Improving the Instrument and Analysis Capabilities of the São Paulo LALINET Lidar Station in the Framework of the APEL Project

***F. J. S. Lopes*[1]**, *G. A. Moreira*[1], *J.L.Guerrero-Rascado*[3,4], *J. A. Silva*[1], *D. Gouveia*[2], *A. Gomes*[1], *L. Belegante*[5], *V. Freudenthaler*[6], *H. M. J. Barbosa*[2], *L. Alados-Arboledas*[3,4], *D. Nicolae*[5], *A. Geiss*[7], *A. G. Straume*[7], *E. Landulfo*[1].

(1)Instituto de Pesquisas Energéticas e Nucleares – IPEN, Av. Prof. Lineu Prestes 2242, São Paulo-SP, Brazil, fabiolopes@usp.br
(2) Universidade de São Paulo, Instituto de Física, Rua do Matão1371, São Paulo-SP, Brazil.
(3) Andalusian Institute for Earth System Research (IISTA-CEAMA), Av. del Mediterráneo s/n, 18006, Granada, Spain,
(4) University of Granada, Fuentenueva s/n, 18071, Granada, Spain.
(5) National Institute of R&D for Optoelectronics, 409 Atomistilor Str., Magurele, Ilfov county – Romania.
(6) Ludwig-Maximilians-Universität, Meteorologisches Institut, Experimentelle Meteorologie, Theresienstraße 37, 80333 München, Germany.
(7) European Space Agency (ESA/ESTEC), PO Box 299, 2200 AG Noordwijk, Netherlands

Background and objectives

Considerable uncertainties remain in assessments of long-term trends of global properties of aerosols, mainly due to lack of observations and the difficult in measurements of important aerosol parameters. In order to solve these issues and reduce the sources of aerosol uncertainties, it is necessary to increase the number of observational stations and the number of experimental field campaigns to improve the global observations of aerosol and its optical and physical properties, therefore, helping to improve the climate numerical model validations. An important step further to increase the accuracy of aerosol measurements is to develop the capability of aerosol measurement networks, implementing rigorous and systematic protocols of measurements. In this context, the Latin America Lidar network (LALINET) [1] has been monitoring the vertical distribution of particle optical properties since 2001, and started to be operative with systematic measurements since 2013. LALINET has the purpose to develop a database of the vertical distribution of aerosols over South America, and also from other atmospheric components such as water vapour and clouds, and to provide quality assurance data for atmospheric satellite missions such as CALIPSO, and ESA's future missions Aeolus and EarthCARE [2]. In order to concentrate efforts on the validation processes of ESA's missions, selected LALINET stations are working to implement quality assurance standards based on EARLINET procedures. These actions aim to increase the capability to provide a reliable dataset in collaboration with three EARLINET stations (Bucharest, Granada and Munich) in the framework of the project entitled "**A**ssessment of atmospheric optical **P**roperties during biomass burning **E**vents and **L**ong-range transport of desert dust" (APEL). The main objective of APEL is to promote the exchange of expertise between EARLINET and LALINET to increase the capability of joint research, and thus setting the groundwork for the future Cal/Val of ESA's atmospheric satellite missions. Furthermore, quality assurance (QA) and quality control (QC) programs developed by EARLINET are being implemented at the selected LALINET stations: São Paulo (SPU), Manaus (MAO) and Natal (NAT). These programs deal with algorithm corrections and their implementation made to optimize the measurements and improve the data analysis. In the present study we show only the results from SPU station for the sake of brevity.

Methodology

During the APEL project, QA/QC programs based on the EARLINET standards were implemented in the SPU lidar station to provide quality assured particle backscatter and extinction profiles, and to identify possible improvements for this system. The first steps were implemented by establishing the Handbook of instruments (HoI), the operating procedure standards and the protocol of QA tests in order to pinpoint hardware problems and consequential optimizations of the lidar system. We applied six QA tests: dark current, zero bin, telecover in-out, telecover quadrant, bin-shift and Rayleigh fit. Several tests were performed continuously until the system achieved a reasonable optimization. Concerning the data analysis, the inversion algorithm of the SPU LALINET station was improved by implementing the dead-time correction and the analog and photon-counting dataset "gluing" procedure. In addition, the overlap correction was improved and the Klett-Fernald inversion (KF inversion) technique by tuning the aerosol optical depth with values from AERONET was automatized. For the inversion retrieval the error uncertainties calculation were implemented using the Monte-Carlo method. One of the goals of the APEL project was the implementation of the EARLINET Single Calculus Chain (SCC) [3] in order to fully automate the lidar measurement process together with the aerosol optical properties retrieval procedure.

Results

Here we present the main technical results achieved within the APEL project in order to improve the performance of the SPU lidar station at São Paulo. The left panel of Fig. 1 presents the overlap function calculated for the 355 and 532 nm channels. The right panel of Fig. 1 presents the overlap correction applied to the lidar backscatter profiles at 355 and 532 nm.

