egusphere-2024-2195

Responses to comments from Referee2

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

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

This study develops a novel method to estimate the volume of supraglacial lakes during the 2022 melting season in Southwestern Greenland by integrating Sentinel-2 imagery and ICESat-2 data.

Major comments

This study employs Sentinel-2 Level-1C images which provide top-of-atmosphere (TOA) reflectance and do not include corrections for atmospheric effects which can lead to biases in the reflectance values and can impact the accuracy of the depth estimation. Was there any atmospheric correction made during the pre-processing of the sentinel-2 imagery?

Response:

In our study, we chose not to perform atmospheric correction to maintain consistency with previous research, including Pope et al. (2016), Williamson et al. (2018), Datta and Wouters (2021), and Melling et al. (2023). Consequently, the potential impact of atmospheric effects on the reflectance values, which could affect depth estimation, was not considered.

Datta, R. T. and Wouters, B.: Supraglacial lake bathymetry automatically derived from ICESat-2 constraining lake depth estimates from multi-source satellite imagery, The Cryosphere, 15, 5115–5132, https://doi.org/10.5194/tc-15-5115-2021, 2021.

Melling, L., Leeson, A., McMillan, M., Maddalena, J., Bowling, J., Glen, E., Sandberg Sørensen, L., Winstrup, M., and Lørup Arildsen, R.: Evaluation of satellite methods for estimating supraglacial lake depth in southwest Greenland, Ice sheets/Glacier Hydrology, https://doi.org/10.5194/tc-2023-103, 2023.

Pope, A., Scambos, T. A., Moussavi, M., Tedesco, M., Willis, M., Shean, D., and Grigsby, S.: Estimating supraglacial lake depth in West Greenland using Landsat 8 and comparison with other multispectral methods, The Cryosphere, 10, 15–27, https://doi.org/10.5194/tc-10-15-2016, 2016.

Williamson, A. G., Banwell, A. F., Willis, I. C., and Arnold, N. S.: Dual-satellite (Sentinel-2 and Landsat 8) remote sensing of supraglacial lakes in Greenland, The Cryosphere, 12, 3045–3065, https://doi.org/10.5194/tc-12-3045-2018, 2018.

The paper does not provide enough details about the annotation process for supraglacial lakes. It is unclear how the 50-pixel samples were defined and whether they included a mix of lake and non-lake pixels or if separate negative samples were used. Furthermore, does a sample size of 50 pixels capture the variability in lake sizes? For the evaluation of the random forest model, the method for randomly selecting five lakes is not well explained, and if the five supraglacial lakes chosen per image were excluded from the training dataset. A suggestion would be to split the annotated dataset into training, validation and testing sets instead of randomly selecting supraglacial lakes for the evaluation.

Response:

Thanks for these questions. To extract SGLs from Sentinel-2 images using the RF model, we randomly selected 50 pixels of SGLs and 50 pixels of non-SGL areas from each set of images across different time periods. As a result, the training dataset comprised 350 positive samples and 350 negative samples. To ensure diversity of the positive samples, both typical lake water pixels and those from the edges where ice meets water were included. The number of selected pixels was not influenced by size variations of the SGLs, as the classification process operated on a pixel-based level. For classification evaluation, five lakes from each time period excluded from the training samples were selected to assess accuracy. Additionally, the Intersection over Union (IoU) metric was employed to evaluate the completeness of extraction for entire lake regions. Unlike methods that split samples into training and validation sets, this approach enables an assessment of overall lake region extraction, rather than solely focusing on the classification accuracy of individual pixels.

We have clarified the selection of the training samples.

(Line 223 in the marked-up manuscript): "… *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, …*"

Minor comments

Why is the 2022 melt season selected for this study? Was this melt season used due to significant meltwater?

Response:

Studies have shown that surface meltwater in Greenland has been increasing in recent years (Shepherd et al., 2020; Slater et al., 2021). Therefore, we selected the recent year of 2022 to investigate the characteristics of supraglacial lake variations

throughout the entire melt season, as their formation and drainage play a significant role in influencing surface meltwater dynamics.

