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Atmospheric Measurement Techniques Discussions

# *Interactive comment on* "EARLINET lidar quality assurance tools" *by* Volker Freudenthaler et al.

**Anonymous Referee #1**

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The paper "EARLINET lidar quality assurance tools" describes check-up tools, tests and methods for improving of the lidar systems and data products.

General Comments The paper is of scientific significance within the scope of this journal. The manuscript represents important new tools and methods for tests of lidar systems and improvement of data quality. The scientific approaches and applied methods are valid. The results are discussed in an appropriate way. Presentation quality can be improved.

The "Abstract" should include some of the key results. I suggest re-writing of "Introduction" section. It should be organized in several paragraphs. It is unusual the introduction of a present paper to be a section from another paper published 4 year ago. The values of the numbers should be limited to the significant digits only. All the figures can be enlarged. Axis labels and legends are hard to read. Conclusions/Summary section is



missing.

Specific comments p2, Section 2, paragraph 1, Authors should provide more information about origin of the trigger delay between the actual laser pulse and zero-bin. The delay can originate from trigger source and/or design of the transient recorder. Trigger source usually is one of: laser flash lamp out pulse, laser Q-switch out pulse or a photodiode picking up a fraction of the outgoing beam. Usually triggering by a photodiode ensures minimum trigger delay and fluctuations.

The bin shift between photon counting and analog signals is an expected result caused by specific of Analog to Digital Convertors. For example, Licel provide information about factors for bin shifting of their transient recorders as well as software for correction of delay/shift between photon counting and analog signals. The information can be found on the web in section "9.5.6 Tutorial" in "Lidar transient recorder" manual (http://licel.com/manuals/ethernet_pmt_tr.pdf). I suggest authors to comment on the information provided by manufacturer.

p2/3, Section 2.1 The equations and symbols into the text have inaccuracies that I assume are typos. Please see details below.

p3,L1 (eq.1) in the equation "P(ïĄňR,r)" is used for received power. Term is "PïĄňR" in the text. Symbols in the equation are different from symbols in the text also for Raman backscatter coefficient, extinction coefficients of air molecules and aerosol particles.

p3,L7 (eq.2). The power "4.085" should be negative "-4.085"

p3,L8 The value of parameter fp is 1.09 according to the eq.2. In the text value is reciprocal. "ïĄňLaser" should be "ïĄň0", "ïĄňRaman" should be "ïĄňR"

p3,L9 (eq.3) The term "[1+fm]" should be "[1+1/fp]". The term "[1+fp]" should be "[1+1/fm]".

p3,L15 (eq.4) and L18 (eq.5) The term "(1+fp)" should be "(1+1/fp)". The term "(1+fm)" should be "(1+1/fm)".

p3,L19-23 (eq.6)and p4,Figure 2. The common definition of absolute error is the difference between the measured or inferred value of a quantity and its actual value. Please provide more information about the differentiation approach. The Eq.6 has unit 1/mˆ2 or 1/kmˆ2, while the unit on delta alfa in the figure 2 is 1/km.

p4, Figure 2 should be discussed in the text.

p4, L2, Sentence starting with “Note: as the error. . .” is not clear. Please rephrase it.

p5, section 2.2 “How to measure the trigger delays”. It will be good if authors include into this section some results from a triggering by fast photodiode placed near to the laser output. All the results in the section are based on LICEL transient recorders only. Please comment on applicability of the method for other type ADC/photon counting equipment.

p5,L6, “. . .to decrease the signal length . . .” should be “. . .to decrease the signal intensity . . .”

p6,L2, The range can be measured in steps with much better time/range resolution by fast oscilloscope. The signal from PMT can be electronically splited and measured simultaneously by LICEL transient recorder and an oscilloscope. For example, a 200MHz, 5GS/s oscilloscope allows 1ns or 15cm lidar range resolution.

p6,L4, “. . .several electronic delays. . .”. Can you please give a little more info?

p6,L8, “. . . are distributed between two rangebins.” A better time resolution is required to conclude about main peak distribution.

p6,L11, Figure 7 caption. “Trigger delay / zero-bin. . .” is better to be “Trigger delay (zero-bin). . .”.

p6,L15-16, Please include that the delay is an expected result according to the manufacturer. One can conclude that delay is fixed for individual module base on fig.7 and fig.8



p6,L22 “The small correlation peak in plot C. . .” should be “The correlation peak at -11 lag is smaller than peak at 0 lag in plot C because of the noise. . .. . .”

p.8, Section 3 “Rayleigh fit”. Authors should include a separate paragraph/subsection regarding to calculation of the Rayleigh signal from a radiosonde data. The resolution of radiosonde data is much smaller than lidar range resolutions which require extrapolation and/or fit of sonde data. It will be good to include more information about this process together with typical errors and uncertainties.

p8,L9 and Figure 11, Please provide more details about photon counting unit “counts/rangebin”. A reader can confuse about this units. SI unit for photon flux is “count per second” and usually Mc/s (million counts per second) is used. The Licel acquisition software use so called “MHz” that is count normalized on rangebin (25ns @40MHz digitizer) and number of laser shots. I think only glued signal can be shown on figure 11. The combination of the analog and photon counting is well described in Licel’s user manual and a reference about that should be sufficient.

p8,L10-11, It is not clear why LSB units are used in additional y-scale. The analog signal is measured in “mV”. “. . ..level of the analog signal.” In fact on the figure 11 is present the analog signal but scaled to the photon counting signal, not original one. This is so called by Licel “scaled analog signal”. The sentence “The analog signal is at the lowest bit. . ..”. If the lowest bit limit is at 2.8km then how is measured the analog signal from 2.8km to 14km?

