ACTRIS TNA Activity Report

Error estimation in calibrated depolarization lidar measurements, ECAD

Project leader: Prof. Lucas Alados Arboledas
Participant: Juan Antonio Bravo Aranda

- Introduction and motivation

Due to their impact on climate and humans health, the quantification and dynamics of atmospheric aerosols are of crucial importance. Because of their variable microphysical and chemical properties, which are related to their composition and size (Dubovik et al., 2002), the characterization of aerosols on a global scale is very difficult. Moreover, their properties are highly influenced by the meteorological conditions and transport paths. Theoretical and experimental studies performed during the last decade have demonstrated that the multiwavelength Raman lidar technique is able to provide comprehensive information about aerosol optical and microphysical variables (Müller et al., 1999a, b; Veselovskii et al., 2002) along with the occurrence, extent and development of vertical aerosol structures. Depolarization adds a significant value to lidar measurements, because it is directly related to the shape of the particles (Biele et al., 2000), allowing to distinguish between spherical (water clouds, biomass burning smoke) and non-spherical particles (mineral dust, ice clouds).
A quantitative characterization of aerosol's shape is provided by the linear volume depolarization ratio which is defined as the ratio of the cross–polarized lidar return signal to the parallel-polarized backscatter signal (Behrendt and Nakamura, 2002). For an ideal system, this would be equal to the ratio of the received signals in cross and parallel channels. For a non-ideal system, a calibration function taking into account the whole system depolarization effects and the differential detection on the two channels has to be considered (Freudenthaler et al., 2009).

- Scientific objectives

We propose a combination of theoretical and experimental research using the multiwavelength depolarization Raman lidar (RALI) located at the RADO ACTRIS station, in order to:
a) formulate the calibration function and associated uncertainties of the RALI's depolarization channel, using the T-Matrix approach
b) analyse the influence of the optical blocks in the total uncertainty of the calibration function and study the overall effect of the uncertainties in depolarization products
c) perform different depolarization calibration methods in order to assess the influence of the polarizing sensitivity of the lidar system on the calibration methods.
The project will be organized as an intensive training part, followed by a measurement campaign. During the training, the applicant will learn to align, calibrate and use the instruments, as well as to handle the data processing programs available at RADO. This will include the analytical description of the optical blocks using the Stokes-Müller formulism. Sensitivity studies will be made concerning the depolarization calibration function. Regular lidar measurements and calibrations will be performed during the training, and continued up one month. Data will be used to retrieve the linear volume depolarization ratio and the

aerosol backscatter coefficient achieved through Raman inversion. The uncertainty on these aerosol optical properties due to the different depolarization calibration methods and the comparison with theoretical results will be analysed.

- Reason for choosing station

RADO infrastructure provides a unique opportunity to study the polarizing sensitivity of a lidar system. RALI, the lidar system operated in this station, allows for performing different depolarization calibrations and, because the high quality of its laboratory, allows for adapting the experimental tests to the needs of the on-going research. In addition, the good collaboration between the manufacturer of the lidar system (Raymetrics, S.A.) and RADO is very important to understand the polarizing sensitivity of the lidar system due to its design and its optical devices which make up the system. Finally, the scientific support staff is crucial to the good development of the project.

- Method and experimental set-up

Based on the Stokes-Müller theory developed by Freudenthaler for the polarizing sensitivity of the lidar system (manuscript in preparation), the calibration function and the associated uncertainties of the RALI's depolarization channel was determined.
In order to determine the influence of the receiving optics (M_O) of the lidar system, two types of depolarization calibrations (C(Ψ)) identified in Figure 1 has been considered. To determine these calibrations several experimental tests were performed during this project. The calibration methods considered were the Δ90º calibration method using a polarizer and a rotator located in front of and behind the receiving optics, respectively. In addition, a new test which uses a set of rotator Δ90º calibrations. Usually, Δ90º calibration required to rotate Δ90º around the measurement position which can be 0º and 90º. However, in this test, several calibrations are performed respect to different position around the measurement position (e.g., 80º, 85º, 95º, 100º).

