egusphere-2024-2195

Responses to comments from Referee 2

Volumetric evolution of supraglacial lakes in southwestern Greenland using ICESat-2 and Sentinel-2

We thank editor for your constructive comments and suggestions. In the following responses, we use "**bold text**" for editor's comments, "non-bold" text for our responses, and "*italic*" for text extracted from the manuscript.

Major comment:

Section 3.1. Shadows can be misclassified as supraglacial lakes in the optical satellite imagery since they have similar spectral properties. I noticed that the section (3.1.) describing cloud and shadow removal was removed from the current version of the manuscript.

It would be helpful if the authors could clarify how they addressed shadow misclassification, especially considering the limited number of lake pixels used for training, which might not capture the spatial variability of lakes to distinguish between shadows and lakes.

Response:

Thanks for the suggestion. We adopted reviewer 1's suggestion to remove the cloud-removal description from the original version of the manuscript. On one hand, the QA60 band is unavailable in Google Earth Engine (GEE) for Sentinel-2 data during our study period (mid-2022). On the other hand, cloud coverage in the images we used was not significant. Therefore, we did not perform cloud and shadow removal in this study.

Specifically, we use a total of 81 images in this study, 53 of which have 0% cloud cover. Among the remaining 28 images, only one has a cloud coverage rate of 11.09%, while the others exhibit minimal cloud coverage, with an average of 1.62%. This image, acquired on August 28 and belonging to the last study period, is located as shown in Figure R1. According to the Sentinel-2 cloud possibility product downloaded from GEE (https://developers.google.com/earth-engine/datasets/catalog/COPERNICUS_S2_CLOUD_PROBABILITY), areas with a cloud possibility exceeding 60% (indicated in blue area in Fig. R1) are primarily located on the right side of the image, at elevations of about 1800–2000 m. Based on the development characteristics of supraglacial lakes, during this period, the lakes are retreating from higher to lower elevations as it marks the end of the melt season. Therefore, we conclude that the cloud coverage in this image does not significantly impact the results of this study. However, if future studies use images with extensive cloud coverage, careful consideration of shadow misclassification issues will be necessary.

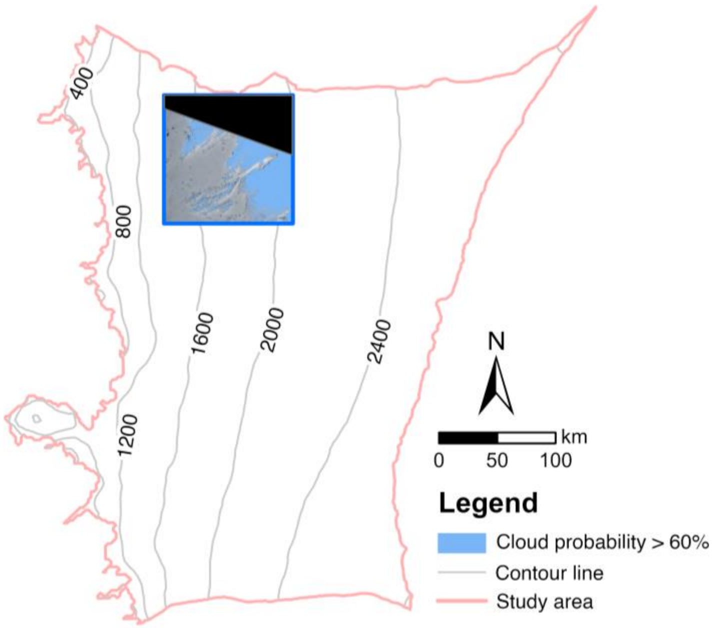

Fig. R1 The location of the image with a cloud coverage rate of 11.09%.

We have added the description regarding cloud coverage in the images used in this study.

(Line 131 in the marked-up manuscript): "… *In this study, we use a total of 81 images in this study, 53 of which have 0% cloud cover. Among the remaining 28 images, only one has a cloud coverage rate of 11.09%, while the others exhibit minimal cloud coverage, with an average of 1.62%. …*"

Minor comments:

I suggest moving the sampling strategy for RF classification, the explanation of IoU and MAE evaluation metrics, and formulas 3 and 4 from the Results section to the Methods. It would be clearer to know this information before the results are presented.

Response:

Thanks for the suggestion. We have moved the RF sampling strategy for RF classification to the Methods section. We have also added Section 3.4 to Method Section, including the explanation of IoU and MAE evaluation metrics, and the empirical formula approach for depth estimation.

(Line 178): "… *For each time period, we randomly sample 50 pixels from SGL areas and 50 pixels from other areas in the mosaiced Sentinel-2 image as training data, then employ an RF algorithm with 30 decision trees to classify the image into lake and non-lake. …*"

(Line 215): "*3.4 Evaluation methods*

To quantitatively evaluate the performance of the classification algorithm, the intersection over union (IoU) metric is used, which is the proportion of the overlap between the classification results and manually selected SGLs relative to their combined area. To evaluate the performance on depth prediction, we compare the effectiveness of both MLP model and the empirical formula approach (Box and Ski, 2007). The empirical formula approach establishes an empirical relationship between SGL reflectance and depth as shown in equation (3). The same training and testing data is adopted, allowing for a comparison of the performance between MLP and the empirical formula method.

$$D = \frac{\alpha_0}{R+\alpha_1} + \alpha_2 \quad (3)$$

Where D represents the estimated depth of the SGL. R denotes the reflectance in the green or red band, and parameters α_0, α_1, and α_2 are empirical coefficients fitted by using training data.

