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Interactive comment on "Glacier algae accelerate melt rates on the western Greenland Ice Sheet" *by* Joseph M. Cook et al.

Anonymous Referee #1

Received and published: 5 May 2019

The study by Cook et al. aims to quantify the impact of glacier algae on surface melt and runoff across the western Greenland Ice Sheet by combining the field observations, radiative transfer modeling, remote sensing classifications, and surface runoff modeling. The topic of this study is important and interesting to the cryosphere community. However, some issues need to be addressed before publication.

1) The title is too general, given that the algae observations are from a single field site and the surface runoff estimates are based on a transect with forcing data from three automatic weather stations. After reading the whole manuscript, I find that it is not so convincing that the field observations of this site are representative for the entire Greenland Ice Sheet.

2) The estimation of surface runoff caused by algae over the western GrIS is not clearly

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Discussion paper

presented. Did you use the classification results from UAV and Sentinel-2 to estimate the surface runoff over the entire western GrIS? How? Your sentinel-2 and UAV imagery cover a very small portion of the western GrIS. How did you generalize the results? It seems that you only modeled the surface runoff over three points along a transect where forcing data from weather stations are available, and then extrapolated the runoff estimates across the whole area based on elevations. I believe there are lots of uncertainties here, even without considering the spatial heterogeneity of surface albedo. So in your abstract where you concluded that 'algal growth led to an additional 5.5-8.0 Gt of runoff from the western sector of the GrIS in summer 2016', an uncertainty estimate is mandatory.

3) Cook et al. attributed the albedo reduction to glacier algae because mineral dust was considered as less effective on albedo reduction based on the radiative transfer modeling. However, the surface meltwater itself has a significant role in reducing the albedo, which was not considered and evaluated.

4) Many critical details on methods and results are missing, which need clarifications. See specific comments below.

5) The overall writing needs to be improved, particularly the writing style. The method and result parts are poorly structured, which seem like a simple but loose stacking of various materials, while the logical linkages between different parts are weak and not clear. This study involves several different components, including fieldwork, radiative transfer modeling, image classification from UAV and Sentinel-2 data, and surface runoff modeling using 'an SMB model.' In the second section 'Field sites and methods,' all the materials related to those components are just put together, which are very difficult for readers to follow. There are also many redundant descriptions between the method and result parts, which seems like that this manuscript was not thoroughly proofread. There are also some grammar errors and typos.

6) The most recent literature about ice algae mapping using remote sensing data is not

cited and discussed, like:

Wang, S., Tedesco, M., Xu, M., & Alexander, P. M. (2018). Mapping Ice Algal Blooms in Southwest Greenland From Space. Geophysical Research Letters, 45(21), 11,779–11,788.

Huovinen, P., Ramírez, J., & Gómez, I. (2018). Remote sensing of albedo-reducing snow algae and impurities in the Maritime Antarctica. ISPRS Journal of Photogrammetry and Remote Sensing: Official Publication of the International Society for Photogrammetry and Remote Sensing, 146, 507–517.

Both these two papers are using remote sensing data to detect snow/ice algae. Although the second paper is dealing with snow algae, the first paper is utilizing the chlorophyll-a signature to map ice algae from satellite imagery over the southwestern GrIS. Your presented field data and radiative transfer modeling results (particularly your Figure 2A) are consistent with Wang et al. (2018) who used the reflectance ratio between 709 and 673 nm to quantify the ice algae.

Specific comments.

Introduction: This section should be expanded, at least including a more detailed literature review about the current research progress and efforts on ice algae and their relationship with albedo and surface melting.

Line 62. The study by Wang et al. (2018) should be cited, which used the spectral signature of chlorophyll-a to map ice algae in Greenland.

Line 78. Adjust your figures. It's a bit odd to put your first figure in the text as Figure 3c.

Line 86. Do you have multiple sites? What's your sampling area size? Did you take point measurements at different places within a specific area? Explain those details in your field site description part.

Line 99. Update your reference 'Cook et al. (2017b)' in the reference list.

