The Cryosphere Discuss.,
https://doi.org/10.5194/tc-2020-67-RC2, 2020

The Cryosphere Discussions
Open Access
EGU

Interactive comment on "Effects of surface roughness and light-absorbing impurities on glacier surface albedo, August-one ice cap, Qilian Mountains, China" *by* Junfeng Liu et al.

Alvaro Ayala (Referee)

alvaro.ayala@ceaza.cl

Received and published: 9 July 2020

Review for The Cryosphere

Title: Effects of surface roughness and light-absorbing impurities on glacier surface albedo, August-one ice cap, Qilian Mountains, China. Authors: Liu, Chen, Ding, Han, Yang, Liu, Wang, Guo, Song, Qing

PAPER SUMMARY AND RECOMMENDATION

Liu et al. present a dataset consisting of field measurements of albedo, surface roughness and surface concentration of Light-Absorbing Impurities (LAIs) collected during a

Printer-friendly version

Discussion paper

melt season on the August-one ice cap in the Qilian Mountains, China. The measurements were collected from July to October 2018, spanning most of that melt season (July to September) and one month (October) of the next accumulation season. The collected data are used to propose statistical relations between the three main monitored variables (albedo, surface roughness and surface concentration of LAIs), and to discuss the physical relations between them, among other analyses. In particular, they propose that there is a combined effect of surface roughness and LAIs surface concentration on the albedo of snow and ice.

I think that the topic of this investigation is relevant for the scientific community and The Cryosphere. Although some additional details about the sampling methodology are needed, the data seem well collected, and the physical processes that are proposed to explain the observations are interesting and reasonable. Unfortunately, I don't think that the authors convincingly prove their hypothesis about the combined influence of surface roughness and LAIs, because i) they tend to ignore or minimize the role of snow metamorphism on snow albedo, and ii) the impact of snow patches on a bare ice surface. Please see my main point below for details in this regard. Importantly, the structure of the article is confusing, and the text and figures can be condensed and better organized. Finally, the use of English language should be revised, as it sometimes obscure the ideas of the authors. My recommendation is to reconsider this article after major revisions.

GENERAL COMMENTS

1. Physical connections between surface roughness, LAIs and albedo

a. Process understanding

My main comment is that the authors tend to overestimate the influence of surface roughness on albedo in their analyses and conclusions. I have no doubt that there is a statistical relation between these two variables (as shown in Figure 5), and also some physical connection (Larue et al., 2020), but the collected data does not necessarily

suggest a causal relation. As the authors do in the paper, I divide my arguments for the periods of snow melting and bare ice melting.

- Period of bare ice exposure: Figures 2b and 2c present a good summary of the main idea discussed by the authors. A rough ice surface (with a surface roughness of about 1-10 cm) hides some LAIs, raising the area-average albedo relative to surfaces with uniform debris cover (Bøggild et al., 2010). If the surface smooths over the melting season, the LAIs emerge and the albedo decreases. The authors parameterized this effect using equation (4). However, based on the data shown by the authors, I would say the positive relation between surface roughness and albedo over an ice surface (Figure 5b) can be solely explained by the high-albedo snow patches (shown in Figure 4f) resulting from the snowfall events discernible from the occasional albedo increases during August (Figure 4a). In that respect, can the authors add a figure with the meteorological variables measured at the AWS shown in Figure 1? I think that in order to demonstrate that the albedo increases are only due to changes in surface roughness, the authors would need to show data without snow patches. Otherwise, it seems very plausible that the high-albedo snow patches resulting from the occasional summer snowfall events are responsible for the positive relation between surface roughness and albedo, during the ice melt period.

- Period of snow melting. It is well known that snow albedo decreases due to snow metamorphism and large grain sizes, which affects the light scattering. The increasing grain size can have an effect on the surface roughness, but the latter is also explained by differential melting of the surface. From lines 505-507, the authors seems to suggest that the lowering of the albedo is caused only by the increasing surface roughness.

b. “Physically-based” parameterizations and their potential for large-scale albedo estimates

The statistical relations between albedo, surface roughness and concentration of LASs presented by the authors are described as “physically-based”. Although it is interesting

Printer-friendly version

Discussion paper

that the authors include these variables in an albedo parameterization, these equations are not “physically-based”, because they are not derived from a fundamental principle or process (e.g. energy conservation) and their parameters (obtained from a scatter plot) cannot be directly measured in the field.

In the abstract and conclusions, the authors suggest that albedo can be retrieved from surface roughness at large scales. However, this seems unrealistic because the necessary high-resolution DEMs to derive surface roughness can only be obtained by sensors carried by Unmanned Aerial Vehicles (UAVs), which are only used at the glacier-scale. Are the authors referring to that scale? Using satellite products, albedo is much easier to retrieve than surface roughness at regional scales.