Shepherd, A., Ivins, E., Rignot, E., Smith, B., van den Broeke, M., Velicogna, I., Whitehouse, P., Briggs, K., Joughin, I., Krinner, G., Nowicki, S., Payne, T., Scambos, T., Schlegel, N., Geruo, A., Agosta, C., Ahlstrom, A., Babonis, G., Barletta, V. R., Bjork, A. A., Blazquez, A., Bonin, J., Colgan, W., Csatho, B., Cullather, R., Engdahl, M. E., Felikson, D., Fettweis, X., Forsberg, R., Hogg, A. E., Gallee, H., Gardner, A., Gilbert, L., Gourmelen, N., Groh, A., Gunter, B., Hanna, E., Harig, C., Helm, V., Horvath, A., Horwath, M., Khan, S., Kjeldsen, K. K., Konrad, H., Langen, P. L., Lecavalier, B., Loomis, B., Luthcke, S., McMillan, M., Melini, D., Mernild, S., Mohajerani, Y., Moore, P., Mottram, R., Mouginot, J., Moyano, G., Muir, A., Nagler, T., Nield, G., Nilsson, J., Noel, B., Otosaka, I., Pattle, M. E., Peltier, W. R., Pie, N., Rietbroek, R., Rott, H., Sorensen, L. S., Sasgen, I., Save, H., Scheuchl, B., Schrama, E., Schroder, L., Ki-Weon Seo, Simonsen, S. B., Slater, T., Spada, G., Sutterley, T., Talpe, M., Tarasov, L., van de Berg, W. J., van der Wal, W., van Wessem, M., Vishwakarma, B. D., Wiese, D., Wilton, D., Wagner, T., Wouters, B., and Wuite, J.: Mass balance of the Greenland Ice Sheet from 1992 to 2018, Nature, 579, 233–9, https://doi.org/10.1038/s41586-019-1855-2, 2020.

Slater, T., Shepherd, A., McMillan, M., Leeson, A., Gilbert, L., Muir, A., Munneke, P. K., Noël, B., Fettweis, X., van den Broeke, M., and Briggs, K.: Increased variability in Greenland Ice Sheet runoff from satellite observations, Nat Commun, 12, 6069, https://doi.org/10.1038/s41467-021-26229-4, 2021.

L 305-306: Area, depth and volume were mentioned, however only area and volume have values, with depth being mentioned with no specific value. Additionally, please clarify "the individual supraglacial lake" further as this is also used in the caption of Figure 10 and figure 11 as well.

Response:

We have specified the value of depth. The term 'individual supraglacial lake' refers to each separate supraglacial lake. To ensure clarity, we have revised the words to "each individual SGL" in this sentence as well as in the caption for Figures 10 and 11.

(Line 327): "… *At this time, the area and volume of each individual SGL are relatively small, measuring less than 1×10^6 m^2 and 1×10^6 m^3, respectively, with a mean depth of less than 1 m. …"*

Figures

Figure 1: Please include the study period in the caption.

Response:

We have added the study period in the caption of Figure 1.

(Line 123): "*Figure 1. Study area. Contour lines calculated from ArcticDEM mosaic version 4.1 (Porter et al., 2023) are visible as grey lines at 400 m intervals. Yellow points indicate the locations of the lakes in the study area, as shown in Fig. 5 and Fig. 13. The study period is from June to August 2022.*"

Figure 4: Please include the date range in the figure as well.

Response:

We have added the date in the Figure 4.