2.3 Biological Measurements. Did you also differentiate different species when counting the cells?

Line 126. What is PSD? Particle size distribution? Do not use abbreviation when you use the term first time in your manuscript.

Line 135. Provide more details on how you used the ASD to measure the surface reflectance of the materials pressed on the microscope slide, such as your measurement setup, the field view of the ASD probe, and the background material (white, grey, or black) where you put your microscope slide.

Line 144. Any references for the BioSNICAR_GO? Is BioSNICAR developed for this study? Provide more details.

Section 2.5 paragraph 2. As I asked before if you considered the different cell numbers of different algal species, did you take into account the different shapes of the Ancylonema nordenskiöldii, Mesotaenium berggrenii? Ancylonema nordenskiöldii is filamentous while Mesotaenium berggrenii is unicellular. If you consider the geometrical optics, how would these two different shapes affect the radiative transfer modeling? Can you comment on the sensitivity of radiative transfer modeling on algal cell shapes?

Can you combine sections 2.5 and 2.6?

Line 187. 'utilise 5% of this ...' any references for this?

Line 191. determine -> determined

Section 2.7 paragraph 2. This paragraph is overall difficult to read. Could you use some equations to show your calculations?

2.8 UAV remote sensing. When did you conduct the UAV mapping, the same time with your field spectral collection? Also specify the multispectral camera parameters, like band wavelength, bandwidth and so on.

Line 210. oin -> in

Line 216. What do you mean by time-dependent regression?

Line 222. What do you mean by 'generally good'? Move this to the results or discussion part and make clarifications.

Section 2.9. It's very odd to have just two sentences in a single section. You should combine this with classification, or introduce more about the Sentinel-2 data. How does the Sen2Cor perform? Can you provide a figure showing the atmospherically corrected surface reflectances of Sentinel-2 data? What are the acquisition dates of your Sentinel-2 data?

Line 231. remove the word 'novel' as random forest classification has been widely used.

Line 234. What tiles? Sentinel-2?

Line 236. How did you reduce the ASD spectra to the UAV bands considering the difference between their bandwidth? Please clarify.

Line 240. This part is not clear. The reflectances at five wavelengths (reduced from ASD spectra?) were used as the feature vector, what's your classification vector? How many classes and what classes you were training? How many training samples do you have?

Line 269. clarify the 'rolling-window approach' or use reference

Line 271-276. Rewrite this part. Specify your surface class.

Line 283. 'surface albedo is adjusted from MODIS...' How?

2.12 Runoff modeling. What's the relationship between your remote sensing classification and runoff modeling. Did you use the classification results to constrain your runoff modeling? Uncertainty estimation should be included. The surface runoff estimation is not rigorous considering the albedo difference.

Line 301-307. Combine these texts with your field site and measurements description in section 2.

Line 312-313: Does the number after '+/-' mean standard deviation? Change the symbol to '±'. What standards did you take to separate the samples into those four classes? Can you show the histogram of your samples and the separating boundaries of the classes?

Line 360. Plot the absorption spectrum for the purpurogallin pigment, with other photosynthetic and photoprotective pigments.

Line 374. Be cautious about making this conclusion based on your field measurements over just one specific area.

Line 383-385. You didn't take any biological measurements over those 'wavy' areas. Generalizing your single-site observation to the entire GrIS is inappropriate.

Section 3.5. This part needs to be rewritten. Many texts should go to the methods section. I find that this manuscript has a lot of those redundant descriptions. Some texts should be in the previous section but were put in the results section. Can you plot out the spectra (reduced to UAV and Sentinel-2 bands) of the four different classes, in comparison with your original ASD spectra? The ASD spectra may well differentiate four different classes, but the reduced spectra would mask out lots of unique spectral signatures considering the coarse spectral resolutions. Otherwise, your classification (no matter what advanced methods to be used) is not supported. Besides, you should also plot out the real UAV and Sentinel-2 spectra, in comparison with your ASD spectra.

Line 444. The this -> The.

Section 3.8. Discuss the potential impact of meltwater itself.

Table 1. explain the abbreviation in your table title or put a note on this.

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