

## ***Interactive comment on “Correction of albedo measurements due to unknown geometry” by U. Weiser et al.***

**U. Weiser et al.**

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We thank the reviewer for the helpful comments and suggestions on how to improve the manuscript. In the course of revision of the manuscript several changes were made. Therefore, some of the suggestions have been included and others were obsolete due to the changes. Please see our answers to the points below:

The paper proposes a method to correct broadband albedo measurements from errors caused by the unknown slope of the underlying surface and the imperfect levelling of the sensor. This problem is common and not often addressed in the literature. This makes the goal of this paper important. Unfortunately the paper and more specifically the introduction and first subsections of the method are not well written, not rigorous enough and as a consequence subject to mis-interpretation. Many statements lack

C2072

proper references, are vague or are only valid for a very specific context (e.g. alpine conditions) without this context being explicit. This is incompatible with the international audience of The Cryosphere. The discussion is short and provides too basic information. At last, the terms referring to optical variables do not follow scientific standards or are not precise enough (in the introduction, this improves in the other sections). Various terms seem to be used for the same meaning (e.g. radiance / irradiance, global / total, directly, . . .) which is confusing. The description of the direct model and the fitting approach is exhaustive and well done. The assumptions are also clearly stated. However, the assumption that the (true) albedo of snow surface is constant over the day is overoptimistic. It is well known that snow albedo depends on the solar zenith angle and many studies present this result through analytical derivation, experimental results or numerical computations. The correction proposed by the authors relies on the measured albedo variation as a function of the SZA during the day and is designed to minimize the albedo variations during each day. By doing so, it removes not only the geometrical artifacts (which is good) but also the variations of physical origin (which is bad). It over-corrects the albedo and it is difficult to know if the corrected one is better than the un-corrected one. To solve this major issue, it is suggested to either include theoretical/analytical calculation of snow albedo into the direct model presented in the paper or, at least, show a few computations (or find some data) to evaluate the relative effects of the slope versus “normal” SZA dependence and demonstrate the physical variations are second order compared to geometrical artifacts. As a conclusion, the method presented in this paper may be interesting once the albedo dependence to SZA is taken into account and the text is improved. The following detailed comments should help for a first correction. At last English should be revised.

Detailed comments: \* P2710 L17 “The energy balance of a glacier surface defines the amount of energy available for the ablation processes, once the underlying snow/ice is isothermal”. Please clarify isothermal. Do you mean “reach freezing point”? We refer here to the freezing point as we are on a glacier, isothermal means a constant temperature.

C2073

- \* P2710 L20 What is an “isolated area of a glacier” ? ‘isolated’ changed into ‘remote’
- \* P2710 L25 “ideally southwards”. Specify in which hemisphere Due to changes in the manuscript this part is now changed.
- \* P2710 L25 it is not clear what “changing conditions” refers to: weather, snow or instrument ? Due to changes in the manuscript this part is now changed.
- \* P2711 L1 “In the method described in this paper”. Give first the objective of the paper. It is not clear at this point that the paper is about a method (introduction must be independent of the abstract). Due to changes in the manuscript this part is now changed. References were added and we explained it in more detail.
- \* P2711 L1 “cosine law” is not clear for most readers, especially when it is used to refer to the error with respect to the ideal cosine law. Give a reference or details and check throughout the paper the use of this term. Due to changes in the manuscript this part is now changed. References added and explained in more details.
- \* P2711 L3 “Many publications”. Give references of several of them. Due to changes in the manuscript this part is now changed. More references added.
- \* P2711 L9 “caused by the specular components of daily albedo”. What is “daily” albedo ? Is it the averaged ? Explain also “specular components” (especially the plural). Explained, rephrased and referenced. (specular reflections)
- \* P2711 L14. Remove the parenthesis Corrected.
- \* P2711 L14 “global radiation”. The term global is not clear. Correct throughout the text. Due to changes in the manuscript this part is now changed. It is now explained better in the text.
- \* P2711 L19. References needed. References added.
- \* P2711 L23 “described problems of albedo” is vague Due to changes in the manuscript this part is now changed.

