The Cryosphere Discuss., 7, C306–C309, 2013
www.the-cryosphere-discuss.net/7/C306/2013/

The Cryosphere Discussions

Interactive comment on "The effects of additional black carbon on Arctic sea ice surface albedo: variation with sea ice type and snow cover" *by* A. A. Marks and M. D. King

Anonymous Referee #2

Received and published: 14 April 2013

This paper explores the sensitivity of sea-ice albedo to black carbon (BC) additions in different types of ice, and also covered with snow of varying thickness and type. The approach taken in this study is a bit unconventional. Rather than starting with pure forward modeling of separated ice and BC species, the authors prescribe bulk optical properties for sea-ice needed to match measured albedo and penetration depth from Grenfell and Maykut (1977). Though unconventional, this approach adds diversity to the spectrum of methods applied to understand radiative impacts of BC in sea-ice, and hence is valuable.

A key limitation of this approach, however, is that the reported BC sensitivities are

dependent on the amount of light-absorbing matter that was present in the sea-ice observed by Grenfell and Maykut, possibly quite different in the 1970s than today, and also likely variable in space. This issue is certainly acknowledged by the authors (e.g., by using "additional black carbon" in the title and throughout the manuscript), though I think its importance and potential variability in space and time were understated. The authors could address this by exploring the sensitivity of BC-induced albedo reductions to a wider range of sea-ice optical properties (e.g., by varying the absorption cross-section of the unperturbed sea-ice). I suggest either carrying out such sensitivity studies, or clearly acknowledging in the abstract the limitation of basing the analysis on two sets of measured sea-ice properties from the 1970's.

Otherwise, I found the discussion and analysis to be interesting, and I suggest publication in The Cryosphere after minor issues are addressed.

Minor issues:

Section 2.1-2.2: Related to my main comment above, do the sea-ice optical measurements conducted by Grenfell and Maykut (1977) represent the current state of science? Are there more recent measurements of sea-ice albedo and light extinction, and if so, how do they compare with those reported by Grenfell and Maykut (1977)?

944,7: "are calculated" - Please briefly explain the type of approach that was applied to calculate this (i.e., incorporation of measurements and modeling).

945,4: Gardner -> Gardner and Sharp

947,4: A 1% reduction in 500nm albedo caused by 100 $ng\,g^{-1}$ of soot, ascribed to Grenfell et al (2002), sounds extremely small. It may be accurate, but I suggest verifying it and including possible explanations (in section 4) for why the sea-ice albedo modeled by Grenfell et al (200) was so insensitive to BC.

947,10-30: The analysis of reduced BC impact in snow-covered sea-ice is useful, but the snow overlying sea-ice may also be contaminated with BC, reducing surface albedo and altering evolution of the snow/ice column. I suggest briefly mentioning this.

947,21: The 8cm and 20cm appear to be reversed here.

Equation 1: It is useful to include this, but the first two terms (σ^{ice} and σ^{+}) were not separated in this study, correct? I suggest clarifying at this point in the text that the approach taken in this study is to infer the sum of σ^{ice} and σ^{+}) from measurements.

Equation 1: The symbol σ and term "cross-section" are often used to denote extinction/scattering/absorption cross section with units of m^2. Please clarify here that these are cross sections normalized to mass, with units of $m^2\,kg^{-1}$

950,18: "diameter of 0.2um" - Was a monodisperse size distribution assumed?

950,20: Please list the BC mass absorption cross-section resulting from these assumptions.

951,9 and 951,28: Use of the term "extinction coefficient" is a bit confusing here, because it differs from the "extinction coefficient" used in basic radiative transfer equations. Here, it represents the reduction in flux within a scattering medium. I suggest briefly clarifying this to avoid confusion.

951,24-25: Please fix the wording in this sentence.

951,27: Are there necessarily unique combinations of scattering and absorption mass cross-sections that yield an optimal fit with measured albedo and extinction coefficient? Please include a sentence or two about this, and how it relates to the uncertainty depicted in Figure 2 and described in section 4.4.

Also, could the fit with measurements be influenced at all by variability in the scattering asymmetry parameter (g), which was held constant?

954,20: "each sea ice/snow" -> "each sea ice/snow combination"?

956,5: "increase observed" - increase of what?

956,3-17: Doherty et al (2010) concluded that about 40% of the light absorption in their Arctic snow and sea-ice samples was caused by non-BC species.

957,20: "... implies a large value of the scattering cross-section will result in black carbon having less effect on surface albedo." - OK, but this is not entirely consistent with the data cited from Light et al (1998) and Grenfell et al (2002). For example, Light applied higher scattering cross-sections than Grenfell and those used for first-year ice in this study, and yet Light et al calculated a *larger* albedo reduction from BC than either study. This suggests that other factors or assumptions also play key roles in determining the albedo sensitivity to additional BC. Please comment on this.

958,11: Please fix this sentence.

960,12-15: "These values of uncertainty were calculated through making small changes to the fit of the albedo and extinction coefficient data from Grenfell and Maykut (1977), and judged by eye, to ascertain how small changes affect the derived scattering and absorption value." - This description of uncertainty determination needs clarification. Can it be stated that the uncertainty bars represent reasonable ranges of absorption cross-section that can produce an optimal fit with observed albedo and extinction coefficient, while holding all other variables (e.g., scattering asymmetry parameter) constant? Please clarify, and perhaps elaborate on the approach used to quantify uncertainty.

Interactive comment on The Cryosphere Discuss., 7, 943, 2013.