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Atmospheric Chemistry and Physics Discussions

Interactive comment on "UV albedo of arctic snow in spring" *by* O. Meinander et al.

O. Meinander et al.

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Reply to Referee #1

The Referee's comments were very valuable and will improve the value and content of the paper.

Referee#1 states that "our data set is unique and the scientific motivation and conduction of the investigation are sound and clearly presented". However, the Referee would like the interpretation of the measurements and the total uncertainties to be discussed in more detail. This will be made according to the Referee's more specific comments, as discussed more in detail below. As the discussion section was already quite long, we will insert a new separate section on the conclusions.

Local and regional albedo The Referee notes an important point we fully agree with: the irradiance ratios are influenced not only by the local snow albedo underneath the radiometers but also the combination of low-albedo and high-albedo surfaces within a

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larger radius. However, to the Referee's suggestion on the new title including the term "regional albedo", we feel we have to disagree. Although the local albedo is affected by the regional albedo, we are strongly of the opinion that our measurements at a height of 2 m represent local albedo. Instead of "local albedo", a term "effective local albedo", for instance, could be more descriptive for the albedo quantity derived in our study. The critical question is whether the downwelling radiation field on the snow surrounding the observation point (i.e., in the area where the observed F(arrow up) originates) differs systematically from F(arrow down) at the observation point. If not, F(arrow up/arrow down) should be an accurate estimate of the local albedo. As then suggested by the Referee, we agree and will include new discussion on the results related to the heterogenity of the local and regional surface albedo, including a new reference of Kylling et al. (2000) in the discussion. The Referee also states that "additionally the snow albedo may have a specular component (MIE scattering), giving rise to a SZA dependent variation". We fully agree with the Referee on the potential SZA dependency in the albedo. At high SZAs, the Mie scattered photons scattered forward into the snowpack have a greater chance of escaping the snow and still reach the downward-looking sensor. This could partly explain the diurnal U-shape of the albedo. We agree that the specular component may have an important role.

Title: As suggested by the Referee, we have reformulated the title of our work. It will be "Diurnal variations in the UV albedo of arctic snow".

Arctic versus Antarctic albedo: The Referee suggests that we should consider what other reasons than grain size and impurities (already mentioned by the authors) might be behind the lower Arctic albedo compared to Antarctic albedo. We like to suggest a further discussion on the impurities based on the Hansen and Nazarenko 2004 (Proc. Nation. Acad. Sci. 101:423-428). We then suggest that the possible other contributors than grain size and impurities might be, at least: - differences in precipitation snow grain shapes; and these differences might be due to differences, e.g., in the atmospheric moisture (Antarctic air is known to be dryer than the Arctic atmospehere), temperature

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(Antarctic atmosphere is colder than Arctic, and sometimes stratospheric air masses reach down into the troposphere there) and aerosol amounts (Antarctic clean air) - the effect of topography; although the measurement area is quite flat, the local albedo may be affected by the topography

Total uncertainty: As pointed out by the Referee, it is true that the total uncertainty is not given. By including a new reference, we will make the following addition about the total uncertainty: According to Hülsen and Gröbner (2007), the typical total uncertainty for SL-501 instruments is 1.7 - 4.3 %. In addition our article includes the statement that according to WMO (1996) the differences in SL501 sensors should be less than 1 %, when similar spectral responses are in question (in connection to this, please see the next chapter). The following new reference will be added: Hülsen G. and Gröbner J. 2007. Characterization and calibration of ultraviolet broadband radiometers measuring erythemally weighted irradiance. APPLIED OPTICS ,Vol. 46, No. 23.

Similar or changed spectral responses (Page 4157 and Page 4170): Prior to the measurements, the spectral and cosine responses of the sensors had been determined to be similar, as presented in Fig 1 and Fig2. In the albedo data, the SZA-dependency (U-shape) became evident. We suspected this to be due to changed spectral response. This was confirmed in the post-calibration measurements (Fig. 4). Our study increases the knowledge of the scientific community of the need to have regular response measurements for filter instruments. As suggested by the Referee, the U-shape in the results might also be partly due to the different components the upward and downward radiometers see (for downward looking sensor the diffuse and specular, while for the upward sensor the direct and diffuse), and this point will also be added in the Discussion.

Multiband data: Yes, we agree to the Referee's point that utilization of the full multiband data set could have added more general relevance and could have been discussed in relation to the spectroradiometer based albedo results. The use of these multiband data will be included in a future analysis. We have continue the SL501 and the multi-

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band measurements in 2008, too.

Empirical calibration: The Referee wants the two calibration options to be discussed in more detail. We will include more discussion on this issue as suggested by the Referee. We will include, as mentioned by the Referee, that the general measurement equation requires a thorough characterisation of the two radiometers but may then remove the most SZA dependent artefacts. How ever, the problem of changed spectral response remains. Accoring to our experience, it is important that when applying this equation, the spectral responses are determined prior and after the measurements. The empirical calibration provides a direct comparison of the two radiometer readings but then only a smaller SZA range is utilized and the SZA influence on the albedo remains unresolved.

Error sources of the empirical calibration: The Referee thinks that the error sources of the empirical calibration should be discussed more detailed. We will include the relevant points as suggested by the Referee: 1) issue on diffuse and specular versus direct and diffuse 2) effects on the internal temperature.

Julian day: We will clarify the text by using Julian date (or the day of the year) and the day and month in parenthesis.

Albedo and snow grain size and technical improvements Yes, it is true that here we give the albedo only as a function of snow height but not as a function of snow grain size. The latter we will do only in the future with a larger data set. The Eq. 4 has the term -6 E-05 where E is for the exponential and there is a typo error in the formula marking E in italics. We will edit E to be regular font. All the technical improvements to the Figures and Tables will be made as suggested by the Referee. As there is a large number of figures and tables, we agree to the Referee's suggestion to omit some of them: Tables 2 and 5 will be removed as suggested by the Referee. We agree that this information is available in the text. Figures 1 and 2 we think should be kept to clearly point out that these responses have to be taken into consideration. Instead of removing them, we

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suggest to improve the titles for these figures to include information of the relevance of the responses. Also, Figure 11 we suggest to be included as it confirms the SL501 data of diurnal change in UV albedo.

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 4155, 2008.

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