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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Aircraft observations of enhancement and depletion of black carbon mass in the springtime Arctic" *by* J. R. Spackman et al.

Anonymous Referee #1

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This manuscript presents in-situ airborne BC measurements in the springtime Arctic in Alaska. The authors discuss briefly the occurrence of BC enhancement in the free troposphere due to long-range pollution transport and the depletion of BC in the Arctic boundary layer. The latter issue is evaluated more thoroughly by a detailed analysis of the measurement data and the application of a box model. The authors thus elaborate a very important aspect by relating advected BC to its deposition on snow and ice and compare their results to surface measurements. Understanding the behavior of BC in the Arctic is of high relevance for understanding Arctic climate change. This work is clearly structured and the figures support the key findings. I recommend publication of this manuscript in ACP after consideration of the comments below.

General comments

In the introduction, p. 15170, lines 11ff, there is a brief discussion of the different characteristics of sulfate and BC aerosol. I understand that your main goal of argumentation is the possible importance of dry deposition of BC. However, a more detailed consideration, including references, of the mixing state and therefrom resulting characteristics of BC aerosol advected to the Arctic and a clarification of your mixing state assumption for this paper will improve the introduction (e.g. Schwarz et al., 2008; Subramanian et al., 2010; Moffet and Prather, 2009, Shiraiwa et. al, 2007). BC emission is usually accompanied by emission of various types of trace gases (SO2 - coal combustion, organic vapors - anthropogenic and BB etc.) that might condense on it in the course of transport (aging). So BC aerosol might not be as pure as I understand from your introduction. Especially, during Arctic springtime, when weather conditions are relatively stable and little wash-out happens, even BC coated with more hydrophilic compounds might survive transport to the Arctic.

The use of the box model complements your measurements very well and makes them comparable to surface station observations of BC loadings in snow. The general functioning of the model is explained sufficiently in the paper, however, there are a few details that deserve elaboration: Did you develop this box model especially for this study? If so, you should state it, if not, then a reference should be given. After the introduction of the model you present the results right away with little discussion on how you derived them. The paragraph on p. 15180, lines 4ff, is not clear to me: How many values did you try between 1 and 8 hrs? I would expect to see the same number of lines as selected kbl's (or an area comprising all assumed values) in Fig. 10. It is not clear which value the red curve depicts (single assumption for kbl or an average?). line 6: "The model *better* reproduces the . . .", here I don't understand what you compare the removal efficiency factors between 0.1 and 1 to. To which kbl value(s) does this range correspond? You should also formulate an argument why you focus on 5 % removal efficiency for the following calculation. By displaying the model results in a graph you can give the readers the chance to see for themselves how robust the model output is and include much of the discussion in a single figure.

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p. 15169, paragraph lines 15-24: From this explanation a non Arctic-specialized reader might not fully understand why there is an enhancement of BC (and other aerosol types) during Arctic winter and spring. You should elaborate this paragraph by answering the following questions: What are the origins of the Arctic aerosol and where are the sources located (within the Arctic dome)? Why is there build-up of Arctic haze (stable weather conditions, little wet deposition)? Line 22ff: "Together, these phenomena lead to an increase in BC aerosol . . ." increase compared to what? ". . .we refer to as aged Arctic air in this work." You should clarify that you exclude influence from (fresh) pollution plumes in your definition of aged Arctic air.

Specific Comments

p.15168, line 11: "Maximum average BC mass loadings. . ."It is not clear what you mean by this term. (Do you mean maximum average per altitude bin?)

p.15168, line 16ff: ". . .across the boundary layer transition in the ABL. . ." This formulation is unclear: Does the gradient increase within the ABL or within the transition between ABL and the lower troposphere?

p.15168, Line 18-22: The logic of this sentence is unclear. The relation between the release of Br2 and the dry deposition of BC is not mentioned.

p.15170, paragraph lines 8-17: do you have a reference for these statements?

p.15171, line 10ff: It is unclear whether 7 hrs of measurement in the ABL took place or if only 7 hrs of these data are discussed.

p.15171, line 20: 2 g/cm^3 density, is Schwarz et al., 2006 also meant to be the reference for this value or is this assumption based on different considerations?

p.15171, line 25ff: What do you expect to be the losses due to your inlet system? Is there a reference for the low-turbulent inlet? How long was your inlet system tubing, what kind of tubes did you use, how large is your sample flow?

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p.15172, line 18: “BC mass” should be named “BC mass concentration” (here and throughout the paper, also in the figure captions)

Figure 2: Not the lines but the round markers denote the 1 km mean values. For the black curve the markers seem to illustrate a 500 m average. One-sided error bars seem rather confusing to me.

p.15172f, line 25ff: This sentence should be rephrased for more clarity. (“increase with altitude” and “with increasing altitude from the lower to upper troposphere” is redundant) It is not clear to me if you mean both, the blue and red curve given that the blue curve continues like the red one >5.5 km, or only the red curve.

p.15173, line 4ff: Do you refer to the Texas Air Quality Study shown in Fig. 2? If yes, you should mention the black curve and reference already here. If not, then you should give another reference.

p.15173, line 6ff: This paragraph needs some restructuring for the reader: “Although one would not necessarily expect agreement. . .” It is unclear whether you refer to the comparison of midlatitude boundary layer and Arctic free troposphere BC concentrations or to the comparison of SP2 and aethalometer measurements. If the latter is the case you should start a new paragraph and start with one introductory sentence that puts this paragraph into context. You should also state that both campaigns took place in the same geographical area.

p.15173, line 26f: red points, do you include or exclude data points that might be influenced by the aircraft’s own off-gas during take-off or landing (if your instrument was already acquiring data during that time)?

