

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.

Anonymous Referee #1

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REVIEW: Liu et al., TC

Journal: TC Title: Effects of surface roughness and light-absorbing impurities on glacier surface albedo, August-one ice cap, Qilian Mountains, China Author(s): Junfeng Liu et al. MS No.: tc-2020-67 MS Type: Research article

General Comments

Authors measured the spatial and temporal surface albedo variations over the Qilian mountain glacier. They analysed the albedo fluctuation considering the presence of small-scale surface roughness and light-absorbing impurities. They proposed an appropriate parametrization of albedo with these two parameters. Reviewer gives a

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certain appreciation for the reasons that authors show a strong impact of these contributions on the surface albedo at different location (snow cover, ice cape, bare ice) using an extensive dataset of in situ measurements. However, unfortunately, the organization of the manuscript and presentation of the data and results are too hard to follow. In particular, it is not clear what is the novelty of this paper compared on earlier work of Warren, Cathles, Pfeffer, Lhermitte and many others. The explanations and some results are insufficient. For now, the paper is not a significant advance or contribution, even though it has the potential with interesting measurements. In addition, the structure of the paper can also be much improved and the paper can be condensed. Substantial revisions are needed before having a merit for the publication in the TC. Reviewer is particularly concerned about the fact that no SSA measurements were acquired and the impact of the variation of the snow grain sizes with the metamorphism is barely spoken. It is difficult to believe in an exhaustive study of the impact of surface roughness/LAP on albedo without having an idea of the impact of snow metamorphism, since these 3 parameters are strongly linked in albedo variations. Authors should carefully confirm the results by including this analysis, maybe by adding a section speaking of this parameter (or using existing values of snow grain size published in the literature over this region). Moreover, reviewer suggest to modify the structure of the manuscript to present the results clearer. The organization of the manuscript and presentation of the data and results need some improvement. Indeed, sections are mixed, and there are many repetitions that can be easily avoid. The protocols of measurements are not enough detailed whereas it is very important to be confident on the measurement analysis. Finally, a deep revision of the english grammar has to be done to make the lecture easier.

Specific comments:

1) The english has to be carefully corrected. Reviewer tried to highlight some errors in the 'technical corrections' section but there are many english mistakes making the reading difficult.

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2) Sections have to be read carefully to remove repetitions and to make the conclusion clearer. For example, it is often that in a 'snow section' authors speak about ice albedo measurements. Moreover, reviewer suggests to add small sentences at the end of each section to highlight the result. For example 'over ice cape, the albedo increases while the surface roughness increases and the LAI decreases'.

3) Explanation and results are insufficient: scatter plots presenting field observations have to be followed by physical analysis, according to what has been shown in the litterature. Deeper explanations are needed to better understand the novelty of this work.

4) Figures need to be well called in the text, it is hard to follow the analysis when the text does not refer to the right figure. Moreover, reviewer suggests small changes in the graphs to be clearer (in the 'technical corrections' section). For example, It could help the understanding if authors replot the Figure 3 with different symbols/colors associated to 1) measurements taken over snow cover 2) measurements taken over ice surface.

5) As said in the 'General comment' section, it is not clear what relationships have been highlighted in this paper. There is a strong relationship between SZA/SSA/LAI/roughness/albedo. The impact of the solar zenith angle and SSA variations needs to be analysed deeper.

6) The Protocols/Measurements sections need more explanations. For example, the accuracy of the instruments should be precise, and references presenting the instruments are missing. Reviewer has some questions about the protocol performed to acquired albedo measurements: How do you estimate the direct/diffuse part of the albedo? Measurements are acquired in clear sky conditions? At which height was located the sensor (ie what is the area actually seen by the sensor) ? What if you measure the aluminium square in addition to the snow surface?

7) There is a problem of unity in equation 2, epsilon is in cm while the h^* variable is in meters.

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8) Nothing is new in the discussion part, except the parametrization method. Authors insist on the fact that it is physically-based, but it is not, it is fitted over the area so it is empirical. The sections should be better organized, this is very confusing.

Moreover, the new parametrization should be investigated deeper, the associated error needs to be estimated for each type of surfaces (using control points over the snow covered surface, the ice surface, ...).

