we use

$$f_f = \text{mean}\left(\frac{\phi_{o,i}}{\rho_i \, g \, (z_{s,i} - z_{b,i}) + \rho_w \, g \, z_{b,i}} \right) \quad , \tag{4}$$

where the denominator represents the hydraulic potential at overburden pressure ($f_f = 1$ in Equation 3).
ϕ_0 represents the hydraulic potential evaluated from summing the hydraulic gradient Ψ in Equation **??** up glacier from its outlet. ϕ_0 at each cell i is evaluated as

$$\phi_{o,i} = \Psi_i \cdot \lambda + \sum_{j=1}^{n_r} (\phi_{0,j} \cdot w_{r,j}) \quad . \tag{5}$$

Here, Ψ_i comes from evaluating Equation **??** from the receiver cell j of i, λ is edge length of a cell on a regular grid, n_r is the number of receivers that the cell i has, and w_r is the proportion of hydraulic potential fed by the upstream cell j. The operation is executed on a cell by cell basis, beginning at the base of the glacier and moving up the flow paths evaluated in the routing scheme.
Using the routing scheme above, but performing the operation from the top of the glacier, we evaluate the water discharge in a cell $Q_{w,i}$ from melt upstream as

$$Q_{w,i} = \dot{m}_{w,i} \cdot \delta + \sum_{j=1}^{n_d} Q_{w,j} \cdot w_{d,j} \quad , \tag{6}$$

where $\dot{m}_w$ is a prescribed meltwater source term in cell i, n_d is the number of cells directing water at cell i, and $w_{d,j}$ is the percentage of water flow from cell j directed at cell i.
Sediment mobilization into a cell $\overline{Q_{s,i}}$ is like-wise computed by implementing Equation 2 from the top of the glacier through the stack as

$$\overline{Q_{s,i}} = \begin{cases} \displaystyle\sum_{j=1}^{n_d} \left(\frac{Q_{sc,j} - Q_{s,j}}{l} \cdot w_{d,j} \right) & \text{if } \sum_{j=1}^{n_d} \left(\frac{Q_{sc,j} - Q_{s,j}}{l} \right) \cdot w_{d,j} \leq \dot{m}_{t,i} \quad \text{(7a)} \\ 0 & \text{if } H_j = H_{lim} \quad \& \quad \frac{Q_{sc,j} - Q_{s,j}}{l} \leq 0 \quad \text{(7b)} \\ \dot{m}_{t,i} \lambda \;\; (1 - \sigma(H)) + \displaystyle\sum_{j=1}^{n_d} \left(\frac{Q_{sc,j} - Q_{s,j}}{l} \right) \cdot \sigma(H) \, w_{d,j} & \text{otherwise} \quad \text{(7c)} \end{cases}$$

where $Q_{sc,j}$ is the sediment transport capacity from cell j flowing to i, $Q_{s,j}$ is sediment discharge entering from cell j to cell i, again l is a response length scale and λ is cell length.
Sediment discharge $Q_{s,i}$ out of a cell i is evaluated as

$$Q_{s,i} = \overline{Q_{s,i}} \cdot \lambda + \sum_{j=1}^{n_d} Q_{s,j} \quad . \tag{8}$$

We evaluate the change in till height at a cell by implementing Equation 1 as

$$\frac{dH_i}{dt} = \frac{-Q_{s,i} + \sum_{j=1}^{n_d} Q_{s,j}}{\delta} + \dot{m}_{t,i} \quad , \tag{9}$$

where again δ is cell area.

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We appreciate this review and the need to improve the description of the model's implementation. Additionally, we have taken to heart the reviewer's comments regarding the clarity of the text and figures. As a result, we have addressed the reviewer's comments to the best of our ability and interpretation of the comments.

Below, Reviewer 4's comments are in bold and our response is in normal font. Changes to the manuscript text are in italics.

