Reviewer 1: Author response

Thank you for the constructive comments on our manuscript.

First, we agree that additional quantitative methods exist to assess glacial lake evolution and GLOF hazard. However, given the limited data availability, uncertainty of many processes, and complexity of the lake bathymetry, glacial bed, and geological setting at Fjallsjökull, our conclusion is that retreat rates resulting from numerical ice flow and calving models with uncertain boundary conditions will not add significantly to the results or change the main conclusions of this study. Thus, we prefer to take the simple approach presented here and to focus on the impact and broad time scale rather than a detailed, but widely uncertain, timing of events. The results of this study also contribute newly collected field data of proglacial lake bathymetry, which provide the foundation for several additional studies along the lines suggested by the reviewer, but which are beyond the scope of our project. We address the separate points of the review in detail below.

1) Glacier retreat/lake growth rates:

Glacier advance and retreat rates depend on numerous factors that we describe in lines 308-317. Estimating the future retreat rate can be done with an ice flow model coupled with a mass balance model at the outlet glacier scale. At Fjallsjökull, however, there is large uncertainty in the climate projections, subglacial bedrock topography, and glacier dynamics, as we explain in lines 320-322. Therefore, our assessment is that applying a numerical model of Fjallsjökull's future retreat rate will not provide more accurate results than extrapolating the current rate. Furthermore, though global scale models have made projections for surface mass balance under different climate scenarios, these have large bias corrections, come with many assumptions, and are 2D flow line models that do not capture the detailed terminus geometry that we focus on in this study.

What we can use in this study with relative certainty based on observations is that the glacier will continue to retreat under a future warming climate, and we use the retreat rate of recent decades to project this into the future. We selected a simple linear rate as a first order approximation based on a recent period of warming (2000-2021), which is the observed retreat rate that most closely matches climate projections (described in lines 139-143). We also explain limitations and likely differences in retreat rates due to lake–glacier interactions in lines 323-339 (Discussion) and 481-484 (Conclusion). While equations to quantify these interactions exist, we decided not to apply them because some crucial input parameters are unknown at Fjallsjökull without knowing future glacier surface mass balance.

However, to clarify these points, we will make these changes in the manuscript:

1. Add a few sentences to Section 5.2 explicitly stating how future glacier retreat rate could differ from the 2000-2021 rate—for example, by discussing studies that project temperature changes in Iceland (i.e. Bosson et al. (2023); Noel et al. (2022)).

2. Revise terminology throughout the manuscript to emphasize that retreat rate projections should be interpreted at an order of magnitude scale, i.e. decades, rather than an exact year.

3. Revise the manuscript title to "Proglacial lake **development**…" instead of "evolution" to emphasize that these are potential scenarios rather than future projections.

4. Add two additional scenarios to the study for estimated future retreat rates to assess result sensitivity: 1) A rate based on projected climate change in Iceland from Noel et al. (2022), where glacier retreat rate slows until ~2040 and then increases; and 2) a faster retreat rate (doubling compared to the 2000-2021 rate) after the terminus enters the northern (deeper) overdeepening in the lake. Though these rates will still be linear, taken together, they will represent three relative "paces" to reflect the influence of overdeepening depth and future climate warming variability.

5. Explicitly state which parameters are needed to quantify lake-glacier interactions such as calving (namely future ice thickness and surface mass balance), expanding the discussion currently in lines 323-339.

2) Potential GLOF triggers:

We agree that methods exist for slope stability/deformation analysis to map potential release zones and landslide volumes. However, we emphasize that this study is a preliminary assessment of future lake development, potential slope failure zones, and GLOF scenarios at Fjallsjökull rather than a comprehensive landslide susceptibility assessment. As the reviewer mentions, field data from geological and structural mapping is necessary to delineate potential slope failure planes and calculate landslide volumes, as we explain in lines 341-343. However, geological mapping in necessary detail has not been done for the Fjallsjökull area; regional geology is too complex to interpret based solely on remote sensing data such as drone or satellite imagery or InSAR; and these mapping methods would be significant projects in themselves and beyond the scope of this study.

However, we will:

1) Expand our discussion after line 343 to specifically list methods (such as InSAR) that could be used to geologically map this area and describe which information they could yield (i.e. likely failure planes; landslide volume; areas of ongoing deformation; existing fractures).

2) Add references that describe the complexity of mapping bedrock at other outlet glaciers of Öræfajökull (Svínafellsjökull and Skaftafellsjökull), which are close to Fjallsjökull:

- Helgason, J., Duncan, R.A., 2001. Glacial-interglacial history of the Skaftafell region, Southeast Iceland, 0-5 Ma. Geology 29, 179–182. https://doi.org/10.1130/0091-7613(2001)029<0179:GIHOTS>2.0.CO;2
- Ben-Yehoshua, D., Sæmundsson, Þ., Helgason, J.K., Hermanns, R.L., Magnússon, E., Ófeigsson, B.G., Belart, J.M.C., Hjartardóttir, Á.R., Geirsson, H.,

Gu, S., Hannesdóttir, H., 2023. The destabilization of a large mountain slope controlled by thinning of Svínafellsjökull glacier, SE Iceland. Jökull 73, 1–33. https://doi.org/10.33799/jokull2023.73.001

3) Displacement wave and GLOF scenarios:

Without comprehensive geological mapping to estimate realistic landslide source areas and volumes into the glacial lake, we cannot accurately model displacement wave propagation, dam breach dynamics, or downstream flood behavior. Though we describe the required input parameters in lines 416-420 and 455-461 and potential displacement wave or GLOF societal and geomorphologic impacts in lines 421-447, we will expand this discussion to explicitly state which parameters are known (i.e. lake bathymetry—new data presented in this manuscript) and unknown (i.e. landslide volume and velocity) in Section 5.4.

Second, our study is a preliminary assessment, but we argue that this does not reduce its scientific contribution. This is the first study that investigates mass movement-triggered GLOF hazard in Iceland (with the exception of a 1967 paper that described the geomorphologic impacts of the only documented event in Iceland). The study of Fjallsjökull's environment and GLOF risk is designed to be a pioneering example of assessing this emerging hazard at glacial lakes in Iceland. Our method enables identification of sites that should be top priorities for future studies and/or monitoring, which is especially important in areas like Fjallsjökull with rapid increases of visitors and infrastructure development, but where detailed site studies are time-consuming and costly. This approach can also be applied to other global proglacial areas that, like Iceland, are understudied but rapidly changing; in other words, where the growth of potential risk is outpacing the speed of research. We will emphasize this broader application and objective in the Introduction, Conclusion, and end of Section 5.4 (lines 454-466), and also list examples with relevant citations of additional sites that should be prioritized for future study due to increasing tourism and mass movement-triggered GLOF potential in Iceland (i.e. Svínafellsjökull and Sólheimajökull) and other global proglacial areas (i.e. Alaska).