

## ***Interactive comment on “Vertical profiles of aerosol and black carbon in the Arctic: a seasonal phenomenology along two years (2011–2012) of field campaign” by Luca Ferrero et al.***

**Anonymous Referee #1**

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This study reports vertical profiles of aerosol number size distribution and black carbon (BC) concentrations from balloon measurements during a field campaign in Ny-Ålesund, Svalbard spring and summer 2011-2012. The authors divide the number size distribution into 3 modes and classify the vertical profiles in four shapes during spring. The authors also discuss secondary aerosol formation and emissions from shipping during summer.

This study is important because 1) the vertical distribution of aerosols affects its radiative forcing and 2) measurements of the vertical distribution of aerosols in the Arctic are particularly sparse. Since such measurements are highly needed and valuable, I think this study is relevant and within the scope of ACP.

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The Method section is clearly outlined and the different instruments used are sufficiently and well explained. The figures are nice and easy to follow. However, I think the overall presentation of the results should be improved before it can be published. The manuscript needs more work in terms of language and structure. If this can be achieved, I recommend the manuscript for publication.

General comments:

1. The quality of the English language in this manuscript is variable (some parts are good, but others less good), and I think it would benefit by a thoroughly review of the language (and a spell check!). I have added a few examples under minor comments.
2. The Results section would be easier to read if it was shortened a bit. Description of the methodology should always be under Methods, not Results. I have a few specific suggestions below.
3. I miss a broader implication of this study. Why did you separate the profiles into the four shapes? Comprehensive measurement studies like this can provide physical understanding for evaluation/improvement of the modeling of aerosol processes. Do you have any suggestions? I understand that you cannot add any modeling, but I would like to know more what we can learn from this study.
4. Measurements of vertical profiles in the Arctic are sparse, but there are a few, e.g.:
  - two ARCTAS campaigns in the North American Arctic (Jacob et al. 2010) in April and June/July 2008
  - the ARCPAC campaign conducted together with ARCTAS in spring 2008 (Brock et al. 2011)
  - the PAMARCMIP campaign in April 2009 (Stone et al. 2010) -the HIPPO campaign (Schwarz et al. 2010, 2013; Wofsy 2011) January and October 2009 + winter and autumn 2009

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- the ARCTAS/ARCPAC campaign in spring 2008,
- the ARCTAS campaign in summer 2008
- the PAMARCMIP campaign in spring 2009.

On a general basis; How are those compared to your study? I suggest you also include more of these studies in the introduction.

Jacob, D.J., J.H. Crawford, H. Maring, A.D. Clarke, J.E. Dibb, L.K. Emmons, R.A. Ferrare, C.A. Hostetler, P.B. Russell, H.B. Singh, A.M. Thompson, G.E. Shaw, E. McCauley, J.R. Pederson and J.A. Fisher, 2010. The Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (ARCTAS) mission: design, execution, and first results. *Atmospheric Chemistry and Physics*, 10:5191-5212.

Brock, C.A., J. Cozic, R. Bahreini, K.D. Froyd, A.M. Middlebrook, A. McComiskey, J. Brioude, O.R. Cooper, A. Stohl, K.C. Aikin, J.A. De Gouw, D.W. Fahey, R.A. Ferrare, R.-S. Gao, W. Gore, J. Holloway, G. Hubler, A. Jefferson, D.A. Lack, S. Lance, R.H. Moore, D.M. Murphy, A. Nenes, P.C. Novelli, J.B. Nowak, J.A. Ogren, J. Peischl, R.B. Pierce, P. Pilewskie, P.K. Quinn, T.B. Ryerson, K.S. Schmidt, J.P. Schwarz, H. Sodemann, J.R. Spackman, H. Stark, D.S. Thomson, T. Thornberry, P. Veres, L.A. Watts, C. Warneke and A.G. Wollny, 2011. Characteristics, sources, and transport of aerosols measured in spring 2008 during the aerosol, radiation, and cloud processes affecting Arctic climate (ARCPAC) project. *Atmospheric Chemistry and Physics*, 11:2423-2453.

Wofsy, S.C., 2011. HIAPER Pole-to-Pole Observations (HIPPO): finegrained, global-scale measurements of climatically important atmospheric gases and aerosols. *Philosophical Transactions of the Royal Society*, 369:2073-2086.