Figure 3: Minor tick marks for the vertical axis (100 m) would be helpful since you mention “several hundred”, “700 m” etc. in the text. The captions say that the lines with markers represent 1 km altitude bins: However, there are 5 markers per 1 km. Again, not the lines but the markers represent the averages. Neither the text (p.15174, line

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3f) nor the caption state if the Fairbanks data is included in the black curve. Optionally, you might shade the ABL for quicker understanding by the reader.

p. 15174, paragraph line 1-12: I recommend stating clearly what you consider ABL, lower, free and upper troposphere as you mention these terms continuously throughout the text. In this paragraph it is not clear that you consider <300 m the ABL. This only becomes evident later.

p. 15174, line 16: 160 ppb CO background value, is that your definition based on the observations or is it a literature value (if so, reference should be given)

Figure 4: Uppermost panel: You can either insert a legend or color the axes

p. 15176, line 15f: The BC removal needs to be defined to more detail at this point. What time scale does 15 ng kg-1 refer to? It is unclear what exactly determines the top of the profile.

Figure 6: You should add a legend to the plot, in the legend you can include example error bars for the data points.

p.15177, line 9ff: "Although open leads *also* inject water vapor into the ABL, clouds were generally not observed over the open leads during ARCPAC *because* many of the leads were observed to be at least partially covered with thin ice (Brock et al., 2010)." This explanation should be elaborated. It is not clear why there should be no clouds above "partially covered open leads" if water vapor injection from open leads is only a contribution to water vapor abundance in the atmosphere. So clouds might still form.

p. 15177, line 22: Why did you choose 750 m in this case when using 700 m before? Do 700 and 750 m make a significant difference?

p.15178, line 15ff: This sentence does not state the logical connection between Br2 release, i.e. sea-ice formation, and BC removal by contact with snow. A reference for this general theory should also be given.

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p.15178, line 25: how big is the uncertainty of the size distributions? Is there a significant difference between the two modes? What is your explanation for the more aged aerosol mode being smaller than the fresher one advected by the BB plume? Do you assume that more thickly coated particles have been removed from the aged air while they still survive within the fresher air mass?

p.15178, line 26: Is there a specific reason you only refer to 18 April and not the other flights?

p. 15180, line 4: What is the basis for this assumption?

p. 15181, line 3: A reference should be given.

p. 15181, line 12ff: "... amount of snowfall at a given site and the mass of BC advected to the Arctic." If, for example, there are only very little biomass burnings during springtime season the amount of BC will be less, so less can be deposited.

p.15182, line 3ff: From this sentence and the following I understand that enhanced deposition of BC occurring in the region of open leads is an observation made during your measurements. From the paper I understand that this is an interpretation of the data.

Technical Comments

Figure 1: The aircraft base, degree latitude and longitude and a scale should be indicated.

Figure 5: "The gray-shaded regions..." in the online version the shaded areas appear red.

p.15168, line 8: POLARCAT should be spelled out

p.15168, line 18: rephrase "remained constant, evidence for" to "...remained constant. This is evidence for ..."

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p.15168, line 20: rephrase “in the ABL suggesting that . . .” to “. . . in the ABL. This suggests that. . .”

p.15170, line 23: “. . .in the rest of the paper.” can be dropped.

p.15171, line 1ff: rephrase “The . . . research aircraft deployed to. . .” “The . . . research aircraft was deployed to. . .”

p.15171, line 19: there is a “-“ between 600 and nm

p.15172, line19f: “The individual data points are 30-s averages of BC mass each representing a horizontal spatial resolution of 3 km.” Rephrase to either: “The data points are 30-s averages with a horizontal spatial resolution of 3 km.” or: “The data points are 30-s averages each representing the average mass concentration along 3 km of the flight track.”

p.15175, line 17: for more clarity you can repeat the vertical interval you refer to

p.15175, line 22: Is this meant to be a new paragraph which is not visible due to current formatting? If not, you should start a new one here.

p. 15176, line 22: change “. . . limited anthropogenic. . .” to “. . . limited local anthropogenic . . .”

p. 15177, line 22: there is a “-“ between 750 and m

p.15180, line 11: change “. . . to be a 10 times. . .” to “. . . to be 10 times . . .”

p. 15180, line 19: change “. . . less likely continuous as modeled and more likely. . .” to “. . . less likely continuous as modeled but more likely . . .”

p. 15181, line 5ff: “The meteorological surface data at Barrow indicate an average *5.3-cm* snow accumulation with measurable snow *an* average of 18 days in April.” Remove the “-“. I don’t understand the meaning of this sentence.

Interactive comment on Atmos. Chem. Phys. Discuss., 10, 15167, 2010.