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Atmospheric Measurement Techniques Discussions

Interactive comment on "EARLINET Raman Lidar Polly^{XT}: the neXT generation" *by* R. Engelmann et al.

Anonymous Referee #2

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"EARLINET Raman Lidar Polly ....." by Engelmann et al, AMTD 7737, 2015 The authors report on the latest development of a mobile lidar system, POLLY XT that is used for measurements of particle backscatter and extinction coefficients and depolarization ratios at 2-3 wavelengths. In addition, water vapor is measured. The system is compact and comparably light in weight, which allows for deployment to remote regions on earth. The authors present details of the system and put the system in comparison to previous versions of the system, the prototype of which was developed around 15 years ago.

This research group has the potential of developing what they claim could become an AERONET-similar network of ground-based, well calibrated, standardized remote sensing instruments (lidar). As in the case of AERONET the same data analysis pro-

cedure are used, hardware is well characterized and calibrated, (near) real-time display of the data products is offered. Helping other research teams with issues in case their instruments fail or provide low quality profiles (AERONET is offering the same service) is another asset. In that sense POLLY could also be a candidate for complementing the AERONET network at some aerosol supersites.

In general the paper is well organized, informative and well written.

General comments: The paper is acceptable for publication, but I ask for some mandatory changes which mainly concern improvements of the technical part, i.e. the description of hardware and data acquisition and some additional information on the hardware and calibration. Furthermore, the measurement example at the end of the manuscript would be an ideal platform to show how calibration and other technical improvements improve the quality of the derived optical parameters. Otherwise the example section is more like a "instrument indeed works" section, and I believe that the instrument is capable of providing the data products shows in the manuscript. The interesting part however would be to show in how far the quality of the data products been improved with the new Polly system. This part will also be important for the follow-up paper, as in that case the authors may be able to refer to this present paper when it comes to presenting the data of many different Polly systems that took data over the past decade.

In that sense the link between the technical part of the paper and the short experimental part has potential for improvements, not in the sense of scientific interpretation of the results, but in the sense of convincing the reader that the high-end technical improvements transfer into trustworthy, high-end optical parameters which are among the goals of EARLINET: "quality assured data products." The authors should explain in more detail the calibrations that are needed before deployment to field site. Are these calibrations (and their parameters) really stable, also in view of the various environmental conditions (very hot to very cold air)? How are conversion efficiencies of the SHG and THG affected by external temperature changes? Is the cabinet of the lidar completely sealed off (isolated) in terms of outside temperatures? You mention the

overlap: it would be helpful to see if the overlap is the same for all channels, and achieving the same overlap function for all channels is a challenge. The approach as shown by Wandinger and Ansmann (2002) cannot be done in the case of the backscatter at 1064 nm. You only derive the overlap function at 532 nm? What makes you confident that the same overlap can be applied at 355 nm? Are the overlap functions solely based on simulations carried out during the design phase of Polly?

More details on specifications of the photon counting system would be helpful. How does the laser behave under various humidity and temperature conditions? The photos that show field sites of the instrument obviously show the challenges involved. In space technology environmental chambers are used to test the behavior of the equipment. Note: The size of this instrument would allow for developing such an environmental chamber at TROPOS and simulate the various environmental conditions under which the system needs to operate.

That comments brings me back to calibration and stability of the system design. A few more plots and tables detailing the variability of important parameters, like expansion or retraction of the carbon-fiber parts, laser performance, alignment of the optics, stability of the overlap function would help convincing the reader a) why this instrument in fact could become a standard instrument for the research-based lidar community and b) why such a system may be more suitable than commercially available instruments for setting up a worldwide network of multiwavelength Raman lidars. What material is the primary mirror? Can the distortions of the frame be reduced by choosing lighter mirror material? What are the dead time corrections beyond 40Mcps? Is this dead time correction (figure 6) done for all detectors? What is the uncertainty of the 5-th order fit?