Stone, R.S., A. Herber, V. Vitale, M. Mazzola, A. Lupi, R.C. Schnell, E.G. Dutton, P.S.K. Liu, S.M. Li, K. Dethloff, A. Lampert, C. Ritter, M. Stock, R. Neuber and M. Maturilli, 2010. A three-dimensional characterization of Arctic aerosols from airborne Sun photometer observations: PAMARCMIP, April 2009. *Journal of Geophysical Research: At-*

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mospheres,115:doi 10.1029/2009jd013605.

Schwarz, J.P., J.R. Spackman, R.S. Gao, L. Watts, P. Stier, M. Schulz, S.M. Davis, S.C. Wofsy and D.W. Fahey, 2010. Global-scale black carbon profiles observed in the remote atmosphere and compared to model. Geophysical Research Letters, 37:L18812,doi:10.1029/2010gl044372.

Schwarz, J.P., B.H. Samset, A.E. Perring, J.R. Spackman, R.S. Gao, P. Stier, M.G. Schultz, F.L. Moore, E.A. Ray and D.W. Fahey, 2013b. Global-scale seasonally resolved black carbon vertical profiles over the Pacific. Geophysical Research Letters, 40:5542-5547.

Specific comments:

Abstract: You should mention in the abstract that these were balloon measurements up to 1200 meters height.

Page 2, L 17: 'to influence with semi-direct effects the atmospheric properties'. Could this be rewritten and explained further, maybe by 1 or 2 examples?

Page 2, L 34: You mention Arctic Haze here without explaining it. Since this is an important part of your study, I think you should briefly explain the phenomena with a few references (e.g. Stohl 2006)

Stohl, A. (2006), Characteristics of atmospheric transport into the Arctic troposphere, J. Geophys. Res., 111, D11306, doi:10.1029/2005JD006888.

Page 3, L 25: 'These reports may well highlight opposing forms of behavior'. I am not quite sure what this means?

Page 3, L 25: One reason for this difference between the observations could be the strong influence of biomass burning during spring 2008 (Warneke et al. 2010).

Warneke, C., K.D. Froyd, J. Brioude, R. Bahreini, C.A. Brock, J. Cozic, J.A. de Gouw, D.W. Fahey, R. Ferrare, J.S. Holloway, A.M. Middlebrook, L. Miller, S. Montzka, J.P.

Schwarz, H. Sodemann, J.R. Spackman and A.Stohl, 2010. An important contribution to springtime Arctic aerosol from biomass burning in Russia. *Geophysical Research Letters*, 37:L01801, doi:10.1029/2009GL041816.

Page 3, L 30: Drop 'should', as this is written it seems like you tell the emissions to do so? In bracelets: we do not know for sure if these emissions will warm the surface and be deposited, but as you write above; studies show that there are higher probability for this to happen when the concentrations are located close to the surface.

Page 4, L 23: Could you add just one sentence summarizing this table? E.g. 25 measurement days, balloons measured 2-14 profiles each day, altitude range?

Page 5, L 5: Is there a reference for this instrument and the calculated uncertainty in mass concentrations?

Page 6; L 18: Could you briefly here explain what you mean when the atmosphere is 'stable' and does not encourage vertical mixing? (in terms of potential temperature)

Page 8, L 28: In this paragraph you define the 3 modes of particles, 'Aitken', 'Accumulation' and 'course' and say that you will also use these names for the rest of the discussion, but most of the time you use N14-260, N260-1200, and N>1200 anyway. I suggest you use the names Aitken etc. throughout the text once you have defined them, as this is easier to read.

Page 8, L 36: Since there are many figures in this paper; I suggest removing fig 2 (or move to the supplementary).

Page 9: There are various methods to measure BC concentrations, and they can disagree by a factor of seven or more (Petzold et al 2013). Since the (common) filter-based method like you have used is not a direct measurement of BC, it is recommended to report the resulting BC concentration (eBC) together with the assumed MAC value. Maybe you should change 'BC' to 'eBC' to make sure that we know that this is equivalent BC? I also think you should add a brief discussion on how your measurements

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depend on the assumed MAC number (you use 12.5 m<sup>2</sup>/g?) (or at least make a note about this).

Petzold, A., J.A. Ogren, M. Fiebig, P. Laj, S.M. Li, U. Baltensperger, T. Holzer-Popp, S. Kinne, G. Pappalardo, N. Sugimoto, C. Wehrli, A. Wiedensohler and X.Y. Zhang, 2013. Recommendations for reporting “black carbon” measurements. Atmospheric Chemistry and Physics, 13:8365-8379.

