Interactive comment on "Airborne high spectral resolution lidar observation of pollution aerosol during EUCAARI-LONGREX" by S. Groß et al.

Anonymous Referee #1
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We thank the anonymous reviewer for the useful comments and suggestions which help us to improve the clarity and scientific quality of this paper. The answers to the comments are given in a direct response (bold, italic).

General comments

This manuscript presents results from a number of flight campaigns, where an advanced lidar (HSRL) on-board is able to retrieve the intensive properties of the aerosol (lidar ratio, depolarization ratio, etc), which do not depend on aerosol concentration. Characterization of these properties can then indicate aerosol type. The vertical and horizontal coverage of such flight campaigns is incredibly useful in extending the comprehensive vertical-only profiling available from active instrumentation from a number of ground-based EARLINET sites, for example, by placing such point-based measurements within a much broader continental-scale context. Methodology is accurate and relevant.

However, there should be more emphasis on examining how variable the intensive parameters are within the flights, and within the profiles of each flight, given that this is the ideal dataset to perform such an analysis. Considering that it is often difficult to identify the mixing level height with confidence, especially throughout the entire diurnal cycle for the back-trajectory analysis, it will then be difficult to identify air masses that have remained as 'continental pollution' and distinguish these from pollution layers that have potentially experienced mixing with aerosols from other air masses. The authors do note that this is an issue and attempted to constrain their sampling, however, in providing flight-leg-averaged profiles, a lot of information on variability is removed.

Specific comments

Abstract: Not really true that no variation was found! Should add a sentence to the abstract to explain the significance of the results.

We removed the sentence that we did not see a variation of the optical properties, and we discussed differences of the different days in the results section.

26845 line 25: The lidar ratio is one suitable measure to help classify aerosol types, isn't additional information is required for unambiguous classification?

We agree with this reviewer. We removed the sentence "Previous studies show that the lidar ratio is a suitable measure to classify different types of aerosol (Müller et al., 2007; Mattis et al., 2004)". Instead we refer to the publications of Groß et al., 2011, 2012, and Burton et al., 2012 showing the potential of coordinated lidar ratio and depolarization measurements for aerosol type classification.

26849 line 25-end of section 3.1: Figure 6 also suggests differences in the lidar ratio and depolarization between the lower and upper layers, and variation within the lower layer. Is this related to mixing of other (local) aerosol types within the mixed layer (lower layer)? Figure 7 also shows the influence of the mixed layer on lidar ratio values on certain days - are there better ways to identify / exclude data from within the mixed layer? The mixing layer depth over land reached nearly 2 km over parts of Europe under the flight leg on 8 May, while reaching < 1 km on 13 May. These seem to correlate well with the uniform nature of certain observed parameters within the boundary layer on these days

We extended our manuscript with respect to the vertical layering of the lidar derived optical properties and to possible mixing with other aerosol types.

The values stated in the abstract, in Table 1, and on page 26851, are reported as mean values, +/- their standard deviation. Given that you also state that the lidar ratio varies from 33-77 sr, depolarisation varies from 3-11.
We modified Table 1, showing the mean values and mean uncertainties of the optical properties in the pollution layer indicated in Figure 6 and 7. Furthermore we included a second table giving more information of the mean values for the different days and their statistical information.

Figure 8 It would be more informative to plot the data as a 2-D number density histogram, rather than as a scatterplot of grey dots, and then overplot the mean values from Figs. 6-7 in the same manner. Figure 9a, 9b, 10 Is there any variation versus height? Again, it might be more informative to plot these as 2-D number density histograms (lidar ratio versus height, depolarisation versus height, colour ratio versus height).
It would also be useful to see what the effect of your trajectory analysis is on these 2-D number density histograms, and could even be used as a test of the criteria given on page 26849.
We agree with this reviewer that a modified presentation of the information of Figure 8 would be more informative. However, we did not plot the information in Figure 8 as 2-D number density histogram. But we modified Figure 8, 9 and 10 in a way as we integrated all information in one single figure. This gives more information on the joint frequency distribution of the lidar ratio and the particle linear depolarization ratio.

Technical comments
26844 line 6: Remove comma after 'Both'.
We removed the comma.

