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Dr. Editor and Anonymous Reviewers,

we wish to thank the Reviewers for their feedback and careful consideration of this paper. We summarized below the changes we have made on the manuscript in response to their constructive criticisms. We hope the revised version of the manuscript clarify better all the points underlined by the Reviewers.

Our answers and comments for all the specific requests are provided in the following pages. Italic fonts have been used to report the Reviewers comments while authors comments have been written using roman fonts.

Thank you again for your consideration.

Yours Sincerely,

Giuseppe D'Amico, Aldo Amodeo, Ina Mattis, Volker Freudenthaler, and Gelsomina Pappalardo

Reviewer #1

All the Reviewer's comments have been considered and addressed. We report below the changes applied to the paper with respect to each specific Reviewer's comment.

1. *General comments: Even though the authors claim that their tool can be used both autonomously and as part of Single Calculus Chain, it is not obvious from the text. The authors should be clear throughout the text how this tool can be used in an autonomous way and be useful to lidar scientist outside the EARLINET. Along the text the authors refer many times the need for the "SCC database" or to some parameters defined in the optical processing module of the SCC and it is not clear how this is possible for the autonomous way.*

   The ELPP module can be used as stand-alon module or as part of the SCC framework independently. The main difference between the usage of the ELPP module as stand-alone module or as integrated SCC tool regards mainly the way in which the ELPP executable is started. In case of stand-alone module the user needs to start it via command-line providing also all the necessary options. If there are many measurement IDs to be pre-processed, the module needs to be started manually several times on each measurement ID. In case the ELPP module is used within the SCC framework it is automatically started whenever it is needed by another SCC module which takes also care to provide the right command-line options. Anyway in both cases the ELPP executable is always the same.

   As described in section "ELPP technical aspects", the ELPP is command-line module written in C. In principle, it can be installed and used on any platform which is supported by the GCC compiler and meets all the requirements reported in the manuscript. One of these requirements is the presence of a MySQL database containing the set of parameters to be used in the pre-processing phase. Sometime we needed to refer to "SCC database" and not to a generic MySQL database to underline that actually the ELPP module requires a MySQL database with a specific structure. For istance, the name and the number of the database tables cannot be set arbitrarily. The same is true for the variables (in terms of name and type) defined in each table.

   Moreover, in our opinion, the presence of ELDA specific variables in the ELPP output files is not a limitation for the general use of the ELPP module. Actually, these variables could be useful for other optical processing module different from ELDA as well. In case they are not relevant they could be just ignored considering only the main variables (for example, range-corrected pre-processed time-series) which are included anyhow in the output files.

2. *I consider Section 2.1. kind of confusing. Please try to reorganize the material in a more logical way and a better-structured manner. A suggestion*

could be to introduce first all the possible input and output files, then introduce all the checks done to the data, the most important input variables etc.

The Reviewer is right. We have re-arranged the whole section following his/her suggestion: first we introduce general aspects of the ELPP module, then we talk about the ELPP input and output files and finally we provide all the other related information.

3. *Section 2.2. – Please just describe the procedure with text because I found references to loop variables (p, c) confusing. Moreover, the authors start counting from 0, which is also confusing. The text in this section should definitely be improved to avoid misunderstandings.*

   According to the Reviewer suggestion, the authors tried to provide more details in the text to better clarify the meaning of Fig. 2. In particular, the practical example already used to comment the Fig. 2 has been extended to describe what happens in case of multiple scheduled products. Moreover, as requested by the Reviewer, the indexes p and c now start from 1 (and also the Fig. 2 has been edited accordingly). The authors hope the changes applied meet the Reviewer request.

4. *Section 4-Please discuss in here limitations and future developments (if any) of this software.*

   The following text has been added in the "Conclusions":

   "A new SCC module devoted to the automatic cloud masking of the raw lidar data is under development and will be implemented in the SCC in the framework of the ACTRIS-2 project (http://www.actris.eu). A big improvement in the automatism of both the ELPP and the whole SCC is expected when this new module will be available."

5. *p. 10388, l 2: The authors claim that this is a pre-processing tool for lidar data. But in the text you refer only to aerosol lidars. Is the tool useful also for other types of lidars (ozone, temperature, . . .)? Please clarify.*

   The Reviewer is right. The ELPP (and in general the SCC) is a tool which at moment is related only to the retrieval of aerosol-related products. We clarify better this point as it follows:

   "In this paper we describe an automatic tool for the pre-processing of aerosol lidar data called ELPP (EARLINET Lidar Pre-Processor)."

   Anyway the authors would like to mention that most of the corrections implemented in the ELPP module are, in principle, valid and applicable also to other types of lidars. The dead-time and the trigger-delay correction, the background subtraction, etc. are general corrections which, in principle, can be used to pre-process the raw data measured by any type of lidar system. In this view the ELPP module can be easily extended also to pre-process ozone, temperature, water vaopur, etc. raw data.

6. *p. 10391, l 2: "Each lidar configuration includes this definition of a use-case". This is not clear. Aren't use-cases predefined? Are they flexible to define in each lidar configuration? ...)? Please clarify.*

   The authors agree with the Review in considering this part not very clear. Actually the usecases are defined for the products and not for the lidar configuration. A single lidar configuration may be connected to the calculation of different products linked to different usecases. This means that, in general, a lidar configuration can be linked to more than one product usecase. To clarify this point the following text has been added to the manuscript:

   "As it will be discussed in sub-section 2.2, each lidar configuration is connected to the retrieval of a specific set of aerosol products. The way in which each product is retrieved is determined by a specific usecase according to the lidar configuration characteristics."

7. *p. 10392, l 24: "without any recording". It is not clear to me what this means.*

   It is "recoding" and not "recording". The authors wrote "without any recoding" meaning the compilation of the ELPP module on different platforms does not require the modification of the ELPP source code as long as the platforms are supported by the GCC compiler.

