Interactive comment on “Combining airborne in situ and ground-based lidar measurements for attribution of aerosol layers” by Anna Nikandrova et al.
Anonymous Referee #1
Received and published: 20 February 2018
This is a nice workup of case studies using multiple sources of data (lidar profile measurements, relative humidity from radiosondes, in situ size distributions, and backtrajectory analysis). Although it is somewhat limited in scope, I think the analysis successfully uses these multiple disparate data sources to gain a deeper understanding of the atmospheric layers in the case studies. The figures are informative and well constructed for showing correspondence between different measurement types and for illustrating interesting aspects of the case studies. I recommend publication after addressing a few points.

Response to comments from Anonymous Referee #1

We thank the referee for the constructive comments to help us to improve the manuscript. Below please find our answers to the comments.

Specific comments:

Page 2, line 30. Delete “at higher latitudes”. Smoke aerosol is not limited to high latitudes.
-Deleted as suggested.

Page 4, line 13. “the cross-polarization channel measures the degree of circular polarization”. I think this should probably be reworded. I don’t think just one channel by itself can measure the degree of polarization; it must be compared to another channel.
-Rephrased: the cross-polarization channel measures the degree of circular polarization relative to the combined channel.
A related question: what is the polarization state of the combined channel? That is, does the polarization split occur before or after the Rayleigh-Mie split?
- The polarization split occurs before the Rayleigh-Mie split.

Page 4, line 14. I would have liked to look up the answer to my previous question in the quoted reference (Goldsmith 2016) but it isn’t in the bibliography.
-Added to the bibliography

Page 4, line 24. What is the particle size cut off of the inlet?
-The aerodynamic particle cut off diameter is 5.0 um. (McNaughton, 2007)
Aerosol size distributions in the figures 2,4,7, 9 are now shown until 5 um.

Page 5, line 29-31. Are these quoted sizes radius or diameter?
-Added ‘with diameters’

Page 10, line 11. “aged dust, especially since the low HSRL circular depolarization values suggest more spherical particles”. I am confused by this sentence. Dust, even aged dust, would be expected to be dominated by non-spherical particles. Either I’m misunderstanding the intent of the sentence (in which case, please reword) or else you are suggesting that aged dust would be expected to have spherical depolarization values similar to what’s observed. If that’s the intent, please include more discussion and references to support this idea.
-We suspect that this is a response of aerosol growing rapidly as it moves from very dry air to much moister conditions, supported by the lowering of the depolarization ratio in the same region. This requires some mixing over small vertical length scales between two otherwise stable layers,

otherwise such a signal would be rapidly ‘smeared out’. Additional evidence is required to confirm this hypothesis.
A clause was missing from our sentence. The sentence has been rephrased ‘This thin layer could be either a result of limited small-scale mixing between two layers, that were probably stable, or the result of large-scale transport of smoke or dust; however, we suspect that this is a response of aerosol growing rapidly as it moves from very dry air to much moister conditions, especially since the low HSRL circular depolarization values suggests that particles in this thin layer were relatively spherical’

Figures 1 seems to show enhanced depolarization during the time period selected for the case study (8 April). Any comment about what this might indicate?
-It might be long-range transport of pollution, that is already discussed on p. 7:
‘The second middle layer had a similar size distribution shape for particles smaller than 100 nm but higher concentrations, and displayed the highest concentrations of supermicron particles, even higher than in the BL. The second middle layer also exhibited much more depolarization than the other layers (Fig. 1b), together implying long-range transport of large non-spherical particles’

Lidar ratio can give important insight into aerosol type and therefore would potentially provide another useful clue for analyzing the case studies. Also, there is significant interest in the aerosol lidar community in cataloging lidar ratio for different aerosol scenarios. HSRL measures backscatter and extinction separately and therefore includes lidar ratio. Why not include lidar ratio in Figures 1 and 6 and in the analysis?
- Lidar ratio was outside the scope of this work, but it will be provided to the community in the next papers including data from the whole BAECC campaign, not only from our case studies.

