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The Cryosphere Discussions

Interactive comment on "Brief communication: An alternative method for estimating the scavenging efficiency of black carbon by meltwater over sea ice" *by* Tingfeng Dou et al.

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We thank the reviewer for a comprehensive and helpful review. The reviewer's comments have guided further improvement in the problem statement and data interpretation. We have also reviewed the relevant literature to further support our central hypothesis and expanded the discussion of study's results. A detailed response follows below.

Others have observed and discussed the seasonal influence of black carbon in melting snow (e.g. Flanner et al, 2007; Doherty et al., 2010, 2013; Dou et al., 2017). Here the authors propose a new method to estimate meltwater scavenging of black carbon

using field measurements made near Barrow, Alaska. The idea is to eliminate the need for repeat sampling at sites by collecting just one profile during the melt season, and assuming mass conservation to estimate the scavenging efficiency.

Some comments and questions: 1. Figure 1 shows locations of sites far from Barrow that are not used to support your new technique for estimating BC scavenging efficiency. I do not think that referencing these extra sites: South Korean Antarctic Ocean expeditions 2010 -18; 3rd Chinese Arctic Expedition; Hiking through the North Pole; Dye 2 etc) adds to the primary focus of your paper (i.e. meltwater scavenging of BC). I think it would be less confusing for readers if these references were not included.

- Response: In order to make the MS more focused, the sites in Svalbard and Greenland in original figure 1 were removed. The observational locations in the 3rd Chinese Arctic Expedition and the first Chinese expedition hiking through the North Pole are retained because we observed ice layer over sea ice in these regions, which effectively extended the application scope of this new method.

2. Not all readers will be familiar with your field measurements near Barrow, Alaska (Dou et al., 2017). It would be useful to expand on details of those measurements here. Also in the abstract it would be important to state specifically that Elson Lagoon and Chukchi Sea are in the vicinity of Barrow, Alaska.

- Response: Thank you for your comments. The description of the field measurement was added in the revised MS (See P3, L62-77). We clarify that Elson Lagoon and Chukchi Sea are in the vicinity of Barrow in the revised abstract. Besides, the measurement locations in Elson Lagoon and Chukchi Sea have been shown in figure 1.

3. I do not follow your eqn. 1, which you mention comes from Flanner et al (2007). Their eqn. 3 assumes mass rate of change of BC in layer 'i' is proportional to its mass mixing ratio multiplied by a scavenging factor, which appears to be quite different to the one you are using.

Instead, it might be better to follow the method described by eqns. 2, 3 and 4 in Doherty et al., (2013), which shows how measurements of mB (average original mass per unit volume of BC before melting), and m'B (average mass per unit volume in the near surface snow can be used to calculate an average scavenging efficiency. In your case, you could use the method you propose to calculate mB = h1rïĄš1CB1, and calculate m'B from your measurements of CBsfc hsfc and rïĄssfc in the near surface snow after melt has started (from your Table 2).

- Response: Thank you for your valuable comments. Using the method of Doherty et al. (2013) (Eq.2 in that reference), we recalculated the BC melt water scavenging coefficient (MSC) in Elson Lagoon based on the observations in this study. It indicates that the average value is 0.204, slightly higher than the result calculated by the method proposed in this study (0.145). It is known that Doherty et al. (2013) made two assumptions in estimating MSC of BC, leading to their estimate should be the upper limits of MSC. Thus, the difference between MSC values obtained using these two different methods is reasonable. We re-checked the definitions of MSC in different literatures, and found that we did not make this issue clear in the manuscript (MS). Due to different focuses and uses, there are differences in the form of the calculation formula. Flanner et al. (2007) gave a method that is applicable to BC simulation in the CLM model; Doherty et al. (2013) proposed a formula that is applicable to continuous sampling method. Previous studies determined MSC by comparing the BC content in snowpack before and after ablation. This study estimated the BC taken away from the melt water directly by measuring its content in the melt-refreeze ice layer (this is a feature of this study). Different methods are essentially the same. This allows comparison to the values used in the Doherty et al. (2013) and Flanner et al. (2007). In view of this, we have retained the original method in the revised MS, but the introduction of this method has been modified in the revised MS (L132-134): "By determining the burden of BC per unit area (ng BC/cm2) in the ice layer and in the partially melted snow layer above it, the scavenging efficiency estimated using the proposed approach is given by.. . .." The limitations and possible uncertainties of this method have been discussed in the last part of

the MS according to the suggestions of the reviewer (Please see the response to the last comment). Reference Flanner, M.G., Zender, C.S., Randerson, J.T. and Rasch, P.J., Present-day climate forcing and response fromblack carbon in snow, J. Geophys. Res., 112, D11202, doi:10.1029/2006JD008003, 2007. Doherty, S. J., Grenfell, T.C., Forsström, S., Hegg, D.L., Brandt, R.E. and Warren, S. G.: Observed vertical redistribution of black carbon and other insoluble light-absorbing particles in melting snow, J. Geophys. Res. Atmos., 118, 5553-5569, doi:10.1002/jgrd.50235, 2013.

4. I am confused by the data presented in Tables S1 and S2 and how they have been used to construct Figs. 2, 3, S1. Some questions: (i) are there 3 different sites at Elson Lagoon that were sampled in 2015 only, and another 3 different sites at Chukchi Sea that were sampled in 2017 and again in 2018? (ii) if so, are data for the first site at Elson Lake shown in Table S1: BC concentrations (ng/g) of 0.31 in the ice layer and 1.72 in the overlying snow layer measured on May 18. Does that imply melt had started by that time? On May 31, an average value of 14.9ng/g was measured in the near surface snow. What is the density and thickness of the surface layer? (iii) For the first site at Elson lake in Table S2: CB1=1.1, and presumably CB2 = 1.72; CBice = 0.31 and CBsfc = 14.9. What is the density and thickness of the surface layer? When were the measurements of h1, rïĄš1 and CB1 made? (iv) Perhaps it would be less confusing if the tables were combined with relevant data (depths, densities, concentrations for Elson Lake and Chukchi Sea) and included as a single table in the main text.

- Response: All observations of thickness and density of snow cover and BC concentration, and thickness and concentration of the melt-refreeze ice layer before and after the ablation event in different regions and the corresponding measurement date are included as a single table (Table 1) in the revised MS. The density and thickness of the surface layer were also included in the revised MS.

5. It would be good to mention some of the limitations of the method – for example, (i) a melt-season ice layer may not form in regions of strong melt; (ii) the model does not account for influxes of BC from snowfall during the melt season; (iii) the model pro-

vides an estimate of the average seasonal scavenging efficiency but does not capture temporal variations in efficiency.

- Response: Thank you a lot for your suggestion, we have included a discussion of the limitations of the method in the section of “Result and discussion”, please see details in L187-206 in the revised MS.

Please also note the supplement to this comment:
https://www.the-cryosphere-discuss.net/tc-2019-147/tc-2019-147-AC3-supplement.pdf

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