

Review of “Volumetric evolution of supraglacial lakes in southwestern Greenland using ICESat-2 and Sentinel-2” by Feng et al.

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General comments

This paper was an absolute joy to read. I believe it to be a great addition to the literature. In particular, comparing machine learning methods against the more traditional methods will help future researchers and bolster our scientific understanding of lake depth calculation. I have some comments (the vast majority of which are purely technical, so please do not be concerned by the number) that I would like addressed before publication.

Specific comments (minor)

Introduction –

1. Line 31-32, you refer to Shepherd et al. (2020) here but there is no corresponding reference in your references list. Please add one.
2. Line 46, remove “U-net”. This is a convolutional neural network and is therefore already included in your list within “convolutional neural networks”.
3. Line 48, I am unsure what you mean here by “favorable outcomes”, perhaps give an example or remove this statement as it is currently vague. Suggest removal of “in the area extraction of SGLs” or changing to “SGL area extraction” for readability.
4. Line 49, change “the area extraction of SGLs” to “SGL area extraction” for readability. Change “observation” to “calculation” as you are not observing.
5. Line 50, suggest change “reason” to “factor” (personal preference).
6. Line 54, change “data coverage insufficient” to “data coverage which is insufficient” for readability.
7. Line 58, Philpot (1987) is the original paper which outlines the radiative transfer equation for calculating supraglacial lake depth. See References section at the end of this review. Remember to remove other Philpot reference from References list once no longer in use.
8. Line 70-71, suggest rewording from “By measuring the height difference between the surface and bottom photons, the depth of SGLs can be calculated.” To “The depth of SGLs can be calculated by

measuring the height difference between the surface and bottom photons.” Front-loading this sentence makes it easier to parse.

9. Line 85, suggest change “utilized” to “used” (personal preference).
10. Line 93, I think there should be a slight change here unless I am misunderstanding the sentence. I think it should be “The use of machine learning-combined optical images” instead of “The use of machine learning combined optical images” but this is only true if the optical imagery has been combined by machine learning methods. Otherwise, I would suggest altering this sentence to read “The use of machine learning to combine optical images and altimetry data”. As it is, this sentence is difficult to understand and needs to be altered in some way.
11. Line 97, suggest changing “intending to combine” to “leveraging”.

Study area –

12. Line 123-124, suggest changing “Sentinel-2 consists of two polar-orbiting satellites (Sentinel-2A and Sentinel-2B), and the dual satellite operation allows Sentinel-2 image data to provide a” to “Sentinel-2 consists of two polar-orbiting satellites (Sentinel-2A and Sentinel-2B), which provides a”
13. Line 128, change “Considering that SGLs occur only below” to “Considering that SGLs only form below”
14. Line 133-136, I am confused by the two sentences starting, “It should be noted that the” and “Therefore, we use”. Are you using multiple images from different days to make a composite image of one day which you then consider to be the ‘average’ day? You need to rephrase these sentences and make them easier to understand.
15. Line 139-140, suggest changing from “It can provide elevations of sea ice, land ice, forest canopies, water height, urban areas, etc.” to “In achieving this objective, it can provide elevations of sea ice, land ice, and water height amongst other data” – the forest canopies and urban areas are irrelevant for your study.
16. Line 140-141, change “Equipped with the topographic laser altimetry system Advanced Topographic Laser Altimeter System (ATLAS)” to “Equipped with the advanced topographic laser altimeter system (ATLAS)” – the first part of the sentence is made redundant by the name of the laser altimeter system.
17. Line 144, please add a citation for this revisit time, I am assuming it is Neumann et al. (2021) but this is not made immediately clear.
18. Line 146, remove “ellipsoid as the” as it is not necessary.
19. Line 153, suggest change “utilized” to “used” (personal preference)

Results –

20. Line 232, you mention that there are 28 lakes in this line, but you show (what I presume are) 35 unique lakes in Fig. 4. Is it just that only 28 of these lakes coincide with the ICESat-2 track? If so, you need to change “, coinciding” to “which coincide”. At the moment, this is unclear.
21. Line 234, suggest change “utilized” to “used” (personal preference)
22. Line 262, reword the sentence beginning “Within the 1-2 m range”, it is currently confusing to read and longer than it needs to be.

