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Interactive Comment

Interactive comment on "Snow physics as relevant to snow photochemistry" *by* F. Domine et al.

F. Domine et al.

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Our paper was reviewed by Richard Essery (Ref. 1), Steve Warren (Ref. 2) and an anonymous referee (Ref. 3), whom we thank for their useful and numerous comments.

Responding to each of the detailed comments would produce a very long document that would be difficult to read. We will of course consider all the comments with great attention, but what follows focuses on the most important issues and details only those points with some degree of disagreement. The specific points not discussed will be changed following the reviewers' suggestions.

GENERAL CHANGES

In response to the comments of the referees, we will :

- Compare snow to other porous media such as soils and forests in the introduction (in response to Referees 1 and 3).

- We will add 6 figures (in response to Ref. 2) showing the rate of decrease of SSA, the range of permeability values, the effect of mineral dust in snow on its optical properties, an illustration of the use of microwave remote sensing, a diagram showing the location of impurities in snow and a figure detailing the thickness of the quasi liquid layer.

- We will reorder the sections (Ref. 3). Essentially we will move the optical properties of snow just before the remote sensing section. This will allow a smooth transition between optical properties and optical remote sensing.

- We will explain why remote sensing is inseparable from snow physics studies (Refs. 2 and 3). Paragraphs in section 1.1 and the beginning of section 3.1 will explain why field studies provide only limited data and why upscaling field data can only be done using remote sensing. It is true that remote sensing data provides less accurate data than direct field measurements, but in many cases, large scale snow modeling can only use physical variables derived from remote sensing as input data. We therefore believe that readers interested in the modeling of snow photochemistry will be interested in the remote sensing section. We will significantly condense the microwave part.

- We will shorten the part on the quasi liquid layer. However, this discussion is crucial to our paper. Any future modeling of snow photochemistry will need to consider the QLL in detail, so that a significant discussion is required. Even though we will do our best to shorten this section, we feel that we will have to add a paragraph to describe recent developments in the study of the QLL using chemical probes by the group of Donaldson. These recent studies are particularly relevant to this paper, which is intended for chemists.

- We will add a significant number of references, most of them not from the authors. We however think that the comment of Ref. 3 "The self-citation rate is alienating" is exaggerated. There are many authors to this paper, all of them very active in the field, so that a significant degree of self-citation is inevitable, as in any overview paper with a large number of senior authors. Moreover, in some aspect of snow studies, most of

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the work available in the literature has been done by the authors. This is particularly true for the specific surface area, so that in that section it is inevitable to have a high self-citation rate.

SPECIFIC CHANGES

We will mention wet snow a few more times (Ref. 3). However, this paper focuses on snowpack types where snow photochemistry studies are currently under way. These are mostly in polar regions and we therefore chose not to detail the description of wet snowpacks.

We will mention the new measurement of the ice absorption coefficient indicated by Ref. 2. We have examined the work of Warren et al. (2006) but find nowhere the e-folding depth values of 3 m in snow mentioned in the review by Ref. 2. From Fig. 3 of Warren et al. (2006), an e-folding depth value of about 1 m can be found for layer C, 1 m below the surface. But we clearly stated several times in our paper that our focus is on surface snow, which can interact easily with the atmosphere. The data of Warren et al. (2006) show that for higher layers, about 50 cm below the surface, the e-folding depth is in the range 10-20 cm, just like in the Arctic. We will mention these values but feel that there is no need to expand the discussion further. In any case, the value of the absorption coefficient of ice in the visible has little impact on the e-folding depth, since absorption is due almost exclusively to impurities, and not to the ice itself.

We will change equation 1.4-4. There are in fact many possible definitions of gas diffusivities in porous media, but the new one will be chosen among the more commonly used ones and will be intuitively more appealing. It will also be consistent with our discussion in section 2.9. We will use a log scale in Figs. 6 and 8. Fig 8 will thus show clearly the impact of low soot concentrations on snow reflectance.

We disagree with the statements that the measurement of snow SSA in the field have been common for many years (Refs. 2 and 3). Unlike mentioned by Ref. 2, there is today no reliable way to measure SSA from snow optical properties. The mentioned

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"one-to-one correspondence between SSA and effective radius" has no experimental validation and the preliminary studies of Matzl and Schneebeli (2006) and Domine et al. (2006) are too recent and preliminary to support the Ref.'s statement. Regarding Ref. 3's statement on stereology, SSA measurements of surface snow using stereology are few, with the latest extensive study in 1971 by Narita. Moreover, that paper is in Japanese with only an English abstract, so that its use is limited for most people. It can nevertheless be seen that Narita's work shows few measurements on surface snow. Lastly, we are not certain that stereology can detect microstructures in fresh snow, because filling snow with dimethylphthalate (or other compound) will certainly affect them, and even if they are preserved, visualizing them will be difficult. We therefore feel that it is reasonable to say that most SSA measurements on surface snow to date were done in the past few years using the CH4 adsorption technique.

We will discuss the effect of wet snow on the analysis of optical remote sensing data, and will remove statements referring to thin snowpacks as semi-infinite. We will just say that our analysis applies to sufficiently thick snowpacks, and we will give indications of what that means.

We will discuss aerosol concentrations in snow in terms of chemical concentrations. Data on particle number densities exist only for ice cores, to the best of our knowledge, and this paper focuses on surface snow.

Ref. 3 did not like our listing of snow types and suggested that it be replaced by a reference. On the contrary, we feel that photochemists will need a simplified description of the main crystal types. Referring them to ICSSG, which is designed only for specialists, would not be useful. We will modify the order of the listing, so that it follows somewhat more a metamorphic logic. However, since metamorphism does not follow a linear progression and involves several possible inter-related sequences, any order is debatable.

The statement by Ref. 3 that depth hoar formation continues to very high density is

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vague. To the best of our knowledge, the highest published values of depth hoar density are around 0.3. Granted, we have seen indurated depth hoar of density nearing 0.4, but even Sturm does not report that in his papers. And we would not call 0.4 "very high density".

Contrary to the statement by Ref. 3, we are fully aware of the layered nature of snowpacks, which we mentioned several times. In any case, the Ref.'s comment appears to suggest that the size of the samples required for the measurements discussed are too large to account for the snow stratigraphy. This is often not the case. While it is trivial to say that mm-thick layers can only be studied with great difficulty, most measurements (though not all) can be done on layers 1 to 3 cm thick. We are surprised by Ref. 3's suggestion of an obscure reference, available only on a private website and prefer to cite Sturm and Benson (2004) and Matzl and Schneebeli (2006), as illustration of the layered natured of the snowpack, as observed in field studies at various scales, from mm to km.

As suggested by Ref. 3, we will discuss Sommerfeld and Rocchio (1973) but will conclude that their data are too few and over a too narrow range to allow any definite conclusion. Moreover, their SSA values are surprising and further measurements appear required to test their conclusion further.

We agree with the other points raised by the reviewers and will make the corresponding changes. We are thankful to the referees and editor for their time and constructive suggestions, which will allow us to produce what we believe will be a significantly improved version of this paper.

Interactive comment on Atmos. Chem. Phys. Discuss., 7, 5941, 2007.