Technical corrections

L13: 'Fluctuations in surface albedo are due primarily to variations in micro scale surface roughness (ξ) and light-absorbing impurities (LAIs) in this region.' => Please add the SSA+solar zenith angle L.22: by consider => by considering L.43: english => if we want to improve the accuracy of the energy budget estimate L.52: can accelerates => can accelerate L.54: which enhance => which enhances L. 60: Please rewrite: 'For the Qilian mountain glaciers, where the measured daily mean albedo decreased to the lowest of 0.13 ± 0.06 due to the effect of LAIs for four glaciers observed during melting season' => For example: For the Qilian mountain glaciers, the measured daily mean albedo decreased to 0.13 ± 0.06 due to the effect of LAIs for four glaciers observed during melting season L63: Please put this sentence before, in the section above: 'As the snow melts, insoluble LAIs are retained at the snow surface, so concentrations of LAIs in surface snow increase with snow melt, further reducing snow albedo (Doherty et al., 2013)'. L75: Studies have indicates => Studies indicated L80: the distribution LAIs=> the distribution of LAIs L85: Surface roughness structure => 'Surface roughness features' seems more appropriate.

L88: 'During the past 5 years the August-one ice cap has become darker due to the accumulation of LAIs' => Please add a reference. L90: has indicate => has indicated L97: we try to investigate => we investigated L100: at different altitudes and times => and resolution? Or please add the resolution. => This section needs to be rewrite to present clearly the plan of your study. For example: 'first, to study the spatial

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variation.../second. . . Considering the following structure of your paper: 1st objective: spatial variation, just the relationship between manual photo/lai/albedo 2nd objective: temporal variation. L100: Combine with => these measurements were combined with L108: based on => using only ... or both ... L118: It ranges in elevation => the elevation ranges from ... L125. The glacier becomes darker with years? It was said in the introduction. Please clarify. L134: Please specify if you are talking about 3D photogrammetric acquisitions or 2D photogrammetry, and the references need to be adapted (for instance, Manninen = 2D acquisitions with a board, Irvine-Fynn = 3D acquisitions) L139: of $\sim 1.75 \text{ m}^2$ => it is a very small area, is it representative? How was the area chosen? L 139: Please clarify: 'by surrounding the target area of snow or ice surface', do you mean by turning around? If yes, what is the space between each step/picture? L143: Please specify the number of sampled areas. L147: 'Glacier surface albedo was calculated from measurements of up and downward shortwave radiation.' => how were acquired the up and downward shortwave radiation? Please add details about this protocol and sensor.

L160: 'For automatic photogrammetry': how were process the pictures? With a software? Did you use only one reference target? Did you use control points? What is the error of the final DEM? Please clarify.

Figure 2: Please rename a) and b) because they have the same caption. + remove '[Figure 2]' in L 181 => please removed this typo for all figures. L185: repetition => 'Ice surface albedo is very sensitive to the LAIs concentration over ice surface.' Please add a sentence of transition, for example 'the surface roughness features impact the distribution of the snow impurities'.

L190: by direct => by directly affecting L 192: There is a problem with the unity of equation 2. epsilon is in cm while the h^* is in meters? L192 : equation 2 is the first equation => it is equation 1 here. Please correct the other equation notations in the text. L 195: 'from Lettau (1969) developed aerodynamic surface roughness' => 'from Lettau (1969) who developed aerodynamic surface roughness...' L198: adopted =>

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adapted L202: Please add a reference to introduce this metric. L205: This sentence needs to be rewrite: 'For rough ice surface means more surface area and less concentration of LAIs over ice surface, I don't understand. L207: by consider => by considering L207: this is a new metric? If yes, please change 'defined' by 'introduced'

L220: 'For that reason, we used only half-hour albedo data taken when zenith angles were less than 60° ' => Did you test the accuracy of the sensor considering the zenith angles? Is this a known angle of limitation? Or please add a reference. L222: from 11:00 to 17:00 o'clock => what range of zenith angle it is? It strongly depends to the date of your measurements + elevation of the studied site. Please clarify. => It seems that this section should be written in the protocol of albedo measurements, not here in this 'result' section. L225: field investigation => is it based on your automatic photogrammetric measurements? Please clarify. L230: Surface roughness => replace it by 'the associated epsilon measurements decreased ...' L236: 'Surface roughness fluctuated between $1.4 \pm 0.4 \text{ cm}$ to $3.3 \pm 1.1 \text{ cm}$; An increasing trend of surface roughness could be detected as altitude increased (Figure 3e). ' => please, inverse these two sentences to be clearer. L245: 'surface roughness and LAIs decreased as altitude increased.' => not clear because it is only the case in July. In August 3: surface roughness increased as altitude increased and there was some snow cover at the top of the ice cap. Please clarify. L247: 'There was a much higher concentration of LAIs on the uncovered ice surface than snow surface' => I don't understand the 'much', the trend is not so strong? It could help the understanding if your replot the Figure 3 with different symbols/colors associated to 1) measurements taken over snow cover 2) measurements taken over ice surface. L248: 'As a consequence, albedo tended to be low on the ice surface and higher on snow-covered surfaces.' => be careful with this sentence, this is also mainly due to SSA values that strongly impact the albedo. There is a strong relationship between SSA/LAI/roughness/albedo. Please rewrite this sentence. L251: repetition with L240-243 => this section needs to be re-structured in order to remove repetitions and to be clearer on conclusions.

