

The Cryosphere Discuss., referee comment RC2
<https://doi.org/10.5194/tc-2022-122-RC2>, 2022
© Author(s) 2022. This work is distributed under
the Creative Commons Attribution 4.0 License.

Comment on tc-2022-122

Anonymous Referee #2

Referee comment on "Subglacial lake activity beneath the ablation zone of the Greenland Ice Sheet" by Yubin Fan et al., The Cryosphere Discuss.,
<https://doi.org/10.5194/tc-2022-122-RC2>, 2022

I really don't think the main premise of this study is correct. The authors have found 61 locations on Greenland where ICESat-2 and ArcticDEM strips indicate that the ice-sheet surface height has changed, and they take these changes to indicate the presence of subglacial lakes, in some cases arguing that the temporal pattern of height change is diagnostic of subglacial lake activity. I think the simplest assumption, that needs to be carefully considered, and requires strong evidence to be disproven, is that the height changes observed here are the result of supraglacial lake activity.

I did a spot check of the locations in table S2 against Google Earth, and, of the locations for which Google Earth had high-resolution imagery available (i.e. most of the west-coast lakes, and most in the far northeast), every single one had at least some sign of a supraglacial lake, although most were not identified in column I as being twinned with a supraglacial lake. In some cases, the lake was partially snow covered, and in others it was drained at the time of the Google Earth imagery, but it seems plausible that all of the observed height changes were a result of supraglacial water motion. It appears that the authors only identify lakes as being associated with a supraglacial lake when they can clearly see a double surface in the ICESat-2 data, but inspection of visible imagery is an easy way to see whether a particular location is in a lake basin, and it's often possible to see water at the surface.

Supraglacial lakes are known to be common in the ablation areas of Greenland. They can fill and drain in a single season, or can be present over multiple years, freezing partially or completely in the winter, and often have lids of frozen lake and snow that may or may not melt in the summer, and whose height can vary over time as water flows into or out of the lake (for example, the lake in figure S1 appears to be partially covered with frozen lake ice). As a result, height changes at the surface of the ice sheet may reflect changes in supraglacial lake volume, even when water is not visible at the surface. Because of this, any height-change within a lake basin should be suspected to be as a result of supraglacial processes. These can include not just changes in the level of exposed water, but also, changes in water level below a floating layer of lake ice, or enhanced ablation due to water flow or due to the presence of low-albedo sediments in the lake basin.

For a few of the lakes, water is obviously present in the ICESat-2 data, and the authors have attempted to use a technique based on ATL03 photon data to measure changes in the lake-bed height at times when the lakes are ice filled. This technique (the Watta algorithm) involves estimating the depth of the lake water based on the returns from the surface and bottom of the lake. There are two problems with the current study's estimates of ice-surface height (i.e. lake-bottom height) based on these results. First, the return from the bottom is typically quite diffuse, so that the photons used for measuring the lake bottom can come from a range of depths below the lake bottom itself. This leads to an uncertainty in the depth that is not quantified here; because lighting conditions, sediment load on the bottom of the lake, and the scattering characteristics of the lake bottom could all influence the diffuseness of the bottom reflector, it seems likely that uncertainty in identifying the height of the lake bottom in the ATL03 data could lead to substantial scatter in estimates of lake-bottom height and thus to apparent height and volume change where there is none. Second, the authors use the lake-bottom heights as calculated from (presumably) single ICESat-2 beams to replace the heights in the ATL11 time series (see my comment on line 124) without using the ATL11 polynomial surface to correct for the position of the measurements relative to the ATL11 reference point. This can lead to potentially large inconsistencies between the ATL11 time series and the heights from the Watta algorithm.

If the supraglacial lakes are paired with subglacial lakes, there should be a diffuse lake-like signal that extends outside the supraglacial lake boundary. It might sometimes be possible to see the water that leaves draining supraglacial lakes as it inflates the subglacial water system. However, in the few examples where this kind of behavior has been observed using GPS (see Das et al, 2008), the uplift was so brief that it would require considerable luck to observe it with ICESat-2 or with a Worldview DEM.

Comments on specific lines within the paper follow.

Line 47: "ICESat-2 has an improved footprint size (approximately 17 m with 0.7 m along-track)." The authors should be clear that the footprint size is 11 m (not 17, see Magruder et al, 2020) and the along-track pulse-to-pulse spacing is 0.7 m.

