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The Cryosphere Discussions

Interactive comment on "Retrieval of snow Specific Surface Area (SSA) from MODIS data in mountainous regions" *by* A. Mary et al.

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Review

The Cryosphere Discussions

Retrieval of snow Specific Surface Area (SSA) from MODIS data in mountainous regions

Mary et al TCD, 6, 1915-1961, 2012 doi: 10.5194/tcd-6-1915-2012

This paper describes an analysis of topographic treatment of solar radiation in mountainous terrain with the intention of quantitatively retrieving snow specific surface area from NASA Moderate Resolution Imaging Spectroradiometer radiance data. The

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Interactive Discussion

Discussion Paper

central model treats anisotropy in the hemispherical irradiance per pixel and snow anisotropic reflectance and the differences between spherical and nonspherical assumptions of particle shapes.

The motivation for this paper is strong – snow specific surface area/snow grain size is important for understanding the metamorphic state of the interface of snow with the atmosphere and incident radiation. In turn, the SSA/grain size partially controls snow albedo and modulates the influence of impurities on albedo and radiative forcing by those impurities.

This paper will be suitable for publication once some issues are addressed – mainly correction of the context of this retrieval relative to those already existing for grain size/SSA and more comprehensive discussion of the vulnerabilities of this approach. Nevertheless, it is worthwhile to pursue. Below, I describe the major issues that should be addressed before publication and then page/line-wise indication of issues.

Specific major issues: Mixed pixels The approach described here focuses on the topographic influence on retrieval of snow SSA but does not address mixed pixels. At the spatial scale of the MODIS pixel (even at nadir), homogeneous snow pixels are rare in rough mountain terrain such as the Haute-Alpes/Isère. Non-snow surfaces such as rock and vegetation have hemispherical-directional reflectance factors (HDRF) that are relatively orthogonal to those of snow. Therefore, a mixed pixel will have an inferred HDRF that is contaminated, influencing the retrieval of the SSA by any of the band scenarios described here.

Additionally, vegetation and rock through their surface roughnesses have directional reflectance distributions with prominent backscattering components unlike snow, which has distinct forward scattering with a minor backscatter. The mixed pixel then has a directional reflectance distribution that is a composite of those from snow and from the non-snow exposed surface.

The paper indicates that it uses the normalized difference snow index to mask for snow

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covered pixels but we know from Salomonson and Appel (2004, 2006) that for a given NDSI value, there is a large range of fractional snow covered areas. As such, the NDSI cannot be treated as a reliable metric by which to find pixels that are covered 100% by snow. No details are provided as to the interpretation beyond the simple calculation of the NDSI.

Moreover, you use a 90 m DEM and downgrade it to 125 m (without acknowledging uncertainties injected by that step) and 500 m. In either case, 125 m or 500 m, rough mountain terrain is not represented well – sub-125 m variation in slope and aspect, and in turn local irradiance and local view geometry are markedly different from those calculated from a kernel of a 125m and 500m.

Geometry Despite the fact that you are addressing topography and anisotropic reflectance, there is never mention (that I can find) of the local sensor zenith angle for the particular scenes that you are using and the impact of sensor zenith on ground instantaneous field-of-view (GIFOV). The at-surface range of sensor zenith angles of nadir to 65° result in a variation in pixel size from 463 m at nadir to twice as large in along-track and nearly five times in cross-track – nearly 10 times the area. As such, pixels are far more likely to be mixed with respect to surface cover and distribution of subpixel surface slopes and aspects. In turn this markedly affects the directional reflectances and the topographic interpretation from the 125m and 500 m SRTM DEM sets. This must be addressed before publication particularly given the core topic of the paper.

Note that later you indicate (p1921 line 23) that the MODIS sensor was chosen because "it provides daily coverage of the area of interest".

Grain shape What are the non-spherical grain shapes that are used? "Fractal" is not descriptive enough. You allude to the modeling by Kokhanovsky and Negi/Negi and Kokhanovsky in which they used plates and columns. These too are not physically consistent with observations in the snowpack except immediately after snowfall. Please give more description.

Perspective This will be a clarification of Painter et al 2009 in light of the authors' misunderstanding or misinterpretation of our paper. This point has little bearing on the results of the Mary et al paper but given that it features prominently in the Introduction, it warrants correction.

The text states, "In addition, the snow end-members used in MODSCAG are based on theoretical spectra whereby snow grains are assumed to be spherical, the effect of soot on reflectance is ignored, as well as the effect of the anisotropy of snow reflection." True that we model snow endmembers under the assumption of spherical particles, true that we consider clean snow as opposed to that affected by dust or soot. However, it is not true that we ignore anisotropy of snow reflectance. The snow endmembers are HDRF – so, they are expressly addressing the directional reflectance. However, the misinterpretation may come because we do not vary the directional snow endmembers with view geometry. This is based on the work presented in [Painter et al., 2003; Painter and Dozier, 2004] in which we show the relative insensitivity of the MEMSCAG/MODSCAG approach for local view zenith angles of $< 40^{\circ}$ and the relative paucity of local view zenith angles that exceed 40°. We can then maintain the computational efficiency of the algorithm.

The text also states on p1929, lines8-9 "2. Relying on absolute reflectance values or on the relative shape of the snow's spectrum (i.e., the ration between SSA-sensitive bands and band 4, e.g. Painter et al 2009, ...). It is not at all apparent how the authors have interpreted that Painter et al 2009 suggests the use of band ratios. Perhaps it is a nomenclature issue? Band ratios are as follows: band1/band3. They are used in some remote sensing interpretations but we do not use band ratios. We use matrix inversions in which the solution vector space is spanned by the endmembers. The matrix inversion is solved with the Q-R decomposition in the Modified Gram-Schmidt orthogonalization.

