

Reviewer 1:

Thank you much for the review of our manuscript. We have addressed all the comments. Please see below for our point-by-point responses to the reviewers (in blue and preceded by “REPLY:”).

This study uses microscopy and DNA sequencing to examine the spatial heterogeneity of snow algae across an elevation gradient in Alaska. The study presents an important comparison of supraglacial snow compared to snow over soils and presents evidence that factors related to snowmelt including snow depth and elevation are important factors in snow algae phenotype as well as potential underlying substrate (e.g., ice vs. soil). The manuscript and data are exceptionally well written and presented and the data and findings will be of interest to a broad audience.

REPLY: We sincerely thank the reviewer for the careful evaluation of our manuscript and for the positive and encouraging comments. We are pleased that the reviewer found the comparison between supraglacial snow and snow overlying soils, as well as the analyses of snow-algal spatial heterogeneity, to be important and of broad interest.

I have a handful of comments for improvement:

Line 67: Deposition could still be local. Perhaps a more specific description is needed here.

REPLY: We agree that “locally sourced cells” was ambiguous because it could include cells deposited onto the snow surface from nearby sources. We corrected and changed the sentence as suggested. Now you can read “Within this framework, snowmelt duration can be viewed as an approximation of the time available for in situ algal growth, while snow depth may influence the relative contribution of cells associated with the underlying substrate to surface snow communities.” in Lines 71–73.

Lines 105-106: Why the different depths? Based on Figure 2, snow algae are in the snowpack below 2 cm.

REPLY: We collected the upper 2 cm of red snow because this depth has commonly been used in previous snow algae studies and therefore allowed comparison with published data. However, previous observations indicated that snow algae can also occur below the upper 2 cm of the snowpack (Schuler and Mikucki, 2023, *Arctic, Antarctic, and Alpine Research*, doi.org/10.1080/15230430.2023.2233785). At ice-based sites, where the

snowpack was sufficiently deep, we therefore additionally collected samples extending to a depth of 3 cm to better capture the contribution of subsurface algal cells. In contrast, snowpacks overlying soil were often shallow, and deeper sampling would have increased the risk of contamination by soil particles and soil-associated organisms. We therefore restricted sampling at soil-based sites to the upper 2 cm. We have added this explanation to the Methods and clarified that the sampling depths differed according to snowpack conditions and the underlying substrate. Now you can read “Red snow was collected from a 10 × 10 cm area using a stainless-steel scoop. The upper 2 cm was defined as the surface layer because visible red-snow blooms are generally concentrated in the uppermost few centimetres of the snowpack, and a 0–2 cm layer has commonly been used to quantify surface snow algal communities (Onuma et al., 2022). However, recent studies have shown that snow algae can also occur below the immediate surface, including within deeper snow layers (Schuler and Mikucki, 2023). We therefore additionally collected the underlying 2–5 cm layer as a subsurface sample at the ice-based sites. Subsurface sampling was not conducted at soil-based sites because the snowpack was generally shallow and deeper sampling could have introduced soil particles and soil-associated organisms (Fig. 2)” in Lines 115–121.

Line 130: Is the 100 cells true for each sample, for both geometric size and diameter?

REPLY: The minimum of 100 cells applies only to measurements of spherical-cell diameter, which were conducted separately for each sample to characterize cell-size distributions. For the other algal morphotypes, size distributions were not analyzed; instead, the dimensions of at least five cells were measured using samples in which each morphotype was abundant for geometric cell-size calculation. We added information about the measurement of geometric size. Now you can read “For geometric cell-size calculation, the dimensions of at least five cells were measured for each algal morphotype using samples in which the respective morphotype was abundant.” in Lines 154–156.

Line 149: Remove reaction (redundant with PCR)

REPLY: Corrected as suggested.

Line 210: I like this comparison but I’m confused about the surface vs. subsurface samples. I think the methods need to be updated to better describe the sample collection.

REPLY: As described in our response to the previous comment, we have revised the sample-collection section to define the surface and subsurface sampling intervals explicitly and to explain why subsurface samples were collected only at ice-based sites.

