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Interactive comment on "Grain shape influence on light extinction in snow" *by* Q. Libois et al.

Anonymous Referee #2

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Grain shape influence on light extinction in snow

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General Comments:

This paper evaluates the spherical snow grain assumption that many snowpack radiative transfer models use to calculate albedo and transmission of light through snow. A multi-layer snowpack radiative transfer model (TARTES) is developed that allows the asymmetry parameter and the absorption efficiency parameter to be altered to best match measured radiation profiles in snow at Dome C and in the French Alps. A Monte Carlo (ray tracing) model is used to estimate the asymmetry parameter and absorption efficiency parameter for various geometric shapes. The authors find that the absorption efficiency parameter in simulated snow containing only spherical snow grains is under-

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estimated, which leads to higher e-folding depths compared to the e-folding depths measured in snow at Dome C and in the French Alps. Modeled absorption efficiency parameters are compared to inferred absorption efficiency parameters in the literature.

It would be useful for the authors to consider transmission of radiation in the UV and near-visible wavelength regions. It would be interesting to compare observed UV/near-vis radiation profiles with modeled profiles to obtain an estimate for B. Perhaps this could be a point of future study. This is a well-written paper with a good deal of insightful discussion. I recommend that this paper be published after the minor corrections are addressed below.

Specific Comments/Technical Corrections:

P 2802

12: state what the parameters B and gG represent

14: state which macroscopic optical properties are impacted

27: consider adding “but not necessarily on the albedo of snow” after AFEC. Also, what is meant by “natural” snow?

P 2803

8-11: The amount of solar absorption in snow is sensitive to changes in grain size and impurity content. The light extinction in snow is influenced by both changes in snow grain size and impurity content, but the albedo is not influenced by impurities until the impurity levels are high enough [Warren et al., 2006]. Perhaps alters the sentence to acknowledge that grain size and impurity content (both considered snowpack physical properties) do not influence the albedo in the same way.

13-14: Brandt and Warren [1993] state that IR radiation is absorbed in the top few millimeters. For photochemical reactions, the UV and visible wavelengths are of interest. It would be helpful to be more specific about the wavelength regions of interest in this

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sentence.

19: No comma needed after “energy”

27-28: Remove comma after “properties” to make the sentence clear.

P 2804

7: It would be good to mention equivalent spheres explicitly in this sentence.

26: Zatko et al., 2013

P 2805

14: Is “it” referring to the derivation?

P 2806

7: It would be helpful to mention whether these quantities can be measured in a bulk sense or if they can be measured in individual layers in the field.

13: “profiles” instead of “profile”

26: Ice is weakly absorbing throughout this region (compared to the IR), but ice becomes more absorptive towards the IR, which might be worth pointing out. At 1350 nm, ice is considerably more absorptive than at 300 nm.

P 2807

E6: Please mention that this equation calculates the “co-albedo of single scattering”

P 2808

3: Briefly explain why gD does not change when the snow grain size and shape is changed although gG does change.

8: Cite Warren and Brandt [2008] (or another comparable reference) when stating that the real part of the imaginary index by constant at those wavelengths

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P2809

12: Please add a sentence or two (or perhaps another intermediary equation) to describe how the authors used E10 and E11 to obtain E12.

P 2810

2: “independent”

P 2812

6: “proportional”

E23 and 25: should lm be ln?

P 2813

7: g is the asymmetry factor, which contains gG. Because the asymmetry factor from other studies is used for comparison in the discussion section, it would be more clear to refer to gG as the geometric diffusion term rather than the asymmetry factor throughout the manuscript.

P2815:

6-8: Considerably more shapes are below the iso-albedo line than above in Figure 1b. It is not clear to me that a statement about median albedos being that of spheres can be made from the data in Figure 1b.

9: “those” instead of “that”

22: Clarify the difference between AFEC and ke in the manuscript.

25: E12 is still used if impurities are present, right? Is it correct that E25 is used in E8 and E9 and then that E8 and E9 are used to calculate B in E12.

