

# ***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***

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***We thank the referee for their comments. Our answers and corrections are below.***

**Referee comment:** General Comments

The authors used model to illustrate the effects of additional black carbon on Arctic sea ice albedo considering different sea ice types and snow cover, which is new and fresh to me. From this point of view, this work should be published at last. However, there are still many points needed to be addressed before the formal publication. So I suggest a minor revision at this stage. And if the authors can present some experimental data to support the modeling results, which would be much better. Although I'm not an

English-speaking person, I got confused by the English grammar at some places in this paper. I suggest the authors to check them carefully.

**Response:** *The grammar in the manuscript will be improved. Sentences will be shortened and the readability will be improved.*

**Referee comment:** L11-15 in P944. Would the authors like to address "the albedo of first-year sea ice is more sensitive to BC or that of multi-year sea ice is"? I don't understand. Please also see the relevant sentence in the conclusion part.

**Response:** *The section will be written more clearly: "The albedo of the first year sea ice decreases more than the albedo of the multi-year sea ice from the addition of the same amount of black carbon; demonstrating that the albedo of different sea ice samples may decrease by different amounts for the same addition of black carbon. The albedo of the first year sea ice is more sensitive to additional loadings of black carbon than the multi-year sea ice."*

**Referee comment:** L27-28 in P945. The authors should add the time span for BC climate forcing specially regarding to the IPCC report. As far as I know, the IPCC report addressed the time period of 1750-2005.

**Response:** *The time span will be added and the text will read "The 2007 IPCC report quantified the possible positive forcing as  $0.1 \pm 0.1 \text{ Wm}^{-2}$  for the time period 1750–2005 (Solomon et al. 2007)."*

**Referee comment:** The first sentence in P946. The references should be reordered by time. The last sentence in P946. Also, the time span should be given out according to Holland et al. (2012).

**Response:** *The references on p946 and throughout the manuscript will be re-ordered in chronological order and the text changed to add the time period to the Holland et al. (2012) reference. "...while Holland et al. (2012) conclude that black carbon and dust causes an annual average  $0.2 \text{ Wm}^{-2}$  increase in shortwave absorption in Arctic sea*

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ice over the 20th century."

**Referee comment:** The first paragraph in P947. When reviewing the previous work, the authors should point out they are referring to bare ice or ice with snow covered.

**Response:** *The paragraph will be re-written to provide more information about these studies. The second reviewer also requested more information about these studies be given and thus the reply below may seem fuller than required by referee 1.*

*"Light et al. (1998), Grenfell et al. (2002) and Jacobson (2004) suggest for increasing the amount of black carbon in sea ice (without a snow cover) from 0–100 ng g<sup>-1</sup> will decrease the albedo to 73%, 99% and 92% of the original values respectively for a wavelength of 500nm. For each of these studies the optical properties of the sea ice were different and the distribution of black carbon within the sea ice was different. Thus detailed comparison of the studies is difficult. For example, Grenfell et al. (2002) place black carbon in only a 1 cm layer at the sea ice surface, which may explain the relatively small albedo decrease reported compared to Light et al. (1998) and Jacobson (2004) who distribute black carbon evenly through the sea ice."*

**Referee comment:** The first paragraph in P948. This sentence should be reorganized. The grammar here is a total chaos.

**Response:** *The very and complicated lengthy sentence will be re-written as:*

*"The work presented here has two aims. Firstly, to establish the response of the surface albedo of a first year and a multi-year sea ice to increased black carbon content. Secondly, to quantify the change in surface albedo of snow covered sea ice with increasing additional black carbon in the sea ice. The change in surface albedo of the snow covered sea ice will be quantified as a function of snow depth, snow type, sea ice type and amount of black carbon in the sea ice."*

**Referee comment:** L21 in P954. Why can this equation be used to calculate BC concentration? The authors had better present a reference.

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**Response:** Two references are provided that contain more detail on the applicability of this equation and will be referenced in the text as:

France, J. L., Reay, H. J., King, M. D., Voisin, D., Jacobi, H. W., Domine, F., Beine, H., Anasta- sio, C., MacArthur, A., and Lee-Taylor, J.: Hydroxyl radical and NO<sub>x</sub> production rates, black carbon concentrations and light-absorbing impurities in snow from field measurements of light penetration and nadir reflectivity of onshore and offshore coastal Alaskan snow, *J. Geophys. Res.*, 117, 5502–5509, 2012. 951, 952, 956, 960, 961

Reay, H. J., France, J. L., and King, M. D.: Decreased albedo, e-folding depth and photolytic OH radical and NO<sub>2</sub> production with increasing black carbon content in Arctic snow, *J. Geophys. Res.*, 117, D00R20, doi:10.1029/2011JD016630, 2012. 945, 953

**Referee comment:** L7 in P956. What is HULIS? Please give out the completely spelled name when it is firstly appeared.

**Response:** HULIS will be defined. The text will read: “...atmospheric dust, algae and HUmic Like Substances (HULIS) ....”

**Referee comment:** L4-6 in P960. This paragraph is confusing for its grammar.

**Response:** The text will be improved to:

“The work presented here has several limitations: firstly the method for obtaining scattering and absorption cross-sections of sea ice and snow, secondly, the absorption spectra of black carbon, thirdly, the physical characteristics of the black carbon, and fourthly, the age of the field data on which this data is based. These limitations will now be discussed:”

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

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