8. *p. 10393, l 20: "the SCC database". Why do you call it SCC database and not MySQL database? This is an example of confusing autonomous and SCC use.*

   We agree with the Reviewer. The corresponding manuscript text has been modified as it follows:

   "If used as a stand-alone module, the ELPP executable requires some mandatory command line parameters: i.e., the measurement ID of the lidar observation, that should be pre-processed, and the name of the MySQL database containing all the instrumental parameters needed by the pre-processing phase."

9. *p. 10395, l 6-9: Why do you need to register single measurements in the database to retrieve the parameters?*

In general, all the parameters connected to a particular lidar configuration can be retrieved from the database independently from the measurement registration. Anyway when a measurement gets registered in the database, a link between the measurement itself and a specific lidar configuration is established. Through this link it is possible to get all the information relevant for the analysis of a specific measurement providing only one parameter (the measurement ID). The advantages of this configuration are: a) once the measurement ID is known any other related parameter can be retrieved by querying the database without the need to provide additional information to the ELPP module (like, for example, configuration ID to use); b) we keep track of the lidar configuration used to analyze each measurement improving the analysis traceability.
The corresponding text in the manuscript has been modified as it follows:

"To retrieve the full set of the SCC database parameters relevant for a specific raw data set, each single measurement (e.g. each single NetCDF input file) gets registered in the database and it is associated to an alpha-numeric string (e.g. measurement ID) which is defined in NetCDF input file. To assure a one-to-one correspondence between each raw data set and the corresponding measurement ID string, it is not allowed to submit NetCDF input file with a measurement ID already present in the database. Using the measurement ID in appropriate database queries, it is possible to retrieve all information needed for the analysis of a specific measurement which is not included in the corresponding NetCDF input file."

10. *p. 10395, l 16-20: Is this option available in stand-alone use? . . .)? Please clarify. This is one of many examples of confusing autonomous and SCC use.*

    As already mentioned, the ELPP module is exactly the same tool independently if it is used within the SCC framework or as stand-alone module. So all the functionalities are always available for both options. In this case the interpolated files are generated in any cases and can be used by ELDA or by any other processing module external to the SCC. We tried to explain better this point changing the corresponding text in the manuscript:

    "Even if these two last files typically are not needed in the pre-processing phase, the ELPP module interpolates them at the same vertical resolution of the pre-processed data and save the corresponding interpolated data in new files. In particular, ELDA module is designed to use these files for the retrieval of the aerosol optical properties."

11. *p. 10395, l 29-: Why should the user choose one option over the other? Are both options "quality assured" procedures. This could lead to inconsistent results.*

The gluing should be done at products level in all the cases in which it is possible. The products, being calibrated quantities, need just to be glued within an overlap region. In general, the gluing of the pre-processed signals is more tricky as the (uncalibrated) signals need to be carefully normalized one each other before to glue them. Moreover, if the gluing is made at signal level the gluing error is propagated in subsequent optical retrievals.

However, according to the EARLINET experience, there are some specific situations in which it is better to glue the signals before to apply the optical retrieval algorithm. Typically, the gluing is performed at signal level when the near-range and the far-range signals are respectively the analog and photon-counting signals detected by a single PMT and digitized, for example, by a Licel transient recorder. In this configuration, the Licel company itself suggests to consider the analog signal as an extension to the low range of the corresponding photon-counting signal. As a consequence, it is recommended to apply the optical retrieval algorithms on the glued signals and not separately on the analog and photon-counting signals.

Completely different is the case in which the near-range and the far-range signals are detected both in photoncounting mode using, for example, two different telescopes (and two different PMTs). In this case, it is fully acceptable and prefereable to apply the optical retrieval algorithms separately on the near-range and far-range signals and then to glue the obtained products.

Both the implemented gluing options have been fully tested on many dataset of several EARLINET systems proving to be reliable and quality assured procedures.

Finally, the authors would like to underline that there is no room for inconsistency as long as all the operations made to generate each particular lidar product are logged. As mentioned in the manuscript, this is exactly the case of the ELPP module (and in general of all the SCC modules) as result of the efforts we have made in improving the full traceability of the SCC products.

12. *p. 10397, l 21: "atmospheric and/or electronic background". Is it possible to subtract only electronic background? The authors probably meant "atmospheric and (optionally) electronic background".*

    The Reviewer is right. We modified the sentence according to the Reviewer's suggestion.

13. *p. 10398, l 24: Does the ELPP ensure that the averaging time window includes stable atmospheric scenes, or is this just a suggestion to the users? . . .)? Please clarify.*

The averaging time window is selected by the user and the ELPP does not ensure the averaging under stable atmospheric conditions. We made this point more clear modifying the corresponding sentence as it follows:

"The averaging time window should be selected by the user to ensure the optimal balance between the stability of atmospheric conditions and an adequately high signal-to-noise ratio (SNR)."

14. *p. 10401, l 19: Please define the variable Delta. Also clarify the use of delta t. Is it trigger-delay (as defined in line 7) or rangebin width (as defined in line 24)?*

    The Reviewer is right. There is an inconsistency in the notation as the trigger-delay is first called Δt and then Δ. We fixed this by defining the trigger-delay as ΔT. The variable Δt represents the signal rangebin width.

15. *p. 10402 l.1: The symbol q is an unusual symbol for altitude. Symbols z or h are widely used by the scientific community. Why introducing a new one? It is a little confusing.*

    The symbol z has been used to indicate the altitude through the whole manuscript.

16. *p. 10404, eq. 7: The symbol delta_m is usually used for linear molecular depolarization ratio. Is this the quantity the authors refer to? If not, using this notation could create confusion. Also, the refractive index of standard air should be n_{s}, to be consistent with rho_{s}.*

    The Reviewer is right. The symbol δ_m, usually adopted to indicate the linear molecular depolarization ratio, has been used by the authors to identify the molecular depolarization ratio for unpolarized (natural) incident light scattered at right angle. We have used a new symbol for this quantity δ_n and also the correct definition has been provided in the text. Moreover, the symbol n_S is now used for the refractive index of standard air.

