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Atmospheric Chemistry and Physics Discussions

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

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General comment.

This paper is a useful review. I recommend that it be published after revisions.

The ratio of words to figures seems unbalanced; there are only 10 figures in a long paper.

Major comments.

Regarding the UV absorption coefficient of ice (page 5964 line 19). Perovich and Govoni 1991 (PG) has been superseded by Ackermann et al. 2006 and Warren et al. 2006. Figure 5 of Warren et al. shows that the UV absorption coefficients are a factor of 100 smaller than reported by PG. The consequence is that extinction coefficients in snow computed using PG's values will be a factor of 10 too large (square-root of 100).

The section on remote sensing (Section 3) seems out of place in this paper, given the title of the paper. That section could be removed.

Specific comments.

page 5943 line 6. For comparison, it would be interesting also to give the SAI for the dry-snow zone of Greenland (i.e., integrated down to the close-off depth).

page 5950 eq. 1.4-4. What are the units of C: g per cubic cm of snow, or g per cubic cm of interstitial air? Should phi be in the numerator instead of the denominator?

page 5952 line 14. cite LaChapelle (1969) Figures 52, 53.

page 5959 line 2-3 "Values measured in surface snow range from 19 to 1558" seems to conflict with lines 11-13 "snow . . . has a much lower SSA than . . . 100"

page 5964 lines 1-11. This paragraph implies that the models of Wiscombe and Warren 1980, and Warren 1982, did not use the asymmetry factor g. This is incorrect; Wiscombe and Warren used the delta-Eddington method.

page 5964 line 14. Change "transformation" to "method".

page 5965 lines 10-11. "e-folding depth . . . is between 5 and 25 cm for most snowpacks." This is true only for polluted snowpacks. Add reference to Warren et al 2006, whose Figure 4b for Antarctic snow shows that the e-folding depth is 100 cm (ice-equivalent) at 390 nm wavelength, corresponding to 300 cm snow depth. The e-folding depth decreases with wavelength across the visible spectrum, to 20 cm snow depth at wavelength 600 nm.

page 5967 line 12. "volumetric concentration of grains". This phrase would be interpreted by most readers to mean the number of grains per cubic cm. But here you apparently instead mean c-sub-g = 1- phi (eq. 1.4-1), according to line 14. There is therefore no need to introduce the quantity c-sub-g; just replace it in the equations with (1-phi).

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page 5968 line 9. Change "absorbance" to "absorptance". "Absorbance" is a term used in chemistry, meaning log10(Io/I) (Skoog and West 1963 page 641; Handbook of Chemistry and Physics 73rd edition page 2-10). The chemist's "absorbance" is therefore proportional to optical depth.

page 5968 line 11. Eq. 2.4-11 is valid only for thick snowpacks. In general, a+r+t=1, where t is the transmittance to the ground below the snow.

page 5969 line 13. The imaginary index given by Wiscombe and Warren 1980 is obsolete. Cite instead Warren 1984 and Warren et al. 2006.

page 5970 line 6. Wiscombe and Warren 1980 was for pure snow. Here the appropriate citation is instead Warren and Wiscombe 1980.

page 5971 line 7. "a few ppm by volume of soot can have a dramatic impact". This is true but misleading. Snow does not contain ppm amounts of soot except very close to pollution sources. Arctic snow mostly has values 5-50 ppb (Clarke and Noone 1985; Warren and Wiscombe 1985 Figure 2).

page 5973 line 16. Cite also Brandt and Warren 1997 Figure 11.

page 5974 Eq. 2.6-1. Delete. This equation duplicates eq. 1.4-3.

page 5975 lines 7-8. "SSA is . . . rarely measured in the field." There is a one-to-one correspondence of SSA with effective radius (as explained on page 5967), and effective radius can be estimated in the field as slightly more than half of the short dimension "i.e., the width of a column, the thickness of a plate, or the width of a hollow crystal's wall", as stated by Grenfell and Warren 1999 page 31708.

page 5975 Eq. 2.7-1. Delete. This equation duplicates eq. 1.4-4.

page 5978 line 26. "tortuosity tau". I prefer to use instead a lower-case ksi, because the letter itself looks tortuous (see page 18,736 of Harder et al 1996).

page 5980 lines 13-14. Since you're citing Grenfell & Warren 1999 and Neshyba et al

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2003, you may as well also cite the third paper in this series (Grenfell et al. 2005).

page 5980 line 16. "a snow layer of just 5 cm thick is virtually a semi-infinite medium in the visible". This is true only if the snow contains absorptive impurities. Five cm of snow is 5 mm liquid equivalent of new snow or 25 mm liquid equivalent of old melting snow. To be generous, let's take "semi-infinite" to mean that the albedo is within 3% of the asymptotic value. Figure 13 of Wiscombe and Warren 1980 shows that this limit is reached for pure snow at 10 mm, 30 mm, and 100 mm liquid equivalent for grain radii 50, 200, and 1000 microns. A better criterion for "semi-infinite" would be to reach within 1% of the asymptotic albedo, which would require much deeper snowpacks. [And those calculations in 1980 used the old values of ice absorption coefficient. With the new lower values, snow will have to be deeper to become semi-infinite.] In addition, such a thin snowpack will likely also have grass sticking up through it.

