Review of “Measuring snow specific surface area with 1.30 and 1.55 µm bidirectional reflectance factors” by Schneider et al.

The manuscript presents an interesting device to retrieve snow SSA using active optical sensors. However, the language is not appropriate and requires an extensive revision before publication, the paper is badly organized, and the analysis of the results needs to be deepened. I therefore recommend a major revision.

Main problems:

1. The introduction is in some parts confused and not focusing on the main message. It needs to describe the state of art of the snow SSA measurements (now this is condensed in a single paragraph), and possibly the issues that make the SSA measurements so challenging.
2. The paper includes too many unnecessary technical details. The description of technical details can be justified only if it serves the demonstration or clarification of concepts. This is scientific paper, not a technical manual for users.
3. Results and discussion section need to be reorganized and rewritten. First, a thorough presentation of the results needs to be made (now it is too superficial), and, only after that, a discussion on the usability of NERD can be made (now it is at the beginning of sect 3.1, i.e. before the description of the modelling results!). Instead of discussing the opportunity of using reflectance standards to calibrate SSA detectors based on active optical sensors (which is a very common and obvious procedure), the authors could focus on the implications of the differences in the available devices, and highlight their strengths/weaknesses.

Detailed comments:

p.1, L17-18: “Positive snow internal albedo feedback occurs due to the strong dependence of snow infrared reflectance on snow specific surface area (SSA).” This sentence is too compact. Please explain this internal albedo feedback more explicitly.

P1., L18-20: “The Snow, Ice, and … in Fig. 1”. Fig 1 is not sufficiently justified here. It should be moved later in the paper, when describing the reason for the selection of the wavelengths 1300 and 1550 nm for the detection of SSA.

p.2, L9: “…are equivalent for convex bodies (see Appendix A).” There is no need to write an appendix to make a geometrical demonstration that was already derived more than 150 years ago. Instead, please refer to some book of convex geometry, or better to the original demonstration by Cauchy (as done in Pirazzini et al.: “Measurements and modelling of snow particle size and shortwave infrared albedo over a melting Antarctic ice sheet”, The Cryosphere, 9, 2357-2381, https://doi.org/10.5194/tc-9-2357-2015, 2015).

p.2, L16-17: “observe seasonal scale snow albedo decline in springtime Colorado”. Could you please improve the expression, for instance as “observe snow albedo decline during the spring season in Colorado”?

p.2, L17: “In contrast, however, they find that snow albedo is primarily related to dust concentration.” This sentence is incorrect. First of all, the snow albedo is mostly determined by the optical properties of the snow, and not by dust concentration. You may want to say that it is affected by dust concentration, but you cannot claim that it is the main albedo driver. Secondly, why you wrote “In contrast”? In the paper by Skiles and

Painter (2017) the springtime albedo decline was accelerated by the dust load, which concentrated at the surface during the progress of the melting further decreasing the albedo. Hence, the increase in dust concentration at the surface affected the observed albedo decline, and was not in contrast with it.

p.2, L19: “where the albedo reduction…” Instead of “where” I suppose you meant something like “who showed that…”, right?

p.2, L21: “snow internal albedo feedback” shouldn’t be “internal snow albedo feedback”? As pointed out in my comment above, it is not at all clear what you mean for “internal” snow albedo feedback. Please explain.

p.2, L23-24: “Surface warming can also reduce snow grain growth rates, however, if growth processes from vapor diffusion and strong temperature gradients are affected negatively (Flanner and Zender, 2006).” The meaning of this sentence is very obscure. Could you explain more clearly what you mean, without requiring from the reader to study Flenner and Zender in order to understand what you mean?

p.2, L25-31: “Recent studies …” This section seems to be out of context: it is not linked to the purpose of the paper. Please remove it, or explicitly explain the connection with the content of the paper.

p.3, L16: “The NERD is designed to measure 1.30 and 1.55 µm BRFs”. Please explain here why these wavelengths were selected, and highlight here the analogy with DUFISSS in the wavelength selection.

p.3, L25: “The NERD is similar to that of … in that it uses ….” Please reformulate the sentence improving the linguistic expression and moving it above (see previous comment).

p.3, L27-30: “LEDs are toggled … (20% duty cycle)” A lot of not needed technical details. Please remove.

p.3, L31-32: “Here, rather, we direct photodiodes toward the illuminated surface in a black dome to measure BRFs” The linguistic expression is particularly poor in this sentence. Instead of “we” use a passive expression.

p.4, Sect 2.1 and 2.2. Please remove all the technical details that do not provide any added value to the interpretation of the measurements. E.g. “Waiting 0.75 seconds after toggling the LED allows for enough time for the photodiode current to stabilize. After these currents stabilize, 100 voltage samples (ranging from 0.1 to 1.0 Volts) are then rapidly collected using the Ruggeduino-ET’s ADCs. The average voltage obtained during active illumination is differenced from the average dark current voltage to derive reflectance 10 factors.”, “The reflectance of the targets are measured with high precision across a broad spectrum. At 1.30 (1.55) µm, the white and gray targets have calibrated reflectances of 0.95073 (0.94426) and 0.42170 (0.41343), respectively, as reported by the manufacturer.”, “Small samples of snow are collected in roughly 10 cm tall cylindrical plastic sample holders and placed into the machine. An X-ray source is emitted at 40-45 kV and 177-200 micro-Amps. X-ray transmittance is measured as the machine rotates the sample. Setting the exposure time to 340 ms at a pixel resolution of 14.9 µm with rotation steps at 0.3-0.4 degrees allow for fast scan times of roughly 15 minutes. These short scan times are necessary to complete the scan without too much absorbed radiation melting the snow.”