17. *p. 10404 eq. 8: Smol variable is depending on wavelength. Please add (lambda).*

    Done.

18. *p. 10406 l 1: This screening is performed by ELPP? Please specify the procedure.*

The cloud screening is not performed by ELPP. This was mentioned earlier in the manuscript at section 2.1 (p. 10394, lines 18–24) providing also some information about a new module for the cloud screening which is under development.

19. *p. 10406 l 4-6: Please explain why you propose/use these two different procedures.*

    As already mentioned (see item 11 above) the option to use is selected on the basis of experimental setup: the gluing is made at signal level when the near and far range signals are, for example analog and photoncounting signals detected by the same PMT and split electronically by devices like Licel transient digitizer; the gluing is made at product level in case the near and far range signals are detected by telescopes with different characteristics.

20. *p. 10407 l 19: According to the text (and Fig 3.) if r < r_th, no gluing is attempted. Isn't it possible that you can still find some useful region for gluing? For example, if the first guess produces a wide region, maybe the first half of the bins are not correlated, but the second half are correlated and can be used for gluing. . . .)? Please clarify.*

    According to our experience, it is much more probable to find situations in which the condition on the linear correlation is verified even if the signals are not really good for the gluing than cases in which the signals can be somehow glued but the same condition is not verified. Actually, up to now, we never found cases in which good signals are rejected because of the condition $r < r_{th}$ even for high value of the threshold. This is the reason for which we typically consider quite high value of r_{th} (=0.9) and use the (weak) condition on the linear correlation just to screen out only very bad cases.

21. *p. 10408 l 10-13: Your description is not clear for me. Why you get more than one slopes? Do you mean residuals? . . .)? Please clarify.*

    The corresponding description has been changed (also according to Reviewer #2 suggestion) in:

    "If the signals S_n and S_f are statistically equivalent in the gluing region, the values of the slope k should not be significantly different than zero and the residuals R should be normally distributed around a null mean value."

22. *p. 10408 In your eq 10: This should be "c" not "C". Please write the complete equation (k1 – k2 < . . . ..).*

The Reviewer is right. In the new manuscript version we use always the symbol C to indicate the curvature.

23. *p. 10408 l 14-21:You specify in here that for $N > 30$ you check only that the difference of slopes (k1 – k2) is small, but why don't you check that k1 and k2 are near 0 (zero mean test)? Are these tests equivalent? . . .)? Please clarify.*

    The two tests are not fully equivalent. If the slope test is verified the two slopes k_1 and k_2 are very similar (not necessarily they are both zero). As a consequence, the curvature (defined as absolute difference between the two slopes) is near zero.

24. *p. 10409 l 16: Please specify the default/typical value of n.*

    Done.

25. *p. 10411 l. 10: "generic lidar profile". Please specify if in here you refer to the raw signals.*

    In general, the described Monte Carlo procedure can be used to propagate the error on raw signals but also on signals which have been previously corrected for some instrumental effects. What is really important in both cases is that the array Δs_j provides a reliable estimation of the uncertainties on the signal s_j (independently if it is raw or not). Of course, if the signal s_j is not raw, the array Δs_j should take into account all the procedures applied on the signal before the Monte Carlo propagation (using standard propagation law or also other Monte Carlo simulations).

    To better clarify this point the corresponding manuscript sentence has been changed as it follows:

    "If s_i is either a raw or a processed lidar profile, Δs_i the corresponding error profile, and $\mathcal{F}$ a generic operator..."

26. *p. 10413 l 4: Isn't there a simpler way to describe N? It looks like N is the integer division of integration time width and raw time resolution, or that N is the number of averaged profiles? . . .)? Please clarify.*

    The Reviewer is right, N could be defined in a simpler way. We modified its definition as it follows:

    "...and N is the number of the raw profiles belonging to the same time window (defined as the larger integer smaller than the ratio of the integration time window width and the raw time resolution of $s_j^a(z)$ time series)."

27. *p. 10422 Table 1: "with respect to linear laser polarization direction" .Probably a better way would be "plane of polarization of the emitted laser beam".*

    By definition the plane of polarization of the emitted laser beam is the plane perpendicular to the direction of propagation (i.e. the plane in which the electric field can oscillate). According to this definition the cross and the parallel polarization components reported in the table belong both to the plane of polarization of the emitted laser beam. To avoid any confusion the authors prefer to define the directions of the two possible polarization components as perpendicular and parallel with respect to the direction of the polarization of the (linear polarized) laser beam. To further clarify this point "cross" has been changed in "perpendicular" in all the table entries and "with respect to the linear laser polarization direction" has been changed in "with respect to the linear polarization state of the incident laser beam".

28. *p. 10389, l 21: . . . and [is] described...*

    Done.

29. *p. 10394, l 28: . . . (a) dedicated NetCDF variable(s) . . .*

    Done.

30. *p. 10410 l 5: . . . elastic cross (polarized) signals . . .*

    Done.

31. *p. 10413 l 5: . . . integration time window(s) width . . .*

    Done.

32. *p. 10423 Table 2: According to Bucholtz (1995), the molecular depolarization factor at 355 should be 3.010 not 3.001.*

    The Reviewer is right. Thanks to have pointed out this typo.

33. *p. 10425 Fig 2: Some boxes are used for action ("Read input file") others for the start of a section ("Preprocessing of channel c"). Different notation should be used.*

    The description "Preprocessing of channel c" has been changed in "Read raw time series of channel c". So now all the rectangular boxes refer to some action.

34. *p. 10426 Fig 3: In the box near the text "Slope test" Delta should be Delta_k.*

Done.

Reviewer #2

All the Reviewer's comments have been considered and addressed. We report below the changes applied to the paper with respect to each specific Reviewer's comment.

