Living Planet Fellowship

BI-MONTHLY REPORT

Investigating Greenland's ice marginal lakes under a changing climate (GrIML)

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1 OBJECTIVES OF WORK

This bi-monthly report represents the halfway point of GrIML Year 2 (starting January 2024) according to the proposed project timeline (Fig. 1). By the end of Year 2, the following objectives should been completed:

a. A series of ice marginal lake inventories should have been generated, which cover the Sentinel-era between 2017 and 2023
b. Ice marginal lake inventories should have been validated, using the pre-existing ESA CCI ice marginal lake inventory and other complementary datasets such as in situ observations and oblique terrestrial time-lapse observations
c. Time-series analyses for individual lake studies should have been generated, where lakes are selected based on scientific or societal relevancy

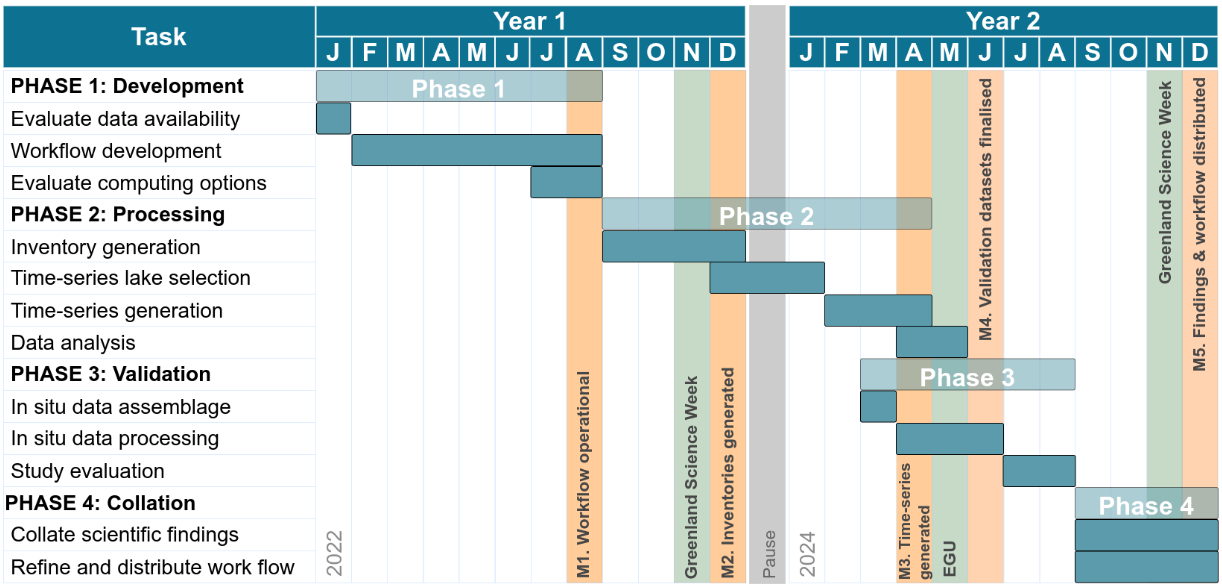

Figure 1. GrIML proposed project timeline. Note that due to parental leave, the project is offset by one year exactly as denoted by the pause between Year 1 and Year 2 (i.e. end of Year 1 is January 2024 and the end of Year 2 is January 2025).

2 WORK PERFORMED

2.1 Lake surface temperature estimates

2.1.1 Inventory analysis

Lake surface temperature estimates will be included with the GrIML inventory series of ice marginal lakes, as previously reported. Surface temperature estimates are derived from the Landsat 8 Collection 2 Level 1 (L8L1) land surface temperature product. A scale factor has been applied to correct to lake surface temperatures rather than land surface temperatures (Dyba et al., 2022):

Water temperature = $2.9 \times B10 - 2.07 \times B11 + 48.48$

Further analysis has been explored with these lake surface temperature estimates, using those derived from the ESA CCI 2017 ice marginal lake inventory (How et al., 2021). The record of lake surface temperature estimates from the 2017 ice marginal lake inventory covers a multi-decadal period between 1985 and 2023 (Figure 2).

