Referee #1

We thank the reviewer for their comprehensive and constructive comments on our work. Below, we present their comments in blue font and describe how we plan to address these comments in a revised manuscript in black font. References to specific lines refer to the initial manuscript.

R1C1: This is a clearly written paper which explains the somewhat unusual situation of increasing large outburst floods occurring from an ice-dammed lake in Alaska during a period of rapid glacier thinning and retreat. There have been few other studies which have described this unique situation before, and this one was a pleasure to read as it well supported by a variety of comprehensive remote sensing datasets and analyses, and a number of useful figures. I believe that it is worthy of publication, and will add to the growing knowledge of glacier lake outburst floods.

R1A1: We thank the reviewer for the positive appraisal of our work.

R1C2: My comments are generally very minor, with the exception being the question of whether the lake outburst volume has decreased (perhaps even rapidly?) after 2015. As described in my comments for L425 below, this is a major current limitation with the study as the other datasets for lake area and lake level extend to 2023 (see Fig. 2). If the lake volume estimates could be extended to 2023, and found to be decreasing, then this would change one of the main thrusts of the paper, and perhaps even require the title to be changed from '*larger* lake outbursts'. I encourage the authors to investigate whether other DEM datasets are available that could be used to resolve this question.

R1A2: We would like to refer to our detailed reply **R1A15**.

Individual Comments

R1C3: L23: change to: 'to up to ~700…'

R1A3: We will change our wording accordingly.

R1C4: L39: I thought that we only had two ice sheets, unless you're calling East and West Antarctica separate ice sheets? Hugonnet et al. (2021) (as well as most other studies) only refer to two ice sheets, the Greenland Ice Sheet and Antarctic Ice Sheet, so I suggest that you specify two here.

R1A4: Yes, we were referring to East Antarctica, West Antarctica, and Greenland. However, we agree with the reviewer that Antarctica is more commonly referred to as one ice sheet in the literature. Therefore, we will change the wording as following: (L38-39) "…accounting for a quarter of the total global glacier mass loss outside the *two* ice sheets (Hugonnet et al., 2021)".

R1C5: L75: change 'storing' to 'storage'

R1A5: We will change our wording accordingly.

R1C6: L89: you state that Alaska has 667 glacier lakes, but this is incorrect: as stated in the title of Rick et al. (2022), this total is for Alaska and NW Canada. A pet peeve of mine is that studies such as yours seem to implicitly assume that Canada is part of Alaska, when clearly this isn't true! Throughout your paper you need to ensure that you properly define which area Alaska refers to, and include Canada when necessary.

R1A6: We thank the reviewer for pointing this out. We will now explicitly focus on lakes in Alaska and will change these statistics based on a manually mapped glacier lake inventory by Zhang et al. (2024): (L89) "In 2020, Alaska hosted 1,408 glacier lakes >0.05 km^2, 132 of which were ice-dammed lakes (Zhang et al., 2024)."

R1C7: L95: figures should be referenced in sequence: you're referencing Fig. 6 here, but haven't even referenced Fig. 1 yet.

R1A7: We will adjust the reference sequence in the manuscript accordingly.

R1C8: L165: change 'which assume' to 'which are assumed'

R1A8: We will change our wording accordingly.

R1C9: L176: missing a bracket after ρ
R1C10: L178: need to enter symbol for area between the brackets
R1C11: L180: symbol and bracket missing at start of line

R1A9-11: We thank the reviewer for identifying these errors and will correct them accordingly.

R1C12: L192: presumably there is also an uncertainty from the change in surface elevation between the acquisition date of the 2019 ArcticDEM and the June 2023 radar survey? Your results suggest that this can amount to several metres per year.

R1A12: We thank the reviewer for bringing this to our attention and will add this as following: (L192) "Uncertainties in ice thickness stem from possible deviation from the assumed radar wave speed (±2 m/µs), from the accuracy with which a return can be picked (about 0.1 µs), and from the interpolation from the discrete point measurements. Based on cross-over analysis from similar surveys, we estimate uncertainties to be ±20 m (e.g., Tober et al., 2023). *Uncertainties in bed elevation further stem from the surface elevation extracted from the 2019 DEM. Based on our latest estimate of elevation change (2013-2019), we expect the glacier surface to have further lowered ~13 m on median between 2019 and 2023."*

R1C13: L335: -2.9 requires a unit (presumably m)

R1C13: We will add the unit.

