Review:

Gallet et al. - Measuring the specific surface area of wet snow using 1310 nm reflectance

This study investigates the effect of liquid water on the measured reflectance and derived specific surface area (SSA) of snow samples using the DUFISSS instrument, which has been previously introduced for SSA measurements of dry snow. This is a relevant research topic despite the small effect of liquid water on the obtained SSA results.

However, the small influence of liquid water on snow SSA measurements and the use of DUFISSS for wet snow for the first time (as I understand) should demand a careful assessment of the uncertainties associated with the presented SSA measurements of wet snow, which is not included in the current manuscript. The lack of a quantitative uncertainty analysis is the main point that should still be addressed before publication (see below for some details).

General comments

-    Uncertainty analysis:

A comparison of two alternative measurement methods is no substitute for an uncertainty analysis (in this manuscript: SSA measurements of wet snow are compared to SSA measurements of the same refrozen snow samples). An uncertainty analysis is based on the uncertainties associated with the input quantities of the applied measurement protocol and the propagation of these uncertainties through the measurement process to yield the combined uncertainty of the final determined quantity. While a full formal uncertainty analysis, e.g. according to the GUM (JCGM 100:2008 "Guide to the expression of uncertainty in measurement"), is probably far beyond the scope of the presented study, I would strongly suggest to present at least reasonable estimates of the uncertainties affecting the SSA measurement of wet snow with the DUFISSS instrument.

Specifically, what are the major uncertainties (quantified e.g. as relative uncertainties in percent) of the uncertainties associated with the assumptions that 'freezing does not lead to any detectable change in structure' (p. 5259 l. 7) and that 'the LWC is not perfectly uniform' (p. 5259 l. 22), with the density and liquid-water-content measurements (p. 5260 l.1, this may possibly be the most important contribution), with the measurement protocol (p.5260 l.5 to end; p. 5263 l.5 'fairly homogeneous snow'), with the 'approximation that wet snow consists of disconnected ice spheres' (p. 5264 l.16), with the 'slight modifications to the code relative to Gallet et al. (2009)' (p.5265 l.26)? Some of these listed effects have already been addressed briefly in the manuscript, but not in a very clear and organized manner. The various uncertainties should be combined in one chapter, and the major uncertainties should be quantified. And how do the major uncertainties affect the final SSA values across a wide range of snow types (i.e. quantify the impact of the input uncertainties on SSA measurements of wet snow for different snow liquid water content, SSA and density)?

In addition to the uncertainty estimates, a more detailed comparison strategy would be useful. Instead of only presenting absolute values, i.e. SSA_frozen – SSA_app_wet, in table 1, adding percent differences would make the analysis more complete.

Only then can the conclusions be drawn:

An uncertainty of x% (including the uncertainty for DUFISSS SSA measurements of dry snow presented in Gallet et al. 2009) is estimated for SSA measurements of wet snow with the presented method; the observed average of absolute percent differences between SSA of wet snow and the SSA of the

corresponding refrozen snow samples is y%. The snow SSA values assuming a dry snow sample, i.e. ignoring all present liquid water, differ from the SSA values including the liquid water content by about z=10% (z is a bias, I guess, i.e. z is calculated from signed percent differences and not absolute percent differences). z is still within the estimated uncertainty of the measurement method (i.e. z < x%) due to the small effect of liquid water. Nevertheless, as a clear bias different from 0 is observed, z describes a 'real' effect or a systematic 'error' in the measurement method. If a reasonable uncertainty assessment is presented, a systematic 'error' can be excluded. Without any quantification of the uncertainty, the small effect caused by liquid water cannot be identified reliably.

Additionally, I would strongly suggest to use the expressions 'uncertainty, difference, bias, deviation' instead of 'error' throughout the manuscript. An 'error' implies knowing the exact deviation from the 'true' value of the physical quantity. This is not known, however; only measured values obtained by other measurement methods (that may be characterized by smaller uncertainties) are known. A comparison between two measured values or different series of measurements then yield differences, deviations, and possibly a bias.