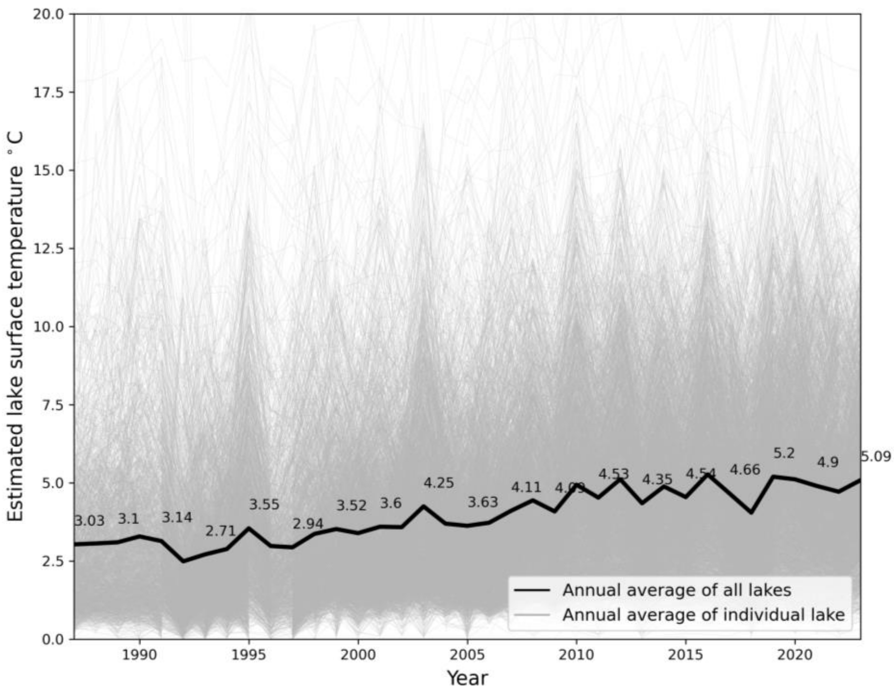

Figure 2: Estimated annual surface temperatures from ice-marginal lakes across Greenland. Lakes are those as defined in the ESA CCI 2017 ice-marginal lake inventory (How et al., 2021), with annual averages from each lake plotted in grey. The average of all ice-marginal lake values, collectively, is plotted in black. All measurements are an annual average derived from valid images between the months of June and September (in order to remove ice-covered lake conditions in the estimates).

Overall, annual averages in surface temperature suggest that ice marginal lakes across Greenland have warmed by 2°C since 1985 (Figure 2). Spatial trends are difficult to discern from this dataset; for instance, ice marginal lakes connected to the northern regions of the ice sheet are not affected differently than those in the southern regions. However, it appears that the rate of lake warming could be linked to the size of the lake, with small lakes (0.05-0.2 km^2) experiencing an average temperature increase of 2.54°C whereas large lakes (above 5.0 km^2) experienced less change with a temperature increase of 1.55°C (Figure 3).