1. *On p.10394 L.21 and p.10406 L.1-2, the authors mention that clouds need to be manually screened before input to the SCC. They also mention that an automatic SCC module for cloud screening is under development. I understand that this is an important milestone before one can really call SCC a "fully-automatic single calculus chain". Therefore, I suggest to the authors to mention the cloud-screening efforts in their conclusions.*

   The following text has been added in the conclusions:

   "A new SCC module devoted to the automatic cloud masking of the raw lidar data is under development and will be implemented in the SCC in the framework of the ACTRIS-2 project (http://www.actris.eu). A big improvement in the automatism of the ELPP and, in general, of the whole SCC is expected when this new module will be available."

2. *On p.10401 at paragraphs starting at L.10 and L.15, the authors describe how they do a linear interpolation of the lidar signal to account for the trigger delays in each channel. They explain that if the delay happens to be exactly an integer amount of time-bins, then the linear interpolation is just a bin-shift.*

   Actually, it depends on the method used to measure the trigger-delay if the measured value is or is not a multiple of the channel rangebin resolution. One possibility to measure the trigger-delay is to check the rangebin at which the peak corresponding to a properly attenuated reflection (or diffusion) of the laser beam by a near-range target (placed at well known distance) happens to be. This measurement method, which is quite diffused for pre-triggered lidar systems, delivers always trigger-delay values which are multiple of the channel rangebin resolution. Actually, this method makes the same approximation mentioned by the Reviewer directly at hardware level.

   There are other methods (including the one mentioned by the Reviewer) providing relative measurement of the trigger-delay which do not necessarily deliver values of trigger-delay multiple of the channel resolution. Typically, these methods deliver more accurate estimations of the trigger-delay with respect to the previous one. However, this added value in the measurement accuracy can be fully exploited only if interpolation routines (like the one described in the manuscript) are used.

3. *However, I argue that because the delay is a real number calculated from a minimization routine, it will never be exactly an integer number of bins.*

The authors fully agree with the Reviewer on that. Actually, this is the reason for which the trigger-delay correction has been implemented as a linear interpolation and not as a simple bin-shift.

4. *Therefore, their algorithm will introduce a correlation between the signals in neighbour bins and thus the noise will not be independent anymore and cannot be estimated as 1/sqrt(counts). At least to my knowledge, the usual procedure would be to round the real value to the closest integer, and then just do a bin shift. Of course this has disadvantages as well, as a positive or negative bias will be introduced.*

   The procedure suggested by the Reviewer can of course be used to correct for trigger-delay but, according to our knowledge, there are no specific reasons to consider it as the most correct one. As the Reviewer mentioned, that are advantages and disadvantages in using both procedures. Concerning the procedure suggested by the Reviewer, the main disadvantage is to not correct using the measured value of the trigger-delay but an approximation of it. The accuracy of this approximation decreases as the channel resolution increases. This means to have an additional systematic error on the corrected lidar signals. The authors already have argued that this procedure could introduce a systematic error of about 6% (at 150m height) on the range-corrected signals of a lidar operating at 30m vertical resolution (which could be further amplified by the non-linear operations involved in the retrieval of the aerosol extinction and backscatter profiles). On the other side, the advantage in using the procedure suggested by the Reviewer is to not introduce any correlation between neighbour rangebins which, in turns, allows the calculation of the statistical errors without considering correlations.

   The procedure suggested by the authors, which is also the one adopted within EARLINET, does not introduce any additional systematic error on the signals after the trigger-delay correction (actually, it compensates exactly for the measured value of the trigger-delay) but it generates correlations between neighbour rangebins through the linear interpolation routine only when the trigger-delay is not a multiple of the channel resolution (in the other case it is fully equivalent to a re-binning and so no correlations are introduced). However, there are many standard solutions (calculation of the correlation matrix, or using Monte Carlo simulations) to take into account such correlations. In particular, the ELPP module implements Monte Carlo simulations to propagate the statistical errors through the trigger-delay correction. The procedure, which is discussed briefly in section 2.4 of the manuscript, takes into account the correlations introduced by the linear interpolation. In each Monte Carlo interaction, the "synthetic" signals are generated starting from the original signal and the corresponding statistical uncertainties (before the correction), by making random extractions (according to a pre-defined probability distribution) in correspondence to all the rangebins. As a consequence, the application of the linear interpolation operator on a so generated "synthetic" dataset can provide information also about correlations. In particular, the stdev of the output dataset (after the application of the linear interpolation operator) includes also the contributions due to the correlations between the neighbour rangebins (if any). Of course, there are some assumptions behind Monte Carlo approach (mainly the type and the shape of the probability distribution) but, in principle, it is an efficient tool to take into account the correlations generated by a generic operator once applied on the input data. Moreover, in this specific case, the correlations introduced by the linear interpolation is expected to be quite low as they are limited only to the two closest rangebins around the interpolation point.

Why should be considered obvious to go for a procedure which introduce not well-quantifiable systematic errors and not for another one generating well-quantified correlations?

Finally, the authors would like to underline that the ELPP module, and more in general the SCC, implements only quality-assured algorithms tested on a large number of EARLINET lidar systems since many years.

5. *As this is an important milestone paper that will potentially guide other researchers outside EARLINET on their own algorithm development, I believe the authors should properly discuss this point. For instance, you could show or cite the papers that showed that linear interpolation is more correct (statistically) than shifting by rounded-integer values. If this is the case, it should be discussed how the error propagation (with correlation) is treated afterwards (in your Monte-Carlo routine).*

   The authors believe that it is beyond the scope of this manuscript to prove that the procedure implemented for the trigger-delay correction is more or less correct with respect to the one suggested by the Reviewer. As already mentioned, both the procedures present advantages and disadvantages and it is not always possible, in cases like that, to establish which approach is the best in general. To our opinion, it is really important to provide the reader with all the information about the implemented procedure in a way he/she can decide what to implement in his/her own algorithm. To make more clear all the implications of the implemented trigger-delay correction, the following text has been added to the trigger-delay section.