page 5981 line 13. Why the subscript w? I think this single-scattering albedo is the same as omega-sub-0 on page 5963.

page 5981 lines 28-29. "The difference of the measured reflection . . . can be attributed to the pollution." This is not true. Pollution can be mimicked by snow thinness. So it is not possible to obtain the soot content of snow by remote sensing without independent knowledge of snow depth. Thin snow has the same spectral signature as sooty snow (compare Figure 13 of Wiscombe and Warren 1980 to Figure 7 of Warren and Wiscombe 1980). The difficulty of distinguishing clouds from snow by visible and infrared remote sensing also needs to be discussed. Also the difficulty of detecting a thin near-surface layer of clean diamond-dust that partially hides sooty snow.

page 5983 lines 10-11 and 16-18. "many snow physical variables can be retrieved using microwave remote sensing." In my opinion, these claims for microwave remote sensing are wishful thinking. The comparisons of retrieved SWE with ground truth that I have seen show poor correlation. A critical assessment is desired. But is a discussion of remote sensing even appropriate for this paper?

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page 5986 line 20. Rensefled and Grody 2000 is not in the reference list.

page 5994. Delete equation 4.3-3. This equation duplicates eq. 1.4-3.

page 6032. Figure 6 might be redone using optical constants of Warren et al 2006.

page 6034 Figure 8. Compare these results to similar plots shown in Figures 1 and 2 of Warren & Wiscombe (1985). Also, it would be more useful to convert the x-axis into a log scale as Warren & Wiscombe 1985 did, because typical soot concentrations are in the ppb range, not ppm.

Spelling and grammar

page 5942 line 9. Change "a function" to "functions"

page 5945 line 1. Change "with" to "will"

page 5946 line 23. Change "know" to "known"

page 5947 line 5-6. Change Waddingon to Waddington.

page 5952 line 6. superscript 3 should be -3.

page 5955 lines 1-2. "actual . . . actually" is redundant.

page 5959 line 11. "beginning of the century". Which century?

page 5962 lines 15, 16. Change LaChappelle to LaChapelle.

page 5965 line 9. Liljequist

page 5973 line 8. Sturm

page 5989 line 3. Change "absorption" to "absorptivity" or "absorptance". Change "Kirchoff's" to "Kirchhoff's".

page 5997 line 20. Change "Doeppenscmidt" to " Doeppenschmidt" to agree with the name in the reference list.

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page 6013 line 23. Umlaut Roethlisberger.

page 6016 line 22. Change Liljquest to Liljequist.

page 6016 line 29. Permeability

page 6016 line 32. "and model"

page 6017 line 32. Umlauts are missing: Beitraege, trueber, Metalloesung.

page 6020. lines 16-18 are duplicated by lines 19-21 (i.e. 2000b is the same as 2000a).

page 6022 line 5. "SMM/I" I think you mean SSM/I.

page 6022 line 14. delete "edited".

page 6032. The last 4 lines of Figure 6 caption are out of place; they belong in Figure 7.

page 6035, Figure 9 caption line 3. Delete "is recalled".

References

Ackermann, M., et al., 2006: Optical properties of deep glacial ice at the South Pole, J. Geophys. Res., doi:10.1029/2005JD006687.

Brandt, R.E., and S.G. Warren, 1997: Temperature measurements and heat transfer in the near-surface snow at the South Pole. Journal of Glaciology, 43, 339-351.

Clarke, A.D., and K.J. Noone, 1985: Soot in the Arctic snowpack: A cause for perturbations in radiative transfer. Atmos. Environ., 19, 2045-2053.

Grenfell, T.C., S.P. Neshyba, and S.G. Warren, 2005: Representation of a nonspherical ice particle by a collection of independent spheres for scattering and absorption of radiation: 3. Hollow columns and plates. J. Geophys. Res. (Atmospheres), 110, D17203, doi:10.1029/2005JD005811.

Harder, S.L., S.G. Warren, R.J. Charlson and D.S. Covert, 1996: Filtering of air through

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snow as a mechanism for aerosol deposition to the Antarctic ice sheet. J. Geophys. Res. (Atmospheres), 101, 18729-18743.

LaChapelle, E.R., 1969: Field Guide to Snow Crystals. University of Washington Press, Seattle.

Skoog, D.A., and D.M. West, 1963: Fundamentals of Analytical Chemistry. Holt, Rinehart and Winston.

Warren, S.G., 1984: Optical constants of ice from the ultraviolet to the microwave. Applied Optics, 23, 1206-1225.

Warren, S.G., and W.J. Wiscombe, 1980: A model for the spectral albedo of snow, II: Snow containing atmospheric aerosols. J. Atmos. Sci., 37, 2734-2745.

Warren, S.G., and W.J. Wiscombe, 1985: Dirty snow after nuclear war. Nature, 313, 467-470.

Warren, S.G., R.E. Brandt, and T.C. Grenfell, 2006: Visible and near-ultraviolet absorption spectrum of ice from transmission of solar radiation into snow. Applied Optics, 45, 5320-5334.

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