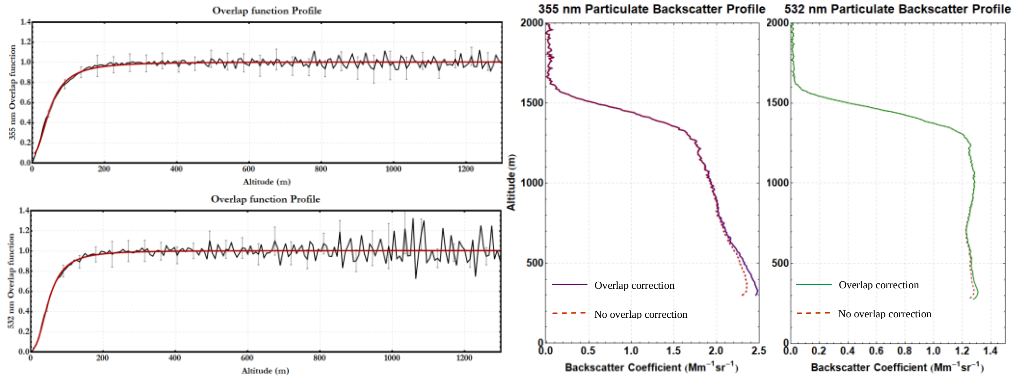

Figure 1. Overlap function profile and overlap correction applied to the particle backscatter profiles at 355 and 532 nm measured by the SPU LALINET station at São Paulo.

Another achievement from the APEL project was the EARLINET SCC algorithm implementation in order to provide the KF and the Raman lidar products for SPU LALINET station measurements. Fig. 2 shows the particle backscatter, extinction and lidar ratio profiles retrieved during the 2017 APEL field campaign. The same figure also shows the comparison of 532 nm particle backscatter coefficient retrieved using SCC and the MILGRAU (Multi-Indexed Lalinet GeneRAlized and Unified) algorithm from SPU station, and the absolute difference less than 0.1 $Mm^{-1}sr^{-1}$ between both retrievals.

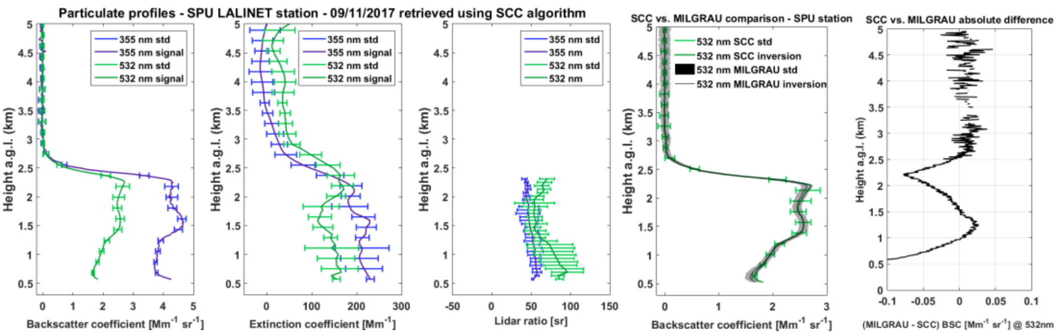

Figure 2. Particle backscatter, extinction and lidar ratio profiles at 355 and 532 nm retrieved applying the SCC algorithm to the SPU lidar system data measured during 2017 APEL campaign. The last two plots show the comparison of the particle backscatter profiles retrieved using SCC and the MILGRAU algorithm from SPU station. Errorbars are calculated using Monte Carlo method for SCC [3] and MILGRAU retrievals.

Conclusions

The APEL project developed in collaboration with the Bucharest, Munich and Granada EARLINET stations allowed the implementation of the standard QA tests to identify problems and optimize the SPU lidar system. The SCC algorithm was successfully implemented showing an absolute difference between MILGRAU less than 0.1 $Mm^{-1}sr^{-1}$for particle backscatter coefficients.

Acknowledgements

The authors would like to thank: CNPQ Posdoctoral program 150716/2017-6, FAPESP Project 2015/12793-0, by the University of Granada through "Plan Propio. Programa 9 Convocatoria 2013", European Space Agency – ESA and National Institute of Research and Development for Optoelectronics – INOE under the Project AO/1-8486/15/F/MOS - Assessment of atmospheric optical properties during biomass burning events and long-range transport of desert dust – APEL. This activity was initiated and financed by the ESA contract APEL, ESA contract number 4000117289.

References

[1] J. L. Guerrero-Rascado et al., *J. Atmos. Sol-Terr Phy*., 138-139, 112-120, 2016.

[2] A. Hélière et al., Development status of the EarthCARE Mission and its atmospheric Lidar, *Proc. SPIE*, Earth Observing Systems XXI, 9972, 997215, 2016.

[3] I. Mattis et al., Atmos. Meas. Tech., 9, 3009–3029, 2016.