   "For all the cases in which the Eq. (5) is not equivalent to a re-binning, the implemented trigger-delay correction introduces correlations between neighbour rangebins. The ELPP module takes into account for these correlations estimating the statistical errors of the signal corrected for trigger-delay by using the Monte Carlo approach described in sub-section 2.4."

6. *On p. 10406, Line 19 until the end of the paragraph. Here the authors are talking about an analog signal that is not linear above a high limit S and below a low limit S/F. It is not clear, however, how S and F are determined for each channel. I tried to do the estimation myself considering a standard Licel ADC with range R (e.g. 500mV). The high limit value S would be R/2 and the low limit value would be 5 * Resolution = 5 * R/(2bits – 1). Hence, F = (2bits – 1)/10 and even a 16bit ADC would be just "sufficiently good" with an F 6500, much lower then the author's*

values. Hence I ask the authors to clarify how S and F are defined.

The authors tried to better clarify this point adopting the same example made by the Reviewer. The corresponding modifications included in the manuscript are reported below.

"Analog signals are in general measured using pre-amplifiers with several input ranges. Each input range is characterized by a minimum level below which signal distortions and/or the signal noise become significant. This minimum level, which is used to determine the upper altitude (z_1) of the gluing region, is expressed by the ratio S/F where S is the maximum detectable input signal level and F is a parameter characterizing the analog to digital converter (ADC). If we assume, for example, the ADC output is reliable only for values larger than N_{res} times its resolution we obtain:

$$F = \frac{2^{n_b} - 1}{N_{res}} \tag{1}$$

where n_b is the number of the bits of the ADC. The values of the parameter F can be defined in the system configuration for each channel. In case the near-range signal is detected in photon-counting mode, the upper altitude z_1 is determined by setting a lower threshold for the SNR."

7. *On p.10408, paragraph starting at L.5, the authors search for the min(Sf – KSn). However Sf and Sn are vectors and hence each position in Sf –KSn could be positive or negative while searching for the best K. Please clarify if this was supposed to be the minimum of the module of the difference vector, or min(|Sf – KSn|), or if it is something else that is not clear.*

   We tried to make this point more clear specifying explicitly that the least square regression $S_f = KS_n$ is performed. In particular, we find the value of K minimizing the sum of the squares of the difference $S_f - KS_n$ calculated in all the rangebins within the gluing region.

8. *On p.10408, paragraph starting at L.10, the author's statement is not clear from the statistical point of view. There is only one value of k so it cannot be normally distributed around a null mean value. A suggestion would be: ". . . the slope k should be compatible with the null hypothesis and the residuals R should . . .". Another alternative is ". . .the slope k should not be significantly different than zero and the residuals . . ."*

   The sentence has been changed according to the Reviewer suggestion:

   "If the signals S_n and S_f are statistically equivalent in the gluing region, the values of the slope k should not be significantly different than zero and the residuals R should be normally distributed around a null mean value."

9. *p.10394 L.21 – ". . . low-level clouds should [be] not (be) included in the NetCDF. . ."*

   Done.

10. *p.10397 L.24 – ". . . window should include[s] only . . ."*

    Done.

11. *p.10398 L.23,24 – ". . .to count the number of [the] events in. . ."*

    Done.

12. *p.10408 L.13 – ". . . resulting from [of] the least square. . ."*

    Done.

Reviewer #3

All the Reviewer's comments have been considered and addressed. We report below the changes applied to the paper with respect to each specific Reviewer's comment.

1. *Please check all variables, parameter, indices some of them are used double for different purposes (see examples in specific comments)*

   The authors thanks the Reviewer for this useful comment. They have carefully checked all the symbols through the whole manuscript and actually they found several cases in which the same symbol was used for different purposes.

2. *-Structure: I still think that the Introduction and the ELPP section can be merged even if there is not so much repetition as in the previous manuscript version. Then you could also make an own section for 2.1. (–> Sec 2) and 2.2 (–> Sec 3).*

   The authors believe it is important to have in the manuscript a quite concise introduction in which only the ELPP development background is described. After this description the main concepts of the ELPP implementation can be provided. With this scheme in mind we have first introduced the EARLINET network and the efforts made for the standardization (introduction) and then, in a separate section (section 2), we started to talk about more ELPP-related concepts. The authors think this approach is more clear than to have a bigger introduction in which the two things are put together. For this reason they would prefer to not merge the two sections as suggested by the Reviewer.

3. *In my opinion also Section Application and Validation and conclusion could be merged as well, as quite some topics are repeated directly after each other.*

   The authors wrote the section "Conclusions" to briefly summarize the topics described in the whole manuscript and to provide some final considerations on the work done. According to this view it is normal to have some repetitions. Probably the repetitions with the section "Application and Validation" are more evident just because it comes right before the conclusions. Actually, the "Conclusions" reports very synthetically the main concepts described in all the previous manuscript sections. The authors think that the merging suggested by the Review would mean to have a quite long "Conclusions" section (which would also include the figure at moment included in the section 3) which is a bit far away to be a synthetic description of the work that has been done. For these reasons the authors would like to keep the "Application and Validation" section separated by the "Conclusions".

4. *-Gluing: The paper states that error calculation is done at every stage and propagated and finally handed over to ELDA. However, I miss realistic error estimation for the gluing procedure. Is it possible for the glued near-range signal to give estimates of the error?*

   To clarify the following text has been added:

   "In case the gluing algorithm described in the previous section ends successfully, the optimal gluing region is returned (z'_0 and z'_1) together with the normalization gluing factor K used to normalize the signal S_n and the corresponding error ΔK resulting from the least square line fit. Finally, the signals S_n and S_f are glued calculating first the quantity $S'_n = KS_n$ and then calculating the gluing point (z_g) as the rangebin, within the optimal gluing region, that minimizes the square differences of the signal S'_n and S_f. The glued signal $S(z)$ and the corresponding statistical error $\Delta S(z)$ are:..."

