Anonymous Referee #1

Received and published: 23 April 2015

I. General comments

This paper presents systematic observations performed during 19 months with an elastic lidar settled in Northern Corsica. The Aerosol Optical Depth (AOD) measurements from an AERONET sun-photometer and from the SEVIRI satellite are used to constrain the Klett inversion and retrieve the average lidar ratio of the aerosol column. Data are then analyzed in terms of monthly mean AOD, monthly mean extinction profiles and average layer height. Case studies of dust or pollution outbreaks are also presented to highlight the main origins and transport mechanisms the particles.

The authors place their work in the line of the numerous previous studies about aerosols that took place in the Mediterranean basin. However, neither the scientific objectives nor the scientific contribution of this paper are clear to me, in regard to this already abundant literature. Indeed, the database is not of exceptional duration and even slightly short to produce a reliable climatology, and the instrument is not a Raman or a depolarization lidar. I understand that not all campaigns can involve world-class instruments and that medium scale projects also need to produce publications. However, in this case, I think that data are not presented in the best way to highlight the seasonal variability of aerosols (see the specific comments) and therefore favor their exploitation by other scientists. Moreover, the discussion is not complete and the paper would probably gain in clarity by adopting a more classic structure – instrumentation, methodology, results, discussion – instead of presenting and discussing first the AOD, and then the lidar observations.

Yet, the most important problem is not one of those, but the major concerns I have about the scientific quality of the data treatment. I do not trust the cloud screening process and I am not confident either about the normalization of the lidar signal to the molecular reference (details in the specific comments). These both are blocking points because the resulting lidar ratio and aerosol extinction profiles will not be trustworthy if these issues are not addressed properly.

ANSWER. We have identified that the degradation in the quality of the extinction retrieval comes from the choice of the reference signal in the upper part of the profile. The cloud screening is not involved in this issue. Selecting a constant altitude whatever is the signal-to-noise-ratio (SNR) has introduced artifacts in the retrieval of the extinction profiles, including spikes and remaining relatively high extinction coefficient in the upper range of the profile. We now use the SNR to delimit the useable part of the profile. The SNR is estimated for each altitude by computing the mean of standard deviation of the range corrected lidar signal at 3 successive altitudes. A threshold value of SNR=10 is still acceptable for most of the profiles and removes spikes and drift in the mean extinction coefficient. However it removes also most of the profiles for which we have identified high AOD and high altitude transport. So the results presented in the last section are affected by a large uncertainty in the extinction coefficient profiles. We suspect that this problem is caused by the dust deposition on the telescope that reduces emission and reception. The case study on the dust event in June-July 2012 is not affected by this problem because during this period an operator was on site. Further investigation on the noise reduction is required to provide accurate estimate of the extinction profiles at high altitude for those cases.

CORRECTION. Although we have solved the issue regarding most of the data presented in this paper, the discussion can't be based on analysis of high AOD events since those cases remains problematic and required further analysis. Such analysis is not possible within the limited time frame requested for revision. As a consequence, we believe it is not worth submitting the present revised version of the manuscript. However, we have followed your recommendations regarding the structure of the paper and we have answered most of your remarks in view of a future submission.

II. Specific comments

Abstract

Page 9508(2) line 10. I suppose the ±0.09 is the standard deviation of the AOD but this must be precised.

ANSWER. Yes it is.

CORRECTION. We have replaced ± by standard deviation in the text.

Section 1. Introduction

This is such a long text without breathing...Please separate this into several paragraphs reflecting the logical succession of ideas. The objectives and scientific significance of the paper should also be presented more clearly in this section. Many references are given, but the novelty of this paper compared to previous literature does not appear clearly to the reader.

ANSWER. Correct. The introduction has been improved. As noticed **by reviewer 2: "the large spatial variability of the aerosols in the area and the complex situation concerning aerosol sources can justify additional information over a less studied area like Corsica**". This has been now clearly stated in the introduction.

CORRECTION. The introduction has been reorganized into paragraphs reflecting a traditional and logical succession of ideas : (i) importance of aerosol for climate (ii) the Mediterranean atmosphere (iii) why setting a station in Corsica (iv) the objective of the paper.