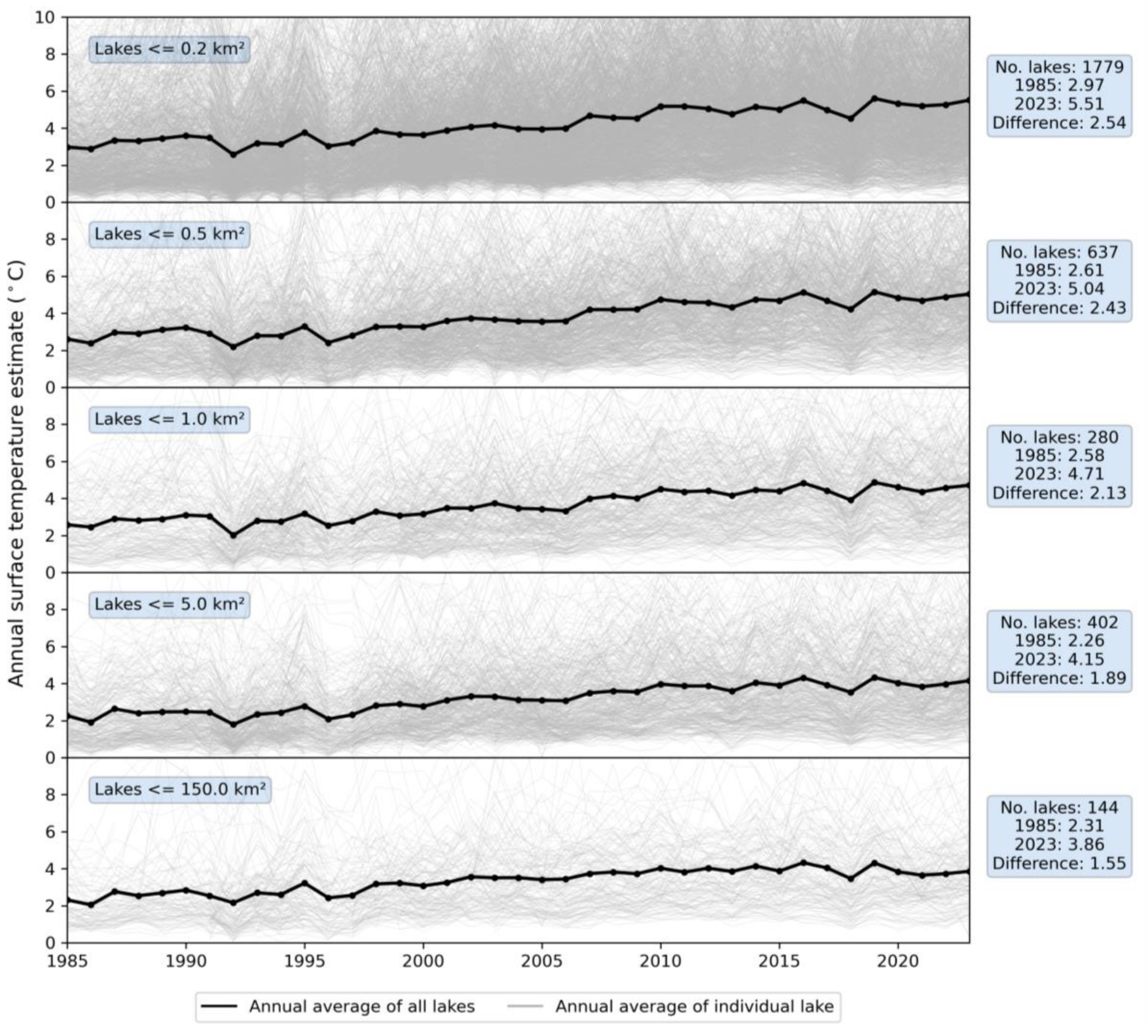

Figure 3: Estimated annual surface temperatures from ice-marginal lakes across Greenland, divided by lake size. Lakes are split into five separate groups, which are shown from top to bottom: 0.05-0.2 km² (top), 0.2-0.5 km², 0.5-1.0 km², 1.0-5.0km² and over 5.0km² (up to the largest lake size, which is 131.2 km²) (bottom)

2.1.2 Validation

Validation of lake surface temperature estimates is being conducted with existing in situ measurements of lake temperature in Greenland, and those collected as part of the fieldwork component of this project. The only known and open in situ measurements are from Badesø/Kangerluarsunnguup Tasia and Qassi-Sø (64,13°N, 51,36°W), two small valley lakes at the bottom of Kobbefjord, near Nuuk. The Kobbefjord catchment area is an intensive monitoring site that is part of the Greenland Ecosystem Monitoring (GEM) programme (https://gem.dk). Water measurements have been collected from Badesø since 2008; such as conductivity, pH and temperature. Temperature measurements have been taken at fixed depths of 2 m and 10 m (GEM BioBasis, 2023).