   Moreover the Figure 3 has been modified accordingly.

5. *Furthermore, the gluing is finally done at one point(bin), right? Is there any additional error introduced to noise of signals? If yes, can this be described? Finally, if gluing is done for Raman signals, does the gluing introduce a "step" which might result in an artificial extinction? If yes, how could one overcome this shortcoming, i.e. by not gluing finally at ONE bin.*

   The Reviewer is right: in general, there is an additional error introduced by the gluing especially if it is made on one single rangebin. However, in our case, as it is explained in the manuscript, before to glue the signals several tests are made to assure a reliable gluing region. According to our experience, in case these tests are passed the error due to the choice of the gluing point can be neglected even if the gluing is made on a single point. There are two main reasons for that:

   - within the gluing region the SNR cannot be too low as the upper limit of the first guess of the gluing region is determined just assuming a reliable signal (see section 2.3.1)
   - the presence of "steps" within the gluing region is minimized once the slope and stability tests are passed (see section 2.3.2)

   The main assumption we made here is that within the final gluing region (which has passed all the tests implemented in the gluing procedure) the error coming from the gluing point choice is negligible whatever is the point (within the final gluing region). So we just select the one for which the discrepancy between the signals to glue is minimized. This assumption seems to be confirmed by a large number of tests made on different lidar systems: up to now, we never observed extinction or backscatter artifacts which can be directly related to step occurring in the gluing point.

6. *-Give formulas also for error calculation while performing vertical and temporal smoothing*

   The authors already mentioned (see the authors' answers provided after the quick review and also the section 2.4 line 6-7) that the error propagation on vertical smoothing is performed exclusively using Monte Carlo method. As a consequence it is not possible to provide any analytical formula for the error calculation in this case.

   In the section 2.4 it is reported that in general the error propagation is handled in different way depending if the signals are detected in analog or in photon-counting mode. In particular, in case of analog signals, the error calculation while performing time average is made using the equations (13), (14), (15) (already included in the discussion paper).

   Concerning the photon-counting signals, the error is propagated by using standard formula of statistical error propagation whenever it is possible or by using Monte Carlo simulation in more complex scenarios (typically, interpolation, smoothing routines). In particular, concerning the time averaging, in case of photon-counting signals, the following text has been added at the end of section 2.4:

   "Finally, in case of photon-counting detection mode, the signal time series (S_h^p) and the corresponding standard errors (ΔS_h^p) after the time integration are calculated using the following equations:

$$S_h^p(z) = \sum_{j=Nh}^{N(h+1)-1} s_j^p(z) \tag{2}$$

$$\Delta S_h^p(z) = \sqrt{\sum_{j=Nh}^{N(h+1)-1} \left[\Delta s_j^p(z)\right]^2} \tag{3}$$

   where $s_j^p(z)$ and $\Delta s_j^p(z)$ are the photon-counting time series and corresponding statistical error before the time integration ($j = 0, \ldots, N_t - 1$)."

   A reference to that has been also added in the section 2.2 when the time averaging is briefly introduced.

7. *-Figure 3: In my opinion a way to complicated, maybe the authors could think of how to make it more illustrative.*

   On one hand the authors agree with the Reviewer in considering the Figure 3 a bit complex. On the other hand the authors would like to mention that Figure 3 reflects the complexity of the gluing algorithm. Actually, it is just a standard work-flow diagram of the ELPP gluing algorithm. In general, the work-flow diagrams are widely used in algorithm development communities as standard tool to visualize algorithms and procedures. They allow the reader to visualize the general concept of the algorithm and they also provide a complete overview of all the implemented sub-procedures.

The authors believe that it is difficult to find a simpler way to represent the complexity of the ELPP gluing algorithm keeping the same level of rigor and completeness. One option would be to split the Figure 3 in two figures but this, in our opinion would provide an even more confusing situation. For these reasons the authors would like to keep the Figure 3 as it is.

8. *-Rayleigh calculation: How do you exactly calculate the molecular contributions? I.e., give formula for molecular density.*

   Done.

9. *-Does the FWHM of the interference filters needed to be taken into account for the very different lidars?*

   In general, the FWHM of the interference filters introduces temperature dependence in the backscattered lidar signals. This is because the interferential filters select only a part of the pure-rotational or ro-vibrational molecular spectrum. As the intensity of each spectrum line depends on the temperature and as the temperature changes with the altitude, the part of the spectrum selected by the interferential filter (i.e., the measured backscattered intensity) has a filter induced altitude dependence. This effect depends on the characteristics of both the filter (center and FWHM) and the molecular spectrum. However, this effect is almost negligible in the elastic lidar channels as well as in the nitrogen ro-vibrational Raman channels. In particular, Whiteman (Whiteman, D. N., Appl. Opt., 24, 15, 2571–2592, 2003) has shown that there is a variation of 0.39% (1.61%) in the intensity of nitrogen ro-vibrational Raman channel passing from 200K to 300K for a narrow (wide) filter bandwidth. For the intensity of the elastic channels the variation is even small (less than 0.36% in any case). These results have been also confirmed by several simulations made by the authors (not reported here).

   On the other hand this effect is particularly important in case of lidar water vapour measurement (Whiteman, D. N., Appl. Opt., 24, 15, 2571–2592, 2003), (Whiteman, D. N., Appl. Opt., 24, 15, 2593–2608, 2003) and for the calculation of molecular linear depolarization ratio (MLDR) (Behrendt, A. and Nakamura, T., Optics Express,10, 16, 805–817,2002). In particular, the MLDR is a parameter needed for the calculation of the particle linear depolarization ratio which is a product that will be implemented in the next SCC development. As a consequence it is already planned to take into account the temperature dependence of the MLDR induced by the interferential filter characteristics.

