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Interactive comment on "The decline of alpine lichen heaths generates atmospheric heating but subsurface cooling during the growing season" *by* Peter Aartsma et al.

Anonymous Referee #3

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This study examines differences in surface energy partitioning and soil microclimate between lichen- and shrub-dominated vegetation in southern Norway using paired measurements made with a set of mobile instrument platforms. The authors find that the lower albedo of shrub canopies leads to higher atmospheric heating, but lichen mats have greater soil heat fluxes and temperatures despite lower net radiation. The latter is attributed shrub canopy shading and a thicker litter layer with lower thermal conductivity. The results provide important context for understanding how shrub expansion will affect microclimate when shrubs replace lichens. The paper is well written, interesting, and I enjoyed reading it. There are several improvements that could help to strengthen the paper before it is considered further for publication.

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Discussion paper

While I don't think there are any technical problems with how the methods were applied, I do find it curious that different approaches were used to analyze the data from different years, and that the data weren't aggregated. Why not use data from 2018 and 2019 in the mixed models to examine differences in microclimate (i.e. in Table 2)? A box and whisker plot showing mean microclimate by vegetation type would be more informative than the individual daily averages shown in Figure 4. Something like Figure 3, but instead showing net radiation, soil heat flux, soil temperature, etc... I also wonder whether it would be more appropriate to model microclimate conditions as a function of incident shortwave radiation, rather than temperature, since this likely affects soil temperature and heat flux more so than air temperature (e.g. L163-165)? Related, are Figure 5 & 7 showing results of the mixed effects models?

Also I recommend that the authors consult Loranty et al 2018 published in PLOS One. This paper examines differences in soil temperature, thermal conductivity, surface temperature, and ET between lichen- and shrub-dominated vegetation patches in Siberia. It reaches many of the same conclusions presented in this manuscript, and would provide useful context in the introduction and discussion.

Loranty, M.M., Berner, L.T., Taber, E.D., Kropp, H., Natali, S.M., Alexander, H.D., Davydov, S.P. and Zimov, N.S., 2018. Understory vegetation mediates permafrost active layer dynamics and carbon dioxide fluxes in open-canopy larch forests of northeastern Siberia. Plos one, 13(3), p.e0194014.

Minor comments: L1: Does your study really address the decline of lichen heaths? The results certainly have implications in this context, but it seems more like a comparison between lichen heaths and shrubs. Something to that effect would be more appropriate in the title.

L45-50: This seems like it refers to another study that uses the same data presented in this manuscript. It would be appropriate to note that.

L80: It should be made clear here that the authors know albedo is higher for lichen as

a result of previous analyses from this data set.

L85: Is there permafrost at this site?

L216: The wording “As for the net radiation” is a little confusing for me.

L229: It is worth noting here that alpine tundra and lichen mats will also have different albedos, and the while lichen does have high albedo and can be somewhat abundant, it is not broadly representative of alpine tundra.

L240: See Loranty et al 2018 in PLOS One for surface temperature and ET measurements of lichens vs shrubs.

L303: ET would affect the canopy temperature more than that ground temperature, and as noted on line 285 the latter likely has more impact on soil temperature. However, higher ET shrubs may cool canopy temperatures, meaning less LW emitted from the canopy, and LW enhancement by canopies can affect the energy balance at the ground surface (e.g. Todt et al, 2018; Wake et al, 2017). This hasn't been shown in shrub tundra, but might be worth considering here.

L361-365: This section could be developed a bit more. It would be worth discussing how pervasive lichens are across alpine and arctic regions more generally. What types of modeling studies might your measurement help to inform, ecosystem or global scale studies, are there any example citations? Which measurements specifically might be useful for modeling?

Figure 7: Why aren't the points included here, but included in Figure 5?

Figure 9: The abbreviations ST, SHF, etc. . . should be used consistently throughout the figures/manuscript.

References: Todt, M., Rutter, N., Fletcher, C.G., Wake, L.M., Bartlett, P.A., Jonas, T., Kropp, H., Loranty, M.M. and Webster, C., 2018. Simulation of longwave enhancement in boreal and montane forests. Journal of Geophysical Research: Atmospheres,

123(24), pp.13-731.

Webster, C., Rutter, N. and Jonas, T., 2017. Improving representation of canopy temperatures for modeling subcanopy incoming longwave radiation to the snow surface. Journal of Geophysical Research: Atmospheres, 122(17), pp.9154-9172.

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