A Framework for Automated Supraglacial Lake Detection and Depth Retrieval in ICESat-2 Photon Data Across the Greenland and Antarctic Ice Sheets

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General comments:

This manuscript uses ICESat-2's ATL03 altimetry product to develop two new algorithms which together provide a scalable framework for supraglacial lake detection and depth determination from ATL03 data.

Surface melt is an important, yet poorly constrained, component of ice-sheet surface mass balance, leading to surface meltwater accumulating as lakes on ice-shelf surfaces and on grounded ice. In Antarctica, this has been linked to the process of meltwater-driven hydrofracture, which can trigger rapid ice-shelf collapse. Accurately measuring supraglacial lake meltwater depths from satellite data is important due to the challenges in obtaining in situ measurements and is needed for modelling meltwater interactions with ice sheet dynamics. However, few studies have developed automated lake depth estimation methods that are scalable beyond small data subsets, and previous studies rely on methods with poorly constrained parameters and a lack of in situ measurements.

The authors apply their algorithm framework to two regions that experience high surface melt (central west Greenland and the Amery Ice Shelf) and are able to reliably detect lakes where lake bathymetry is visible. The methodology appears robust, and the algorithm performs well even for more complex lakes (especially in Antarctica), including thin, elongated lakes and those with patchy ice cover. The authors found 1249 lakes with their algorithm during four melt seasons and conclude that lake depths agree well with manually-picked lakebeds in ICESat-2 along-track segments.

Overall, it is my view that this study is of broad interest to the cryospheric community as it builds upon previous work focused on supraglacial lake depths on both ice sheets, especially in the context of ice-shelf surface hydrology and dynamics, by paving the way for developing pan-ice sheet supraglacial lake depth and volume products. I think the surface hydrology and ice shelf communities would be very interested to see this algorithm applied at an ice-sheet scale in future.

In general, this is a very well-written manuscript with detailed methods, clear figures and most of my comments are relatively minor. Once the authors address these, I can therefore recommend that this manuscript is suitable for publication in *The Cryosphere*.

I have a few general points:

1. The manuscript could elaborate in a bit more depth about how this algorithm framework approach differs from previous algorithms that have been developed for supraglacial lake depth/bed detection with the same ICESat-2 product (e.g. Datta and Wouters, 2021, who use ICESat-2 ATL03 to derive lake depths and constrain empirically-derived depths from Landsat 8, Sentinel-2, PlanetScope and SkySat imagery). It is clear to me that previous approaches have been tested on small subsets and so are not as scalable as the approach presented here, but I think more detail could be provided for readers.

2. 'Lakes with a bathymetric signal' is referred to often throughout the manuscript, and I suggest perhaps the first time this is mentioned adding for clarity: 'lakes with a bathymetric signal, i.e lakes with a visible or partly-visible lakebed'.

3. Performance of the SuRRF algorithm is compared to manual baseline estimates in Section 4.2.2, but I think this could be interesting to elaborate briefly on how the depth estimates are different from results that derive depths using the Radiative Transfer Equation (given that this is a commonly-applied

method). For example, does SuRRF tend to detect deeper lakes, implying previous methods underestimate lake depths?

4. For those who are less familiar with distributed High-Throughput Computing, how widely useable is this algorithm for others to whom the OSG Open Science Pool is not accessible, aka. non-US-based researchers?

Specific comments:

L30: I would cite something more relevant than this EGU abstract here, e.g. Gilbert and Kittel (2024), https://doi.org/10.1029/2020GL091733.

L34: Perhaps add a sentence or two here about what direct observations of supraglacial lake depths do exist, particularly in Antarctica (to highlight the paucity of observations).

L109: add where these in situ measurements were collected (west Greenland).

L484: I would rename the labels ‘CW < 200 m’ and ‘B-C < 1000 m’ to ‘Surface Elevation < 200 m’ and ‘Surface Elevation < 1000 m’ for clarity, or else clarify this in the figure caption.

L543: could also add here that lakes typically are advected downstream year-on-year (e.g. Arthur et al., 2020).

L579-585: This explanation for differences in lake elevation-depth relationships could be better cited. For example, Banwell and MacAyeal (2015) highlight lake deepening by lake-bottom ablation.

L613: I’m not sure about the overall relevance of Section 4.3 and don’t think it adds substantially to the manuscript, because the algorithm application to ocean bathymetry, inland waters or sea ice melt ponds is less relevant in the context of this manuscript. I would suggest removing this section and moving the content from ‘The ephemeral nature of supraglacial lakes…’ to further up in the introduction as justification for your algorithm.

L630: I don’t entirely agree with the part of this sentence that states the calculated water depths prevent the calculation of lake volumes. Surely it would be possible to calculate lake volumes by combining the ICESat-2-derived depths with lake extents derived from optical imagery (Landsat 8) as an initial estimate? I do understand though that with the small datatset you present here it is not enough to track the meltwater through the melt season.

Technical/minor corrections:

In some places the Surface Removal and Robust Fit algorithm is referred to as SuRRF and in others as SuRFF, so check throughout for consistency.

L178: delete ‘each’ (same on L653).

L611: Is a word missing here? ‘.. in between our (deeper) SuRRF estimates *and* the (more shallow) manual baseline estimates’.

L640: don’t hyphenate ‘well-enough’.

L710: ~~it’s~~ origin → its origin