R1C14: L356 (& L409): some references that are missing here and describe opposite patterns (lake drainage volumes increasing over time) are Kochtitzky et al. (2020) and Painter et al. (2024), who describe how releases from ice-dammed Dań Zhùr (Donjek) Lake, Yukon, have been increasing towards present day, primarily as a result of a larger basin becoming available for the lake to form in as the glacier retreats. These damming events and subsequent releases are primarily controlled by glacier surging, but share some similarities to what is being described in this study and so it seems that they should be mentioned:

Kochtitzky, W., Copland, L., Painter, M. and Dow, C. 2020. Draining and filling of ice dammed lakes at the terminus of surge-type Dań Zhùr (Donjek) Glacier, Yukon, Canada. Canadian Journal of Earth Sciences, 57, 1337-1348

Painter, M., Copland, L., Dow, C., Kochtitzky, W. and Medrzycka, D. 2024. Patterns and mechanisms of repeat drainages of glacier-dammed Dań Zhùr (Donjek) Lake, Yukon. Arctic Science, 10(3), 583-595. https://doi.org/10.1139/as-2023-0001

R1A14: We thank the reviewer for bringing these studies to our attention. We will highlight them in our revised discussion: (L380) "However, the lake was able to grow greatly in length and freed a ~5 km-long reach of the valley from ice within a few years. Similar observations have been made for Suicide Basin at Mendenhall Glacier, located ~200 km southeast of Lituya Bay, *and Dań Zhùr Lake at Donjek Glacier, ~300 km northwest of Lituya Bay,* where the lake volume*s* increased due to progressive deglaciation of the basins (Kienholz et al., 2020; *Kochtitzky et al., 2020; Painter et al., 2024*). *However, damming Dań Zhùr Lake followed glacier surges, sealing off the river discharge in the main valley trunk, and thus differs from the case of Suicide Basin and Desolation Lake.*"

R1C15: L425: This is a key point that needs to be better investigated. One of the main contentions of this study is that drainage volumes from Desolation Lake have been increasing over time, but no outburst volume estimates are provided after 2015 (Fig. 2b), during a multi-year period when the level of Desolation Lake is rapidly dropping (Fig. 2c). This lack of recent volume estimates seems to be due to the lowest lake level being 197 m in an ArcticDEM from 2020-09-11. My expectation is that the lake volume dropped after 2015, which if quantified would add significantly to the story being presented, and perhaps change some of the final conclusions. The solution to providing outburst volumes after 2015 would be to use a base DEM collected when the lake is at a lower level than 197 m. I'm unsure how much searching the authors have done for datasets beyond the ArcticDEM, but there are several potential sources of DEM information for this period that address this issue:

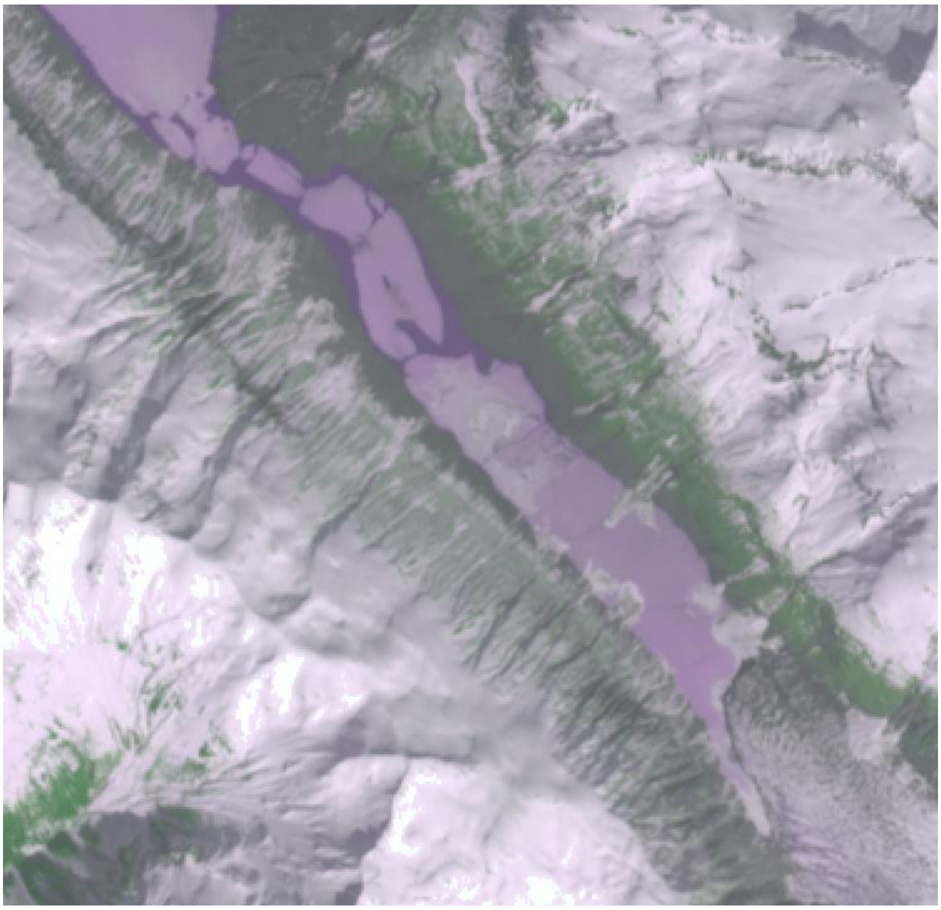
- The USGS collected LIDAR data over at least part of the lake in summer 2019, which can be downloaded from: https://portal.opentopography.org/usgsDataset?dsid=AK_GlacierBay_B3_2019
- DEMs can be generated for free from stereo ASTER imagery, acquired regularly up to present day: https://lpdaac.usgs.gov/products/ast14demv003/
- Cryosat data has been collected since 2010, and standardized datasets are now available such as CryoTEMPO Inland Water which might provide useful elevation data: http://cryosat.mssl.ucl.ac.uk/tempo/index.html
- IceSAT2 has been operating since 2018, with elevation data from tracks over the lake available to download from locations such as: https://openaltimetry.earthdatacloud.nasa.gov/data/icesat2/

