Review for TCD by Stephen Warren, June 2019
Cook et al.: "Glacier algae accelerate melt rates on the western Greenland Ice Sheet".
Recommendation: major revision required.

General statement

This is an interesting and important paper, attempting to quantify the role of algal growth in the energy budget of the Greenland Ice Sheet during the melting season. By comparing and contrasting two dramatically different summer seasons, the importance of interannual variability is shown. The paper should be published after the major comments are addressed.

Major comments

(1) My main concern, the one requiring "major revision", is the inference of optical properties for dust. Figure 2B shows the imaginary part of the refractive index increasing by a factor of 4.4 from 0.4 to 0.7 μm wavelength. This contrasts with the usual finding for desert dust, whose imaginary index *decreases* by a factor of about 4 from 0.4 to 0.7 μm, resulting in a red color in reflection (e.g. Patterson et al. 1977, Müller et al. 2009, Wagner et al. 2012). [These and other references are discussed by Dang et al. (2015, Section 6.4).] The dust of Figure 2B would have a blue color. Blue minerals do exist, but they are rare. I am therefore skeptical that Skiles's method is obtaining the correct answer. If the absorption spectrum of Figure 2B is to be believed, the authors should present evidence for blue minerals in dust that deposits in this part of Greenland. Furthermore, the imaginary index shown for wavelength 0.5 μm (4×10^{-6}) is a factor of 1000 smaller than what is typical of desert dust in the references cited above.

Figure 2C shows the albedo effect of an arbitrary 300 ppm of dust. I didn't find the actual dust concentration given in the paper for the ice that was measured; maybe I missed it. In any case, a plot or table of the albedo effect of the measured dust concentration should be added to the paper.

(2) The size distribution for dust is shown in a supplementary figure 1E, but the interesting data are crowded up to the far left end of the figure, so the location and shape of the peak are hard to see. I would like to see an expansion of the 0-3 μm region of this figure. This is an important finding, so the new figure should be put in the main paper rather than in the supplement.

(3) Color of algae. The algae in Figure 1B are bright red. But the dark zone in Figure 1A is gray, not red. Please explain.

(4) The ice surface is modelled to consist of large hexagonal columns. That is unlikely to be realistic; the shapes are probably irregular. The main thing you need to consider is what is responsible for scattering of light in glacier ice, namely bubbles and cracks, which together determine the most important quantity, namely the specific surface area (SSA). Then a simpler radiative-transfer method could be used, as was done for glacier ice by Dadic et al. (2013, Section 6.1).

(5) The authors collected data from a "dark" year (2016) and a "bright" year (2017), providing an interesting contrast. But the abstract and the conclusion, which should summarize the results, instead give the results only for the dark year, thus exaggerating the average effect of the algae.

The reader will thus conclude that the authors are claiming more importance for their research topic than is justified, which is a shame. The authors have missed the opportunity to use the 2016-2017 contrast to highlight the effect of future climatic expansion of the snow-free season.

(6) It would be good to extend this analysis to cover all of the GrIS. Is that possible, or do the Sentinel satellites not survey the entire ice sheet?

(7) The author-list may be too long. The Author Contribution Statement concludes with the statement: "Other authors commented on the style and content of the final manuscript." This contribution alone does not qualify one to be an author, according to established principles of authorship, as given for example at
http://www.icmje.org/recommendations/browse/roles-and-responsibilities/defining-the-role-of-authors-and-contributors.html
Dr. Cook should carefully consider whether some of his 23 coauthors should be moved to the Acknowledgments. By crowding into the author-list, they deprive the real workers of the credit they deserve.

Minor comments

line 34. Change "albedo-reducing" to "albedo-enhancing" (since addition of dust raised the albedo).

line 35. "western sector of the GrIS" Define, by adding the span of latitudes (65-70 N).

line 187. Give a reference for photosynthesis using 5% of absorbed sunlight.

line 191 (also 425). Latent heat of fusion is 334 J/g, not 334 J/cm^3. This is important since on line 75 the ice density is varied from 0.3 to 0.7 g/cm^3.

line 288. Give a reference for these roughness-heights.

line 313. "SN=0". I am surprised that there was no algae in the snow.

line 400. Define what you mean by "area" of an absorption feature.

line 440-441. "Directional reflectance . . . approximates the measurements made by orbital remote sensing platforms". This is true if the satellite is nadir-viewing, since your surface measurement was a nadir view. Otherwise, your surface measurement is biased low because you are looking directly down into cryoconite holes, whereas the cryoconite material is hidden from the view of an obliquely-viewing satellite.

line 550-551. "We demonstrate that the growth of algae occurs over a large proportion of the ablating area of the GrIS". For this statement to be true, you would need to give estimates for the entire ablation zone, not just latitudes 65-70 of West Greenland.