Specific comments (major)

General to the whole paper –

23. I would like to see correct use of past and present tenses throughout the manuscript. As it is, there seems to be some confusion about which one to use in which section.
24. The manuscript would be made substantially easier to read (and more engaging as a result) by using the active voice. Currently, you have used the passive voice which, although acceptable in scientific writing, is more difficult to read.

Study area –

25. Line 145-155 I have concerns about your use of ATL06. This is derived from ATL03 and doesn't always correctly identify the signal of the ground-return photon events. Please see [ATL06 User Guide @ nsidc.org/sites/default/files/documents/user-guide/atl06-v006-userguide.pdf](https://nsidc.org/sites/default/files/documents/user-guide/atl06-v006-userguide.pdf). I would like to see some reference to the limitations of this dataset. My apologies if this is detailed elsewhere in the manuscript and I have simply missed it.

Methods –

26. Line 164, you mention use of the QA60 band to remove cloud and shadow pixels, but the QA60 band is only available on Google Earth Engine for data pre-Feb 2022 and post-Feb 2024. What mask were you using here? I can't see how you could have used this dataset to mask cloud and shadow for your data which is from mid-2022. I am not convinced that cloud and shadow have been appropriately masked considering this.
27. Equation (2), NDSI is calculated by Hall et al. (1995) with Thematic Mapper (TM) bands 2 and 5 which correspond to Sentinel-2 bands 3 (green) and 11 (SWIR1) not bands 3 and 8 (NIR). Unless you have a good, defensible reason for using NIR in place of SWIR1 here, I suggest recalculating your NDSI and redoing any subsequent analysis. If your training samples are from another time period, you need to specify when they are from (and even if they aren't, you need to be clearer about when they are from).

Technical corrections

Abstract –

28. Line 9, change “has been the primary” to “is a major”
29. Line 10, change “Greenland Ice Sheet” to “Greenland ice sheet”, remove “large amounts of”, change “accumulate” to “accumulates”
30. Line 14, change “Random Forest” to “random forest”
31. Line 15, change “Intersection over Union” to “intersection over union”

Introduction –

32. Lines 31, 33 & 36, change “Greenland Ice Sheet” to “Greenland ice sheet”
33. Line 42, change “Normalized Difference Water Index” to “normalized difference water index”
34. Line 45-46, change “Random Forest (RF), Support Vector Machine (SVM), U-net, and Convolutional Neural Networks (CNN), have also been employed in the area extraction of SGLs” to “random forest (RF) algorithm, support vector machines (SVMs), and convolutional neural networks (CNNs), have also been used to extract SGL area” see comment #2 for removal of “U-net”.
35. Line 68, change “Ice, Cloud and Land Elevation Satellite-2” to “Ice, Cloud and land Elevation Satellite-2” – the capitalisation is strange on this one, so I have no judgement!
36. Line 70, you’re missing a space between “path” and “(Jasinski et al., 2021)”
37. Line 71, change “Lake Surface-Bed Separation” to “lake surface-bed separation”
38. Line 81-82, change “Density-Based Spatial Clustering of Applications with Noise” to “density-based spatial clustering of applications with noise”
39. Line 87, change “Landsat-8” to “Landsat 8”, there’s no hyphen in this satellite’s name
40. Line 96, change “Greenland Ice Sheet” to “Greenland ice sheet”
41. Line 100, change “a MLP” to “an MLP model”
42. Line 105, change both instances of “is” to “are”, change “which offering” to “which offer”

Study area and data –

43. Line 109 (Title), change from “2 Study Area and Data” to “2 Study area and data”
44. Line 110 (Subtitle), change from “2.1 Study Area” to “2.1 Study area”
45. Line 111, you are missing a space between “Fig.” and “1”
46. Line 122, change “2.2 Sentinel-2 Imagery” to “2.2. Sentinel-2 imagery”
47. Line 126, change “Blue” to “blue”
48. Line 127, change “Green” to “green” and “; Red” to “; and red”
49. Line 131-132, change “Top-of-Atmosphere” to “top-of-atmosphere”
50. Line 145, change “ATL03” to “ATLAS version 3 (ATL03)”
51. Line 148, change “ATL06” to “ATLAS version 6 (ATL06)”
52. Line 152, change “Reference Ground Track” to “reference ground track”
53. Line 153, change “it’s” to “it is”

