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## ***Interactive comment on “The importance of Asia as a source of black carbon to the European Arctic during springtime 2013” by D. Liu et al.***

**Anonymous Referee #2**

Received and published: 24 June 2015

This paper covers an interesting topic – black carbon in the Arctic. The paper provides good motivation and background for the necessity of studying the sources of black carbon to the Arctic. The findings are relevant to predictions of future climate and confirm that pollution from Asian sources contribute to the black carbon deposition and radiative warming in the Arctic. But the authors need to discuss the relevance of these findings for March 2013 compared to future years. The paper is well written but could be slightly shortened and more focused.

Major Comments.

The choice of “Arctic clean air” seems strange since the measurements here show influences of polluted air to the Arctic. At what point can the Arctic air be considered

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actually clean when it is influenced from other sources and when pollutants can be trapped? Could this instead be referred to as “Arctic background air” since it may not be perfectly clean? Additionally, is there any evidence that latitudes as far south as Mexico (larger than 30°N) can contribute to pollution in the Arctic and need to be included in the source regions suggested?

The authors note that the black carbon source regions and concentration from biomass burning in this 2013 study are different from those in 2008. For this reason, is it then relevant to use 2013 as the main marker for the sources of black carbon to the Arctic? It is nice that 2013 was a year with low biomass burning emissions which allowed the authors to clearly demonstrate the anthropogenic influence to black carbon concentrations. The authors should add some more discussion on how their findings for 2013 are or are not representative of a current and/or future black carbon contributions. Is 2013 relevant for the future or is it an outlier compared to other years? In years with higher biomass burning, is the anthropogenic source of black carbon from Asia still going to be as important, relatively, or will it be masked by biomass burning emissions?

With the mixing state of the black carbon described in this paper, how much of an influence will it make on reducing the albedo of snow and ice when it is deposited in the Arctic? How much is the effect of coated black carbon on the albedo compared to uncoated black carbon?

How relevant are anthropogenic emission inventories from March 2010 to a study that takes place in March 2013? It does seem that these would remain more consistent than the biomass burning regions over the years, but the authors should comment on this potential difference and whether or not it is important.

For the FLEXPART and HYSPLIT models, the discussion about their usage and comparison needs some clarifying. Why were different numbers of days back used? Why were those chosen? Can black carbon be transported over that many days (at the given altitudes) without being scavenged? How does the height factor into the FLEX-

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PART output? Figure 9 uses HYSPLIT back trajectories that go back 12 days, but the text states that uncertainties increase after 5 to 6 days.

Minor Comments.

More information could be included in the Introduction about the cause of Arctic haze and the springtime meridional transport of air masses and pollutants from the midlatitudes to the Arctic.

How is “pollution” defined in the abstract? Black carbon only or the mixture of the other species measured?

Were any other chemical species measured during this campaign that could be used as tracers for the anthropogenic pollution sources or biomass burning sources?

Other studies that have looked at sources of pollution in the Arctic should also be considered and included in the Introduction or Discussion: Rahn 1981 (used metal tracers to show the European sources of aerosol particles in the Arctic); Hole et al. 2006 (contributions from European anthropogenic sources to Arctic haze); Shaw et al. 2010 (anthropogenic and biomass burning sources, as well as shipping); Frossard et al. 2011 (contribution from European and Asian anthropogenic sources); Stohl et al. 2013, which is in the reference list but not discussed in the paper; Raatikainen et al. recently on ACPD (contribution from continental Europe to black carbon at Pallas GAW in Finland); etc.

Page 14854, Line 6: Why was an anthropogenic inventory from March 2010 used to compare to a fire inventory from March 2013?

Page 14847, Line 2: Transported from where?

Page 14848, Line 23: But if there is less transport of BC to the Arctic during the colder seasons, then the bias in the scavenging estimate should not be as important to the total estimate of BC in the Arctic?

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The authors could add more discussion about the relative importance of black carbon in the Arctic at the different levels of the atmosphere observed in this study.

How was the FLEXPART model calculated at different heights?

Page 14850, Line 1: How reliable or relevant are the chosen refractive indices for the core and the coating? Was all of the black carbon coated?

Page 14850, Line 5: Drewnick et al. 2005 should be referenced here for the C-ToF-AMS. The authors need to include more discussion of the calculated collection efficiency, here or in the supplement. How reliable is this CE given that the black carbon core is refractory? Would that fraction of black carbon cause particles to bounce off of the detector? Or would the non-black carbon fraction just volatilize? How relevant is the Middlebrook CE technique when there is black carbon?

Page 14852, Line 24: Add some numbers to quantify “significantly higher”. Is this ratio consistent with previous studies?

Page 14854, Line 17: What makes up the “residential sector”?

Page 14855: The second paragraph seems like just a list of where the data is presented.

Page 14856: The coating paragraph seems out of place in this section. Are all of the coating organics on the BC?

Page 14858, Line 18: How well do the CO<sub>source</sub> and CO<sub>measured</sub> compare?

Page 14860, Line 25: Add some references for “consistent with previous studies”

Figures and Tables.

Figure 1: Change the flight track color of B759 so that it is not the same color as the land. The outline of the land is very thick and seems unnecessary for this resolution. Could the flight tracks be shaded by time or height?

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Figure 5: It is hard to see the details and labels without making the image a full page. These should be bigger. Additionally, the markers that show the days back in the right-hand column are not that useful, especially when the back trajectories overlap in time (i.e. B2 and C2). Instead, could the back trajectories be colored by days back? Or maybe the markers could be numbers instead of open circles? The color scheme of 1 and 2 is the same even though they are showing different things (FPES vs. precipitation). Making these different could improve the clarity of the figure. Panels D2 and E2 don't seem to provide that much information with the lack of clear direction of the back trajectories. What defines the consistency listed in the text?

Figure 6: Are these both from March 2010? The text states that the OBB is from March 2013.

Figure 7: These two panels should be better explained in the caption. They should either both be time series or both be bar plots. If time resolved data is only available for the BB emissions, then that can be a separate figure. It is difficult to directly compare the two emissions types by region when they are plotted in such different styles. Or, could the biomass burning emissions be just added to the bar plot with a new right axis for scaling?

Figure 8: Change the legend colors to black in (c) for the profiles, since green is already defined as CL.

Technical Corrections. Abstract: Remove the “s” from the middle of the units. Page 14846, Line 21: Add “in the Arctic” Figure 8: There is a “c” in the X-axis of panel B Page 14862, Line 24: Change “European” to “Europe”

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Interactive comment on Atmos. Chem. Phys. Discuss., 15, 14843, 2015.

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