

## ***Interactive comment on “Spatial and seasonal distribution of Arctic aerosols observed by CALIOP (2006–2012)” by M. Di Pierro et al.***

### **Anonymous Referee #1**

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### **General Comments**

This manuscript uses the CALIOP satellite instrument to quantify the spatial, seasonal, and interannual variability in aerosol burdens throughout the Arctic troposphere. I commend the authors on their excellent work – this paper provides an extremely thorough analysis and the first truly comprehensive picture of the seasonality and variability of Arctic pollution above the surface. It also provides context for the representativeness of long-term ground-based sites and short-term aircraft campaigns that have previously been the basis of most of our understanding of Arctic aerosol pollution. In addition, this work will serve as an important benchmark for model simulations of Arctic pollution. The manuscript is generally well written and well organized, and I recommend it for publication in ACP following a few minor revisions.

## Specific Comments

Title – perhaps add “satellite instrument” after CALIOP for those who are not familiar?

4866 line 14: “Arctic aerosols” – is this specific to sulfate? Inorganics? Would be better to specify here since lots of work has been done on BC.

4866 line 16 and line 23: “In addition to anthropogenic” – much of the biomass burning is anthropogenic in origin, especially the agricultural burning mentioned in line 23. Perhaps change “anthropogenic” to “fossil fuel burning.”

4867-4868: This whole section seems like it would fit better towards the beginning of the introduction, when the authors are discussing the aerosol sources. When I first read that section, I thought it was missing all the IPY results. Turns out they are all here, but seem to duplicate some of the other information.

4868 lines 11-12: It’s not clear to me why CO is being discussed since the manuscript is about aerosols.

4868 lines 13-15: A reference is needed for these numbers.

4868: It would be good to refer to Wang et al. 2011 somewhere in this section, as there is very little discussion here of the black and organic carbon aerosols, which are important to the spring aerosol budget. Also Bourgeois and Bey 2011 (which is cited elsewhere but is relevant to source descriptions). Also seemingly missing is a discussion of results from the summer IPY campaigns (e.g. Schmale et al. 2011).

4870 lines 25-27: Where was this validation for? The Arctic, or elsewhere?

4874 lines 20-25: What were the results of this comparison? Should be stated at the end of this paragraph.

4875: The terminology is confusing here. On page 4871, the authors define “mean backscatter” (beta with bar) as  $f^*\beta$ . But here it just seems to be the average of individual beta values. I was confused as to when “mean backscatter” means beta-

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bar and when simply an average of beta. Could beta-bar be given a different name? E.g. “gridded backscatter”? Or something else? Or at least not defined until after this discussion?

4875 line 15: This was defined for points south of 71N – any test of whether it is consistent N of 71N? I’m not suggesting it be changed, just curious whether the consistency for the whole region considered can be quantified.

4877 line 1: Why the different distances for Barrow and Alert? Does this reflect a difference in latitudes affecting number of satellite overpasses? Again, not suggesting a change but a justification would be nice.

4877 lines 24-25: I don’t understand what is meant by “the annual-mean value chosen by the CALIOP algorithm” – can this be clarified?

4878 lines 17-24 and Fig. 5d: On average, CALIOP at Alert overestimates the in situ measurements in SONDJ and underestimates in FMA. I’m wondering whether there is any influence from the choice of gamma, which was chosen based on values from Barrow. I would expect there is more clean aerosol at Alert than at Barrow. Alternatively, perhaps the high altitude at Alert has an impact on the comparison? Again, not suggesting a change, but it would be nice to see some discussion of the causes, and perhaps a quick order of magnitude discussion of how a different choice of gamma would impact the Alert comparison.

4879 lines 22-23: If CALIOP can only detect the strongest haze events, why are the thickest plumes excluded (lines 7-8)?

4881 lines 5-6: “Above 2 km” – it looks from Fig. 8 like there is also a winter to spring enhancement at around 1 km.

4881 lines 11-12: It would be better for the units of backscatter to match between the text and the figure.