Methods –

54. Line 159, change “a MLP” to “an MLP”
55. Line 170, change “Normalized Difference Snow Index” to “normalized difference snow index”

56. Line 171, change “The calculation for NWD_{ice} and $NDSI$ is” to “The calculations for NWD_{ice} and $NDSI$ are”
57. Line 176, change “All these” to “All the”
58. Line 178, change “SGLs’ profile” to “SGL profile”
59. Line 187, change “the actual depth of SGL” to either “the actual depth of each SGL” or “the actual depth of the SGL”
60. Line 191, change “visual inspection. And the” to “visual inspection, and the”, and remove “considered as” as this is not necessary
61. Line 196, change “we construct a” to “we construct an”
62. Line 200, change “SGL” to “the SGL”
63. Line 206, change “within seven periods in the whole study area” to “within seven time periods across the whole study area”

Results –

64. Line 214, change “Intersection over Union” to “intersection over union”
65. Line 219, change “of SGLs” to “of the SGLs” (two instances)
66. Line 220, change “the area of SGLs” to “the SGL area”
67. Line 221, change “for SGLs” to “for the SGLs”
68. Line 230, change “Fig.5. The” to “Fig. 5; the”
69. Line 246 (Equation 4), the top and bottom spacing of this is different from Equation 3 and may be something you want to change for readability.
70. Line 259, change “distribution of depth inversion errors, we plotted the depth” to “distribution of the depth inversion errors, we plotted depth”
71. Line 262, remove “certain”
72. Line 275, change “SGLs’ parameters” to “SGL parameters” and “Melt Season” to “melt season”
73. Line 276, change “results of SGLs’ area” to “results of the SGL area”, change “over seven time periods” to “over our studied time periods”
74. Line 286, I think you may mean “SGLs” instead of “supraglacial” here
75. Line 303, change “volume of SGLs are compared, as shown in Table 3” to “volume of the SGLs are compared in Table 3”
76. Line 304, change “SGL” to “SGLs”, remove “large”, replace “pieces” with “areas”
77. Line 305, change “SGL” to “SGLs”
78. Line 306, change “Afterward, SGLs” to “Afterwards, the SGLs”, change “while” to “where”.
79. Line 307, I think “748%” should read “+747%” (see comment #156)
80. Line 308, I think “1921%” should read “+1938%” (see comment #156)
81. Line 309, change “340%, 84%, and 1215%” to “+340%, +84%, and +1215%”
82. Line 310, change “implied” to “implies”
83. Line 312, change “49% and 85%” to “+49% and +85%”
84. Line 313, change “a decreasing trend” to “decreasing trends”, change “28% and 44%” to “+28% and +44%”
85. Line 314, change “indicating a large number” to “indicating that a large number”
86. Line 316, change “3% and 68%” to “+3% and +68%”
87. Line 321, change “(39%)” to “(-39%)”, change “(23%)” to “(-23%)”
88. Line 334, change “SGLs” to “SGL”
89. Line 337, remove “and”
90. Line 347, change “within” to “below” (I think this is what you mean? If not, find another way to phrase this as it is currently misleading)

91. Line 354, remove “It can be found that”, it is unnecessary.
92. Line 358, change “has” to “have”
93. Line 359, change “meters” to “m”
94. Line 372, change “at seven periods” to “at each of the seven periods”
95. Line 384, change “during the seven periods” to “during the seven study periods”
96. Line 392, change “gray” to “grey”, this is how you have spelt it elsewhere in the manuscript

Discussion –

97. Line 427 (subtitle), change to “5.1 The uncertainty of SGL depth inversion”
98. Line 438, change “overcome the impact” to “overcome this impact”
99. Line 439, remove “of floating ice on the lake surface”, change “underestimation” to “estimation”, change “resulting in depth estimation” to “providing”

