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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Spectral albedo of arctic snow during intensive melt period" *by* O. Meinander et al.

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Searching google.com and going through the reference list of the paper, there are apparently few publications related to spectral albedo changes during the snow melting process. Among the studies cited, they are mostly based on Antarctic snow conditions, which may not be representative for the Arctic, due to deeper snowpack and smaller grain size distribution. In this respect, the paper submitted by Meinander et al. has the potential of improving the knowledge of the variations and a method to parameterizate albedo during the snow melting process, which is of importance for climate models and satellite applications and validation. The data material collected is to my opinion valuable, however far from fully utilized. A revision of the paper is to my opinion needed.

My general comments: 1. I am missing an introduction which gives a qualitative explanation, based on literature and snow RT models, of the factors and their importance for

modifying the spectral albedo during the melting process (eg. Wiscombe and Warren, or Pirazzini, Arola et al in the reference list). Factors to be mentioned: metamorphosis process, snow-ice-water suspension, grain size, extinction, wavelength dependence, snow depth vs albedo of the underlaying ground. Then, in the discussion part, Chapter 4, the relevance of ancillary data and other factors affecting the extinction of radiation from a melting snow pack could be discussed, which potentially could explain why eg. the observed albedo is lower than in Antarctic studies.

2. The results of ancillary data, which potentially aids explaining the albedo observations (grain size, temperature and liquid water profiles, Figure 5, 6) looks separated from the interpretation of albedo variations (Figure 2, 3). To give some clues for discussion: Could it be that the snow pack of melting snow was optically thin due to large grain size, so the low-albedo ground underneath the snow is 'seen'? Eg. in Wiscombes work, 1000 micron grain size would correspond to a liquid-equivalent depth for which the snow pack becomes semi-infinite, to be 50 cm of old melting snow. How is this in relation to the Arctic study, where grain size is even bigger and the snow depth was gradually diminishing to zero (20 cm in Figure 6). How is this related to Arola's work on satelitt reflectivity versus snow depth (Figure 1 in their paper), where apparently the reflectivity of a 0.02 m (2 cm) snow depth is marginally different from a 0.1 m thick snow pack? What is the importance of the surface layer compared with the layer beneath? Looking at Figure 5 in Meinander's study, where the liquid water content of the 0 cm surface layer was very low in the afternoon, and completely wet all the way below, could this observation aid the interpretation of Figure 2, 3, 7? Further, melting leads to radiation entering deeper into the snowpack, where radiation may become effectively trapped if snow is polluted. Looking at Figure 3, UV is relatively more attenuated than visible from 9 to 11 UTC. Does this indicate absorbtive extinction? Effect of debris from nearby trees?

3. Spectral albedo in UV is higher than measured with the two SL-501s. Could it be that the results are not comparable due to different fields? Ratio of area covered by

trees and buildings to area of snow-free land? Has the measurements with the SL-501 been cosine-corrected? Different distributions of up- and down-welling radiance may require different cosine corrections of the two meters.

4. Many of the references cited looks superficially linked to the results and discussion, as they were put in at last, without really going into a discussion of these results. Examples: Page 11, line 12, it is said 'The increase in snow albedo is in accordance with theory', without giving the reader a clue of the theory or which reference to find. Or on page 12, line 7-8, the reference to Wiscombe and Warren is in the context of smaller grain size of this Antarctic study compared with the Arctic study. But this study is highly relevant for the interpretation of the Arctic results, as all factors studied by theory may be related to Figure 2 and particularly Figure 3.

5. The parameterization of a linear relation to SZA-difference may not be of general use for other sites. The air temperature reached almost +10°C in the core-period 22-24 April, which may have had a much stronger effect on the melting process and albedo changes than the radiation energy absorbed. Further, the albedo in the visible is poorly correlated with the UVB albeod (equation 3). In addition to this, the formula is based on the midday albedo of the day, which differs from day to day. The authors suggest including environmental parameters in the parameterization, but which would require a larger data set. If this could be worked out and validated, it would be a really valuable contribution.

6. The SNORTEX experiment is within the framework of satellite application facilities. It would be interesting how the ground measured albedo corresponds to satelitt observations for the same are, using e.g. OMI data.

Specific comments Abstract and in the last paragraph of the Discussion section: The sentence says that '. . . showed a wavelength dependent difference between the modeled and the measured radiation by up to 9 %'. On page 10 and Figure 7, what is shown is 2.5 and 4.5 % for the 22 April, whereas the total change for the 4 days of

melting snow is said by words to be 9 %. Inclusion of a new Figure for the 4 days period, or extending Figure 7 may be helpful.

Introduction, page 3: I recommend restructuring this section, so that the scope of this investigation is listed at the end, and the 'how to do' paragraph (lines 24-29) moved to Materials and method's introduction part. The aims in 2.4 RT model calculations, page 6 (model to measured comparison) should be moved to the aims-part of the Introduction for easier readability, so all aims are collected from the beginning.

2.3 Ancillary measurements, page 5 and 6. How is the 'complex dielectric constant' related to snow water liquid content and density of snow? And how is the semiempirical equations? Please, add a reference. If snow density was measured, it may be another useful parameter to be discussed in relation to the albedo change.

Page 7, line 7: UVI should be written UV-Index.

Page 7, line 18: Is the time step the interval between a complete spectral albedo measurement? Or the interval between switching between up and downwelling spectral irradiance? Should it be in units of seconds instead of minutes? I don't understand the sentence on lines 18-20, as there always will be uncertainties from instable skyconditions when measurements are not fully simultaneous.

Page 8, line 1: 'albedo signal was slightly higher than it had been the previous evening, possible due to frost conditons'. Figure 5 shows that the bottom surface had liquid water (24 cm), and Figure 6 showed a temperature profile close to melting conditions (0 degree), possibly water vapour from the ground enters surface layer, forming ice crust. Which could be discussed further in the Discussion part.

page 8, equiation 1. In order to be valid for forenoon and afternoon, c must be positive in the afternoon.

Page 11, equation 4: The equation is basically the same as equations 1-2-3, but summarizing the c-coefficient. Please, consider if this could be simplified, by a table, or

moved to page 8 where the equation first appeared.

Figures: Figure 2: The small dots are almost invisible. Any explanation why the albedo is not monotonically decreasing during the clear sky day, but has a hump in the middle?

Figure 3: Due to theory of Wiscombe, Spectral albedo is expected to decrease with increasing grain size, as a function of wavelength (observations 15-17 UTC). Observations at 9-11-13, in the melting process shows the opposite. Is this due to increasing extinction in the UV from impurities in the snow, as the radiation enters deeper into the snow?

Figure 4: Maybe this figure is obsolete, as it represents another snow field.

Figure 5: Figure is easier to read if x-axis is given in hourly intervals, for comparison with Figure 2.

Figure 6: Consider switching x-and y-axis, so that y-axis gives the snow depth.

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