- Influence of SSA definition

The analysis in the manuscript is based on SSA values given by surface area per mass. SSA is commonly also referred to as surface area per volume of the snow microstructure. For all dry snow, both definitions are equivalent, only requiring the density of ice for calculating one SSA value from the other. For snow samples with different liquid water contents, however, the conversion factor is not constant across all samples and instead depends on the liquid water content of each sample, due to the density difference between liquid water and ice.

So, what is the effect of liquid water on SSA measurements when measuring SSA in terms of surface area per volume, i.e. only including the geometry of the snow microstructure and not the mass? Is it possible to give an indication for this effect based on the presented results and sum up the conclusions in a few sentences? Intuitively, I would expect the differences between SSA_app_wet values and the SSA values obtained by ignoring liquid water in the snow samples, i.e. assuming dry snow samples, to be even smaller when snow mass is not included in the SSA definition.

Specific comments:

- First sentence of the Introduction:

What are small amounts? There can be more than just small amounts of impurities in snow, e.g. in black/grey snow next to roads. So, I would suggest to remove 'small amounts of'.

- 2nd sentence:

Is snow always the most reflective surface on Earth? At all wavelengths of the solar spectrum? No matter how thin the snow cover is? The actual snow surface itself is not highly reflective, only multiple scattering inside the top part of the snow cover close to the surface makes snow a highly-reflective material. I suggest replacing 'the most reflective surface' with 'a highly-reflective surface material'

- p. 5258 l.5:

The presented values may be true for the cited articles, but the statement implies that all measured snow SSA values fall within this range. Other studies have included snow with lower SSA, both machine made snow and natural snow. For example, Matzl and Schneebeli 2006, Gergely et al. 2010: First experiments to determine snow density from near-infrared reflectance, Cold Regions Science and Technoogy 64, 81-86; Gergely et al. 2013: Simulation and Validation of the InfraSnow: An instrument to measure snow optically equivalent grain size, IEEE Transactions on Geoscience and Remote Sensing.

In fact, some of the low SSA values have been observed specifically for refrozen spring snow, i.e. snow which is sometimes characterized by a substantial liquid water content due to repeated melting and freezing. The lack of such low-SSA samples with SSA < 12 m2 kg-1 in the presented manuscript also supports the requirement for a thorough uncertainty analysis: only a reasonable uncertainty analysis allows transferring or extrapolationg the presented results and conclusions to other measurement conditions and thus to snow samples with low SSA.

- Conclusions: The conclusion that the range of validity for the findings can also be extended to snow types that are characterized by low SSA values and that have not been investigated in this study, like coarse spring snow, can only be reached after an appropriate analysis is included to quantify the uncertainties associated with DUFISSS SSA measurements of wet snow (see comments above).

- Table 1: Also present relative differences for SSA (and maybe remove the reflectance-difference column). SSA is the main analyzed quantity and deserves a detailed analysis.

Technical corrections:

- p. 5260 l. 15: Remove 'careful' and 'most likely'. Instead, quantify/estimate the uncertainty (see comments on uncertainty analysis above)

- p.5260 l.20: Remove 'certainly'

- p.5263 l. 3: Remove 'only'

- l.11: Is there a reason why cen_8 might yield such a different result, is it special in some way (instrument malfunction, more time between sample preparation and measurement, …)?

- l.14, l.26: Which relation was used? As this is a major step in the presetnted analysis, a short explanation of the used relation should also be presented in this article, even though the relation was already introduced in Gallet et al. 2009.

- l.16: Remove 'at the most' and insert 'maximum' in front of 'relative difference'

- p.5264 l.6: Replace 'complex' with one of the following expressions to avoid ambiguity with 'complex' as in 'complex numbers': complicated, non-trivial, involved

- Eq (8): I could not understand how this equation was derived exactly, especially where the exponent '2/3' stems from. Was this obtained using only the equations listed in the manuscript or also using other sources (if the latter is the case, please cite)?

- p.5265 l.3: Remove 'of course'

- l.4: Remove 'Assuming … acceptable,'

- p.5266 l.7: Remove 'actually'

- l.10, 12: Replace forms of 'comfort' with corresponding forms of 'confirm'

- l.27: Remove 'Admittedly,'

- Fig.1 could be removed. The differences/similarities at 1309 nm can be specified in the text.

- Fig. 4 could be removed to streamline the article, i.e. to focus on the SSA analysis and not include that many details on reflectance.