2. LAIs sampling

More details are needed regarding the LAIs sampling. How did you calculate the volume of each sample? Is that the volume of the stainless steel spoon mentioned in line 150? How did you make sure that the volume was the same in every collected sample? Can you include a picture of the spoon? How did you sampled sites with a rough surface, such as one with cryoconites? Did you take the samples at the top or the bottom?

3. Paper structure and English language

Please improve the paper structure. I have the following suggestions: - Section 2.1 is neither data nor methods. Please add a new section called “Study Site”. - Sections 3 and 4 consist of results. I suggest including these sections in a traditional “Results” section. - Sections 3 and 4 have a confusing structure, partly because the titles are ambiguous and repetitive. - The numbering of sections 7 and 8 is wrong. They should be 5 and 6.

I have provided many suggestions to improve the use of English language, but I think that the authors should perform a full revision of the text.

Printer-friendly version

Discussion paper

SPECIFIC COMMENTS

11: “Fluctuations in surface albedo are due primarily to variations in micro scale surface roughness (ξ) and light-absorbing impurities (LAIs) in this region.” I guess you mean fluctuations of bare ice albedo, because snow albedo variations are very large and are due to metamorphism. See my main comment 1a.

21: “ξ could explain 68%of snow surface albedo and 38%of ice surface albedo variation in melt season.” When you write that surface roughness explains 68% of the snow albedo variation, I think that you need to explicitly state that this is a statistical analysis, because the physical explanation for snow albedo variations is snow metamorphism and an increasing grain size. See my main comment 1.

37: “According to Hock (2005), on average it accounts for over 70% of the net energy input to glacier surfaces.” You should mention that that number was obtained for a particular glacier (Storglaciären). In any case, what do you mean exactly by "net energy input"? Net = input - output. Table 1 in Hock (2005) shows that incoming longwave radiation (L_in) is the largest energy input. In general, L_in and S_net are the largest energy inputs to glaciers at daily, and longer, time scales (Ohmura, 2001).

78-79: “poorly investigated, and snow surface albedo parameterization methods based on surface roughness are rarely reported.” However, the relation between snow surface albedo and grain size has been largely analyzed. Please see my main point 1a for snow surfaces.

86: “Surface roughness structures developed during melt season such as crevasses, cyroconite holes, can increase ice surface albedo by hiding LAIs from direct sunlight have been widely reported.” Although, more than "increasing" surface albedo, I would say that they “prevent”, or at least “delay”, a further decrease, because they hide LAis that would otherwise reduce the area-average albedo.

229: How do you calculate the average value and uncertainty of albedo, surface rough-

ness and LAIs concentration at a particular elevation?

242: “LAIs decreased from 0.04±0.03g/ cm3 at middle part to 0.003±0.002g/ cm3 at higher elevations (Figure 3i).” This is based only in one sample at 4700 m, if you delete it, you don’t have any trend. Did you try any other topographic parameter?

247-249: “There was a much higher concentration of LAIs on the uncovered ice surface than snow surface. As a consequence, albedo tended to be low on the ice surface and higher on snow-covered surfaces.” This is not only explained by the LAIs. Ice albedo is usually lower than snow albedo.

378-379: “Although we do not have tandem surface roughness and grain size observations, the evolution of surface roughness calculated at 1mm resolution in snow covered period should quite similar with fluctuation trend of grain size evolution.” Certainly, you have a correlation between grain size and surface roughness, but surface roughness is not only explained by grain size. Differential melting of the surface could be also important.

423-424: “. . .a significant positive relationship rather than a negative relationship was established over ice surface based on manual and automatic measurements. We expect it is related with abundant LAIs over ice surface at the August one ice cap.” This might be explained by the snow patches. See my main comment 1.

448-450: “The performances of the establishes albedo methods either based on surface roughness, LAIs or effective LAIs concentration shows a great improvement over the assumption of a constant mean ice albedo or surrogate variables, such as air temperature, accumulated melt and elevation.” I don’t agree that surface roughness is much better than air temperature or melt to parameterize albedo. Please see main comment 1b.

462-464: “Since surface roughness is dependent and sensitive to topography data resolution (Figure 8a), so which resolution is appropriate for snow and ice surface

albedo estimation?" Was this part of the objectives? Are you writing about the DEM resolution? Please be more explicit in this section and present this analysis earlier in the text.