Best regards,
Ian Delaney, on behalf of all authors

1 General Comments

1. **However, the paper may need to improve the way of describing the modeling framework and explaining the results. For modeling descriptions, first, this paper shows a 2D model, however, the governing equations do not show clearly show how the 2D is represented in the model descriptions. Figures 3 and 9 show the 2D geometry of the studied area are complex geometries. However, it is not clear how these complex geometries are represented by mesh, and how such a mesh is incorporated into the governing equations. These details will be necessary for us to understand how the 2D is represented and variables defined on these 2D geometries are modeled. For the river routing model, Equation 16 shows the algorithm for calculating phi_o, however, the paper does not describe the governing equation for the river routing. It is not clear what governing equation and process are solved here. In addition, the model has a lot of parameters and variables that need to be solved. From the model description, it is not clear what variables are solved. Finally, the model used many equations that do not give sufficient descriptions of why you choose these equations, e.g., equations 2-4, 8, 9, 12, 16, 17, 21. I suggest the authors improve Section 2 to better describe these model equations.**

   We have tried to implement these comments as well as possible. In particular, we have reorganized Section 2.3 and re-written Section 2.3.1 to address how these equations are implemented is a 20dimensional space.

   In response to the last part of this comment, regarding the "sufficient description" of these equations, we have tried to address these. However, many of them are commonly used in the sediment transport and glaciological literature and we have provided citations. In these cases, we believe that the justification for their use is adequately described. To clarify some of the matters, we have added the following comments surrounding some of the equations mentioned above:

   - For Equations 2-4 we have added the following comments:

     the channel's cross-sectional geometry, which impacts water pressure, is accounted for by s (Hooke et al., 1990)... and *The width of the channel floor w_c, needed to evaluate the surface over-which sediment transport may occur, is given by...*

     We note that Equations 3 and 4 have been moved to Section 2.2 as they are a direct control on the sediment transport relationships therein.

   - For Equation 8 (now 6), we have added the following sentences to the description

     We evaluate the mobilization of sediment in both supply- and transport- limited conditions.

     With these three conditions, we can evaluate sediment transport in transport- and supply-limited regimes and pass sediment through the system when till hight is large.

- We gave modified the text surrounding Equation 9 (now 7) to include:

  If H is greater than $3\,\Delta\sigma$, then sediment mobilization is unaffected and the system is in a transport-limited regime. When $H = \Delta\sigma$, then $\sigma(H)$ is close to 0, sediment transport is in a supply-limited regime, and nearly no sediment mobilization takes place.

- With regard to Equation 12 (now), we have added the sentence:

  We assume that till armors the bed from erosion (e.g. Alley et al., 2003; Brinkerhoff et al., 2017; Delaney et al., 2019).

- For Equations 16 and 17, the text has been rewritten substantially in this section and these equations have been modified.

- With respect to Equation 21, we describe the justification below in the specific comments. However, we note that this equation encapsulates seasonal and diurnal variations in melt. This allows us to provide a synthetic forcing to our model that mimics natural conditions.

2. **For the results interpretations, I find it hard to link the conclusions or claims to the figures. In the current version, the conclusions usually come out first and then the claim is referred to a Figure. The linkage between the results and the message the figures describe are missing and is left for the potential audience to have the best guess. For example, on line 228-229, the paper states "Simulations show that over seasonal timescales, sediment discharge increases at the onset of melt and decreases shortly thereafter, prior to the maximum amount of water discharge that occurs each melt season (Figure 4)." However, Figure 4 has two subfigures and 5 lines. It is not straightforward to align the message of Figure 4 to the claim made here. This issue occurs in most of the explanations of the results.For example, at the lines 230 (linkage to Figure 6), 243 (linkage to Figure 4c); line 247 (link to Figure 6); line 265 (link to Figure 3a); line 393 (link to Figure 10a). The paper also has a few issues with missing figure titles such as Figure 4,5 and insufficient descriptions for each data, line, and color of a lot of subfigures (Figure 4a: sloping blue line). The figures use a lot of double y-axes. It is better to clearly define what each axis mean in the caption or inside the figure, not just by using different color of lines and leaving the potential readers to identify which one is which one. I suggest the authors pay more attention to the details of the figure legends, captions, and subtitles, trying to make sure each figure tells the message on its own.**

   We are deeply grateful that the reviewer has identified these issues, and we have addressed them in the manuscript. In this current version of the manuscript, we have followed the reviewer's comments and carefully evaluated all figures to ensure their clarity. This includes reexamining the text to include references to equations and figures that support these comments. Additionally, we have restructured some aspects of the paper so that our interpretation of model outputs and their significance exists in the "Implications" section. Lastly, we note that some sentences in the text have remained from a previous experiment that was modified between the drafts. While we are uncertain of the source of this error, we are grateful that the reviewer identified these cases. I apologize for the confusion and inconsistency that have been created by my oversight.