Section 2. Aerosol optical depth from sun photometer and satellite

Page 9510(4) line 24-25. Why mention this Ersa sun-photometer if it is not used at all in this study?

ANSWER. You are right. The basic idea was to use the data of the sun photometer that was close to the lidar and mentioning that another sun photometer data set was available on the island. This was a bit awkward. In any case we have a gap in spring 2012 and we need the sat. data to fill the gap.

CORRECTION. Now we provide a validation of satellite data with all the available data on the island.

Page 9511(5) line 4. Why not use the best quality level 2.0 AERONET data? The level 1.5 data can still suffer from cirrus cloud contamination while the level 2.0 data have been manually cloud-screened. Using the level 1.5 data is only justified for preliminary results, when the level 2.0 data are not yet available.

ANSWER. We have followed your recommendation. The use of level 2.0 or level 1.5 is always an issue as possible heterogeneous aerosol structures, for example close to dust sources, can be discarded. However in this case, we are far from the main aerosol sources.

CORRECTION. We use the best quality level 2 AERONET data

Page 9511(5) line 19. This threshold of 2 SEVIRI observations seems very low to me. Assuming that half of the surface in the 25 km radius is sea water, that means 8 to 9 pixels. Moreover, the AOD product is available at a 15 minute resolution so that, in perfect conditions, the total number of observations matching the 1h lidar averaging period should be at least 32. When there are only 2 observations out of 32 (about 6%), this can only mean that the scene was more than partly cloudy and make the results doubtful.

ANSWER There is a misunderstanding on this sentence. SEVIRI provides observations every quarter an hour. We mean that we compute the hourly average when we have at least 2 observations out of 4 observations during an hour (50%). This was clarify in the text

CORRECTION. This point is now clarified in the text

Page 9511(5) line 24-25. What type of linear regression is used here? The default ordinary-least-square y-versus-x regression that was probably used is adapted when the aim is to predict y (SEVIRI) using x (AERONET). If the aim is just to compare both datasets, an orthogonal regression method should be preferred. When discussing slopes very close to 1 and small intercepts, the regression method does have an influence on the result.

ANSWER. Least square regression is commonly used in validation exercise (eg. Remer et al. 2005). Could you please provide any reference showing that an orthogonal regression method should be used?

CORRECTIONS. We stay on this statistical model and also following Bréon et al 2011 we provide a new indicator of the statistical significance of the comparison, which is the fraction of good retrievals.

Section 3. Lidar observations

Page 9512(6) line 13-19. The minimum range of 145 m is given in absolute altitude (above see level / a.s.l.) while all the overlap information are given in relative altitude (above ground level / a.g.l.). However, the altitude of the ground is not given anywhere so it is not possible to compare. This does have an importance as the blind zone has to be accounted for when comparing the lidar AOD to the sun-photometer AOD. Another point that surprises me is that you seem to use a fixed a.s.l. minimum range while the instrument was moved before the end of the campaign to a site whose ground level is probably not the same. . .

ANSWER. The site at San Giuliano and Montesoro-Bastia where the lidar was installed are both located on the sea shore at a respective altitude of 10 and 49 m (asl). But you are correct; there is a mix between asl and agl. The minimum range is above the lidar altitude (agl).

CORRECTIONS. We have clarified this in the text.

Page 9512(6) line 22. A 50 km distance between the lidar and the sun-photometer is quite something! The AOD can vary significantly over such a distance so the lidar ratio values retrieved for this last part of the campaign should be used with caution.

ANSWER. You are right but, and it was not clear in text, the lidar **and** the sun photometer were both moved southward at a distance of 50 km during the 2012 CHARMEX Intensive Observation Period.

CORRECTION. We have modified the text to clarify the location and the period of observations for each instrument.

Section 3.1. Cloud screening

The number and/or fraction of remaining hourly profiles should be given for each month of the time series as it is necessary to assess the representativeness of the observations. I suggest indicating it above the upper x-axis of Figure 4 and remind it on the panels of Figure 5.

ANSWER. Correct

CORRECTION. Now we provide the number of clear profiles remaining for each period.