R1A15: We agree with the reviewer that extending the time series of drainage volume could strengthen the discussion and conclusions. We also appreciate the new data sources, some of which we were not aware of before. By searching for suitable DEMs, we had compared different products such as the SRTM DEM, the USGS Glacier Bay Lidar product or the ASTER GDEM. We had selected the 2020 strip of the Arctic DEM because it captures the entire lake surface at the lowest observed level. The 2-m resolution of Arctic DEM is a suitable baseline to robustly estimate lake levels along the steep slopes of Desolation Valley.

Unfortunately, we cannot extend the time series of drainage volumes beyond 2015 using the data suggested by the reviewer. In most cases, we found the lake either veiled in clouds, or no DEMs were available after the drainages in the missing years (2016-2023), in which the lake could be captured at a lower water level than 197 m (height above ellipsoid). Due to the progressively lower post-flood lake levels that we show in Fig. S5, we would require an elevation dataset obtained directly after the latest drainage event to extend the time series until the present. We explored all data sources suggested by the reviewer to test if at least some years following 2015 could be assigned a flood volume. The reasons to exclude the individual data sources are as follows:

- **USGS Lidar data:** This dataset does not fully cover the lake and thus does not allow us to calculate further drainage volumes by filling the DEM to estimated lake levels.
- **ASTER imagery:** We are concerned about the suitability of the ASTER-DEMs to estimate the lake levels and flood volumes of Desolation Lake. The quality of ASTER-images and the resulting DEMs is limited due to satellite jitter that might remain even when extensive correction workflows are applied. Due to the ice cover, low-contrast regions are abundant in our study region and these are problematic for jitter correction, as described in detail by Girod et al. (2017). In addition, cloud-free ASTER images of Desolation Lake are sparse and most available data capture the lake above the 197 m lake level of the

Arctic DEM. We found only one image obtained on 2024-05-08 that captures the lake at a level that would allow us to obtain some further estimates between 2016 and 2019. Yet, we remain cautious about the suitability of a DEM created from these data, in addition to our general concerns, as the lake shore was partially covered with snow avalanches or ice at the time of acquisition:



Aster image of Desolation Lake on 8 May 2024 showing the shore of Desolation Lake partly covered by snow or ice.

- **Cryosat:** This dataset might be valuable for our future work. However, the water areas in Alaska, except for Mackenzie River, are not part of the Inland Water product; neither in the region "USLakes" nor any of the other available spatial subsets of the data.
- **ICESat-2:** Creating a DEM at a level below 197 m is challenging using the IceSat2 point samples because we need optical satellite images from the same date to first delineate lake contours and then interpolate the Arctic DEM within the lake boundaries. However, in all but one case, the ICESat-2 lake level data were obtained either during a high stand of the lake or during periods when no satellite images were available due to the low solar angle in December. The only suitable pair of ICESat-2 and Planet images from March 2024 shows the lake heavily covered with snow and ice, so mapping the lake boundary was impractical. Therefore, we could not obtain further drainage volumes to quantify the apparent decrease in post-flood lake levels and volumes. Nevertheless, ICESat-2 data provide further information on the lake levels in reference to our mapped outlines. We will include this in the manuscript as follows: (L143) "Between 2016 and 2023, there are no elevation measurements for post-flood levels below the 2020 ArcticDEM lake level, hindering the approximation of outburst volumes. *For this time period, we use ICESat-2 data obtained through the OpenAltimetry Explorer (https://openaltimetry.earthdatacloud.nasa.gov/, last access: 2024-11-11) to track lake level changes of Desolation Lake."*

In L235, we will add: "The post-flood levels decreased in a similar manner and dropped below the DEM-derived lake level of 197 m h.a.e. in 2016 (**Fig. 2c**), *hindering the approximation of outburst volumes between 2016 and 2023*. Satellite images show that the lake continued to decrease in width in the following years, indicating that the post-flood lake levels have further dropped since *2015* (**Fig. S5**)*. In reference to our mapped lake outlines, ICESat-2 data acquired approximately 2 months after a drainage* *event in summer 2020 show that the post-flood levels dropped below 183 m until then (**Table S3**). Since 2021, post-flood levels have remained below 172 m, accounting for a decrease of at least 25 m within six years.* In 2023, the last year of our record, *the pre-flood lake level remained* below the DEM lake level of 197 m h.a.e..”