For figure 3, nitrate and ammonium cannot be 0. They would be below the limit of detection. These data points should not be shown on the graph because these numbers do not exist to plot.

REPLY: We have removed these data points from Figure 4. We have also revised the figure caption to clarify that nitrate and ammonium were measured in all samples, but values below the respective detection limits are not shown. Corrected Figure 4 and its caption was shown below.

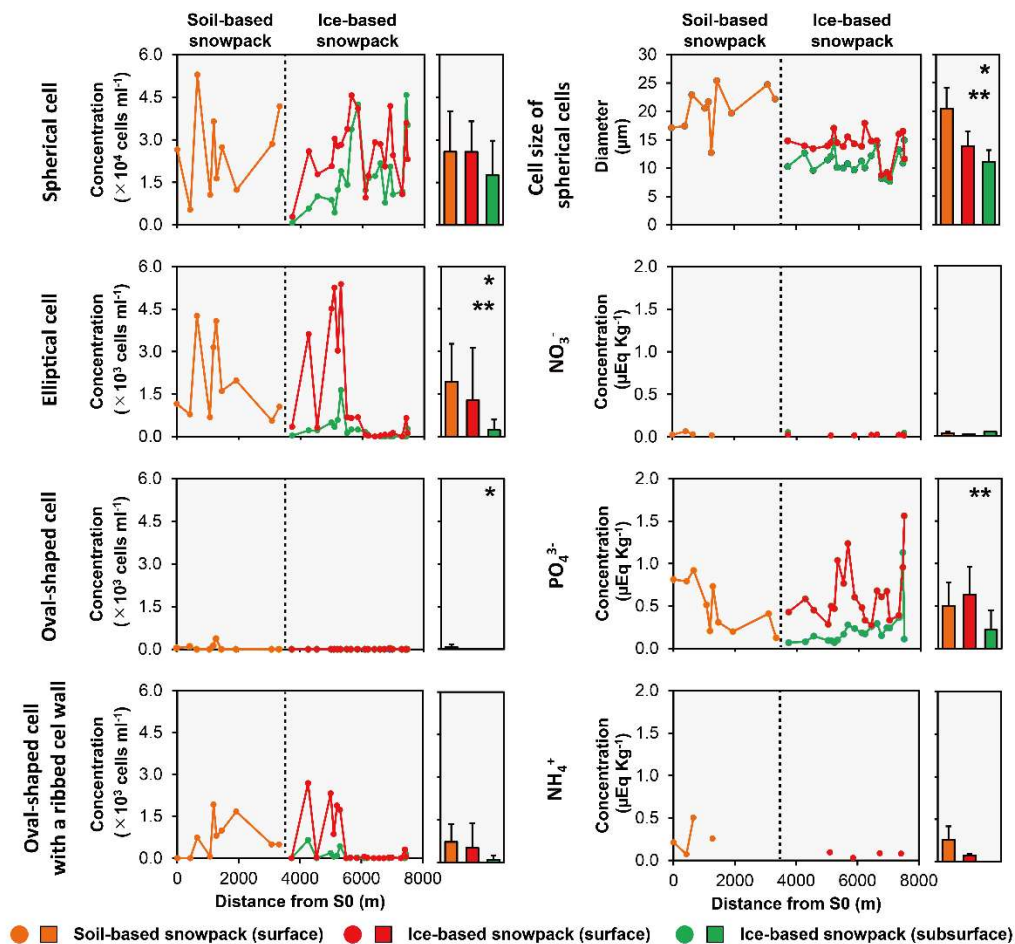


Figure 4: Spatial variability of algal abundance, size of spherical cell, and nutrient concentrations. Spatial distributions are shown in the left panels, and comparisons among the on-glacier snowpack (surface and subsurface) and the glacier forefield (snow surface) are shown in the right panels. * indicates a significant difference between the on-glacier snowpack and the glacier forefield (Dunn's test, $p < 0.05$), and ** indicates a significant difference between the surface and subsurface within the on-glacier snowpack (Dunn's test, $p < 0.05$). NO_3^- and NH_4^+ concentrations below the respective limits of detection were not plotted.

Line 232: Abundant is probably more accurate than dominated

REPLY: Corrected as suggested.