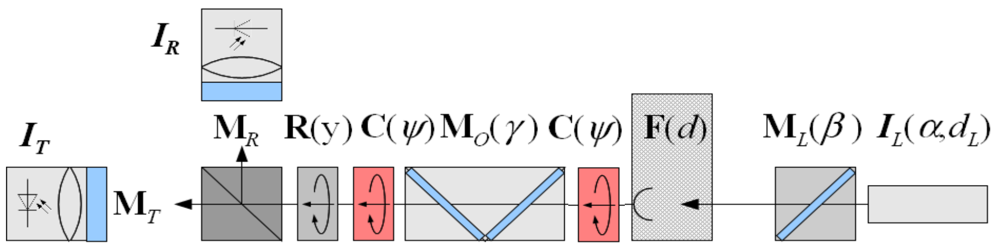

Figure 1: Lidar scheme based on basic functional blocks. From right to left: Laser (I_L), laser optics (M_L), atmosphere (F(d)), Δ90º calibration (polarizer) (C(Ψ)), receiving optics (M_o), Δ90º calibration (rotator) (C(Ψ)), measurement performed at 90º (R_y), polarizing beam splitter cube (M_R, M_T) , reflected and transmitted intensities (I_R, I_T parallel and perpendicular signals, respectively).

- Preliminary results and conclusions

The comparison between the experimental results and the simulations based on the Freudenthaler's theory allowed for confirming that the diattenuation of the receiving optics (dichroic mirrors) is one of the main error sources of lidar system. As it can be noticed in Figure 2, diattenuation around 0.3 (Tp = 0.9), can produce a decrease of the volume linear depolarization ratio around 50%. However, as it was experimentally demonstrated in the framework of ECAD, this error source can be corrected locating calibrator in front of the receiving optics instead of behind. Measurements affected by this error can be corrected by means of a post-calibration combining the polarizer and rotator Δ90º calibration located in front of the polarizing beam splitter cube and behind the optics, respectively.

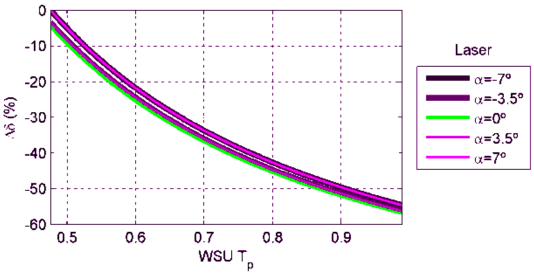

Figure 2: Variation of the volume linear depolarization ratio with the parallel transmittance of the receiving optics parameterizing the misalignment of the polarizing plane of the laser beam respect to the polarizing plane of the polarizing beam splitter cube.

As it was previously indicated, a new test which consists in a set of rotator Δ90º calibrations performing the rotation at different angles around the measurement position. Preliminary results of this test evidence the existence of other error sources related to the misalignment between the polarizing plane of the laser and the polarizing beam splitter cube. However, further investigations are needed.

- Outcome and future studies

As a result of the project's results and contributions made within EARLINET network, two papers, titled "*Polarizing sensitivity simulation for lidars with depolarization capabilities*" and "*Experimental assessment of the lidar polarizing sensitivity",* are under preparation to be published in the AMT special issue dedicated to EARLINET network.

- References

Behrendt, A., Nakamura, T., 2002. Calculation of the calibration constant of polarization lidar and its dependency on atmospheric temperature. Opt Express 10, 805-817.

Biele, J., Beyerle, G., Baumgarten, G., 2000. Polarization Lidar: Corrections of instrumental effects. Opt Express 7, 427-435.

Dubovik, O., Holben, B.N., Lapyonok, T., Sinyuk, A., Mishchenko, M.I., Yang, P., Slutsker, I., 2002. Non-spherical aerosol retrieval method employing light scattering by spheroids. Geophys Res Lett 29.

Freudenthaler, V., Esselborn, M., Wiegner, M., Heese, B., Tesche, M., Ansmann, A., Muller, D., Althausen, D., Wirth, M., Fix, A., Ehret, G., Knippertz, P., Toledano, C., Gasteiger, J., Garhammer, M., Seefeldner, M., 2009. Depolarization ratio profiling at several wavelengths in pure Saharan dust during SAMUM 2006. Tellus B 61, 165-179.

Muller, D., Wandinger, U., Ansmann, A., 1999a. Microphysical particle parameters from extinction and backscatter lidar data by inversion with regularization: simulation. Appl Optics 38, 2358-2368.

Muller, D., Wandinger, U., Ansmann, A., 1999b. Microphysical particle parameters from extinction and backscatter lidar data by inversion with regularization: theory. Appl Optics 38, 2346-2357.

Veselovskii, I., Kolgotin, A., Griaznov, V., Muller, D., Wandinger, U., Whiteman, D.N., 2002. Inversion with regularization for the retrieval of tropospheric aerosol parameters from multiwavelength lidar sounding. Appl Optics 41, 3685-3699.