The Cryosphere
Discussions

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Interactive comment on "Measurements and modelling of snow particle size and shortwave infrared albedo over a melting Antarctic ice sheet" *by* R. Pirazzini et al.
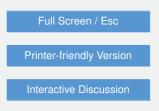
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Overview:

This paper presents a method to extract an effective snow particle size reff that is defined by a shortest skeleton branch from 2-dimensional snow macrophotography. From the vertical profile of reff in snowpack the spectral albedos are calculated with two snow particle models of spherical and droxtal shapes, and are compared with the measured albedo. The agreement was fine at the wavelengths 2.5-1.4 μm when the droxtal snow particle shape is employed, whereas a positive bias was observed at the wavelengths 1.0-1.4 μm for both cases of spherical and droxtal particle model. The

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extracted reff were compared to an optical effective radius roeff calculated from the measured spectral albedo by assuming spheres or droxtal particle models. For rough snow surface cases, the values of reff were smaller than roeff at the wavelengths 1.0-1.4 μm. The authors explain the modeled albedo bias and the disagreement between reff and roeff are related with the millimetre-scale cavities of snow generated during melting. They also concluded that more than just one particle metric distribution is needed to characterize the snow scattering properties at all optical wavelengths.

This manuscript is well-written and addressed the issues on biases of theoretically calculated spectral albedo from the measurements at the shortwave infrared wavelengths reported in many previous articles. It is also discussed their possible reasons due to vertical profile of snow grain size, microstructure of snow grain surface, snow surface roughness, size distribution of snow grain size, and uncertainty of refractive index of ice. A snow particle size metric proposed here is one of the operational and effective methods for studies of optical properties of snow.

However, the unfortunate two things related to observational design of this study are that 1) the analysis at the wavelengths less than 1.0 μm could not be conducted due to Spectralon plate used smaller than FOV of a bare fiver of a spectrometer and 2) spectral albedo was not directly measured but was converted from the nadir reflectance measurement using anisotropic reflectance factor measured by Hudson et al. (2006). This makes the modeled albedo and roeff could contain the potential uncertainties. Nevertheless the discussions on a snow particle size metric and albedo presented in the manuscript are worth. I recommend this paper to be published after revisions of the following issues.

(1) The detailed procedure to obtain a snow particle size metric is a bit hard to understand. How are the skeleton's endpoints determined? The skeleton branch shown in Fig. 6b looks not a straight line but a curve. The white curves in the particles in Fig. 6b do not correspond to the inner structure of the snow particles in Fig. 6a. I do not understand which parts do the red skeleton branches in Fig. 6b correspond to in Fig.

6a as well.

(2) It should be described that the effect of snow impurities on albedo can be ignored in section 3.3 as soot concentration in Antarctica is very low (e.g., Warren and Clarke, 1990).

(3) The discussion on refractive index of ice is too short to exclude it as the possible cause of discrepancy between modeled albedo and measurement or between reff and roeff.

Specific comments:

p. 3409, L18: Add reference Aoki et al. (2011), which demonstrated a long-term broadband albedo successfully simulated with a physically based snow albedo model using the measured shortest snow grain dimension.

p. 3415, L11: Fig. 3b appears before Fig. 3a.

p. 3415, L16: Delete "s" at the end of this line.

p. 3416, L26-27: "an almost-Lambertian white panel" Is it Spectral reflectance target? Please indicate in more detailed.

p. 3417, L1-3: "Snow and reference radiances were acquired using the ASD bare fore optic (with a nominal field of view of 25°) pointing toward nadir," and Fig. 3: Did authors actually confirm the tripod's foots were not included in FOV of the bare fiber? The instrument could have sensitivity at even outer angles of the nominal FOV of 25°.

p. 3417, L26: "The horizontal leveling of the reference panel was checked with a bubble balancer." The same explanation is made on L17.

p. 3417, L27-29: "The uncertainty of snow reflectance related to the horizontal levelling of the reference panel (σref) was +-3% (+-4 %) in the SWIR1 (SWIR2) wavelength region, estimated as the normalized standard deviation of 30 consecutive spectra of reference reflectance." Why can "the uncertainty related to the horizontal levelling of

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the reference panel" be estimated from "the normalized standard deviation of 30 consecutive spectra"? It may be related to uncertainty of the spectrometer itself.

p. 3420, L23: "712 x 1078 pixels" is better to be "1078 x 712 pixels" because of the consistency to the original resolution "4272 x 2848 pixels" on L18.

p. 3421, L17: "The false snow particles" Please indicate them in Fig. 6a.

p. 3424, L2: "Appendix B" appears before Appendix A.

p. 3727, L9-10: "it is unlikely that droxtals (let alone spheres) would represent the phase function of snow particles accurately" Please indicate the reference or explain in more detail.

p. 3427, L11-13: "for the intermediate solar zenith angles considered here ($\theta 0 \sim 50$–$60°$), the Henyey–Greenstein phase function and the full phase function give quite similar results for snow albedo, with differences generally well below 0.01." Please indicate the reference.

p. 3434, L22-24: "Thus, we can conclude that our method is suitable to measure the particle dimension that best corresponds to its scattering properties." This result should be concluded after the discussion of spectral difference between reff and roeff.

p. 3437, L16: "Aoki, 2000" -> "Aoki et al., 2000"

p. 3445, L10-11: "an effective solar zenith angle of 55° for the In measured in overcast conditions" Please indicate the reference for the values of 55° or mention the reason.

p. 3447, L3: Please correct a position of the values "2" (power of root) in (B3).

p. 3474, L2 in caption of Fig. A1: "ad Dome Concordia" -> "at Dome Concordia"

References:

Aoki, T., Kuchiki, K., Niwano, M., Kodama, Y., Hosaka, M., and Tanaka, T.: Physically based snow albedo model for calculating broadband albedos and the solar heating

profile in snowpack for general circulation models, J. Geophys. Res., 116, D11114, doi:10.1029/2010JD015507, 2011.

Warren, S. G. and Clarke, A. D.: Soot in the atmosphere and snow surface of Antarctica, J. Geophys. Res., 95, 1811-1816, 1990.

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