4882 lines 19-21 and Fig. 4: I’m confused about the choice of boundaries for the

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European and Asian sectors. Why is Alaska included in Asia and not North America? And why does the European section extend so far east (typically would expect it to cut-off at the Urals, 60 E). These counterintuitive choices should be justified.

4884 line 25 – 4885 line 1: I'm a bit confused here. The authors seem to be discussing a minimum at 70-80N and a maximum at 60-70N but citing a study that would support low concentrations at 60-70N. Can this be clarified?

Section 4.3: I think this section could precede Section 4.2. As I read 4.3 I found myself wondering why the high emissions in the Low Arctic aren't observed in the High Arctic, but that is generally explained in Section 4.2.

4885 lines 23-24: This wording is confusing since Fig. 9c shows higher concentrations in the European sector than the North American sector. It could be rephrased to emphasize the change from the lower to mid troposphere (e.g. percentage enhancement from low to mid or something similar).

Table 1: Footnote "a" is only about the in situ extinction and doesn't need to be listed for the CALIOP column.

Fig. 2: See earlier comments – is "Mean backscatter" on the x axis mean(beta) or beta-bar? If the latter, why isn't it affected by the day-night variations in f?

Fig. 3: Colorbar needs a unit label.

Fig. 6: I'm not convinced this figure is necessary. The most important part – the observed profiles – are also shown in Fig. 7. The thresholds are described in the text. If they are really necessary, they could be added to Fig. 7, but I think that figure is fine as is.

Fig. 9: It would be a lot easier to read through the text and look at the figure simultaneously if the panels of this figure were rearranged to reflect the order in the text (first f, then e). This would mean the left column would be the High Arctic and the right would be the Low Arctic, with 0-2 km at the top and 5-8 km at the bottom. This would also

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match the altitude structure of Fig. 10. Note that this would also mean rearranging Fig. 13.

Fig. 10: Can the continent lines be made thicker (and/or the circles bigger)? It's very hard to distinguish the sectors discussed in the text, especially for the 0-2 km sectors. Also, is the dashed line the division between the low and high Arctic? If so, please add to the caption.

Fig. 12: Is it possible to demarcate the boundaries between the years on the axis as well as in the figure? It would make it easier to figure out e.g. which Jan goes with which year.

### Technical corrections

4864 line 19: "observations factor of" should be "observations by a factor of"

4864 line 27: "it remains" should be "they remain"

4866 line 22: "in presence of" should be "in the presence of"

4866 line 29: delete "have"

4871 line 9: "value is" should be "values are"

4872 line 24: "method cloud screening method" – delete first "method"

4873 line 25: "7 months period" should be "7-month period"

4879 line 16: "displayed" should be "displays"

4881 line 9: "HRSL" should be "HSRL"

4882 line 18: "low" should be "lower" (especially to help distinguish between Low Arctic and lower troposphere on quick reading)

4884 line 8: "produces" should be "produced"

4885 line 2: "relative CO" should be "relative to CO". In general I think the sentence

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would read more clearly as "... examined the efficiency of transport to the Arctic of BC relative to CO".

## References

Bourgeois, Q., and I. Bey (2011), Pollution transport efficiency toward the Arctic: Sensitivity to aerosol scavenging and source regions, *J. Geophys. Res.*, 116, D08213, doi:10.1029/2010JD015096.

Schmale, J., et al. "Source identification and airborne chemical characterisation of aerosol pollution from long-range transport over Greenland during POLARCAT summer campaign 2008." *Atmospheric Chemistry and Physics* 11.19 (2011): 10097-10123.

Wang, Q., D.J. Jacob, J.A. Fisher, J. Mao, E.M. Leibensperger, C.C. Carouge, P. Le Sager, Y. Kondo, J.L. Jimenez, M.J. Cubison, and S.J. Doherty. Sources of carbonaceous aerosols and deposited black carbon in the Arctic in winter- spring: implications for radiative forcing. *Atmospheric Chemistry and Physics*, 11: 12453-12473 (2011).

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