Interactive comment on "Measuring the specific surface area of wet snow using 1310nm reflectance" by J.-C. Gallet et al.

Anonymous Referee #2

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The authors reported on the measured results of the specific surface area (SSA) of wet snow using the technique for SSA measurement of dry snow (DUFISSS). They compared the SSA of snow under wet condition and that under the frozen condition and concluded that liquid water has little effect on the measured SSA. They also indicated the limitations of the present optical models in predicting wet snow reflection. Their topic is challenging, but has scientific significance; that is, the establishment of a method to measure the SSA of wet snow will contribute greatly to advancing our understanding of wet snow. Therefore, I think it is worthy of publication in The Cryosphere. However, the current version leaves room for improvement to clarify ambiguous explanations before publication. Below I give my specific editorial comments and suggestions for improvements that enable better understanding of the arguments in the manuscript.

We wish to thank reviewer#2 for his/her comments on our work. Our answers are inserted in blue below.

Specific editorial comments

1. Add to the discussion the possibility of structural change due to freezing.
How long does it take to freeze wet snow completely under the experimental condition (-2.2 °C)? There was no information in the present text. I would guess several hours are needed to freeze the sample completely under the experimental conditions, and if this is the case, some metamorphism, such as grain growth, should occur. Have you estimated how much change in grain size occurs because of water in the snow under the experimental conditions? These discussions will support the authors' assumption that any detectable change in structure can be attributed to.

This is an interesting question that we did not answer before due to the small change observed in reflectance after freezing. Indeed, using the Crocus model, we calculated that the time to refreeze the surface of the sample (first cm) is less than half an hour and 1 cm is thicker than the penetration of the light at 1310 nm. Calculations were done with the environmental conditions in the cold room and with the highest LWC that we measured (32.1 %). This means that for most of our samples, refreezing is of the order of 10 mn. Over such a time scale, snow metamorphism is extremely limited. (Taillandier et al., 2007) presented empirical equations to estimate the decrease of snow SSA over time. Using their equation 13, we can estimate the decrease of snow SSA under isothermal conditions. For -2.2 ˚C and for an initial SSA of 40 $m^2\ kg^{-1}$, the SSA decreases to 39.5 $m^2\ kg^{-1}$ after half an hour and to 39 $m^2\ kg^{-1}$ after one hour. This is much lower that the uncertainty of our measurement and considering the lower initial SSA range of our samples, the decrease of snow SSA will be even lower and hardly detectable. We will add a short sentence about that in the corrected version.

2. Evidence that the estimation formula in DUFISSS can be applied to estimate the SSA of wet snow structure.
Wet snow usually has a clustered structure with aggregation of several grains, and its structure should be quite different from that of dry snow. On the other hand, the formula for estimating the SSA from the reflectance in DUFISSS is based on dry snow. I would guess that the SSA estimation formula based on the reflectance should depend on the grain structure characteristics. Thus, I wonder whether the formula in DUFISSS can be applied to the wet snow structure. If the authors have any evidence, such as comparison results of the SSA of frozen snow (it should have the same structure as wet snow) calculated using DUFISSS and that using another method (e.g. the BET method, or x-ray method), I recommend that they add a discussion of the validity of applying the estimation formula in DUFISSS to a wet snow structure; these discussions will support the authors' arguments.

This is in fact the issue of the relationship between SSA and reflectance as a function of grain shape. In theory, the reflectance of snow of a given SSA depends on grain shape. This has been tested in simulations for different ideal and simple shapes, e.g. Picard et al. (2009) CRST, 56, 10-17. Kokhanovsky has also addressed the issue in several detailed papers. However, snow is a mixture of various shapes, so that the observed effect, e.g. in Gallet et al. (2009) but also in Arnaud et al. (2011) JG 57, 17-29, is that reflectance does not appear to depend on grain shape, and the SSA-reflectance relationship is that developed theoretically for disconnected spheres. Since wet snow consists mostly of rounded shapes, we therefore expect its SSA-reflectance relationship to be similar to that of spheres, and therefore also to that developed for dry snow. Moreover, the study of Gallet et al. (2009) included snows made of rounded grains, which showed no detectable difference from the general trend. This will be detailed in the revised version.

3. Explanation of introduction of Eq. (8)
Eq. (8) is a key equation, but I could not understand how it was derived from Eqs. (4) and (5). Please add a more detailed explanation to ensure that Eq. (8) can be derived by the readers themselves.

We will add some intermediate steps in an appendix.

4. How the SSA changes with water in snow
The initial information on the SSA value that was measured before wetting will help readers to understand the effect of water in snow on the change in the SSA value. Thus, if the authors measured these data, I recommend adding them in a table and discussing them.

How the appearance of water in snow changes its SSA is an interesting topic. However, it is disconnected from our current objective. In any case, these values were not measured systematically.

Suggestions for improvements:
P5257 L16: Here, "per mass" should be "per volume". Please check the definition of the liquid water content in Nolin and Dozier (2000).

Thanks for that remark and indeed the definition of Nolin and Dozier (2000) is "per volume" and not "per mass" as we wrote it. It will be corrected.

P5257 L18: Is the value of 26% small enough to neglect?

Yes, indeed. 26% is small enough to neglect. The point is that in the 950-1150 nm range, the presence of liquid water has a negligible effect on snow reflectance, according to Nolin and Dozier (2000). In that range, the ice-water difference is large (380 % and 293 % for the imaginary part, at 950 and 1150 nm respectively, and 1.5 % difference for both real part). At 1310 nm, where the difference is much smaller, the effect of water on snow reflectance is therefore expected to be even smaller and therefore negligible.

P5264 L17: I think the assumption that grains are independent of each other could be problematic, in particular when the liquid water content is high. Please discuss the validation of this assumption more detail.

The idea is that the snow surface is uniformly coated with water. If we accept this assumption, then it is all right to assume that the snow is made up of spheres coated with water. The fact that the spheres are disconnected has no effect. Now, we admit that the issue is the uniform coating, since this is clearly not exactly the case. We have no simple way of testing the effect of this assumption other than an a posteriori verification, in that the use of this approximation does not produce any inconsistency.

Table 1: Does "density"refer to "dry density" or "wet density"? Please clarify the definition of density.

As written in the text p5259 line 26-28, the snow density was measured after the plexiglas box was taken out of the heater system so that it refers to wet snow, but we will clarify in Table 1 that this is the density of wet snow. In any case, freezing should not modify the density value.

References cited:
Taillandier, A. S., Domine, F., Simpson, W. R., Sturm, M., and Douglas, T. A.: Rate of decrease of the specific surface area of dry snow: Isothermal and temperature gradient conditions, Journal of Geophysical Research-Earth Surface, 112, F03003, 10.1029/2006jf000514, 2007.