2 Specific Comments

1. **Line 4: add are after sediment**

   Done.

2. **Line 41: move to to explore**

   Done.

3. **Line 69: change subglacial the to the subglacial**

   Done.

4. **Line 111: is there a reference for selecting $0.5m^2$ as the limit?**

   There is no reference for this, explicitly. However, it is a common issue in the stability of subglacial hydrology models and has been applied previously in (Delaney et al., 2019). This paper is now cited.

5. **Line 122: is w the same as wc shown in equation 3?**

   w and w_c are different. w_c refers to the width of a channel and is calculated based upon the hydraulic conditions and shape of the subglacial conduit. w refers to a patch of the glacier bed over which sediment can be accessed. In the mesh, this would be the width of a grid cell. To clarify this matter, we have added w to Figure 2 (the cartoon of a cell). The text now reads: w *is the width of a patch of glacier bed perpendicular to the direction of water flow overwhich sediment can be accessed by a channel.*

6. **Equation 16: where does this equation come from? Do you have a governing equation for this equation? What is the difference between the two phi_o?**

   We appreciate this comment and realize how our representation of this an be confusing.

   The text now reads:

   We assume that sediment and water moves across the glacier bed following the steepest gradient in hydraulic potential. On glaciers, we define the hydraulic potential at a cell i in the grid, ϕ_i, based upon the elevation of the glacier bed plus the ice thickness, following Shreve (1972).

   $$\phi_i = f_f \, \rho_i \, g \, (z_{s,i} - z_{b,i}) + \rho_w \, g \, z_{b,i} \quad , \tag{1}$$

   where f_f is the flotation fraction across the glacier, z_s is the glacier surface, and z_b is the glacier bed.

   With this information, we use a multi-cell routing scheme (Quinn et al., 1991) to establish flow routing based upon the steepest hydraulic potential in Equation 16and with a single value of f_f across the glacier bed. We implement this scheme in a similar way as Bovy et al. (2016), but on a regular grid in x and y directions, where fluxes can pass to the four surrounding cells sharing an edge. This routing scheme returns a stack (s_t; Table 3), which contains information about the order of cells to perform the calculations, along with the number of cells flowing in to a cell (donors; n_d), number of cells that a cell contributes (receivers; n_r), and the weight of hydraulic potential and water or sediment discharge directed from one cell to another (w_d or w_r).

   For the first time step, the hydraulic potential ϕ is evaluated under the condition that $f_f = 1$. After the first time step, we assume that the flotation fraction, will vary in response to changing hydraulic conditions such as diurnal or seasonal water input (e.g., Iken and Bindschadler, 1986). In turn, to establish an average flotation fraction f_f across the glacier bed for Equation 16, we use

   $$f_f = \mathrm{mean}\left(\frac{\phi_{o,i}}{\rho_i \, g \, (z_{s,i} - z_{b,i}) + \rho_w \, g \, z_{b,i}} \right) \quad , \tag{2}$$

   where the denominator represents the hydraulic potential at overburden pressure ($f_f = 1$ in Equation 16).

ϕ_0 represents the hydraulic potential evaluated from summing the hydraulic gradient Ψ in Equation 1 up glacier from its outlet. ϕ_0 at each cell i is evaluated as

$$\phi_{o,i} = \Psi_i \cdot \lambda + \sum_{j=1}^{n_r} (\phi_{0,j} \cdot w_{r,j}) \ . \tag{3}$$

Here, Ψ_i comes from evaluating Equation 1 from the receiver cell j of i, λ is edge length of a cell on a regular grid, n_r is the number of receivers that the cell i has, and w_r is the proportion of hydraulic potential fed by the upstream cell j. The operation is executed on a cell by cell basis, beginning at the base of the glacier and moving up the flow paths evaluated in the routing scheme.