In general I am missing uncertainty bars of the calibration constants. Please show them for all channels and/or show a table that summarizes the polynomial regression (fit) constants. I am sure these parameters will be checked during maintenance cycles of the instruments. The paper is mainly about the instrument, thus more tables with technical details of the detectors, photon counting, mirrors and optics in terms of

numbers would be helpful.

A table that shows the various improvements and modifications that were made between the prototype and this next generation Polly would be quite instructive and would put the text in a better context, e.g., calibration stability, detector sensitivity, counting efficiency, overlap stability, new procedures for instrument characterization that were not done for the previous versions of Polly? The history of Polly in that way could be clearly followed which is important for future work.

Depolarization ratio measurements are particularly critical, and the authors spend some time explaining the procedure of calibrating the channels and how the automated routines work. A plot showing the calibration numbers and how an offset from these values affects the final data products could be put in a section called “sensitivity study and error analysis”. In fact, the uncertainties that are involved in the calibrations and their dependence on various environmental factors like (fast) temperature changes or extreme temperature regimes might be included in the sample measurement that is shown at the end of this paper. Although the paper is for the most part about the technology of the instrument the measurement example could serve as a platform to guide the reader through the different parts of the calibrations, the photon counting efficiency, dead time corrections, etc,. In that sense the authors may want to reconsider the way they present error bars in the measurement example. I assume the error bars are done in the “usual“, i.e. “traditional” way of averaging the signals in time and space, carrying out calibration in the molecular atmosphere, lidar ratios need to be assumed in the case of the backscatter at 1064 nm, etc . It would be helpful to see how the error bars become larger (smaller?) if the technical components (calibration numbers) of the instrument and the data acquisition properties are taken into account of. In fact this is an important task in EARLINET, i.e. what do the error bars of the profiles in fact mean, what are they made up of (experimental error versus “technical, hardware-driven”, i.e., instrument error), what is the statistical law that determines the error bars (Poisson, Gauss, log(?), random . . .?). Polly could provide a first approach to this more

sophisticated error analysis.

Figure 7: what is the reason for the significantly different water vapor mixing ratios below 600 m between the radiosonde (and MARTHA) and Polly? What is the sensitivity of Polly with respect to measurements above 6 km height? Is there a systematic offset or statistical noise? Are the neutral density filter (e.g. in figure 9) calibrated as well? Do they pose a significant source of uncertainty in the calibration procedure?

Figure 10 shows the overlap function. Was the overlap function measured several times during the ship cruise? What was the scatter of the experimental overlap function? Is the "true" curve (simulated) the one obtained during the design phase on the computer? There is no uncertainty bar of the simulated overlap function. In view of the various parameters that determine the overlap function this uncertainty would need to be included in the presentation of the final data products.

Figure11: what is the reason that the backscatter at 1064 is so much lower than the backscatter at 355 and 532 nm (neutral spectral behavior)? What is the reason that extinction shows wavelength dependence in the center of the aerosol plume, but the 1064 nm backscatter is off? Is this an instrument effect or an aerosol-type effect? If it is an instrument effect it should be explained in this paper.

What do you mean by "predefined adjustment apertures"? What happens if they change their properties? Specify the EARLINET guidelines (7738, line 13) as the reader may not be familiar with them and will not find these numbers (guidelines) in the EARLINET publications. Specify in a table how close Polly is in achieving these "guidelines" or even exceeds them.

Please avoid using qualitative terms like "rather", "appropriate (e.g., 7742, line 6), "sufficient", etc. It is a technical paper, so please provide as many numbers as possible and put them in the context of older Polly versions (in a table). "Smart" (7741, line 12) though I understand what you man to say by this, but is not the right word in this context. Expressions as for example "sophisticated", "thought-out", "mature", "elaborate",

"meticulously thought through design . . .," maybe be better choices.

Some language editing at a later stage of the manuscript preparation could further improve the readability of the paper. Words and grammar are often used in the German context rather than the English context. Sentences lack in verbs in some spots of the manuscript.

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