496-498: "By using manual and automatic photogrammetric measurements of surface roughness, manual LAIs samples and measurement of broadband albedo at the August-one ice cap, we have a general understanding of the surface roughness that controls the albedo of snow and ice surface are quite different." Can you really conclude that surface roughness controls the albedo of snow and ice? See my main comment 1.

505-507: "For snow-covered surfaces, ice particle metamorphism and surface melting and refreezing induced grain size increasing synchronously happened surface roughness increasing, which induced decreasing snow surface albedo in melting season." The last part of the sentence suggests that is the increasing surface roughness that induces the snow albedo decrease.

SUGGESTED TECHNICAL CORRECTIONS

4: Please make the format for last names uniform (sometimes is uppercase and sometimes not).

11: influence on melt

16: the present study consisted of an intensive. . .

19: the middle

19: A detailed analysis indicates that. . .

20: a positive linear

21: for snow and ice, respectively

22: consider -> considering

Printer-friendly version

Discussion paper

25: constant mean -> uniform

33: The energy balance and resulting melt rates. . .

33: the meteorological conditions

34: the physical properties

34: Delete “, which determine glacier melt process”

35: the melting of glacier -> glacier melt

35: dominated-> controlled

35: in the glacier surface -> at the. . .

36: Shortwave radiation is the main energy input causing snow and ice melt

39: net radiation: do you mean net shortwave radiation?

45: “Glacier albedo varies much more dramatically than other land covers” -> Albedo varies much more dramatically on glacier surfaces than on other land covers.

47: “constantly changing surface characteristics”-> I think that you should explicitly mention snow metamorphism here.

47: the solar incidence angle

52: accelerate

57: Simulations

59-62: In general, I suggest improving the writing style by making sentences shorter and more fluid. Here, I would suggest something like: LAIs have decreased the surface albedo of glaciers in Qilian mountains to values as low as 0.13+-0.06 during the melting season (LIT).

59: Please introduce the Qilian mountains before this sentence.

64: I think that you should start a new paragraph when you mention surface roughness.

70: do you mean “first recognized by Kuhn”?

71-72: In which way these field campaigns advanced the influence of roughness on albedo?

75: Studies. Which ones?

75: indicated

75: the inclusion

76: measurements of albedo? Sorry, this is not clear.

76: equations

77: and sastrugi

80: heterogeneous: Please explain better what do you mean by this.

80: of LAIs.

83-85: Please improve the structure of this key sentence.

85: the melt season,

85: crevasses and

86: the direct sunlight

88: Please introduce the ice cap more formally. Where is it? You can give the details in the next section, but give at least some indication here.

90: indicated

93: LAIs on ice

95: combined effects: This is very interesting, and difficult, how do you isolate both

effects? Please see my main comment 1.

96: have been rarely

92: we investigate

93: better understand and simulate. I think that these are very wide and general objectives. Can you be more specific?

106: at the daily scale

101: we investigate

104: on the middle

104: in melting season and accumulation season of 2018 -> in the melting and accumulation season of 2018.

107-108: This is not clear at this point.

114: Study area is neither data nor methods. Create another section.

116: the Qilian Mountains

120: May to September. Mention that this is summer.

120: How short is summer?

126: has been observed.

133: This section should be called data collection and image processing.

137: In some parts of the text you write "we" and in others you write "researchers". Please make it uniform. I would suggest to use an active voice, i.e. "we".

142: several different locations. How many? Make a reference to Figure 1. You don't have any table in your article. It would be good to have one with the coordinates, number of measurements, etc.

142: the top of the ice cap

144: the micro scale topography over different altitudes

145: Physical->You mean topographical in opposition to the turbulent heat fluxes parameter (surface roughness length)?

145: was estimated. How?

146: putting->placing a Kipp and Zonen CMP11 radiation sensor

152: in an oven

156: its operation

157: geo-reference: what do you mean?

159-160: “The photography was repeated at three hour intervals from 9:00 AM to 18:00 AM, UTC+7 time.” But later you work with daily means, don’t you?

159: how many different locations?

168: How did you make sure that the frame stayed horizontally?

185-189: Repetition

190: that surface roughness

190: by directly affecting

195: from the aerodynamic surface roughness parameter developed by Lettau (1969)

196: except that we changed the silhouette area facing upwind to. . .

203: Is V the volume of the spoon?

210: We assumed that

220-224: This sounds like methods to me. Is this the Results section? See my minor

Printer-friendly version

Discussion paper

comments.

225: You also have temporal variability here, not only spatial. Please change the title.

226-227: Again, I suggest shorter and more fluid sentences, something like:

We found a patchy snow cover with many cryoconite holes on the glacier terminus (∼4600 m) at the date of the first field trip (July 12).