The mean absolute error (MAE) is adopted to assess the depth inversion accuracy of both the MLP model and the empirical formula method. The calculation method for MAE r_{mean} is as equation (4).

$$r_{mean} = \frac{\sum |d_{ref} - d_{pred}|}{N} \quad (4)$$

Where d_{ref} represents the lake depth obtained by ICESat-2, d_{pred} represents the predicted lake depth value using the MLP model or empirical formula method, and N is the number of pixels. …"

I recommend including a cross-validation or comparison with in situ supraglacial lake depth measurements from other studies. For example, the study by Lutz et al. (2024), which is already cited in the manuscript and provides direct lake depth measurements from Northeast Greenland using a remote-controlled sonar boat. The data is also publicly available:

Lutz, Katrina; Bever, Lily; Sommer, Christian; Seehaus, Thorsten; Humbert, Angelika; Scheinert, Mirko; Braun, Matthias Holger (2024): In situ supraglacial lake depth measurements using remote controlled sonar boat in Northeast Greenland, July 2022 [dataset]. PANGAEA, https://doi.org/10.1594/PANGAEA.971782

Response:

Thanks for the suggestion. We have downloaded the relevant in-situ data from the links you provided, including bathymetric data for three SGLs (Lake 522 and Lake 610b measured on July 9th 2022, and Lake 610a measured on July 4th 2022). The locations of these three SGLs are shown in Fig. R2(a). We have also downloaded the corresponding Sentinel-2 imagery for these dates, as shown in Figs. R2(b) and (c). However, due to heavy cloud cover on July 9th (Fig. R2(c)), Lakes 522 and

610b are not visible in the Sentinel-2 imagery. Therefore, we evaluate our results using only the bathymetric data from Lake 610a.

The comparison between the in-situ SGL depth measurements and the depth predictions from our MLP model is shown in Fig. R3. The results indicate good agreement for depth below 3 m (with an MAE of 0.50 m), while deviations become more pronounced for depths exceeding 3 m. We attribute these deviations to the limited training samples available for the MLP model. Considering that the validation data is from a region far from our study area (Fig. R2(a)), we have not included these evaluation results in the manuscript.

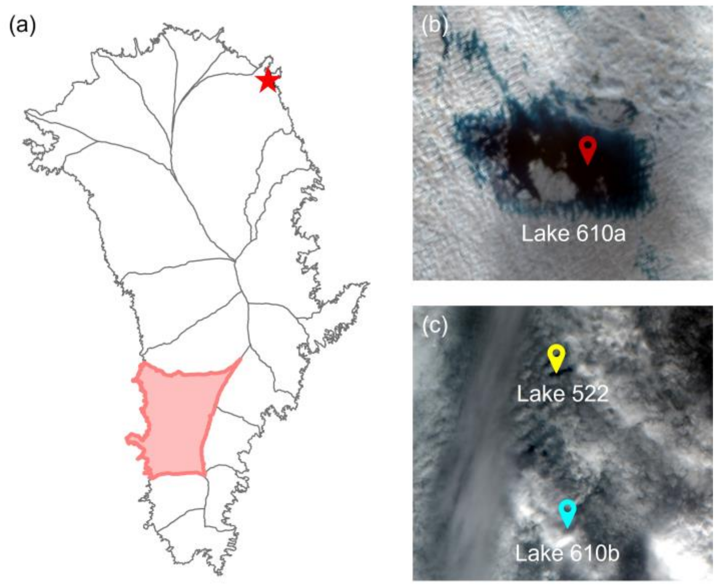

Fig. R2 (a) Location of in-situ depth measurements of SGLs (red star) and study area (red polygon). (b) Sentinel-2 imagery obtained on July 4th 2022. (c) Sentinel-2 imagery obtained on July 9th 2022.

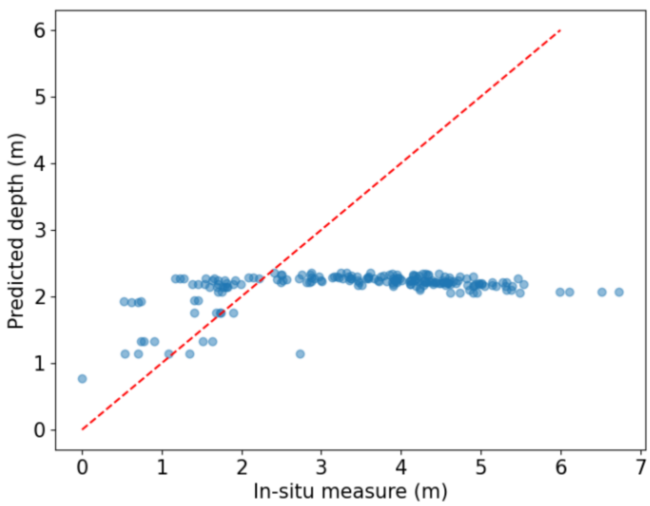

Fig. R3 The comparison of in-situ depth measurements and depth prediction results.