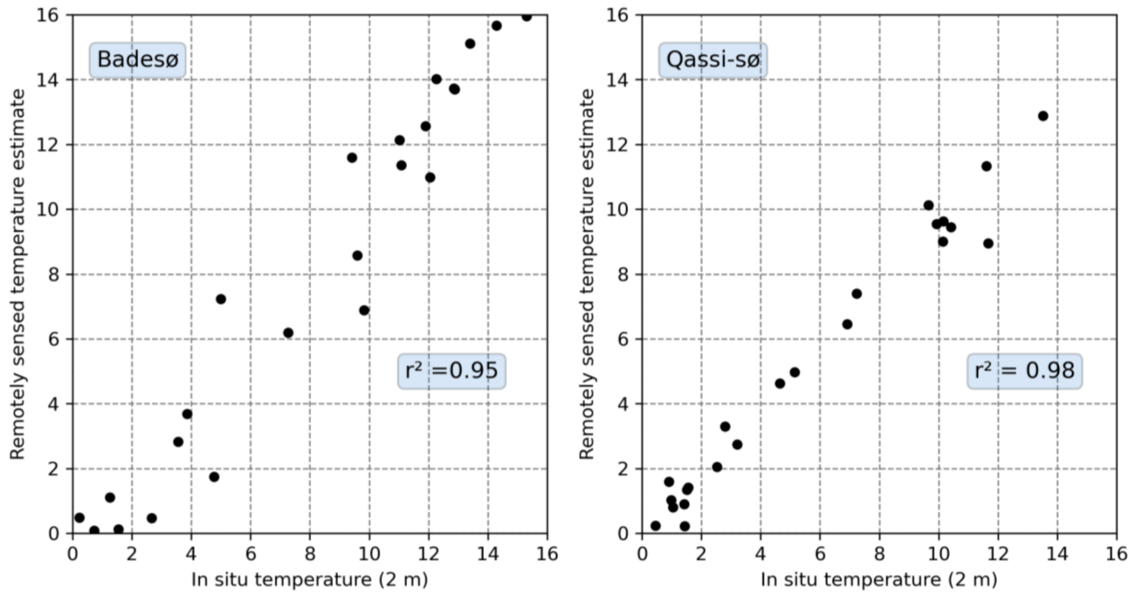

Figure 4: Comparison of in situ surface (2 m) water temperature measurements with remotely sensed temperature estimates from Badesø/Kangerluarsunnguup Tasia (left) and Qassi-Sø (right). Both sites demonstrate a strong correlation, with values at Badesø/Kangerluarsunnguup Tasia and Qassi-Sø exhibiting a correlation of 0.95 and 0.98, respectively.

Comparison of the 2 m water temperature measurements with those estimated using the remote sensing approach adopted here exhibit a strong correlation (>0.9), which suggests that the remotely sensed temperature estimates are reliable (Figure 4). Fieldwork planned in the summer will continue to add to this work with more measurements to compare to the remotely sensed temperature estimates.

Fieldwork is also planned to install instrumentation at Lake 510, which is a glacially-fed lake at the bottom of the fjord Qunnilik, approximately 170 km southeast of the capital city of Nuuk (the lake does not have an official name) (62,91°N,49,83°W) (Figure 5). This lake is part of the hydrological monitoring programme conducted by Asiaq Greenland Survey, with hydrological measurements dating back to 2008.

Surface temperature estimates at Lake 510 have been derived to identify a site for a temperature string to be installed and gather measurements from (Figure 5a and b). Cooler water regions (i.e. 5-6°C) exist around the inflow of cold meltwater from the Greenland Ice Sheet, namely in the eastern main water body. Warmer surface water (i.e. 7-8°C) exist around the lake margins, likely associated with shallower lake bed topography and the influence of the adjacent land. Based on these findings, along with field logistics, a site has been identified on the western side of the lake (indicated by the star symbol in Figure X). This site should not be influenced by near-shore warming effects and is close to existing hydrological monitoring activities.