Furthermore, we will add to our conclusions: (L521) “*A lack of suitable data prevent us from making volume estimates after 2016, leaving open the possibility that lake volumes have recently decreased. Yet,* we observed that the expansion of the lake ceased around 2014, followed by a 4 km² decrease in surface area. In this context, we speculate that Desolation Lake already has returned to the jökulhlaup cycle with diminishing flood volumes (…).”

Table S3: Lake levels of Desolation Lake acquired by ICESat-2.

Date	Lake level
2019-03-31	195 m
2019-09-29	188 m
2020-03-28	209 m
2020-03-29	209 m
2020-06-27	218 m
2020-09-26	183 m
2021-12-24	172 m
2022-12-22	172 m
2022-12-23	172 m
2024-03-21	176 m

R1C16: L446: dam flotation and subsequent channel enlargement has also been invoked as the casual mechanism for floods from Donjek Glacier by Painter et al. (2024)

R1A16: We will include this case in L446: “Dam flotation and subsequent channel enlargement have been inferred for other ice-dammed lakes, including Gornersee, Switzerland (Huss et al., 2007), Hazard Lake, YT, Canada (Clarke, 1982), Hidden Creek Lake, Kennicott Glacier, Alaska (Anderson et al., 2003), and the ice-marginal lakes at Russell Glacier, Greenland (Carrivick et al., 2017) *and Donjek Glacier, YT, Canada (Painter et al., 2024)*.”

R1C17: Fig. S8: this graph is noisy, presumably because you included all available image-pair velocities no matter their separation time? You should be able to reduce this noise by removing image pairs with short and long similar separation times. For example, I used the ITS_LIVE widget tool (https://itslive-dashboard.labs.nsidc.org/) to only plot data with separation intervals of 30-300 days for your location, which produced a cleaner signal than yours.

R1A18: We thank the reviewer for this suggestion. We will replace the figure and now only include data with separation intervals of 100 and 200 days, for which we find a significant reduction of noise compared to the previous graph including all image pairs:

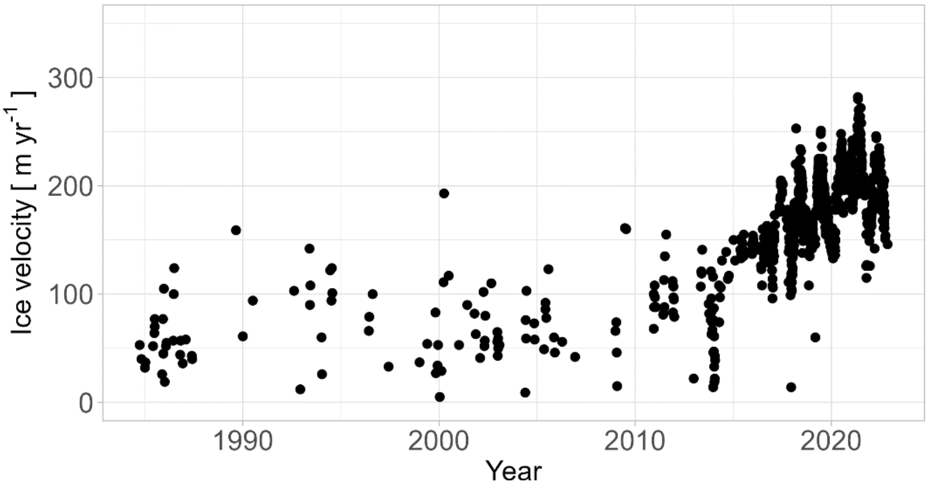


Fig. S8: Ice velocity of Fairweather Glacier at 58.8078°, -137.6848° between 1984 and 2022 extracted from the ITS_LIVE dataset (https://its-live.jpl.nasa.gov/, last access: 2024-11-18). To reduce noise, we only use data obtained in separation intervals of 100 to 200 days.

References

Girod, L., Nuth, C., Kääb, A., McNabb, R., and Galland, O.: MMASTER: Improved ASTER DEMs for elevation change monitoring, Remote Sensing, 9, https://doi.org/10.3390/rs9070704, 2017.

Zhang, T., Wang, W., and An, B.: Heterogeneous changes in global glacial lakes under coupled climate warming and glacier thinning, Communications Earth & Environment, 5, 374, https://doi.org/10.1038/s43247-024-01544-y, 2024.