7. **Line 184: how to determine the w_{rj}?**

   We evaluate w_{rj} based on the commonly used multi-cell routing scheme from (Quinn et al., 1991). The follow paragraph has been modified from the previous manuscript that describes how w_{rj} is evaluated.

   With this information, we use a multi-cell routing scheme (Quinn et al., 1991) to establish flow routing based upon the steepest hydraulic potential in Equation 16and with a single value of f_f across the glacier bed. We implement this scheme in a similar way as Bovy et al. (2016), but on a regular grid in x and y directions, where fluxes can pass to the four surrounding cells sharing an edge. This routing scheme returns a stack (s_t; Table 3), which contains information about the order of cells to perform the calculations, along with the number of cells flowing in to a cell (donors; n_d), number of cells that a cell contributes (receivers; n_r), and the weight of hydraulic potential and water or sediment discharge directed from one cell to another (w_d or w_r).

8. **Equation 17: What is the difference between** ϕ_o, ϕ^*, and Φ_*? **How does this equation relate to Equation 6?**

   We have rewritten this section, and the text pertaining to this part of the hydraulics is discussed above.

9. **Line 191: what is mn?**

   mn refers to minutes. The text has been simplified to reflect this.

10. **Equation 18: what is the governing equation of this equation?**

    This is simply the accumulation of water as it flows up glaciers given a prescribed melt rate $\dot{m}_w$. In Section 2.1 we write *. . . we prescribe a melt rate $\dot{m}_w$ to establish Q_w . . . .* Here, we simply state how water discharge at a cell is established.

11. **Equation 19: is Qs in the right-hand side the same as Qw defined in equation 18?**

    This is correct. Because Q_s and Q_w are calculated in different ways, we have re-written these equations as:

    Sediment mobilization into a cell $\overline{Q_{s,i}}$ is like-wise computed by implementing Equation 6 from the top of the glacier through the stack as

$$\overline{Q_{s,i}} = \begin{cases} \sum_{j=1}^{n_d} \left(\frac{Q_{sc,j} - Q_{s,j}}{l} \cdot w_{d,j} \right) & \text{if } \sum_{j=1}^{n_d} \left(\frac{Q_{sc,j} - Q_{s,j}}{l} \right) \cdot w_{d,j} \leq \dot{m}_{t,i}\lambda \quad \text{(4a)} \\ 0 & \text{if } H_j = H_{lim} \quad \& \quad \frac{Q_{sc,j} - Q_{s,j}}{l} \leq 0 \quad \text{(4b)} \\ \dot{m}_{t,i}\lambda \ (1 - \sigma(H)) + \sum_{j=1}^{n_d} \left(\frac{Q_{sc,j} - Q_{s,j}}{l} \right) \cdot \sigma(H) \, w_{d,j} & \text{otherwise} \quad \text{(4c)} \end{cases}$$

where $Q_{sc,j}$ is the sediment transport capacity from cell j flowing to i, $Q_{s,j}$ is sediment discharge entering from cell j to cell i, again l is a response length scale and λ is cell length.

Sediment discharge $Q_{s,i}$ out of a cell i is evaluated as

$$Q_{s,i} = \overline{Q_{s,i}} \cdot \lambda + \sum_{j=1}^{n_d} Q_{s,j} \quad . \tag{5}$$

We evaluate the change in till height at a cell by implementing Equation 5 as

$$\frac{dH_i}{dt} = \frac{-Q_{s,i} + \sum_{j=1}^{n_d} Q_{s,j}}{\delta} + \dot{m}_{t,i} \quad , \tag{6}$$

where again δ is cell area.

12. **Equation 21: why do you choose Equation 21 to represent temperature?**

    Equation 21 is the temperature forcing as from the Subglacial Hydrology Model Intercomparison Project (de Fleurian et al., 2018). We have chosen this equation to represent temperature as provides a synthetic way for seasonal and diurnal variations in temperature and thus water discharge to be considered. Additionally, the ΔT term allows us to impose a climate trend on top of the seasonal and diurnal melt patterns. To clarify this matter we have modified the text to read: *To represent hydrology that varies over seasonally and diurnally, we implement a simple spatially distributed melt model as in SHMIP…*

13. **Line 228/Figure 4 caption: From Figure 4, I can see that the sediment discharge is highest at years 19-26, why are you saying the highest discharge is in years 14-17?**

    This was a mistake on our part, and the caption reflected a previous experiment. We have modified the text to read:

    Model output from alpine topography and forcing over a 30 year run with diurnal and seasonal variations in melt input. Grey box represents time period of increasing glacier melt. a) Seasonally varying water discharge (Q_w) increases from year 10 to 20, while till height (H) decreases. b) Annual sediment discharge (green) increases over with increasing melt, with highest sediment discharge occurring in year 19, when glacier melt is greatest. Once the new climate stabilizes, annual sediment discharge stabilizes at a higher level than before.