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- \* P2712 L7 “These results are essential because albedo of a forest is expected to be almost constant, in contrast to snow albedo which changes over time.”. It is not clear why the result is essential. Due to changes in the manuscript this part is now changed. Also explained better with more details in the text.
- \* P2712 L12 “Extinction coefficient” seems to be misused here. Do you mean optical depth ? Rephrased and References added.
- \* P2712 L19 “on preceding clouded day” → cloudy. Check everywhere. Thank you, changed.
- \* P2712 L20. Not sure the reference Weiser, 2012 is perennial and useful for many readers (not in English and no doi). Understanding the text should not depend on it. Due to changes in the manuscript this part is now changed.
- \* P2712 L20-21. The sentence is difficult to understand. The value +0.15 depends on the solar zenith angle (+other parameters). Precise the conditions (latitude/period of the year or sza). Due to changes in the manuscript this part is now changed.
- \* P2713 L5. Equations must be ordered (first is (1), second is (2), . . .) Equations ordered.
- \* P2713 L14. References needed. Due to changes in the manuscript this part is now changed.
- \* P2713 L15. What is “Realistic physical range” ? Due to changes in the manuscript this part is now changed. Ranges listed in results and explained in details what is expected.
- \* P2713 L18. “the tilts of the sensors increase over time”. This statements is not always true. Give references, examples or remove it. Due to changes in the manuscript this part is now changed. Explanations and references added.
- \* P2713 L20. “Reasonable” is subjective, remove. Define “diurnal mean albedo” Due

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to changes in the manuscript this part is now changed. Definition added.

\* P2713 L21. "The method described in the present paper shows how to correct the true albedo with unknown tilts and directions of both the slope and the sensor." → the present paper proposes a method to correct measurements of albedo . . . Due to changes in the manuscript this part is now changed.

\* P2713 L23. "the direct incoming radiation being reflected diuently". Do you mean the reflected radiation ? Due to changes in the manuscript this part is now changed. Explained in Discussions and demonstrated in Figure 4.

\* P2713 L24. "the slope of the observed apparent diurnal variation of albedo". Which slope ? Due to changes in the manuscript this part is now changed.

\* P2714 L17. "For an opening angle of 160 the cosine error" is not clear. Due to changes in the manuscript this part is now changed.

\* P2715 L1. "0.5 %". Do you mean 0.5 degrees or 0.5% of something that must be specified in the text? The error details are taken from the data sheet.

\* P2715 L5. "5%". Where this value comes from ? The error details are taken from the data sheet.

\* P2715 L10. References needed for BSRN and Suntracker. References added.

\* P2715 L18. Remove "described". It is not yet described. Due to changes in the manuscript this part is now changed.

\* P2715 L20. The assumption of constant broadband albedo seems not reasonable because snow and probably concrete albedo has a strong dependence to SZA and spectrum of the incident radiance. Due to changes in the manuscript this part is now changed.

\* P2717 L5. "As most glaciological measurements " unnecessarily subjective. Rephrase. Rephrased.

C2076

\* P2719 L13. "On a real measuring site," → in practice Rephrased.

\* P2720 L18. Epsilon is not an extinction coefficient. It includes the path length (which is not constant) and should be renamed to avoid confusion. References were added to epsilon.

\* P2720 L1. Assumption 3 is very strong! Discussion and evaluation of this effect should be done especially regarding the statement P2716 L18. Due to changes in the manuscript this part is now changed.

\* P2720 L3. Reference is needed for the assumption 4 Due to changes in the manuscript this part is now changed.

\* P2721 L12. Give details on the time resolution and the hours (or sza) used for the fitting. Due to changes in the manuscript this part is now changed.

\* P2721 L11 and L19. Is V a atmospheric parameter ? Or is it mainly related to the sensor ? Due to changes in the manuscript this part is now changed. Meaning of V explained. V is the ratio between spectral range of pyranometer and TOA irradiance

\* P2721 L15. "Radiation model" is not clear. Which equation is it referring to ? Explained earlier in the text. Refers to the solar position algorithm (SPA).

\* P2723 L23. I don't understand the sentence with "... where... where..." Due to changes in the manuscript this part is now changed. Meaning of V explained.