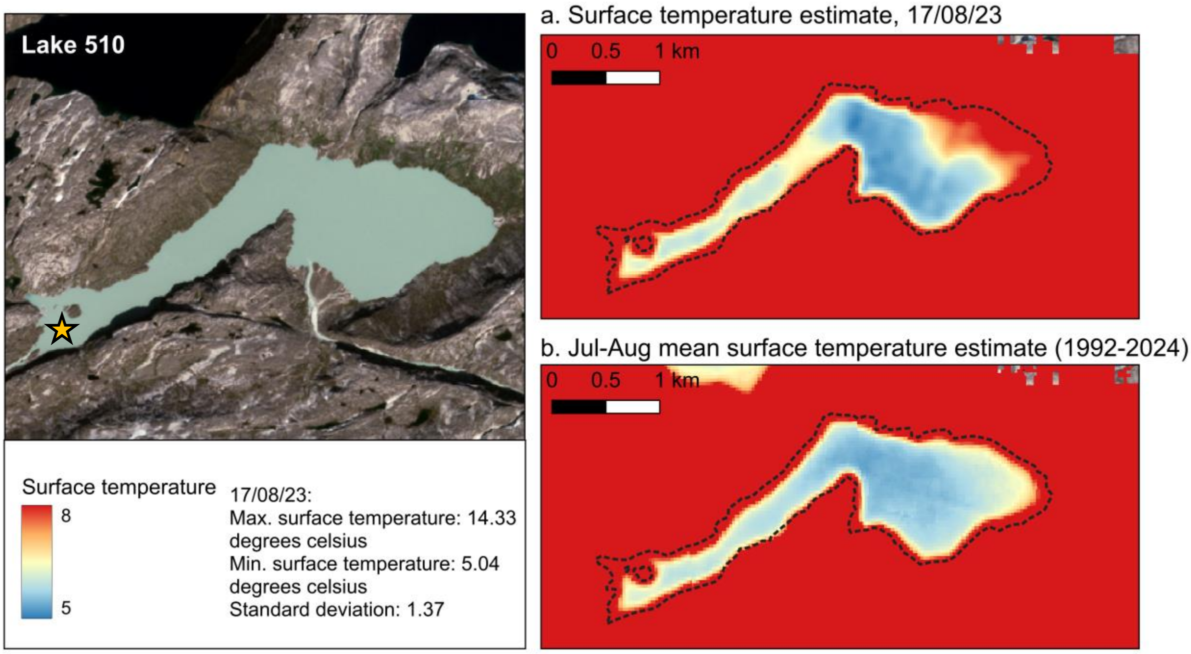

Figure 5: Lake surface temperature estimates at Lake 510, Southwest Greenland. The latest image with valid estimates (i.e. ice-free conditions) is from 17/08/2023 (a), which closely follows the mean July-August surface temperature estimates derived from 1992-2023. The yellow star on the visual band satellite image (Sentinel-2 natural colour image from 15/08/2023) denotes the intended location of the temperature string to be installed during the 2024 field season.

3 CONCLUSIONS

Work conducted in this bi-monthly report has focused on surface temperature estimates of ice-marginal lakes using a remote sensing approach. Surface temperature estimates have been computed from the 2017 ice-marginal lake inventory (How et al., 2021), showing a general increasing trend in temperature with time which is influenced spatially and by lake size. Validation has been performed using in situ lake temperature records from two lakes in southwest Greenland. Comparison suggests a strong correlation, which suggests that the remote sensing approach for estimating surface lake temperature is an accurate representation of in situ measurements.

4 REFERENCES

GEM BioBasis (2023) Temperature data from the two monitoring lakes in Kobbefjord (Badesø / Kangerluarsunnguup Tasia: 64,13°N, 51,36°W and Qassi Sø: 64,15°N, 51,31°W) at 2m and 10m. GEM Database. https://doi.org/10.17897/W1H5-YE53

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