Conclusions –

100. Line 468, change “evolute” to “evolve”
101. Line 469, change “maximum of average” to “maximum total” (I think)
102. Line 474, change “evolution pattern. And” to “evolution pattern, and”
103. Line 475, change “and depth, at the onset” to “and depth. At the onset”
104. Line 477, change “mean depth, suggesting” to “mean depth. This suggests”
105. Line 479, change “Greenland Ice Sheet” to “Greenland ice sheet”
106. Line 480, change “surface of SGL” to “surface of an SGL”

Figures and Tables

Figure 1 –

- 107. Please consider making the colour differences more obvious for the number of Sentinel-2 images. They are currently difficult to tell apart.
- 108. Scale bar, “KM” should be lowercase (“km”)
- 109. Caption, you mention ArcticDEM, is this the mosaic? If so, you need to detail which version and cite the appropriate documentation e.g. “Contour lines calculated from ArcticDEM mosaic version XX are visible as grey lines (CITATION).”

Figure 2 –

- 110. Box “Cloud and shadow removing”, change to “Cloud and shadow removal”
- 111. Box “SGLs Area”, change to “SGLs area” (both instances)
- 112. Box “Region of Interest”, change to “Region of interest”
- 113. Caption, change from “Framework of proposed SGLs’ depth inversion method” to “Framework of the proposed SGL depth inversion method”

Figure 3 –

- 114. Labelling, change “Input Features” to “Input features”, “Hidden Layer 1” to “Hidden layer 1”, “Hidden Layer 2” to “Hidden layer 2”, and “Hidden Layer 3” to “Hidden layer 3”
- 115. Caption, change to “Structure of the MLP model.”

Figure 4 –

- 116. My assumption for this figure is that all of the lakes are different, but you need to be explicit about this in the figure caption at the very least.
- 117. I would suggest labelling the rows with details of each period e.g. Period 1: June 7 etc. This will make it easier to interpret and you won’t have to search the paper for details to understand the figure.
- 118. Scale bar, change “KM” to “km”.
- 119. Caption, remove “The first to seventh rows show” and add “Each row represents a different time period.” To the end of the caption.

Figure 5 –

- 120. Are these results indicative, or are they your only results? What do panels (a), (b) and (c) represent? This needs to be explained in your figure caption.
- 121. Axes labels, each label is missing a space between the label and the unit e.g. “Elevation(m)” instead of “Elevation (m)”, please alter these.

Figure 6 –

- 122. Does each point in each of the plots correspond to an SGL pixel? You need to write this in the caption as it is not currently clear where the points are coming from.
- 123. Caption, “Green” should be “green” and “Red” should be “red”.
- 124. For each panel:

- 125. Y axis label, change to "Depth difference (m)"
- 126. Colour bar label, change to "Probability density"
- 127. I am unfamiliar with probability density but imagine that it has some kind of units, these should be in the colour bar label.

Figure 7 –

- 128. Fig. 8 superimposed boxes, please ensure that these are plotted last as a few are slightly obscured by the SGLs which is making the plot look messy.
- 129. Fig. 8 superimposed box labels, each of these should be "Fig. 8(X)" not "Fig.8(X)", they are all missing a space after the period.
- 130. Lat/Lon dashing, either remove this or make it darker. Right now, it is too faded to be of any use to your reader.
- 131. Legend:
- 132. Change "SGLs Area" to "SGL area"
- 133. Change "SGLs" to "SGL" (after blue box)
- 134. Scale bar, change length to 100 km with markers/intervals at 0, 25, 50, 75 and 100. This will typically be of more use to your reader.
- 135. Scale bar, change "KM" to "km"
- 136. Caption, change "SGLs' area" to "SGL area". Where are the contour lines from? I am assuming that they are from ArcticDEM like Fig. 1, but the reader needs to know if it's the mosaic, which version, and have the citation. Please also include the contour distance in the caption too (400 m) e.g. "Contour lines from ArcticDEM mosaic version X are also shown in grey at 400 m intervals (CITATION)."