Section 3.2. Extinction coefficient

Giving the lidar equations but naming only half of the variables appearing in it will make things hardly understandable for non-lidar specialists, while lidar specialists do not need to be reminded with the equations. . . In an ACP paper, it is possible to stick to the most important facts that are: which hypothesis are needed (and made) to retrieve the lidar ratio and the extinction.

ANSWER. Correct.

CORRECTION. We have followed your recommendation regarding the lidar equation. The equations have been removed and we now give adequate references for the elastic backscatter lidar equation. We focus on the hypothesis made for solving this equation : constant lidar ratio and an initial condition for molecular backscattering in the far range.

Precisions on the algorithmic process used to make the lidar AOD converge to the constraint value are lacking. Is it dichotomy? raising the value from a minimum bound until finding the right answer? I would like to know because the optical depth is some- times not a monotonic function of the LR so the chosen method might also impact the retrieved LR. Also, is there any error estimation process?

ANSWER. Why sometimes not monotonic ? We use a dichotomy approach between a lower bound of 10 Sr and an upper bound of 110 Sr. Between those bound, the aod is a monotonic function of the LR. The error depends on the atmospheric conditions and we recall here that it is an effective lidar ratio used for the retrieval.

CORRECTION. We now provide more explanations on the method used.

Some information also lack about which AOD data is precisely used to constrain the LR value. What I guess is that the sun-photometer AOD is used by default, and that SEVIRI AOD is used to fill in the gaps, but this is never explained properly. The fraction of AERONET and SEVIRI data that is actually used should also be precised.

ANSWER. Correct.

CORRECTION. We now provide in the section Methods which AOD time series we used and we give the respective number of observations used for each instrument.

Page 9514(8) line 14. Please complete the discussion with other, more recent, references giving LR values obtained from Raman or high spectral resolution lidar. Müller et al. (2007) was cited elsewhere, why not use it here? Then, there is also the work by Burton et al. (2012) and Schuster et al. (2012) for dust, and all the Raman observations in the Mediterranean region that are cited in the introduction (Amiridis et al. 2005, Papayanis et al. 2008, Sicard et al. 2011 etc.).

ANSWER. Most of the available LR values in the literature are given in the visible spectrum (532 or even 550 nm) not in the UV at 355 nm. However, we have accounted for your remark.

CORRECTION. We have added new references in the paper.

Page 9515(9) line 12. If this ±23 sr is a standard deviation, please precise it.

ANSWER. Standard deviation.

CORRECTION. We have replaced ± by standard deviation in the text.

Page 9515(9) line 12. From what is said in Section 3.1, there are about 7200 cloudless lidar profiles. However, the LR appears to be estimated on only 1836 hourly profiles: what happened to the rest? Even if half of the 7200 profiles are night-time profiles without matching AOD data, there still miss some. . . I guess convergence with the sun- photometer AOD could not be reached for those profiles, but then, what LR value was used to treat them? If it really comes from the last profile for which convergence was reached, this can bring us pretty far backward in time. . . and give one aberrant LR value a very large weight.

ANSWER. We have improved the presentation of the dataset: number of profiles day/night/cloud/constrained with aod/ reached convergence / without convergence. The LR value obtained by using sun photometer AOD is only valid for a given day.

CORRECTION. We give more explanations on the procedure used.

Page 9515(9) line 13-14. An increase of LR with the AOD? If high AOD means dust events, one would expect the reverse, please push the discussion farther. Also, why not discuss the seasonality of the LR values, at least using 3 months averages?

ANSWER. High AOD does not mean dust events. The baseline of the paper was to highlight the impact of both dust and pollution aerosols in this area.

CORRECTION. We have followed your remark and now we use the seasonal average.

However, this seasonal average is still affected by lacking high AOD events (see our first answer).

Page 9515(9) line 16-21. See my comments on Figure 4 below. By the way, an excellent agreement between the lidar and the sun-photometer AOD is nothing remarkable, as the lidar AOD was constrained to the sun-photometer value. . . On the contrary, I am surprised that such discrepancy can exist in June 2012 or February 2013. . .

ANSWER. Lidar are working day and night why satellite and sun photometer only provide daytime measurements. Moreover not all the lidar retrievals are constrained by AOD measurements. So the discrepancy is natural but it was not properly explained and the other reviewers also made the same remark.