P2816:

5: What are the values most commonly used for $\lambda 1$ and $\lambda 2$ (e.g. UV and visible, or

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visible and IR). I think that this information is reported a bit later in the text, but it would be helpful here to mention the wavelengths used or at least quickly state where this information can be found in the manuscript.

10: Does the Σ(1-gG)/V term have a straightforward word description to go along with it? If so, include it here.

11-12: Mention here why and how the density and reflectance optically measured at 1310 nm.

12-13: B should change with depth in actuality because the snow density and extinction coefficient values change with depth. It's okay to assume that B is constant, but acknowledge that it should change with depth.

13-14: It is true that BC is a dominant absorber above 600 nm, but nonBC material dominates the absorption in the UV and partly visible wavelength range. State here that BC is assumed to be the only absorber because this study is concerned with light transmission through snow in the part of the visible/near-IR wavelength range that is closer to the near-IR. If transmission of UV wavelength radiation were considered, it would be necessary to consider nonBC absorbers.

P 2818:

E29: What is the relationship between λ1 and λ2 and λke and $\lambda\alpha$? It would be helpful to make relationship more transparent so that readers can follow the progression of equations more easily.

17: Are the measurements described in this sentence spectral e-folding depth measurements or reflectance measurements? Please clarify why the measurements were conducted in two different layers.

P2819:

27: Are the vertical profiles of density and reflectance in Figure 2b used to calculate

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the radiation profiles in Figure 2a and Figure 3?

P2820:

13: The large range of B does not necessarily indicate that the spherical grain assumption is not valid. Freshly fallen snow has a very low B in this study while older snow has a higher B. B should be estimated more times for freshly fallen snow to determine whether the value of 0.8 is typical. Also, B should be estimated for transmission profiles of UV and visible radiation before making claims that the spherical assumption is inadequate.

20-22: According to Figure 4, the low end of your BC range (12 ng/g) does not influence more than 5% of the absorption, but the high end (85 ng/g) does at 700 nm. When the concentration of BC is 85 ng/g, there will be some impact on snow optical properties so it would be better to make this sentence less severe.

25-27: State that Figure 5a is for Dome C and Figure 5b is from the Alps in this sentence for clarity.

P2821:

24-25: The aim is to minimize the uncertainty of the retrieved B value.

25: These values are in bold, not underlined.

P2823:

26: Provide the value of B for spheroids here.

Figure 1a: I find Figure 1a quite confusing, but I think Figure 1b is very straightforward. Is there a way to put the field measurements on Figure 1b instead of 1a and get rid of 1a? Also, in 1b, do all of the different grain shapes have the same SSA? Maybe in 1b, add “albedo” to the y-axis and “AFEC” to the x-axis. If they all do have the same SSA, mention the value of SSA used. Also, it would be more clear to mention the wavelengths used to calculate these values.

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Figure 2b: at instead of et for “Reflectance et 1310 nm”

Figure 3: Why is 780 nm used instead of 600 as in Figure 2? Please put the wavelength in the captions for additional clarity.

Figure 4: Why are some of the lines dashed lines while others are solid?

Figure 5: In the caption note the depth of the depth hoar layer and the day of measurement to be consistent the details provided for the Lac Poursollet snow pit.

References: Brandt, R.E., Warren, S. G.: Solar-heating rates and temperature profiles in Antarctica snow and ice. J. Glacio, 39, 131, 1993. Warren, S.G., Brandt, R.E., Grenfell, T.C.: Visible and near-ultraviolet absorption spectrum of ice from transmission of solar radiation into snow. Appl. Opt., 45, 21, 2006. Zatko, M.C., Grenfell, T.C., Alexander, B., Doherty, S.J., Thomas, J.L., Yang, X.,: The influence of snow grain size and impurities on the vertical profiles of actinic flux and associated NOx emissions on the Antarctic and Greenland ice sheets. Atmos. Chem. Phys., 13, 3547-3567, 2013. Warren, S. G., Brandt, R.E.: Optical constants of ice from the ultraviolet to the microwave: A revised compilation, J. Geophys. Res., 113, D14220, doi:10.1029/2007JD009744, 2008.

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