Figure 8 –

- 137. Labelling (dates), ensure the label spacing is the same for the dates in the corners of your plots as some of the labels are currently going over the bounding boxes (e.g. the 'g' of Aug. 28)
- 138. Change either the colouring of the depth colour bar to not include red, or change the colour of the SGL area $> 3 \times 10^6 \text{ m}^2$ box as this is currently a bit confusing. I would suggest changing the colour bar to something more colourblind friendly instead of red as you won't have to change previous figures then like you would have to if you changed the red outline colour for SGL area $> 3 \times 10^6 \text{ m}^2$.
- 139. I would also suggest making the colour bar discrete instead of continuous. You won't lose much definition given that the plots are so small anyway, and it will aid your reader in their interpretation.
- 140. Change "KM" to "km".
- 141. Change "SGLs' Area" to "SGL area".
- 142. Caption, change "on the evolution" to "of the evolution". Where are your contour lines from? Need source, version, citation please.

Figure 9 –

I really liked this way of displaying your data. It's not the most intuitive to interpret from my background, but it explains what you're saying very well and that's what is important.

- 143. Key/legend, change "First Quartile" to "First quartile", change "Third Quartile" to "Third quartile"
- 144. Caption, change to "Figure 9. Violin plots of SGL depth distribution over our seven study periods."

Figure 10 –

- 145. Colour bar label, change to “SGL count”
- 146. Change “Depth (m)” label placement, currently very strange.
- 147. Caption, change to “Figure 10. The area-depth distribution map of individual SGLs...”

Figure 11 –

- 148. 2nd Y axis label, change “Total Volume” to “Total volume”
- 149. Caption, change “SGLs” to “SGL”, change “at different time” to “during the seven study periods”

Figure 12 –

- 150. For each of the August dates, ensure you have a space after the period e.g. “Aug. 1” instead of “Aug.1”.

Figure 13 and Figure 14 –

- 151. Y and X axes labels, ensure you have a space after the label and before the unit e.g. “Elevation (m)” instead of “Elevation(m)”

Table 1 –

- 152. Caption, add “showing the intersection over union (IoU) of each time period’s SGLs” to the end of the current caption.

Table 2 –

- 153. Column labels, “Green” should be “green” and “Red” should be “red”.
- 154. Caption, add “for each depth range” to the end of the caption.

Table 3 –

- 155. Column labels, change “Maximum Area” to “Maximum area”, change “Mean Area” to “Mean area”, change “Maximum Depth” to “Maximum depth”, change “Mean Depth” to “Mean depth”, change “Maximum Volume” to “Maximum volume”, change “Mean Volume” to “Mean volume”.
- 156. Percentages, for July 2 maximum area, I get +747%. For June 17 maximum volume, I get +73%. For July 2 maximum volume, I get +1938%. Please check these calculations as I believe they might be wrong. All of the other percentages are correct using this data.
- 157. Caption, change to “Table 3. Statistics of the maximum and mean values of the SGL area, depth, and volume for the seven study periods, with the growth rate against the previous period given in parentheses.”

References cited within this review

Hall, D. K., Riggs, G. A., and Salomonson, V. V.: Development of methods for mapping global snow cover using moderate resolution imaging spectroradiometer data, *Remote Sensing of Environment*, 54, 127–140, [https://doi.org/10.1016/0034-4257\(95\)00137-P](https://doi.org/10.1016/0034-4257(95)00137-P), 1995.

Philpot, W. D.: Radiative transfer in stratified waters: a singlescattering approximation for irradiance, *Appl. Optics*, 26, 4123–4132, <https://doi.org/10.1364/AO.26.004123>, 1987

Neumann, T. A., Brenner, A., Hancock, D., Robbins, J., Luthcke, S. B., Harbeck, K., Lee, J., Gibbons, A., Saba, J., and Brunt, K.: ATLAS/ICESat-2 L2A Global Geolocated Photon Data (Version 5), <https://doi.org/10.5067/ATLAS/ATL03.005>., 2021.

Final notes

Although I understand that the number of comments in this review is, quite frankly, atrocious (sorry), the vast majority will not take long to implement and are simply technical. I am contactable for further clarification on any of the comments within this review at l.melling@lancaster.ac.uk.

Please accept my warmest regards and good luck with the changes to this lovely manuscript,

Laura Melling