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Interactive comment on "Case study of spatial and temporal variability of snow cover, grain size, albedo and radiative forcing in the Sierra Nevada and Rocky Mountain snowpack derived from imaging spectroscopy" *by* F. C. Seidel et al.

Anonymous Referee #1

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This study represents a nice demonstration of the utility of air-borne hyperspectral measurements for inferring spatial distributions of important snow properties. As the authors note in their conclusions, previous studies utilizing AVIRIS data have mostly focused on algorithm development and demonstrations of feasibility, whereas this study goes a bit deeper to describe actual variability in snow properties determined from a series of flights over the Rockies and Sierra Nevada. Most of the analysis shows variability in snow properties with elevation, aspect, and seasonal progression that are to be expected from basic physical arguments. Other measurements, however, show less intuitive distributions, such as the *positive* correlation between snow grain size

and elevation seen in the Rockies during June, as well as the decrease in spatial variability of snow albedo observed during progression of the melt season. Such findings are really only feasible with remote sensing measurements, thus demonstrating their value. The manuscript is well-written and logically organized. Below are a few general comments and several minor comments that should be addressed prior to publication in The Cryosphere. Overall, however, I find the study and manuscript to be in good shape.

Major comments:

Data presented in Figure 9, panel h (15 June, terrain aspect plot) appear to show no grain size measurements between roughly 500 and 550μm, with many measurements bracketing either side of this range. Is this gap an artifact of the retrieval algorithm (e.g., coarse discretization)? The gap should be explained, in any case, as it does not appear to be natural.

Second, how exactly were surface slope and aspect determined? Were these determined exclusively from the (snow-free) DEMs, or were they determined directly from the AVIRIS measurements? The normal to the surface can obviously change with snow accumulation, as valleys are filled, snow drifting occurs, etc. If DEMs were used to determine slope and aspect, please elaborate on the magnitudes of error that could result from variable (or inaccurate) slope and aspect. If they were determined from the AVIRIS measurements, please explain how.

The term "radiative forcing" is used frequently, and it eventually becomes clear that this refers to surface radiative forcing from light absorbing impurities, but in general "radiative forcing" is ambiguous. It could also apply, e.g., to grain size effects. At first reference (in the abstract), and perhaps throughout the paper, this should instead be referred to with something like 'impurity radiative forcing' or 'LAISI radiative forcing'. It should also be mentioned early that the reference plane for the forcing is the surface (rather than top-of-atmosphere or tropopause or aircraft altitude).

Related to the point above, do the radiative forcings represent local noon values or daily averaged values (or something different)? Please clarify.

Minor comments:

p1,13: Please specify the time period over which albedo decreases from 0.7 to 0.5. Presumably this is during the ablation period, but the ablation timeframe for each location should also be mentioned in the abstract.

p2,13: More precisely, this is the radius of a sphere that has specific surface area of SSA. For a polydisperse size distribution of spheres with collective specific surface area of SSA, it is the effective radius of that distribution.

p3,25: Wording (run-on sentence).

p4,3: particular -> particularly

p4,6: "end year dust concentrations" - Are these concentrations at the top of the snow, or are they column-averaged concentrations? If the former, please specify the thickness of snow over which the concentrations apply.

p4,13-16: Sentence structure problems.

p5,22: Why are '$\approx$' symbols used? Which wavelengths were actually used to determine the NDSI? And, were single AVIRIS bands used, or were spectral averages taken over multiple bands? Please clarify.

p6,6-8 (equation 4): If the ice absorption feature is centered at 1.27μm, why is the upper bound of the integral at precisely 1.27μm? (i.e., why not integrate over the feature, rather than up to it?). Presumably this is explained in one of the cited publications, but a very brief explanation for this may be warranted here.

Equation 5: I would speculate that this equation occasionally produces an observed albedo larger than 1, especially outside of the 1.17-1.27μm grain size calibration window. Does this ever happen, and is it necessary to cap the albedo at 1?

Section 3.6 discussion: This is fine (and helpful), but it should be clarified (e.g., in section 1) that the optical grain radius used here is a sphere-equivalent optical radius.

p7,11: Again, is the radiative forcing uncertainty defined with respect to daily-mean forcing or local noon instantaneous forcing?

p8,3-7: Please rework this passage for grammar and clarity.

p9,11: "In general the albedo increase with elevation is more distinct at the Sierra Nevada study area than in the Rocky Mountain study area." - This is interesting. Do you have any hypotheses for why?

p9,24-25: Again, are these instantaneous RF values?

p10,1: "all of the dust" -> maybe "nearly all of the dust"?

p10,15: Are you arguing here that earlier melt out on the south-west face reduces the time over which forcing can operate, therefore leading to greater forcing on the south-east face? Please clarify the relationship being described between processes on the south-east and south-west slopes.

p11,16: Please check the wording in this section.

p11,19-20: "The observed snow grains in the near-surface layer can therefore be smaller under intense snowmelt." - This is quite interesting!

Figure 6 caption: Following previous comments, please clarify the source and temporal averaging domain of this forcing.

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