CORRECTION. Figure 4 has been removed.

Page 9515(9) line 22-26. I have two main concerns about those monthly mean extinction profiles (Fig. 5). First, there are those spikes (for instance, between 3 and 4 km on the February 2013 profile). They are too sharp for an aerosol layer, especially merged in a monthly mean profile. Instead, these spikes are typical of clouds and indicate that the cloud screening was poor, and/or that the number of profiles included in the average is low. This is a major blocking point: the extinction in clouds is so much higher than in aerosol layers that there is no point is discussing furthermore the extinction values and layer altitudes if the cloud screening process is deficient.

The second problem with Figure 5 are the extinction values at 7 km. If the molecular reference is taken around 7 km as stated earlier, then the extinction should tend toward a strict zero at 7 km, yet I can even see some increases with altitude (e.g. in January). I see two possibilities to explain that. Either the aerosol layer was extending above 7 km and in that case, the altitude of the molecular reference should have been increased (and so does the upper range of the figure). Or they were cirrus clouds in the layer that was used as molecular reference. In both cases, the resulting extinction profile will be false. This is another major blocking point that needs to be cleared before any publication in ACP can be allowed.

ANSWER. See our first answer

Section 3.3. Comparison with ground-level data

Before any comment can be made on this section, questions regarding the cloud screening process and the molecular reference at 7 km need to be answered. If not, all extinction and backscatter values from the lidar are questionable.

Section 3.4. Layer altitude

Page 9517(11) line 17. Does the phrase "daytime variability" refer to the day-to-day variability or to the boundary layer daily cycle, this is not clear.

Anyway, due to the much higher extinction in clouds compared to aerosol layers, gradient detection is meaningless if the cloud screening process is deficient. Therefore, the same comment as for the previous section applies here.

ANSWER. “Daytime variability” was used to refer to the variability of the boundary layer height over 24h.

Section 3.5. Synthesis

I found here some of the points I would have liked to see earlier (discussion about the retrieved LR values for instance). Such concern should disappear if the paper is re-ordered into a proper instrumentation / methodology / results / discussion structure.

Regarding references about LR values, as said earlier, I would expect more comparison to previous work on the Mediterranean basin in the discussion, especially the Raman lidar observations (Amiridis et al. 2005, Papayanis et al. 2008, Sicard et al. 2011). Besides, those references are already in the introduction, why not use them here?

ANSWER. Correct.

CORRECTION. We have introduced the results of the Raman lidar observations at 355 nm previously published in the Mediterranean area. We have reorganized the paper according to your recommendations and now the results are discussed in the appropriate discussion section.

Section 4. Discussion on specific events

I do not see clearly the scientific contribution of this section. Presenting case studies is interesting to outline unusual particle properties, or highlight a special and not yet identified transport mechanism for the aerosols layers. If the aim is to present the most common sources of dust and pollution advected over Corsica and assess their relative contribution, then I would expect more statistical tools such as back-trajectory clustering. So far, this section only appears to me as a catalog of cases without goal.

ANSWER. High AOD is an unusual feature in Corsica. That was the focus of the paper.

Regarding the vertical profiles of extinction, the same remarks as in the previous section apply: spikes indicating clouds and non-zero extinction near the molecular reference layer make all the lidar results doubtful.

ANSWER. See our previous answer on this point.

Regarding the structure, subsections entitled "desert dust" and "pollution" would be clearer than a separation between "satellite data" and "vertical profiles and air mass origin".

ANSWER. Correct

CORRECTION. We have followed your recommendation. We have reorganized this section in two parts: dust and pollution aerosols.

Section 4. Conclusions

This part will have to be rewritten following the other changes requested in the paper.

Figures

Figure 2. Why not show an average seasonal cycle with mustache boxes for each month of the year? This would provide higher level information on the AOD variability than scattered dots. Moreover, why show SEVIRI data from 2011 while the lidar and sun-photometer data presented in this paper start only in 2012?

ASNWER. The objective of this figure was to show how many days we have with an AOD above 0.3 and if the period we are studying was rather similar than the other years.