p.4, L19: “Using both…” What do you mean for “both”?

p.5, Sect 2.3. This section needs to be rewritten in a much more compact and consistent way. Expressions such as “oldest class” are meaningless. You should really apply the snow descriptors listed in The International Classification for Seasonal Snow on the Ground (Fierz, 2009). Instead of repeating 6 times that the

measurements were performed in Hanover and samples were transported to CRREL for X-ray microTomography, focus on the characteristics of the different samples. Eliminate subparagraphs and unnecessary details such as "…distinguishable only by the container they were stored in…", or the sentences in lines 24-27 (until "…nearby lab for X-CT analysis"), and the not relevant sentence "All samples with added LAI included in the NERD SSA calibration dataset were first screened to remove samples with heavy LAI loads that caused direct snow darkening at 1.30 5 and 1.55 µm."

p.6, Sect. 2.4. You need to provide some introduction explaining the purpose of the model simulations

p.6, L30: replace "multiple" with "BRFs"

p.7, L24 and following: this sections need to be moved after the thorough presentation of the results.

p.8, L12-13: "Both instruments make use of Lambertian reflectance standards for calibration and testing." This is a repetition: you have already explained in the lines above. Please remove it. Instead of discussing the opportunity of using reflectance standards to calibrate SSA detector based on active optical sensors, you could focus the discussion on comparing the different working principles, and strengths/weaknesses of the devices.

p.8, L13-16: "Although each instrument…" This sentence is a rather obvious statement that does not add anything to the paper. Please remove.

p.8, L23: "Although photodiode responsivity varies with temperature, frequent calibration minimizes these errors" This is a critical point that deserves further explanation. Is calibration required on the field before/after each measurement (as done for instance when using the IceCube device)? If this is the case, please explain, and describe the needed measurement procedure, including calibration.

p.8, L34 – p.9, L1: "Monte Carlo simulations predict lower BRF values at 60 degrees than at 30 degrees". This sentence refers to radiances at 1.30µm: looking at Fig. 4 I see the opposite, i.e. that for most grain shapes, when SSA is larger than 40 m^2kg^{-1} BRF is larger at 60 degrees than at 30 degrees.

p.9, L17: "Hemispherical reflectance measurements theoretically reduce measurement variations associated with grain shapes". Why? Please explain. Comparing Fig. 4 (top) and Fig. 5 (top) where, respectively, BRFs and directional-hemispherical albedo are illustrated, I would say that both hemispherical and directional measurements show a very similar dependence on grain shape. In my opinion, Fig. 4 would deserve a much deeper analysis. For instance, why the BRFs measured with NERD are so much higher than the model results in 1.30 µm at 60 degrees? And why the modelled BRFs at 1.30 µm are lower at 60deg than at 30 deg? Etc…

p.9, L31-32: "These large variations in reflectance across grain shape are the largest source of uncertainty in snow SSA measurements using infrared reflectance." I disagree. Even larger uncertainties can be associated to the instrument set up in certain snow conditions. You have not discusses the effect of natural light entering into the dome and detected by the photodetectors. Probably, you will have this unwanted light source every time the target snow surface is not perfectly smooth, unless you insert the edges of the dome for several millimeters inside the snow surface. With other optical-based devices to derive SSA (such as DUFISSS and IceCube), a large source of uncertainty may derive from the snow sampling procedure (especially in case of surface hoar or very soft new snow). In my opinion, even your Fig. 4 shows that the large scatter in the optically derived SSA is not only attributable to a grain shape effect. The instrumental and set up error sources deserve much more discussion.

p.10, L16-17: “These calculations confirm this hypothesis, as 1.55 µm narrow band albedo with a full width at half maximums of 0.26 µm (doubled from 0.13 µm) closely agree with NERD BRF measurements.” Please show these results in a Figure.

Figure 2: A much clearer photo of the sensor is needed, which would show only the essential components. The text in the figure should be less technical, or the technical terminology should be explained (what is the meaning of “LCD”? Is the whole sentence “LCD provides … data collection” needed? If yes, you should better explain its content, possibly in the main text and not in the figure. Is the diagram of the Transimpedance amplifier circuit needed? Instead of providing so many technical details, you should explain what the achieved performance is and why it is needed. Also the meaning and scope of the sentence “Using feedback resistances as low as …” in the figure caption is totally obscure. What is the scientific message behind it?

Figure 4: Please mark the vertical and horizontal grids, to facilitate the comparison among the plots.

Figure 5: what is the added value of this figure? The considerations on the effect of grain shape drown on the basis of directional-hemispherical albedo calculation can equally well been drown on the basis of Fig 4 (showing BRF calculations). I would simply remove the figure.

Table 1: in the table caption please explain the meaning of the used symbols and the content of each column and row.