14. **Figure 4b: the y-labels are the same for the two lines.**

    We thank the reviewer for this comment. However, the orange line represents "instantaneous" sediment discharge and has units ms^{-1}, while the green line is an annual quantity and has units ma^{-1}. We have adjusted some of the text in the caption to reflect this, for example: *Annual sediment discharge (green) increases over with greater melt*.

15. **Figure 4a: it seems the water discharge starts to increase at year 10, but the captions say from year 12. Could you explain?**

    We have addressed this comment above.

16. **Figure 4: subfigure title a, b are missing.**

    These components have been added to the figure.

17. **Line 230: Figure 6 includes 6 subfigures. Which subfigure should I see to support the claim you made here?**

    We have changed the text to reference Figure 6 b, d, f. Text and pointers have also been added to the figures in order to point to processes discussed in the text.

18. **Line 234-239: The descriptions in this paragraph are not well supported by the model results. These descriptions are more like conclusions but are not results. It is hard to link these claims to the results.**

    We understand the reviewer's concern on this matter. In response, we have largely moved this material to Section 5.

19. **Line 242: Figure 5 shows the results are distributed values, which means these variables vary with coordinates x and y. However, I didn't see an equation in the method section describing x and y. What equations are solved to obtain these distributed values?**

    We thank the reviewer for these comments and as mentioned in comments above, we have provided a more through description of our 2D implementation.

20. **Line 243: Figure 4c is missing.**

    The new reference in Figure 4a.

21. **Line 247: Which subfigure in Figure 6 am I supposed to observe to understand the claim here? What is the meaning of early melt season? Do you mean the time at year 8.3? This needs accurate descriptions.**

    We modified the phrasing in the text to read. Additionally, we have chosen to reference Figure 4 as it is a simpler figure, lacking the detail and complexity of Figure 6.

    Additionally, we have added labels to Figure 4 that point to the features we describe.

22. **Line 250: It will be useful to draw a line in Figure 4 to show which time is spring.**

    Done.

23. **Line 251-252: This claim cannot be observed in Figure 4b. I can observe that the highest sediment discharge occurs at years around 11.5 and 16.5. The sediment discharges in this time period do not show a decreasing trend. Where does this claim come from?**

    These sentences have been removed from the text. Our comments come from a previous version of the paper.

24. **Line 253: Need to show where is winter time in Figure 4b.**

    Done.

25. **Line 266-271: In the paragraph at line 260, Figure 6a, b has been referenced, however, the difference between different subfigures is defined in the paragraph at line 270. This makes it hard to understand the paragraph above. The order of these two paragraphs needs to switch.**

    We thank the reviewer for this comment and appreciate the lack of clarity that this could cause. We have largely omitted the first paragraph and moved some of the material to the second paragraph.

    The text now reads:

    For the cases described above, bedrock erosion relies only on driving stress and till thickness. Sliding and bedrock erosion did not vary seasonally with increased subglacial water discharge (Figure 4 a). This causes sediment to accumulate during the winter months, which subsequently provides ample material for transport when melt increases in the spring. To test the effects of spatially variable erosion and the role of hydrology, we present two additional cases to supplement the alpine glacier case above, ORIGINAL. One additional case, SEASON, simulates bedrock erosion by only allowing sliding, and thus erosion, *during the summer months (e.g., Iken and Bindschadler, 1986); the same erosion relationship is applied as the case in Section 3.1. In this case, however, erosion only occurs when the amount of water input substantially exceeds the background basal melt input rate, that is present in the winter. We choose this case to capture the seasonal variations in bedrock erosion (Ugelvig et al., 2018). In the other additional case, CONST, bedrock erosion remains constant over the entirety of the glacier at a rate of* $2\,\mathrm{mm\,a^{-1}}$*, independent of glacier sliding velocity.*

26. **Line 291: As you randomly select parameters, does this mean you are performing a sensitivity study? Why do you need to randomly select these parameters?**

    Given the results that follow, we are performing a sensitivity study of sorts. We have chosen to randomly select parameters as this reduces the dimensionality slightly compared to using a grid search, with uniformly spaced parameters.