Figure 3 caption. On line 1, "Albedo map" is for what wavelength? On line 3, change "D" to "E", change "E" to "F". On line 4, change "F" to "G".

Figure 4C,D. The tick marks for months are for the beginning of the month or the middle of the month?

Figure 4D, vertical axis label. What does the adjective "cumulative" mean? Normally "cumulative" implies an integral.

Table 2. The percentages for the UAV add to 94%. What is the remaining 6%? For the Sentinel columns, the percentages add to 1%; probably they should all be multiplied by 100.

Figure S1A, vertical axis label. Define IRF.

Figure S1B. Change the color coding to agree with Figure 1C.

Figure S1 caption, line 1-2. Delete "per unit wavelength", because the values are just unitless.

Very minor comments

line 64. Ryan et al 2018. Do you mean 2018a or 2018b?
line 76. Define IMAU.
line 107. Define GNU.
line 109. Hildebrand. The reference list says instead Hillebrand.
line 127. Define PSD.
line 152. Cook et al 2017. Do you mean 2017a or 2017b?
line 160. Dauchet et al. 2015 is missing from the reference list.
line 169. Warren and Brandt 2008 is missing from the reference list.
line 180. Define IRF.
line 362. Lee and Pilon 2013 is missing from the reference list.
lines 535-537. Say that this sentence applies to the year 2016.
line 614. Update reference from TCD to TC.
line 620. Reference is out of order.
line 739. Reference is out of order.
line 743. Update reference from TCD to TC.

Spelling and punctuation

Hyphenate these adjectives:
albedo-reducing (lines 31, 61, 339, 343, 347)
light-absorbing (lines 48, 69, 324, 531)
bare-ice (line 63, 263, 269)
long-term (line 65)
ice-sheet (line 67, 231, 389)
remote-sensing (line 72, 78, 441)
high-algal-biomass (line 115)
volume-weighted (line 152)
satellite-derived (line 222)
random-forest (line 232)
cloud-free (line 235, 272)
dark-ice (line 265, 266)
two-stream (line 346)
low-albedo (line 496)

line 87. Insert comma after “conditions”
line 191. Change “determine” to “determined”.
line 210. “oin”. You probably mean “in” or “on”.
line 238. Insert comma after “columns”.
line 256. Change “model are” to “models are”.
line 262. Insert comma after “Terra”.
line 275. Insert comma after “year”.
line 276. Insert comma after “available”
line 441. Change “are” to “is”
line 443. “The this” needs fixing.
line 645. Capitalise “smith”

line 658. Fix the author-list.
line 678. Change Fettweiss to Fettweis
line 714. Fix "H.-G.rensen"
line 746. Fix "sheetL"
Supp Info 3. Change "Assymetry" to "Asymmetry" in three places.

References

Dadic, R., P.C. Mullen, M. Schneebeli, R.E. Brandt, and S.G. Warren, 2013: Effects of bubbles, cracks, and volcanic tephra on the spectral albedo of bare ice near the Trans-Antarctic Mountains: implications for sea-glaciers on Snowball Earth. *J. Geophys. Res. (Earth Surfaces)*, 118, doi:10.1002/jgrf.20098.

Dang, C., R.E. Brandt, and S.G. Warren, 2015: Parameterizations for narrowband and broadband albedo of pure snow, and snow containing mineral dust and black carbon. *J. Geophys. Res.*, 120, doi:10.1002/2014JD022646.

Müller, T., A. Schladitz, A. Massling, N. Kaaden, K. Kandler, and A. Wiedensohler (2009), Spectral absorption coefficients and imaginary parts of refractive indices of Saharan dust during SAMUM-1, *Tellus B, 61*, 79–95.

Patterson, E. M., D. A. Gillette and B. H. Stockton (1977), Complex index of refraction between 300 and 700 nm for Saharan aerosols, *J. Geophys. Res.*, *82*, 3153-3160.

Wagner, R., T. Ajtai, K. Kandler, K. Lieke, C. Linke, T. Müller, M. Schnaiter, and M. Vragel (2012), Complex refractive indices of Saharan dust samples at visible and near UV wavelengths: a laboratory study, *Atmos. Chem. Phys.*, *12*, 2491-2512.