\* Section 2.3.3 is obscure. E.g. P2723 L5 "factor C should be as constant as possible" and the following sentence: "the constant C" and again at the end of the section "C is as constant as possible". Rephrased.

\* P2724 L2. I don't understand "flat" zenith angle. Due to changes in the manuscript this part is now changed. 'Flat' should be 'high'.

\* P2724 L6. What is "SD" ? SD = standard deviation, it is now explained in the text.

C2077

- \* P2724 L11. Remove the middle equation Removed.
- \* P2724 L14. I don't understand Alpha means albedo in general, measured, modeled, corrected and true albedo.
- \* P2724 L20. Where are the results/data ? References to Tables with results added.
- \* P2724 L21. Not sure to understand "weighted". Due to changes in the manuscript this part is now changed. 'Weighted' means 'determined', but sentence rephrased anyway.
- \* P2724 L21. How the range is obtained ? Can it be shown in a figure ? Why is it so large ? Explained, referenced and discussed.
- \* P2724 L22. This is not shown by the results and should be moved to the discussion (with references). Due to changes in the manuscript this part is now changed.
- \* P2724 L22. Same question. Why such a ranges ? Explained, referenced and discussed.
- \* P2725 L24. I don't understand. Rephrased and paragraph added for explanation.
- \* P2725 L25. Remove "Reasonable" and give uncertainty range or other scientific arguments. As far as I see, the corrected albedo is not more constant than the uncorrected one (please give standard deviation or any statistical metric that can help to give objective arguments). It means the correction is not efficient, can you comment on this ? Due to changes in the manuscript this part is now changed. Detailed explanations given are in the discussion section.
- \*P2726 L13: "acceptable zenith angles" is subjective. Again L14 Due to changes in the manuscript this part is now changed.
- \*P2726 L22: observed albedo ? Rephrased and explained in more details.
- \* P2727 L2: "directly" is not clear and not used before, which is disturbing. Due to changes in the manuscript this part is now changed.

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- \* P2727 L3: remove "(true)". True albedo is the goal. Estimated or corrected albedo is ok. Due to changes in the manuscript this part is now changed. We decided to still use 'true' albedo, because the true albedo is the unknown albedo we want to find.
  - \*P2727 L25: "flat" is not adequate + I don't understand the end of the sentence. Due to changes in the manuscript this part is now changed.
  - \*P2728 L3: which "direction" ? Due to changes in the manuscript this part is now changed.
  - \*2729 L10: "flat" Due to changes in the manuscript this part is now changed.
  - \*2729 L10: "differences" between what ? Due to changes in the manuscript this part is now changed.
  - \*2729 L20: "flat" Due to changes in the manuscript this part is now changed.
- Figures 3 and 5. Instead of using UTC for a specific day and latitude, why not to compute as a function of SZA ? Otherwise, add the relevant information of latitude and day in every figure and in the text. We decided to leave UTC and not add a specific day, as these Figures show the diurnal variation of albedo when either the slope or both, the slope and the sensor is tilted, no matter which surface in any area is observed.
- Figure 4. Can be removed because it is not useful unless angle notations are added. We decided not to remove it for better understanding.
- Figure 5. The colors of the curves should be taken from a circular continuous color scale. South and north facing could be shown with a stronger face (instead of showing the 315 degrees curve with dash). Colors are continuous now, we left the output values, as there are shown four different Figures with different tilts and directions.
- Figure 6. Title should include "... and compute the net SW radiation" Changed into: net shortwave radiation balance.
- Figure 7. the albedo labelling on the right y-axis needs to be extended down to 0.

C2079

Irrelevant, because only  $SZA < 50^\circ$  was considered.

Solve the overlap of the date and label on the x-axis... Solved

The cyan color should be avoided. We decided to leave the color.

Most figures: Units should be written without slash, use scientific notation. Symbols and units explained in the Appendix with scientific notations.

Additional changes of the manuscript: Abstract, Introduction, Discussion and Conclusions rewritten. High resolution radiation model introduced to improve and expand the described method. Solar zenith angle limited to  $50^\circ$ , where no albedo dependence occurs. Appendix with all used symbols and their units was added.

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