27. **Line 300: As the parameters affect the model results, it is necessary to show the final parameters that give the lowest absolute error.**

    The text has been updated to reflect the parameters:

    The parameter search yields an optimum grain size parameter D_m *of* $2\ \mathrm{cm}$*, sliding parameter* B *of* $2.05 \times 10^{-11}\ \mathrm{MPa\,m\,s^{-1}}$ *and initial till height* H_0 *of* $2.5\mathrm{mm}$*. The model's ability to reproduce the validation data largely depends on the grain size parameter,* D_m*. Compared to* D_m*, the sliding parameters and initial condition parameters (*B *and* H_0*) have a reduced influence in representing the data, given that similar values of* B *and* H_0 *can produce largely different results in the context of* D_m *(Figure 7).*

    Additionally, the parameters are presented in Table 2.

28. **Line 304: From Figure 7, It seems the relative error between the model and observation is very large for most years except for the time between 2015-2016. Why do you only say it has trouble during 2012-2013?**

    We thank the reviewer for the comment. In addressing it, we have tried to remove the subjectivity that has been addressed. The text now reads:

    The optimized model reproduces the interannual variability in sediment discharge from the Griesgletscher (Figure 7g). The absolute error between the model and the measurements is roughly $62,600\ \mathrm{m^3}$*. The error from this parameter search is slightly less than half of the* $131,300\ \mathrm{m^3}$ *total sediment discharged from the Griesgletscher over this time period (Delaney et al., 2018). The model runs captures the third period from late* 2014 *to late* 2015 *well. However, the runs systematically overestimate the second and fourth periods and generally underestimate the high discharge period from late* 2011 *until late* 2013 *(Figure 7g).*

    Additionally, we have updated Figure 7 to reflect the outputs of all model runs.

29. **Line 313: How is this claim supported by the results?**

    We appreciate the reviewers comments here and understand how this claim may fall outside of the results supported by this section. As a result, we have omitted this comment and moved all comparisons with the one-dimensional model to Section 5.

30. **Line 314: The absolute error corresponding to B and Ht0 vary a lot. How does this support the claim of "minimal influence" of these parameters?**

    The error corresponding to B and H_0 varies substantially, as the reviewer points out. However, large and small errors can occur for very similar values of B and H_0, and the results do not show a systematic change in model output with respect to B and H_0 as they do with respect to D_m.