Page 9: Filter-based methods are sensitive to absorbing and non-absorbing non-BC particles. Could you please add a few sentences about the uncertainties in your method as well?

Page 11, L 15: ‘Figure S1a shows a larger interannual springtime variability.’ Of what?

Page 11, L 13 - 20: Since you are referring to figures in the supplement, maybe you could rewrite this paragraph so this is easier to follow without the figures? Not ‘Fig Sxx shows ..’ but instead just briefly state that the spring season had surface temperatures close to the climatology, summer season had .. etc. and then mention that figures are in Supplementary (–OR– move the sup. figures to the paper, but then you already have many figures there).

P11: ‘Particularly, the maximum wind speeds registered at ground during balloon flights in spring 2011 and in summer 2011 2012 were 4.9 m s and 10.7 m s lower than the absolute wind speeds registered during the same periods: 27.9 m s and 16.3 m s.’ I’m not sure if I understood this. The absolute winds measured by ..? With movement? How do you conclude that the measurement periods are representative for days with low winds?

Page 11, line 32 - page 13, line 14: I think you spend too much time explaining figure 3. Parts of this can be moved to Methods, e.g. what type of information you can retrieve from the measurements. You can also move parts to Introduction as a way of motivating the study. When I read the ‘Results’-chapter I want to read about the results

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right away. Could you also try to merge some of this information when you present the other results? I would skip everything between L31, p11 to L21,p12 and start on 'An example ..'. Is fig 3 needed at all? Why cannot the measured potential temperature and the RH for each group be plotted in fig 5 instead?

On the other hand, figure 7 is hardly mentioned. Can the wind roses be put in better context with the profiles described in 3.3.1-3.3.4? Also, this text is a bit hard to read, because of all the numbers listed. Do you need to list them all? Maybe put them in a table?

Page 17, L3: does this text and forward belong to 3.3.4 or should it have a separate heading?

Page 18: anything that has to do with methodology should be under Methods, not Results.

Page 19, L16: what is meant by a 'meaningful' impact of ship emissions?

Page 20: It is interesting to see the impact of ship emissions. Could you remind us here how far the measurements were from the ships? This also relates to your final conclusion on page 21 (where you suggest that increased shipping could significantly increase BC concentrations during summer and enhance climate change in the Arctic). Currently, BC emissions from shipping in the Arctic comprise a small fraction of within-Arctic BC. Browse et al. 2012 found that even under a high-projection of shipping, by 2050 BC emissions from shipping would still contribute less than 1 % of total Arctic deposition. Do you suggest that current emission inventories are too low and that future emission projections should also be higher?

Browse, J., K.S. Carslaw, S. Arnold, K.J. Pringle and O. Boucher, 2012. The scavenging processes controlling the seasonal cycle in Arctic sulphate and black carbon aerosol. *Atmospheric Chemistry and Physics*,12:6775-6798.

Page 20, L22: 'forbidden' – by who/what? What is meant by: '. And the locally formed

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aerosol becomes in summer' ?

Do you find any (systematic) correlation between the different vertical profiles and the measurements at the ground? E.g. for special ground conditions, one can assume (with some certainty) a particular profile? Or that when using ground measurements (which are more abundant) when comparing to models, it is not such a bad assumption?

Minor comments/technical corrections (language etc):

Line 28 page 2: write the Q as a full sentence, e.g. How does the aerosol (...) vary by season?

Page 2, line 31: 'Very pronounced' → drop 'very'

Page 3, line 1: know → known

There are several long sentences in this paper, which makes it a bit hard to read. E.g. Page 3. Line 2-7 is one sentence over 6 lines. Could this be split in 2? Also in this sentence: 'leads' → 'could lead'.

Page 4, line 28: form → from

Page 6, line 5 double ..

Page 6, line 13: operates since 2009 → 'have operated'

Page 6, line 21: 'during snow covered or not periods' Please rewrite.

Page 8, line : closets → closest

Page 11, line 2: 'Aerosol and BC and vertical profile (...)' Please rewrite. By vertical profile do you mean the meteorological fields? And aerosol are the size distributions?

Page 11, Line 10: 'Before to introduce' .. please change

P 11, L 24: 'Moreover, quite all measurements were conducted' quite all? You mean

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'all'?

P11, L31: drop 'now'

P11, L34: 'Several information can be derived' please rewrite

P20, L24: reasing → rising?

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