Page 10, line 23 discusses the depth of cumulus clouds. Since these block the laser light, it’s not clear how you estimate the top-heights of these clouds. Please explain.
-The cloud-top height was seen in the cloud radar that operated during the BAECC campaign. The sentence is rephrased: The cloud radar showed that occasional cumulus clouds were formed from 1000 m in altitude and were able to grow to at least 3000 m in altitude by late afternoon.

In the discussion section, please include more discussion of the proposed mechanisms for new particle formation in the particular cases discussed. I realize there are no measurements available to explain this definitively, but I think some more specific discussion of possibilities supported by literature references would be helpful. Specifically, you discuss new particle formation in the boundary layer for case 1 and then use back-trajectory analysis to infer that the airmass originated over the Arctic Ocean.
Does this mean that the new particle formation occurred over the Arctic Ocean? Was this area covered by sea ice? You also suggest that new particle formation occurred in the elevated layer at the same time. What are published mechanisms for new particle production over sea ice and in elevated layers that would be consistent with these observations?
- The NPF described in the manuscript happens in the boreal forest. Air masses coming from the Arctic Ocean (clean area) are known to be good for NPF in Hyytiälä. Tunved et al. (2006) shows not only that NPF in Hyttiälä is preferred in originally clean marine air masses, but that the NPF is initiated soon after this air enters the boreal forest zone.

Tunved, P., Hansson, H. C., Kerminen, V. M., Ström, J., Dal Maso, M., Lihavainen, H., Y. Viisanen, Y., Aalto, P.P., Komppula, M. and Kulmala, M.: High natural aerosol loading over boreal forests. Science, 312(5771), 261-263, 2006.

Other references describing NPF at the station have been added:

Dal Maso, M., Kulmala, M., Riipinen, I., Wagner, R., Hussein, T., Aalto, P. P., and Lehtinen, K. E.: Formation and growth of fresh atmospheric aerosols: eight years of aerosol size distribution data from SMEAR II, Hyytiala, Finland. Boreal Environment Research, 10(5), 323, 2005.

Kulmala, M., Kontkanen, J., Junninen, H., Lehtipalo, K., Manninen, H.E., Nieminen, T., Petäjä, T., Sipilä, M., Schobesberger, S., Rantala, P. and Franchin, A. et al.: Direct observations of atmospheric aerosol nucleation. Science, 339(6122), pp.943-946, 2013.

Typos, etc.
Page 4, line 14. "Goldsmith" misspelled
-Changed
Page 4, line 24. Is this liters per minute? Can the "L" be capitalized? It looks like a "one".
-Changed to L min^{-1}
Page 5, line 14. "for the algorithm" is not clear. Do you mean for the layer-detection algorithm?
-Added as suggested
Page 5, line 18. "most often indicate edges of layers". Fragmented sentence.
-Rephrased: Layers classified with the HSRL were confirmed with the RS measurements, where edges of layers could be seen in changes of specific and relative humidity profiles.
Page 7, line 1. "this layer" is not clear, since you mention four layers. Which layer?
-Changed 'this layer' to 'the BL'.
Table 1. Please explain acronyms in the table caption (particularly "NPF").
-Changed: Acronyms are explained in the table caption.
Also, the formatting of the "MidLII" column is strange in that it is unlike any other column in having both the height and depth. I realize this is to save space since there is only one layer. Another possibility that might be clearer is removing the "MidLII" column and putting two sets of measurements (separated by a comma) in that row of the "MidL height" and "MidL depth" columns.
-Changed as suggested.
Figures 2 and 7, the annotations are hard to read. Repeating the information from the color legend in the caption would help. It would also be useful to indicate the layer boundaries as lines or markers on the humidity profile or lidar curtain so that it would be more immediately obvious where the in situ size distributions are applicable.
- Boundaries are added to the RH plot on fig. 2 and 7 as suggested, and legend is changed, so it can be easier to read.
Also, it would be useful to make the axis labels bigger in Figures 2, 3, 7, 8 and 9.
- Figure axes are already as big as possible to fit text nicely.
There seems to be a rendering or smoothing artifact in the lidar curtain in Figure 2e that shows as a series of horizontal lines where the lidar backscatter profile does not change for 15 or 20 minutes between 11:50 and 12:10.
-Smoothing artefact due to MATLAB plotting issue in data gaps - Fig. 2e now corrected. Data gap was due to calibration period.