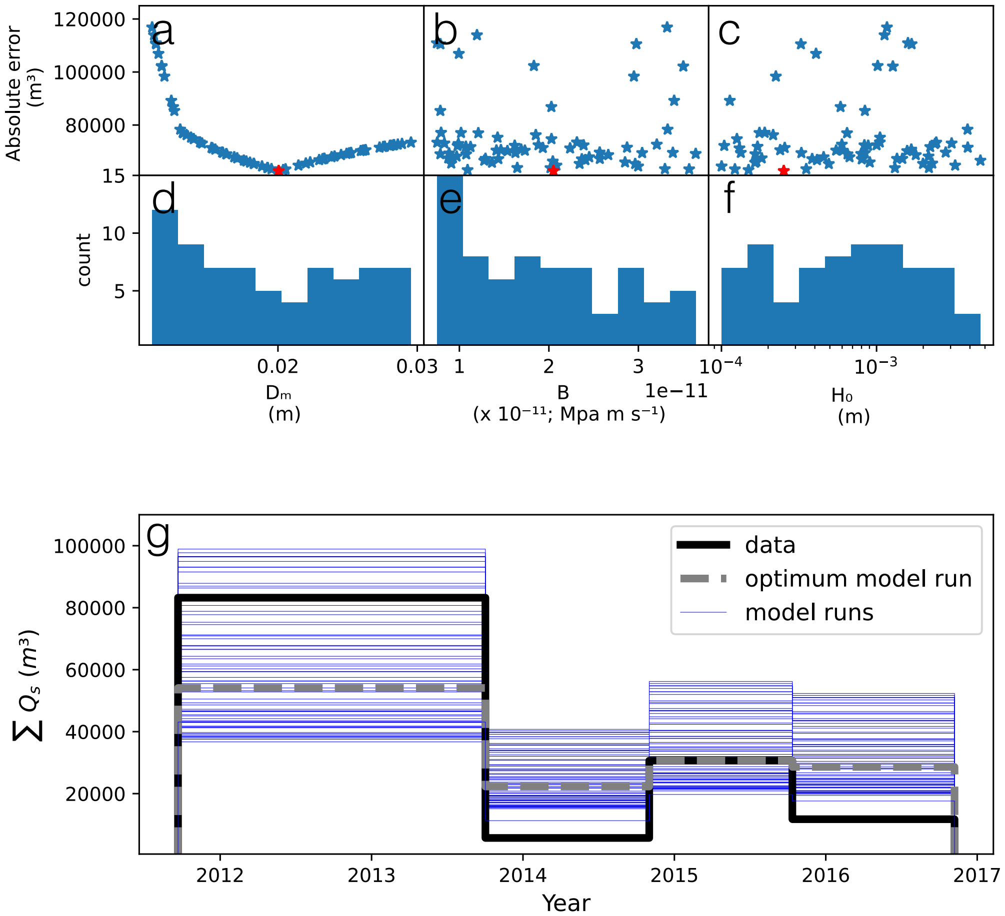

Figure 1: Results of the parameter search (a, b, c), the frequency of parameter values that produced a rank correlation of 1 (d, e, f) and the best fit model run amongst the parameter combinations (g). Red stars represent optimum parameter combination. Blue lines represent all model outputs, while gray line represents the optimum parameter combination.

We have slightly modified the text to make this clearer. It now reads:

The model's ability to reproduce the validation data largely depends on the grain size parameter, D_m. The sliding parameters and initial condition parameters (B and H_0) have a reduced influence, compared to D_m, in capturing the data, given that similar values of B and H_0 can produce largely different results in the context of D_m (Figure 7).

31. **Line 329: In Figure 7e, the units for B is Mpa m/s. How does variable B in Figure B related to the "B" here? It seems the B has a velocity unit here, different from that in Figure 7e.**

    The text we have modified the text slightly to read

    The value of B, from the parameter search, results in an average sliding velocity of $39\ \mathrm{m\ a}^{-1}$, and the range of values for B in the parameter search result in mean sliding velocities roughly between $14\,\mathrm{ma}^{-1}$ and $70\,\mathrm{ma}^{-1}$ (Equation 14).

    We point out that sliding is defined as $u_b = B\tau_b^m$. As a result, the value of B in the parameter search *results* in a sliding velocity, thus we believe that the units are correct.

32. **Line 330: How does this slide speed are calculated? From the model?**

    We appreciate this comment. We have added a reference to Equation 14 in the manuscript (see previous comment). This shows the relationship between basal shear stress and sliding velocity with respect to B that we use to evaluate sliding velocity.

33. **Line 339: How do you calculate this value 2 m^3 s^{-1} ?**

    This sentence has been omitted.

    The best performing model run shows strong temporal variability in sediment discharge. Peaks in sediment discharge occur during the short-lived increases in water discharge (Figure 8 a). Despite the strong dependence on grain size and fluvial transport of sediment in the parameter search, sediment transport capacity Q_{sc} still remains roughly an order of magnitude higher than sediment discharge Q_s (Figure 8 a, b).

34. **Line 341: I guess sediment discharge should be Qs?**

    This has been corrected.

35. **Figure captions: most of the current figure captions include certain explanations of the results. These explanations make the captions very long and not easy to understand. I suggest only including the descriptions for the line title, legends, and meaning in the captions, but leave the explanations of the results in the main text. Please try to make the captions short but can sufficiently tell the meaning of each line.**

    We thank the reviewer for the comment and understand the concerns. We have adjusted the figure captions accordingly.

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