10. *- Maybe a comparison with already published Rayleigh profiles can be useful, as this is an important input for the optical profiles.*

The authors agree on the importance of Rayleigh calculation in any lidar retrieval. This is the reason for which a specific manuscript section (2.2.4) has been dedicated to this topic. Furthermore, thanks to the Reviewer suggestions, the section 2.2.4 has been already enriched by new relevant information and by the Table 2 which summarizes all the important parameters used to compute the Rayleigh calculation for the most common lidar wavelengths. The authors think that the Table 2 provides all the information needed to compare the SCC Rayleigh calculation with other available published results.

Moreover, the formula used to compute the molecular numerical density profile has been explicitly provided (as suggested by the Reviewer) and the related assumptions are mentioned in the section.

As a consequence the authors believe that the section 2.2.4 in its present form already provides a quite complete picture of the topic.

Finally, the authors tried to keep the level of information provided in the four similar sections 2.2.1–2.2.4 quite consistent. Adding further information only in section 2.2.4 would somehow break that.

For these reasons the authors would prefer to not include the comparison suggested by the Reviewer.

11. *-Table 2: Please also give values for the Raman wavelengths, i.e., 387 and 607 nm*

    Done.

12. *In general it would be interesting to have a table what parameter are needed to be provided by the lidar operator before ELPP can successfully be operated and what choices the lidar operator is allowed to do (i.e. choose method for smoothing). This would give a consistent picture what is done automatically and for which parameter the lidar operator has still its own responsibility.*

    In principle the authors agree with the Reviewer in considering such table useful. However, on the other hand, the authors believe that this table would be too long and also a bit confusing as there are many parameters that the user needs to provide before to submit the raw data to the SCC. We report here some of them:

    (a) register system configuration(s) in the SCC database providing system name, configuration name, coordinates, altitude asl, starting date for the configuration

    (b) register the laser source in the SCC database providing manufacturer, model, repetition rate, type, emission wavelength(s)

    (c) register telescope(s) in the SCC database providing manufacturer, model, type, primary mirror diameter, focal length, full overlap height

(d) register each lidar channel providing channel name, scattering mechanism, signal type, detection mode, interference filter center and bandwidth, raw range resolution, dead time value, trigger delay value, background subtraction mode

(e) define the optical products to calculate providing for each of them product type, usecase, the lidar channels needed for its calculation, pre-processing integration time, pre-processing vertical resolution, smoothing/interpolation options

(f) generate the SCC input file in NetCDF format according to a predefined structure taking care to not include low cloud contaminated profiles in the raw timeseries

Moreover, there are other parameters (mainly optical product options) used only by ELDA module that need to be set by the user as well.

For there reasons the authors prefer to not provide the table suggested by the Reviewer in the manuscript. Probably such table is more appropriate in the SCC usage manual (in preparation).

13. *-What do you mean with "fully traceable" (e.g. Conclusions, line 21) ? How do you ensure that an end user can completely follow which methods /parameters/corrections were applied.*

    The procedures that have been used to pre-process each SCC product are logged in different places:

    (a) ELPP output file. As explained in the manuscript in these files are stored not only the pre-processed lidar data but also a quite large number of metadata and ancillary data

    (b) SCC database. In the manuscript we have mentioned that each measurement is registered in the SCC database using a unique measurement ID. Using this measurement ID in appropriate database queries, it is possible to retrieve all the instrumental parameters (used in the analysis) corresponding to the lidar configuration at which the measurement ID is linked to. If the configuration changes over the time this change is also reflected in the SCC database.

    (c) ELPP log files. As briefly mentioned in the section 2.1, the ELPP generates a log file in which all the applied procedures are written for each pre-processed measurement. The quantity and the typology of the information to be written in the log file can be controlled by setting (globally) the ELPP log level.

14. *10389, Line:17 ff. I would prefer to add 1-2 sentences more for motivation here in the introduction why it is so important to have a unified pre-processor module (i.e. because of the heterogeneity of lidars within the network). This is stated somewhere later, but should be given already here as the introduction should motivate the work.*

The following text has been added:

"The implementation of the ELPP as a unified pre-processor module has been mainly triggered by the heterogeneity of the EARLINET lidar systems. Moreover, the ELPP module provides a way to standardize all the instrumental corrections and the data handling which must be applied to the raw lidar data before they can be used as input for the optical retrieval module. This is fundamental for the application of a rigorous quality assurance program on the lidar data analysis, in which all the analysis steps starting from the raw lidar data up to the final lidar products (including pre-processing procedures) should be included."

15. *10392, line 2: What do you mean with quality-certified procedures, can you give reference to literature or section in your paper.*

    The following references have been added:

    (a) (Böckmann et al. 2004)
    (b) (Pappalardo et al. 2004)
    (c) (Freudenthaler et al. 2016)

16. *10394, line 12: add data before acquisition*

    Done.

17. *10395, line 2: How is it possible to put the measurement ID in the raw files as it is associated only after registering in the data base according to line 8-9 at the same page!*

    The Reviewer is right! This point is a bit confusing. Actually the measurement ID is defined inside each NetCDF input file and during the submission phase it is taken from there. Moreover, there is a control which does not allow to upload two different NetCDF input files with the same measurement ID. The format of the measurement ID string is "YYYYMMDDccnn" where "YYYYMMDD" is the start date of measurement, "cc" is a unique code identifying each EARLINET station (for example "po" corresponds to Potenza EARLINET station, "at" to Athens EARLINET station) and "nn" is a two digits number identifying the measurement session.
    The authors tried to make this point more clear in the manuscript:

    "To retrieve the full set of the SCC database parameters relevant for a specific raw data set, each single measurement (i.e. each single NetCDF input file) gets registered in the database and it is associated to an alpha-numeric string (i.e. measurement ID) which is defined in NetCDF input file. To assure a one-to-one correspondence between each raw data set and the corresponding measurement ID string, it is not allowed to submit NetCDF input file with a measurement ID already present in the database. Using the measurement ID in appropriate database queries, it is possible to retrieve all information needed for the analysis of a specific measurement which is not included in the corresponding NetCDF input file."