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L260: 'The automatic measurement setup in the middle of the ice cap' => 'The automatic measurement setup was in the middle of the ice cap' L.264: 'Intermittent snowfall decreased surface roughness and increased albedo' => you should add that it is because there is fresh snow, and fresh snow has high SSA, inducing a high albedo. Figure 4: It could be clearer if you add the intermittent snowfall with vertical lines + air temperatures (to know when it is melting). L265: 'When snow began to melt'=> when is it ? How do you measure that? Do you have air temperature or snow surface temperature? If yes, you could add it on Figure 4 (see comment above). L276: 'When the snow melted, leaving patchy snow cover, surface roughness increased and albedo decreased quickly to around 0.3 ± 0.05 within two day'. Here again the sentence needs to be rewrite: snow melting = lower SSA = lower albedo, the decrease of albedo is not only due to the increase of surface roughness and LAI. Please clarify. L276: 'from September 4 to 15, ice surface roughness fluctuated and increased to 2.63 cm on September 13.' => not clear, is it increasing from september 4 to 15, or for september 4 to 13? L277: 'Ice surface micro scale structures of cryoconite holes hidden LAIs from direct sun light.' => this sentence needs to be detailed to highlight the observations. => Reviewer suggest to recall this section (for example '3- Field observations'), since it details all the field observations, but not clearly enter in the physical analysis of the relationships between LAI/roughness/albedo. The analysis should include SSA variations. Even if no measurements were taken, it has to be mentioned (relating to the snow type of the area for example).

Figure 5: Please rewrite the x axis 'Surface roughness (cm)' with the epsilon metric. L301: Figure 2s => I am not sure this figure provides a lot, since it is well resumed in Figure 5a. In Figure 5a, the measurements taken manually and automatically should be separated by two different symbols to be clearer. L302: 'The combined manual and automatic scatter diagrams of Figure 5a display a significant negative power function between snow surface roughness and snow albedo (Figure 5a, $r=0.82$).' => this is a repetition.

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L314: Figure 3s => same as above, the Figure 5b gives approximately the same information. Authors could put different symbols for manual/automatic measurements on Figure 5b. Figure 4s: snow, patchy snow and bare ice surface => In the 'data and methods' section you should defined this terms. How do you classify an area as a 'patchy snow'? Is there a quantitative measurement of the proportion of snow in the area, or is it qualitative? How do you distinguish areas with very dense snow surface to ice surface? Please clarify. L 324: 'Scatter plots of Figure 5c and 5d shows relationship between C LAIs and albedo' => Reviewer suggests to introduce a new section dedicated to LAI-albedo relationship, or to separate the section to put the analysis of the LAI-albedo relationship over snow surface in the 'snow surface section', and over ice surface in this 'ice surface melting season'. L325: 'LAIs concentration is lower than patchy snow surface' => ' LAIs concentration is lower than the one measured over patchy snow surface' L327: Figure 4c => Figure 5c, and Figure 4d => Figure 5d Please a particular attention should be taken on the notation of Figures in the text, this is confusing.

L329: Please introduce a new section, or reorganise this section into the 'snow surface section' and the 'ice surface section'. L329: 'the effective LAIs concentration of C ξ ' => 'the effective LAIs concentration (C ξ) ' by considers roughness effect' => 'by considering roughness effect' L330: C ξ is estimated based on equation (4). => this is a repetition L334: 'It indicateS that the Ceps concentration IS not affectED by surface roughness.' => english L335: 'Equation (3) is more appropriate to calculate LAIs concentration than equation (4) over snow surface.' => I don't understand. Do you mean 'to retrieve LAI concentration directly from albedo measurements'? Please clarify. L339: 'by consider surface roughness effect over not consider it in Figure 5d' => english L341: 'It means equation (4) estimate C ξ could explain more ice surface albedo than equation (3) calculate C LAIs .' => please clarify. Do you mean: could explain ice surface albedo variations? L352: english mistakes L354: 'In accumulation season, except snow particles metamorphism process, constant blowing snow and intermittent snowfall was the main reasons which induced surface roughness fluc-

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tuation;' => More explanations are needed. In this Result section: the english has to be carefully corrected, some sections has to be restructured, the field observations and scatter plots have to be followed by physical analysis, according to the litterature, with more explanations. Figures need to be well called. Some changes in the graphs are suggested to be clearer.