26844 line 24: Replace this sentence with 'The European integrated project on Aerosol Cloud Climate and Air Quality Interactions (EUCAARI) was supported by the European Commission under the Sixth Framework Programme with the aim of investigating the role of aerosols on climate and air quality (Kulmala et al., 2009).
We followed the suggestion of this reviewer and replaced this sentence.

26845 line 18: Replace 'to observe both, the' with 'for observing the' line 20: To help qualify this statement better, suggest that you replace 'backscatter' with 'backscatter-only' to avoid any misunderstanding with Raman or other lidar systems. line 26: Replace 'Currant' with 'Current'. line 27-29: To make it clear that this statement refers to elastic backscatter-only lidar systems, suggest that you replace 'measure the attenuated backscatter signal on a global scale. The retrieval of vertical aerosol extinction profiles relies on a-priori assumptions on the lidar ratio.' with 'provide global coverage, but only measure the attenuated backscatter signal, hence the retrieval of vertical aerosol extinction profiles requires an a priori lidar ratio.'
We followed the suggestion of this reviewer and chanced the corresponding sections.

26846 line 2: Replace 'informative value' with 'information content' line 11: Replace 'originally has been developed' with 'was originally developed' line 14: Insert comma after 'H2O channels'.
We changed that.
line 22-24: Is this strictly true? Averaging in the vertical is useful for reducing statistical error in the extinction retrieval but not 'necessary', or do you mean that numerical differentiation is necessary? If the atmosphere has well defined layers, with different optical characteristics, but is not varying rapidly in a horizontal sense, then vertical averaging across these layers could introduce additional errors. Smoothing of the retrieved intensive properties would make this an issue for aerosol type classification. Why not integrate temporally for longer instead? Or is this because the instrument is flying? An example is the profile obtained in figure 6; there is layer at 1.5 km with markedly different properties to the rest of the profile. Averaging with large vertical bins could presumably smooth the properties from this layer through to the layers above and below, with implications for retrieved

properties, and then aerosol type classification. Some further background text and/or references should be added to justify the choice of averaging, together with implications for non-ideal situations.
We agree with this reviewer; the description of signal smoothing for the extinction retrieval is misleading. Averaging was done to reduce statistical uncertainties. As our system is flying, long temporal integration is not always possible as this would introduce additional uncertainty due to horizontal inhomogeneity. Averaging was adjusted case by case.

26847 line 5: Replace 'considerably frequented' with 'busy'. line 19: Remove 'undefined'.
We changed that.

26848 line 13: Insert comma after 'not the only'. line 14: Replace 'high' with 'a high enough'. line 15: Replace 'accurate' with 'accuracy'. line 16: Replace 'We present a case study on 14 May 2008 to exemplarily show an analysis of the used measurement data. This day was chosen, as extensive' with 'We present a case study on 14 May 2008 which shows an exemplary analysis of the measurement data since this day has extensive'. line 23: Insert comma after 'coast of Ireland,'.
We changed that.

26849 line 1-3: Replace sentence with 'Backward trajectories (Fig. 2 red line) show that the observed air masses were transported from westerly directions, crossing over Northern Germany, the Netherlands, Southern England and Southern Ireland.'
We followed the suggestion of this reviewer and replaced this sentence.
line 4: First clearly define AOD as the aerosol column optical depth from surface to flight altitude, before using this abbreviation later on.
We inserted a definition of the aerosol optical depth.

line 9-: Defining marine boundary layer height as <0.8 km seems rather arbitrary. I agree that it is rather difficult to define the 'boundary layer' from back-trajectories, but a statement or reference to justify this choice of height is necessary.
We inserted a reference to the publication by Hamburger et al., 2012 describing the procedure of trajectory analyses in detail.
line 23-26: The statements about colour ratio should be qualified by references. It may be safe to assume for typical aerosol types, but not necessarily so for other particles.
We assume referee #1 means 26851, line 23-26 with the last statement. We modified the text and added references for this statement.

26853 line 1: There are obvious differences with respect to height though. In Figure 6, the layer at 1.5 km has a different depolarisation and lidar ratio to the rest of the profile. Such variation is also seen in 3 out of the 4 flights shown in Figure 7.
Figure 7: How long is the averaging time for the profiles shown in this figure?
We inserted the averaging time in Figure 7.

References: Some capitalisation is required in a number of references. I assume that this just a formatting issue.
We corrected the formatting errors in the references.