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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Light-absorbing impurities in Arctic snow" *by* S. J. Doherty et al.

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COMMENT: Page 18810, line 29 "reduce the broadband albedo of snow by much as 0.04" : please specify the wavelengths referred to here.

REPLY: The text has been changed to: "reduce the broadband (0.3-2.8μm) albedo of snow by as much as 0.04"

COMMENT: Page 18811, line 5, "is significant for climate." needs an appropriate citation for study that shows significance to climate.

REPLY: References to Hansen and Nazarenko (2004), Jacobson et al. (2004), Hansen et al., (2005) and Flanner et al. (2007) have been added.

COMMENT: Page 18811, line 25, citation of Conway et al 1996 for soot concentrating in the surface of snow is not an appropriate reference for this statement. Conway et

al showed that the soot particles deposited on the snow surface were quickly flushed into the snow pack, which then brightened after application. They did show that BC persisted in the surface, but did not show substantial concentration of soot in the surface. This theory has often been hypothesized, but to my knowledge has not yet been shown conclusively.

REPLY: On re-reading the Conway et al paper we see that the reviewer makes a very good point! We have revised the text as follows: "(7) it has been hypothesized that melting may tend to concentrate soot at the top surface (e.g. in the modeling study of Flanner et al., 2007), where it is exposed to more sunlight."

COMMENT: Page 18812, line 1, "Soil dust is about a factor of 50 less effective at reducing snow albedo.": this needs a citation, unless the Painter et al 2007 also refers to this statement. If so it needs to be clarified.

REPLY: The statement has been edited as follows: "By comparing Figures 4 and 7 of Warren and Wiscombe (1980), Warren (1984) concluded that soil dust is about a factor of 50..."

COMMENT: Page 18818, line 18, Use of the Angstrom exponent of 5, for non-BC light absorbing aerosol should be explained/justified a little further, given that the Grenfell 2010 paper is still under review. Hadley et. al. (2008) also found and used an Angstrom exponent of 5 for brown carbon, but I have not seen that number used elsewhere.

REPLY: Justification for the use of an Angstrom exponent of 1 for BC and 5 for non-BC light-absorbing aerosol has been added to the manuscript. We also discuss the possible range of both in our (newly added – Section 6) uncertainty analysis. See .pdf included as a supplement.

COMMENT: Page 18826, line 10, typically typed twice.

REPLY: Thanks for catching this! We will remove the second incidence of "typically".

COMMENT: Page 18827, line 15, The cited Bond papers discussing industrial emissions with Angstrom exponents greater than 2 are specific to inefficiently burned coal and not all fossil fuels. This should be specified here.

REPLY: The text has been modified to read: "However, this can vary depending on the material being burned, the burn temperature and other conditions, so Å can be >2 for aerosol from e.g. inefficient coal burning (Bond et al., 1999; Bond, 2001)."

COMMENT: Page 18841, line 7-11. A very excellent point.

REPLY: Thank you. To make this point more prominent, we now also include it in the abstract.

COMMENT: Page 18841, line 15 -20, although larger snow grains lead to a greater decrease in albedo, the same amount of BC in larger grains relative to smaller grains has a much greater potential to lower albedo. (Flanner et al 2007). This probably should also be mentioned.

REPLY: This was first shown by Warren and Wiscombe (1980, Figure 7), as we stated on page 18811 lines 22-24. However, in response to the reviewers' request we now elaborate on this effect on page 18841: "The major variable affecting snow albedo is the effective grain size (Wiscombe and Warren, 1980), which for a nonspherical snow grain is proportional to the volume-to-area ratio (Grenfell and Warren, 1999). The effective grain radius for new snow is 50–100 μm, and for old melting snow it is $\sim$1000 μm; the corresponding broadband albedo reduction in pure deep snow is$\sim$0.12 (Fig. 1 of Warren and Wiscombe, 1985). This difference is much larger than the albedo difference caused by the typical concentrations of impurities we find in arctic snow. These two influences (grain size and BC content) also interact: the change in albedo for a given concentration of BC will be greater for larger grained snow than for smaller grained snow (e.g. for 50ng/g of BC, delta-albedo at 470nm is 0.03 for snow with 100 μm grain radius but 0.08 for snow with 1000 μm grain radius) (Fig. 2 of Warren and Wiscombe, 1985)."

Please also note the supplement to this comment:
http://www.atmos-chem-phys-discuss.net/10/C9454/2010/acpd-10-C9454-2010-supplement.pdf

Interactive comment on Atmos. Chem. Phys. Discuss., 10, 18807, 2010.