230: Be consistent with the digits, i.e. 5.49 cm = 5.5 cm.

244-245: On July 12, surface. . .

246-247: the transient snowline retreated up-glacier.

247-248: On what plot do you base that sentence

248: bare ice surface than on snow.

249-250: Albedo didn't really increased over time.

251: minimal albedo: Do you mean the season minimum?

251: "but it also did not increase"-> and it did not show a clear trend with altitude

259: This is almost the same title as the previous sub-section.

262: October 17

270: mostly bare ice with occasional snowfall events

285: was mainly induced

259: The title of this section is very similar to that of section 3.

298-300: Snow surface albedo and the corresponding surface roughness are analyzed using. . .

301: functions

301: observations

304: Please use the same coefficient in the text and the figure (either r2 or r).

321: What is a patchy ice cover? A bare ice surface covered by snow patches or by debris patches?

322-323: This is not clearly written. Better say that the patchy snow cover is the limit between the two periods that you identified.

324: the relationship

324-325: Delete “without consider surface roughness effect over LAIs concentrations.”

328: Do you mean 5d?

328: manually

331: power function, do you mean linear function?

333: that considering

334: . . .albedo during the snow period.

334: It indicates

365-373: All these lines can be removed, moved to the introduction, or condensed.

369: Meltwater

378: should be quite similar

380-383: This should be mentioned earlier in the text.

386: it means that

388: LAIs are another critical factor affecting snow albedo

392: “increasing surface roughness decrease albedo” But, only in your snow melting

period

396-400: This should be in results.

400: What is the explained variance of each variable?

402: During the accumulation season

403: Please explain better the observed snow metamorphism in the accumulation period

403: During the accumulation period

413-421: This belongs to the introduction

430-433: Please re-write this sentence in a clearer way.

437: over smooth ice -> than smooth ice?

447: are based

TABLES

There are no tables in the article. At least one summarizing the distributed measurements would be useful.

FIGURES

Figure 1: Please add an inset showing the ice cap and the Qilian Mountains in the Tibetan Plateau.

Figure 2: Why is important to have rain or fair weather? Provide a brief explanation.

Figure 3: I would place altitude in the x-axis. Elevation should not be a dependent variable.

Figure 3: In the text of this figure, you write several times that there is a relation with the altitude, but based on your data, this is true only for 3a and 3b.

Printer-friendly version

Discussion paper

Figure 4: Make a uniform tick spacing in the x-axis. Example, 1-07 15-07, etc.

Figure 4: From this plot is evident that there were 3 or 4 snowfall events in August. See my main comment 1.

Figure 4: Add a line in panel a to show when were the pictures taken.

Figure 4: Show the dates of the pictures in the pictures.

Figure 5a: Note that for low albedo (<0.4) you can get very different surface roughness (1-6 cm).

Figure 5: Consider the use of different markers (in a-b and c-d) to reduce the number of panels. As in Figure 4s.

Figure 5: I would strongly suggest using only one paragraph to describe one figure. This is a big help for readers.

Figure 5: How many different sites are included in the manual measurements shown in this figure?

Figure 6: Can you merge both plots in one panel by using different markers? A logarithmic scale might be useful.

Figure 7: Apart from the high albedo for low surface roughness, there is a poor relation between the two variables. Maybe move to the supplementary?

Figure 8: What is the difference between these pictures and those shown in Figure 1s?

Figure 2sa-3sa: How many different sites did you use to build this plot?

Figure 4s: This is a very nice figure, because it shows both periods in the same plot. Can you move this figure, or a similar one, to the main text?

REFERENCES

Bøggild, C. E., Brandt, R. E., Brown, K. J., and Warren, S. G.: The ablation zone

in northeast Greenland: ice types, albedos and impurities, Journal of Glaciology, 56, 10.3189/002214310791190776, 2010.

Ohmura, A.: Physical Basis for the Temperature-Based Melt-Index Method, J. Appl. Meteorol., 40(4), 753–761, doi:10.1175/1520-0450(2001)040<0753:PBFTTB>2.0.CO;2, 2001.

Larue, F., Picard, G., Arnaud, L., Ollivier, I., Delcourt, C., Lamare, M., Tuzet, F., Revuelto, J., and Dumont, M.: Snow albedo sensitivity to macroscopic surface roughness using a new ray-tracing model, The Cryosphere, 14, 1651–1672, https://doi.org/10.5194/tc-14-1651-2020, 2020.

Interactive comment on The Cryosphere Discuss., https://doi.org/10.5194/tc-2020-67, 2020.

Printer-friendly version

Discussion paper