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The Cryosphere Discussions

Interactive comment on "Temporal changes in snow albedo, including the possible effects of red algal growth, in northwest Greenland, simulated with a physically based snow albedo model" *by* Yukihiko Onuma et al.

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The role played by snow algae in contributing to albedo is currently of relevance and likely to be of interest to the larger cohort of scientists working in this field. This paper describes seasonal changes in the 'cyst stage' of a species they have identified as mostly, 'Chlamydonomas nivalis' type cells, documenting changes in numbers with time and modelling the contribution these cells make to a physically based snow albedo model. This species has now been renamed as Sanguina nivaloides (Procházková et al. 2019. The measurements have been made on a snowpack in northwest Greenland

during the ablation period of 2014. Samples were also collected to quantify mineral particles and organic and black carbon content. However, an assumption is made that the cells are actively growing on the ice, i.e. that cell division leads to an increase in numbers through time. However, the cysts do not divide on the surface of the snow, but will, once buried, potentially provide the inoculum for the following year should suitable conditions arise. In the spring or early summer, once melt water forms, the flagellated algal cells will swim up to the snow surface to form a bloom. On the surface, they lose their flagella and formation of the red pigments occur. Members of the so-called water-melon snow are likely more speciose than was once thought. The development of blooms on the surface can show considerable spatial and temporal heterogeneity, at any one point in time, making it difficult to reliably quantify their distribution. This patchiness may be due to species-specific pigment differences as well as change in their relative abundance, and these factors needs to be carefully considered for inclusion in any model where the aim is to quantify their contribution to albedo. However, I do not have expertise in the modelling sections and my comments refer to the biological sections of the manuscript.

It is recommended that consideration be given to rewording the title for two reasons: i) the named algae are green algae, members of the Chlorophyta or green algae, and readers may be confused into thinking that this paper is about red algae (Rhodophyceae); ii) these particular algae are not considered to grow (as in cell division) once on the surface; they rapidly form cysts, though the cysts themselves may potentially show size changes through time, and they can still be photosynthesising but at very low rates i.e. they can still be metabolically active if the conditions are right. But, it is these cysts that will eventually act as the inoculum for the next year hence their persistence on the surface is fundamental for species survival from year to year. They also form an important food source for a number of grazers. Through the text, including the abstract, it is important that the term red algae is revised accordingly. It needs to be emphasised that the cells, on reaching the surface would turn into cysts and that an increase in the concentration of cell numbers on the surface is as a result

of cell accumulation as the snow melts and algae concentration as they get behind. For this reason, all reference to algal growth must be removed. That said, it is possibly that some other microbes may be found growing on the snow but the particular species mentioned here would not. The researchers may find these additional papers of use. Fogg (1967) Phil. Trans. Soc , 252, 279-287. Fjerdingstad et al., 1974, Arch. Hydrobiol. 73, 70-83 as well as the newer review by Hoham & Remias, Journal of Phycology, 2020. Line 27, clarify what is meant by proper estimates? Suggest revise wording; Line 33, add Yallop et al., 2012 to the references reporting changes in surface albedo with ice melt; kline 41 – check all references made to ranges for visible light as they vary through the text; Line 45 – What is meant by ppbw (provide full definition); Line 46 Suggested reordering of this sentence: ..... was reported to be lower, by 0.7%, than that by BC...; Line 49 – change absorb to absorbs; line 51 – after present add an on; Line 57 Revise to read A physically based snow .....; Line 83 – and elsewhere – revise references to 'growth' of cells on the surface and references to growth model where the 'growth' is likely resulting from an accumulation of cells in a defined area rather than active division of cells. line 65, Yallop et al 2012 discussed potential ice algal albedo impacts not snow; line 96, Field not filed; Line 103 – through more recent molecular work it is likely that any surface blooms may contain a number of different species that have very similar morphologies and it may be better to use Chlamydomonas spp., to infer that. There is also an indication that there were some cells that were not spherical red cells. Can any more information be provided regarding the identity of these cells?; line 116. It would be useful to add more information about the density samples (make, model); line 120 . It is recommended that more information is provided in the text to provide details about the spatial sampling protocol. Line 135 – change bag to bags; Line 145 – after USA), change the 'in' to an 'on';Line 145 – were the samples preserved or rather maintained. Using the term may imply some preservative was added. Line 192 cell sizes were measured. Do these sizes account for any shrinkage as a result of the preservative used?; Line 194 and 195– remove the 's' from compositions; Line 195 – revise sentence as meaning is not

clear; Line 245 – Why is there a – sign in the equation for cell numbers?; line 261: Relevant to this comments is the potential for aggregation of material on the snow. The cells can be sticky and aggregate to form larger clumps, together with mineral particles and other associated matter, including bacteria. Aggregation may affect their motility. line 285 – change the word 'constitution' for 'constituent'; Line 268 – change 'amount' to 'amounts'; Line 309, here and elsewhere in text, if the cell numbers being reported are averages, can the SD or SE of cell number be added ;351 more literature and information could be added to support this statement that there may be different pigments in ice surfaces. The authors are referred to the new paper by Williamson et al. 2020 (PNAS , www.pnas.org/cgi/doi/10.1073/pnas.1918412117), for further views on the role of pigments. Importantly, whilst it is possible that snow algae may be found in ice environments, some of the major players on the ice sheet e.g. Ancylonema may not grow on the snow. Further, the latter species is actively growing and not in a resting stage hence it might be expected that their pigments would be very different. Line 410 onwards – references of growth of snow algae need to be removed here, though some snow algae may have vegetative stages in the snow.

Many references are made in relation to the growth of the snow algae on the surface, as the snow is melting. It would be very useful to add in more detail about the life cycle of the collective group of snow algae, detailing the light triggers that promote the of the biflagellate stage to the ice surface and their modification to form the resulting cyst stage, with loss of the flagellae. The transition period from one form to another, and the time period over which this may happen, is critical. Fogg et al. (1974) report that the increase in cell numbers in snow is sometimes as a result of cell concentration due to ablation (sublimation) which leaves the algae behind. Previous researchers report on active photosynthesis in these surface cells, though possibly activity would cease once the surface temperatures become too high. The review of Hoham and Remias, (2020) would also be useful here.

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