(Line 237): "

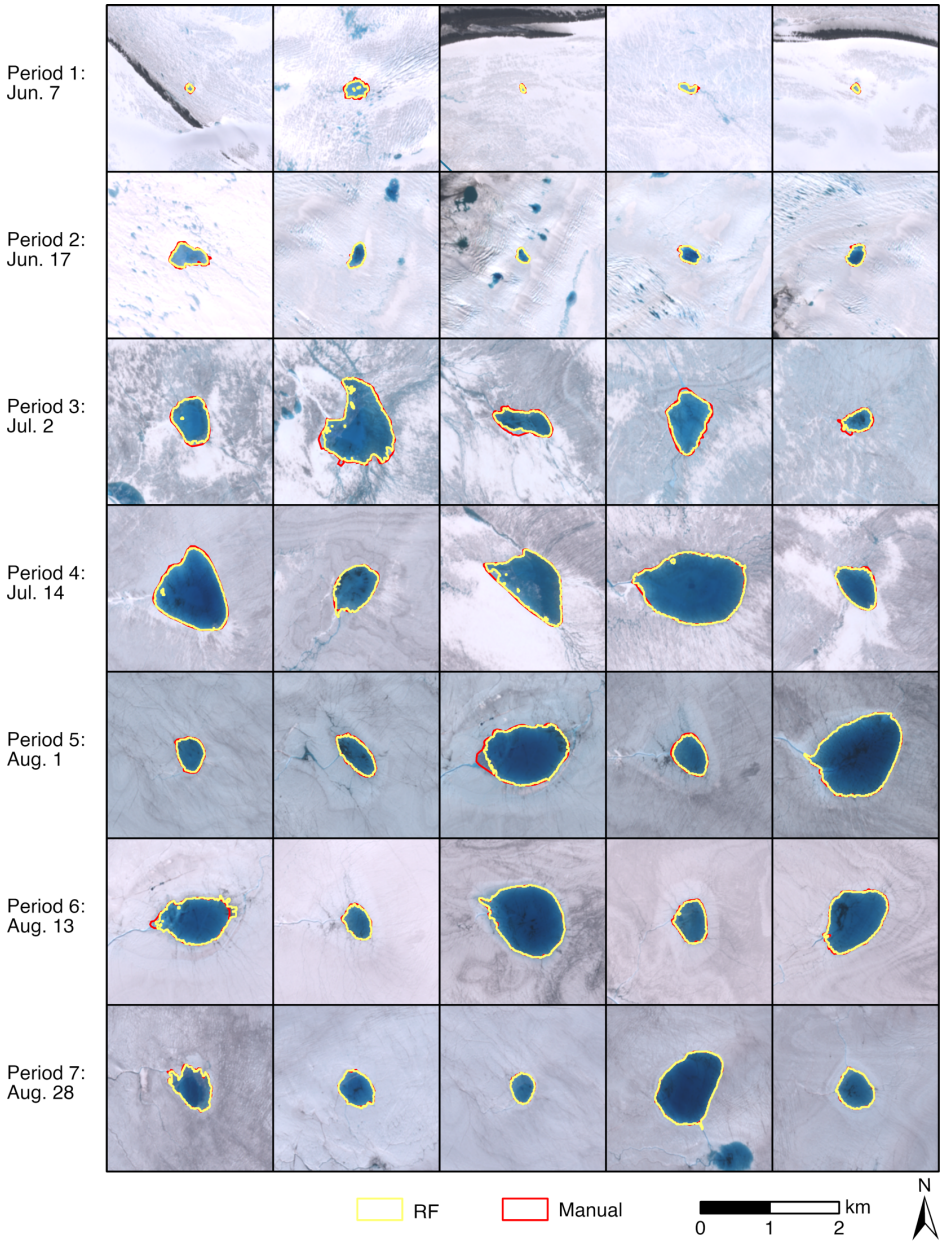

Figure 4. The comparison between the extracted extents and manually delineated contours for five different SGLs randomly selected from each study period, using the corresponding Sentinel-2 images as background for each period. Each row represents a different time period. ”

Figure 12: The color scheme is difficult to follow. Use more distinguishable color and match the maximum value (star) to the corresponding line color.

Response:

We have changed the colors of the lines and the stars.

(Line 424):