p8,L12, Please provide more information about what is the “glued signal ” and give a reference about glue procedure.

p8,L14-L15,and L20-L22 “The uncertainty of the fit. . ..”. This discussion should be after the details of fitting procedure (Eq.7-Eq13).

p8,L22, “. . . fits the lidar signal sufficiently good.” Authors should provide a numerical criterion of “sufficiently good”.

p8,L22, and Figure 12. Why only analog signal is shown? I suggest using of glued signal. This is the real advantage of simultaneously measurements of both analog and photon counting signals. If authors would like to discuss on limitations on analog signal only as well as on limitations of PC signal only that should be done in a separate section. p9,L4-L19, This is in fact detailed description on fitting procedure and should be moved to the top of the Section 3. p9,L5, "..attenuated molecular backscatter coefficient ". It is a profile according to definition by Eq.8. I think "range corrected Rayleigh signal calculated from radiosonde or standard atmosphere data" is a better name for this term. Also, the term "..attenuated molecular backscatter " is common used in High Spectral Resolution Lidar technique for profiles attenuated by BOTH molecules and particles. p9,L8, (eq.8), "$\beta$p(r)" should be "$\beta$m(r)". p10, Figure 13. The figure is similar to Fig.12, but includes examples with both analog and photon counting signals. One of these examples could be used instead of Figure 12 (only analog signals) and then Fig.13 could be skipped. p9,L11, (eq.10),Authors should explain in the text that this normalization is possible only in particles free ranges. p9,L12-L14, Lidar signal can be smoothed to improve signal to noise ration. Then Fernald-Sassano-Klett inversion can be applied. Please give more details what is new here. p10, Section 4, Error sources of analog signal should be discussed in more details. References from previous studies on A/D errors and limits will be useful. Low intensity signals can be measured in photon counting mode. Please comment on reasons to use analog signal for ranges that signal is usually measured by photon counting. p11, L8-L10, "Their response. . .." Please provide more details with numbers form specifications. Performance of a commercial pulse generator can be tested with fast oscilloscope first and then compared with A/D converted respond. p11, L11-L15, and p12, first paragraph. This should be a presentation of new equipment. Please provide more detailed specifications or reference if they are already published. Adding a table with specs should be useful. Please concrete which specs are unique and not available in commercial pulse generators. p11, Figure 15. The figure is not discussed in the text. p12, Figure 16 and p13, Figuure17. Please discuss if the A/D convertors are in specifications by manufacturers. How the results



can help to improve lidar signals processing? Section 6. The information and specs of the telescope, and other optical elements could be summarized in a separate paragraph. "defoci" should be "defocus" in several places in the text. p16,L16. "ZEMAX" now is "OpticStudio". Please insert the version of the software used for the simulations. p18,L4 and Figures 25,26 and 27. Please provide more information about atmospheric model used for these simulations. Is it an aerosol free standard atmosphere? p16,L19. Please explain why the obstructions of secondary mirror are neglected. Is it neglected for Fig23. only? . p21,L2. "-1200/70=-17" should be "-1200/70$\approx$-17" p21,L7 (eq14). The term " (($\lambda$_0-$\lambda$)/$\lambda$_0 )" should be " (($\lambda$_0^2-$\lambda$^2)/($\lambda$_0^2 ) )" p22,Figure 29D. The legend is missing. The number of the curves could be reduced for this plot. Section 7, General. It is hard to read this section as an independent text. To follow the text one need to read together with another paper referred as Freudenthaler (2016a) in reference list. Definitions of parameters and variables should be provided in a little more details. Text in this section could include few of the key equations from Freudenthaler (2016a). All the values of linear depolarization ratios (LDRmeans, LDRcorr, LDRmol) are significantly smaller than theoretically calculated molecular depolarization ratios in section 9.2.1, Table 1. Can you please explain what that means? More information should be provided about how exactly are obtained uncertainties of all the values of LDR. Is it the standard deviation of LDR values in some range? p23,L24, Please provide the definition of the linear depolarization ratio (LDR). p23,L25-26. A short description of $\Delta$90 calibration should be provided. p24,L2. ". . . so-called Rayleigh signals. . ." One can see clouds desk and aerosols in ITRayleigh and IRRayleigh signal on top left plot in Fig.31. Please provide more information about these signals. Other term for these signal should be used – a reader can easy confuse with term "Rayleigh signal" used in Section 3 (p8,L13). p24,L18. "The broken lines.. " should be "The dashed lines. . .". Please provide in the text the numerical values of Vplus_mean and Vminus_mean together with uncertainties, as well as the calibration range. p24,L19. At least a simple description of GHK parameters should be done. p24,L33. ". . .very clean down . . ." How clean has been the atmosphere can be quantitative checked by methods

in Section3, for example Eq.12. p25, Figure 31, All the curves (except ITRayleigh) are very noisy above 11km height, and it seems cannot provide any sufficient information. Typical bars of standard errors should be included or limit the heights to 11 km could be applied for all the plots. Vplus_mean and Vminus_mean are really hard to read (to find them I zoomed the screen to 800%). p27,Eq.15. The symbol $\beta$ is an angle here, but backscatter coefficient and other sections. p31,L5-L8, (eq.37). The statement that equation 37 is wrong should be proved and explained in details about assumptions and approximations in both approaches. I think these lines can be skipped. If authors exist to keep them then should provide more details. p32-33, Table 1 should present only significant digits.

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