Ultimately, the MODSCAG algorithm accounts for fractional snow cover in retrieving grain size (SSA), whereas the algorithm presented in the Mary et al paper requires homogeneous snow cover. MODSCAG does indeed though make the assumption that the directional reflectances do not vary markedly with sensor zenith angle so that it can maintain its computational efficiency.

Lack of field measurements The authors acknowledge that the uncertainties of this retrieval would be better understood with field measurements instead of the SAFRAN-Crocus results. There is no problem with the comparison with SAFRAN-Crocus. However, the authors mention the inference of SSA from the integrating sphere technique of Gallet et al 2009 for future validation. Given that Gallet et al have made measurements already and MODIS covers Earth, why can they not be used here? Please address.

Specific points: p. 1917 Snow covers a large part of the Earth's land surface. p. 1917 Since it is . . . -> reference [Flanner et al., 2011] p. 1918 The justification of the use of SSA versus grain size is rather weak. p. 1918 Gallet et al are not the only ones making these measurements - [Matzl and Schneebeli, 2006; Painter et al., 2007]. Moreover, all of these measurements are natively point measurements and not spatial. p.1919, line 4 spaceborne and airborne p. 1920, 22 be more specific about "radiation". Shortwave, longwave, reflected, emitted? p. 1925, 2 point to the website – this paper is UV/VIS. p. 1927, 14 Where does SCA actually get calculated? p. 1927, 1 alpha is usually used for albedo or spectral albedo p. 1927, 4 explain better the place of R here while not addressing the Ediff p. 1927, 24-25 "measured values of the anisotropy factor R . . ." how many, how were they applied? p. 1927, 23 remember that mixed pixels will require a different directional "correction" p. 1928, 14 DISORT calculations to 88° will be highly uncertain – p. 1928, 16 this paper ignores impurities as well. p. 1929, 6 band 2 (0.858 μm) is affected by impurities p.1929, 1-2 this relationship is highly uncertain – look at their plots – then how do you apply it here? What uncertainties do you have in SSA retrieval relative to the NDSI retrieval? p. 1929, 14-20 you need to mention [Nolin and Dozier, 1993] for similar technique. p. 1930, 1-9 how is this a test of grain shape if you do not use the same algorithm/method? p. 1930, 24 the Grandes-Rousses massif has strong spatial mixing at the MODIS pixel resolution p. 1931, 1-4 what are their view

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geometries in the Grandes-Rousses? p. 1931, 2 need a figure that shows the setting, topography, etc. perhaps a photograph p. 1931, 7 "reported as accurate in terms of SSA" – accurate is a relative term. Give the quantitative values. p. 1933 the discussion of the change d(alpha)/dTE is not sufficiently clear to justify the conclusion that "... leading to d(alpha)/dTE < 0." This needs considerable improvement. Moreover, a better description of TE is needed from the outset. p. 1934 the description of the band ratioing is very difficult to find p. 1934 again with "Painter et al (2009) suggested the use of band ratio in order to overcome the error on absolute reflectance, largely due to ignoring topographic effects." Where does this come from? We do not use a band ratio. Are you talking about the shade-normalization? That comes from the additive complement to the sum of the coefficients in the matrix inversion. p. 1935, 13 "non-neutral"?? p. 1935, 16 anisotropy correction is to the reflectance, not the SSA. Downstream of the correction of the reflectance is the impact on SSA. p. 1935, 21 anisotropy factor is not measured, it is inferred from measurements p. 1935, 25 seems to make sense that the fractal grains would have larger SSA, right? p. 1936, 19-26 it is not clear what "asymmetry" you are describing here p. 1937, 4 please explain "signal entropy" in this context p. 1938, 25 mixture of terminology – "grains growth at low SSA" p. 1939, 16-17 snow's forward scattering peak is more often sampled from MODIS here p. 1939, 24 monotonic p. 1940, 5 replace "confrontation to" with validation against. Again, why have you not used the previous measurements of Gallet? p. 1940, 19-20 "decreases with the incidence of the solar radiation" – this sentence is not clear. p. 1941, 1 "very close" has no meaning. Be quantitative. p. 1942, 16 not your title, but note that it is physically impossible to measure the bidirectional reflectance distribution function p. 1949 again, the "band ratio" is hard to find. p. 1955 no remotely sensed images are shown – please insert a color composite of MODIS images for each of these dates. p. 1957 indicate the 1:1 line.

Flanner, M. G., K. M. Shell, M. Barlage, D. K. Perovich, and M. A. Tschudi (2011), Radiative forcing and albedo feedback from the Northern Hemisphere cryosphere between 1979 and 2008, Nature Geosci., 4, 151-155, doi: 10.1038/ngeo1062. Matzl, M.,

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and M. Schneebeli (2006), Measuring specific surface area of snow by near infrared photography, J. Glaciol., 52, 558-564. Nolin, A. W., and J. Dozier (1993), Estimating snow grain size using AVIRIS data, Remote Sensing of Environment, 44, 231-238. Painter, T. H., and J. Dozier (2004), The effect of anisotropic reflectance on imaging spectroscopy of snow parameters, Remote Sensing of Environment, 89, 409-422. Painter, T. H., J. Dozier, D. A. Roberts, R. E. Davis, and R. O. Green (2003), Retrieval of subpixel snow-covered area and grain size from imaging spectrometer data, Remote Sensing of Environment, 85, 64-77, doi: 10.1016/S0034-4257(02)00187-6. Painter, T. H., N. P. Molotch, M. P. Cassidy, M. G. Flanner, and K. Steffen (2007), Contact spectroscopy for the determination of stratigraphy of snow grain size, J. Glaciol., 53, 121-127, doi: 10.3189/172756507781833947.

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