Line 90: "The elevation-change anomaly associated with subglacial lake filling and/ or drainage should have a characteristic spatial pattern comprising an obvious elevation anomaly at the lake center while the outside remains stable." I don't think this is necessarily true. For a lot of subglacial lakes, the height-change signal is fairly spatially diffuse, with smooth variations in the height-change signal reflecting the flexure of the ice. It seems reasonable for subglacial-lake-driven height changes to be smooth at a scale of around one ice thickness. Truly sharp spatial patterns in height change are more likely associated with supraglacial lakes.

Line 100: "Subglacial lakes which also coincided with elevation anomalies during the ArcticDEM period were confirmed as subglacial lakes" Is this the definition of "confirmed" and "unconfirmed?" I don't think this is a good way to confirm that a given lake is subglacial rather than supraglacial—ArcticDEM data can show height changes associated with changes in lake ice on top of supraglacial lakes, and can show height differences between filled supraglacial lakes with frozen lake ice and drained supraglacial lakes. Similar problems can be seen in comparisons between ArcticDEM and ICESat-2 data.

Line 124: "The bottom height was taken as the corrected ATL11 elevation"—I take this to mean that the bottom height calculated based on the Watta algorithm was used in place of the elevation from ATL11 for that cycle. Simply replacing an ATL11 value with a single-beam elevation from ATL03 risks mixing values that have had different corrections applied. ATL11 heights are calculated relative to the ATL11 reference surface, which takes into account the local shape of the ice-sheet surface. The appropriate way to do this calculation would be to use the ATL11 polynomial coefficient fields to calculate the height of the reference surface at the location of the Watta height estimate, and subtract the reference surface height from the Watta height.

Line 125 (figure S1). As noted in my comment about line 90 (above), the surface-height changes associated with subglacial lakes in Antarctica are spatially smooth, which is expected based on the mechanics of ice deformation. Although the authors do not plot the height change they would estimate between 2019 and 2020, the difference between the lines in figure S1b indicates that it would be fairly jagged. This suggests to me that at least part of the signal visible in figure S1 is either due to errors in the bottom-height estimate from the Watta algorithm or due to melt.

Section 3.4 (129-136): I don't see a good reason to believe that subglacial lakes on Greenland should show the "multi-year pattern of filling and then rapid drainage" that the authors take as indicative of a subglacial lake. Supraglacial water inputs to the bed of the Greenland ice sheet are large and seasonal, which could quickly fill or overflow subglacial lakes, leading to filling and drainage on subseasonal timescales.

Section 3.5. I don't see a description of how height anomalies are calculated. In figure 3 and in table S4, some of the lakes have anomalies that are always negative or always positive. To what are these anomalies relative?

Section 3.6: This section should come before section 3.2, where the results of the ArcticDEM strip registration are used to try to confirm the lake locations.

Line 145: what does it mean that "the effect of the buffer size on the elevation-change rate was neglected"? Does this mean that the authors do not account for the effect of the buffer size in their uncertainty calculations? Or does it mean something else?

Line 177: “missed by ICESat-2”—do the authors mean that the lakes locations were sampled by ICESat-2, but no height anomaly was detected? This would be typical for subglacial lakes in Antarctica, which often show episodic activity.

Line 179: “No classic bright, flat and strong reflections were found from analysis of RES data.” How many of the lake locations were directly sampled by RES surveys? I’d be surprised if all 61 were. Please specify which were and were not sampled.

Line 184: “ However, since lakes occur 185 at all latitudes, we infer that their occurrence has no connection with the spatial density of ICESat-2 tracks.” Obviously, the occurrence of subglacial lakes has no connection with the spatial density of ICESat-2 tracks. The detection of the lakes, on the other hand, almost certainly does, because many of the lakes are small compared to the track-to-track spacing of ICESat-2 data. It seems likely that at low latitudes, ICESat-2 misses many more lakes than it does at high latitudes.

187-197—the simplest explanation for the association between the lakes in this study, negative surface mass balance, and thin snow cover, is that the lakes observed here are supraglacial, not subglacial.

198-204 : the sizes of the lakes are also consistent with supraglacial, not subglacial lakes.

References:

Das SB, Joughin I, Behn MD, Howat IM, King MA, Lizarralde D, Bhatia MP. Fracture propagation to the base of the Greenland Ice Sheet during supraglacial lake drainage. Science. 2008 May 9;320(5877):778-81. doi: 10.1126/science.1153360. Epub 2008 Apr 17. PMID: 18420900. =

Magruder, L. A., Brunt, K. M., Neumann, T., Klotz, B., & Alonzo, M. (2020). Passive ground-based optical techniques for monitoring the on-orbit ICESat-2 altimeter geolocation and footprint diameter. Earth and Space Science. <https://doi.org/10.1002/essoar.10504571.1>