L380: 'The grain size is one of the most critical factors affect snow albedo' => 'The grain size is one of the most critical factors affectING snow albedo.' L385: 'which is very similar with scatter plot of surface roughness and snow albedo provided in this study in Figure 5a and Figure 7.' => Please specify if this studies worked with the same snow type as you.

L386: 'It means surface roughness as substitute of grain size is quite suitable for snow surface albedo explanation and parameterization at millimeter scale' => Please be careful with this conclusion, the study areas are not the same. To conclude this you should have both measurements (ssa and roughness) at the same site, at the exact same time (same sza) and over a dry and clean snow (no impurities, no liquid water content). Please clarify. Several contributions affect the albedo, and it is very difficult to separate each contribution to better understand/quantify their impacts on the albedo. L388: english L406: 'We expect that different mechanism of surface roughness evolution over melting season and accumulation season are the main reasons of different statistical relationship.' => This is not the main reason, the SSA variation also plays a strong role. Please clarify.

Section 7.2: The name of the section should be changed: authors speak about macro-scale surface roughness effects in this section, and in the section before it was at millimeter-scale. L415: 'more incident radiation is absorbed by the slope facing the sun than by the slope facing away from it.' => this is not the only reason (see Warren et al 1998). The main reason is that photons are trapped between cavities, which increases the chance of a photon to be absorbed. Please clarify and detail the physical analysis. L430: filed investigation => english L430-433: Please rewrite the

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sentence, I do not understand L441: 'Rough surface means lower concentration of LAIs and high albedo over smooth ice surface with heavy loading of LAIs and low ice surface albedo.' => this is confusing to speak about rough surface of a smooth ice surface.. how do you define a smooth ice surface? What is the scale of roughness features that you are talking about? Please clarify. => this is very confusing between Sections 7.1 and 7.2 => when are you talking about ice surface and snow surface? For example: the first section of the section 7.2 is talking about snow surface (see the litterature), and not the ice surface. Please clarify. L447: 'Most of the established and widely used snow surface albedo parameterization ARE either based on snowpack age, snow depth, snow density, air temperature' => english => Please add the SSA and SZA (see the litterature of Kokhanovsky) => This sentence should be put in the section 'snow surface', not 'ice surface'. L450. Please add a reference L451: 'We expect the new parameterization methods provides' => english 'are more physically based than some of the studies presented.' => What new parametrization? Please refer to the equation here. (as equation 5 but for ice surface) This sentence needs to be rewritten: this is not a physically based parametrization, it is empirical. Indeed your equation 5 strongly depends of your study site and your measurements.

L466: 'For snow covered surface, the coefficient increases quickly from -0.67 to - 0.74 when 1m plot resolution increases from 333.3 mm to 200.0 mm' => but the Figure 8a shows a very flat and smooth snow surface? Please clarify the studied surface. L485: 'This could be a practicable way to parameterize surface roughness and albedo on a whole-glacier scale' => Please add some details. It could be interesting to apply the method proposed by Smith et al 2016 here, to estimate a temporal mean albedo at the whole-glacier scale.

Section '7.3 Glacier surface albedo parameterization at whole-glacier scales based on surface roughness' => the title needs to be changed since you investigate the sensitivity of the albedo relationships at a plot-scale, but not at the whole-glacier scale in this section. => Moreover, please rely your analysis with the litterature (Irvine-Fynn et al

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2014; Smith et al 2016 ..) to clarify what is the novelty of what you propose. => It could be interesting to estimate the LAI coverage with your photogrammetric acquisitions as Takeuchi et al 2018.

L497: 'we have a general understanding of the surface roughness that controls the albedo of snow and ice surface are quite different.' => english L502: 'necessity to consider' => english L504: 'Surface roughness seems play a quite' => english L535: 'field data of LAIs, surface roughness and albedo need to collect to help us to present more detailed analysis and modeling research about surface roughness and LAIs at micro scale over ice or snow surface energy and mass balance process.' => SSA measurements should be acquired too.

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