18. *10396, line 9: Wouldn't it be better to have all detected signals in one file?*

    At moment, the products are defined in the SCC database for a single emission wavelength. This has the consequence to have pre-processed signals at different wavelengths stored in different intermediate files. Anyway the authors agree with the Reviewer that sometime it could be useful to have all the detected signals in one signal file. This is the reason for which the implementation of new multi-wavelengths SCC products has been planned in the framework of ACTRIS-2 project. The other advantage in having multi-wavelengths products is the better consistency of the temporal and vertical effective resolutions corresponding to the products at different wavelengths.

19. *10396, line 11: atmospheric transmission you refer to molecular extinction only, right? This should be stated clearly!*

    The Reviewer is right. The sentence has been changed according to his/her suggestion:

    "Other information included in the ELPP output files is, e.g., the molecular extinction and the molecular atmospheric transmission profiles, the range resolution and the vertical resolution, the number of averaged laser shots, and so on."

20. *10398: line 11: Is it useful to offer linear, cubic, spline smoothing? What is the preferred option for what? Can the user choose? If yes, what's about the homogeneity promised for the SCC if the user can choose so many options.*

    The preferred smoothing option is the linear one. Anyway all the other implemented smoothing options have been well-tested within EARLINET community since many years. Before to start the SCC implementation it was asked to all the EARLINET groups to provide the details of their own analysis procedure. All the reported algorithms and methods allowing a fully automated analysis (request by the SCC) have been considered. In case several suitable approaches are widely used in the community for the same specific problem, they were implemented in the SCC as parallel options allowing the user to choose among them. This is the case for example of the smoothing options. All the smoothing procedures implemented in the SCC are well-tested within EARLINET and each of them shows advantage and disadvantage. As the lidar systems used within EARLINET show very different characteristics it is not realistic to use only one option for all the cases.

Finally, the authors believe that the homogeneity of the SCC products should be intended more in terms of their quality than in terms of the way in which they have been retrieved. As already mentioned, the EARLINET systems show large differences in terms of hardware specifications: to be very strict on fixing all the options of the retrieval scheme would mean to be not able to assure the same level of quality on the products retrieved by different EARLINET lidar systems.

21. *10399/10400: Do you have a reference for all four formulas? You cannot just write down the equations and criterion without any reference or explanation.*

    The reference (Evans, 1955) has been added.

22. *10400: line 3: Same as above: "It is easy to show" –> show it or give reference*

    Following the Reviewer suggestion more information has been provided in the manuscript:

    "The correction for dead-time, in case of not paralyzable model, is made by inverting the Eq. (2):

    $$c_r = \frac{c_m}{1 - \tau c_m} \tag{4}$$

    As $c_r \geq 0$ and $c_m \geq 0$, the Eq. (4) can be solved only if the following condition on the measured count-rate is valid:

    $$c_m < \frac{1}{\tau} \tag{5}$$

23. *10404: line 5: Is it valid to use the ideal gas law for calculation the molecular number density for air? If yes give reference and best give also formula.*

    The point has been clarified as it follows:

    "The molecular number density profile (ρ_{mol}) is calculated by the ELPP from vertical profiles of temperature and pressure using the ideal gas law and assuming as 1 the value of the air compressibility factor (Penndorf, 1957)."

    Moreover, the formula has been provided.

24. *10404, equation 9: How do you integrate this formula from a numerical point of view? There are many options in the literature...*

    The following sentence has been added:

    "The integral in the Eq. (9) is computer numerically using the trapezoidal rule (Press, 2007)."

25. *10408, line 17 ff. I am confused you use "c" sometimes with lower case sometimes with upper case. Are these different variables?*

    The Reviewer is right. In the new manuscript version we use always the symbol C to indicate the curvature.

26. *10408, Eq. 10 and 11. Where does this formula(criterion) come from? Can you give reference? Otherwise explain why it should work.*

    Both Eqs. 10 and 11 are the usual way to evaluate the agreement between two independent variables affected by statistical uncertainties (Taylor, Introduction To Error Analysis, 1997). At left hand there is the absolute difference between two variables while on the right hand there is the product of a positive integer (let's call it n here) times the total statistical uncertainties of the variables difference. In the theoretical case in which the value of the two variables is known with an infinite accuracy (null uncertainties) they agree if their difference is zero (exactly). In the more realistic case in which the variables are affected by Gaussian statistical uncertainties, it is needed to evaluate the difference in terms of its uncertainty (standard deviation). If we consider $n = 1$, and the condition expressed by the Eq 10 (or by the Eq. 11) is not verified, there is still a probability of about 32% that the two variables agree one each other. In case we set $n = 2$ ($n = 3$) the same probability is reduced to the 5% (0.3%). So the choice of the integers n and m in the Eqs. 10 and 11 respectively has a statistical sense: the less these integers are the more strict is the condition to evaluate the agreement and the more is the risk to have false negatives.

    The authors tried to explain better this point adding the following description in the manuscript:

    "The integer m represents the level of confidence of the Eq. (10) as exclusive condition. For a Gaussian distribution and for $m = 1$ there is about the 32% of probability the two slopes (k_1 and k_2) agree (in statistical sense) even if the Eq. (10) is not verified (Taylor, 1997). For $m = 2$ the same probability is reduced to about 5%."

27. *10409,line 16. What is "n". It is a positive integer, ok, but for which variable does it stand for?*

The following sentence has been added in the manuscript:

"... and n is a positive integer (default value is 1) having the same statistical meaning of the integer m in the Eq. (10)."

28. *10410,line 16. "C" was already used as a variable; even if you refer to a region you should try to use symbols etc. only once!*

    The region has been called "G".

29. *10413, Eq. 14,15: I think "k" was already used somewhere else, for example Eq. 5*

    The index mentioned by the Reviewer has been renamed as "h".

30. *10413, line 8 and 9: Time –> time and add bracket before "Fig. 2"*

    Done.