CORRECTION. We have modified this figure according to your recommendations and we indicate the mean monthly values along with the number of significant events. The Time range is put between 2008 (start of sun photometer operation in Corsica) and 2013. Available similar results (number of events per seasons) from the sun photometers have also been added in the discussion.

Figure 3. I a not convinced of the utility of this Figure. Showing that the cloud screening process works on one case will not convince me – or anyone familiar with lidar data – that the spikes on the extinction profiles (Fig. 5) are not clouds that escaped screening. . .

ANSWER. This figure is a good illustration of how the cloud contaminated profiles can be filtered out with a simple procedure. It's always good to show that at least the screening works fine on an example.

CORRECTION. We keep this figure.

Figure 4. In order for the comparison to have meaning, please indicate the number of observations included in each monthly average and plot the standard deviations as well. Like for Figure 2, the time interval should be limited to the campaign period. If Figure 2 is turned to an average seasonal cycle then Figures 2 and 4 should probably be merged as the lidar AOD (constrained to the sun-photometer AOD) does not bring much more information.

ANSWER. We have followed your recommendation.

Figure 5. Please indicate the number of profiles included in each average profile. Figure 6. Same remark as for Figure 2: why not show an average seasonal cycle?

ANSWER. We have followed your recommendation and now provide average seasonal cycle.

Figure 8. Same remark as for Figure 5: please indicate the number of profiles included in each average profile.

ANSWER. We have followed your recommendation.

III. References

Amiridis, V. and Balis, D. S. and Kazadzis, S. and Bais, A. and Giannakaki, E. and Papayannis, A. and Zerefos, C.: Four-year aerosol observations with a Raman lidar at Thessaloniki, Greece, in the framework of European Aerosol Research Lidar Network (EARLINET), J. Geophys. Res., 110, D21, doi:10.1029/2005JD006190, 2005.

Burton, S. P., Ferrare, R. A., Hostetler, C. A, Hair, J. W., Rogers, R. R., Obland, M. D., Butler, C. F., Cook, A. L., Harper, D. B. and Froyd, K. D.: Aerosol classification using airborne High Spectral Resolution Lidar measurements - methodology and examples, Atm. Meas. Tech., 5, 73-98, doi:10.5194/amt-5-73-2012, 2012.

Müller, D., Ansmann, A., Mattis, I., Tesche, M., Wandinger, U., Althausen, D. and Pisani, G.: Aerosol-type-dependent lidar ratios observed with Raman lidar, J. Geo- phys. Res., 112, 16202, doi:10.1029/2006JD008292, 2007.

Papayannis, A. and Amiridis, V. and Mona, L. and Tsaknakis, G. and Balis, D. and BöSenberg, J. and Chaikovski, A. and de Tomasi, F. and Grigorov, I. and Mattis, I. and Mitev, V. and Müller, D. and Nickovic, S. and Pérez, C. and Pietruczuk, A. and Pisani, G. and Ravetta, F. and Rizi, V. and Sicard, M. and Trickl, T. and Wiegner, M. and Gerding, M. and Mamouri, R. E. and D'Amico, G. and Pappalardo, G.: Systematic lidar observations of Saharan dust over Europe in the frame of EARLINET (2000-2002), J. Geophys. Res., 113, D10204, 10.1029/2007JD009028, 2008.

Sicard, M. and Rocadenbosch, F. and Reba, M. N. M. and Comerón, A. and Tomás, S. and García-Vízcaino, D. and Batet, O. and Barrios, R. and Kumar, D. and Baldasano, J. M.: Seasonal variability of aerosol optical properties observed by means of a Raman lidar at an EARLINET site over Northeastern Spain, Atm. Chem. Phys., 11, 175-190, doi:10.5194/acp-11-175-2011, 2011.

Schuster, G. L., Vaughan, M., MacDonnell, D., Su, W., Winker, D., Dubovik, O., Lapy- onok, T. and Trepte, C.: Comparison of CALIPSO aerosol optical depth retrievals to AERONET measurements, and a climatology for the lidar ratio of dust, Atm. Chem. Phys., 12, 7431-7452, doi:10.5194/acp-12-7431-2012, 2012.