Statistical Intercomparison of Aeolus B10 SCA and SCAmb Backscatter Coefficient with Ground-Based Measurements of ACTRIS/EARLINET Stations in South-Western Europe

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Introduction

Since 2018 the European Space Agency (ESA) is developing the Aeolus satellite mission, based on the ALADIN (Atmospheric Laser Doppler Instrument) wind lidar, encouraging large-scale dynamic studies through near real-time wind retrievals at global scale.

Besides wind profiles (L2B products), aerosol optical properties, known as L2A, are retrieved as spin-off products, such as particle backscatter and extinction coefficient profiles. Measurements are generated under specific data processing, called baselines, which are constantly being updated, and through different algorithms separately, such as SCA (Standard Correct Algorithm) and SCAmb (Standard Correct Algorithm middle bin), which differ in the way SCAmb bins are obtained (from two adjacent SCA bins, aiming to reduce noise). ALADIN emits circular-polarized radiation at 355 nm and receives the co-polar component of the signal, what will cause an underestimation of backscatter coefficients. A complete description of the instrument and the L2A products is given by Flamant et al. (2020).

In this work, we perform an intercomparison of Aeolus reprocessed B10 (baseline 10) SCA and SCAmb co-polar backscatter coefficients (β_{Aeolus}^{part}) with analogous ground-based measurements from the ACTRIS/EARLINET stations of Granada (Spain, 24 matching overpasses), Évora (Portugal, 15 overpasses) and Barcelona (Spain, 16 overpasses). Ground-based total particle backscatter coefficient is converted into Aeolus-like profiles ($\beta_{Aeolus\ like,355}^{part}$) through the linear particle depolarization ratio at 355 nm ($\delta_{linear,355}^{part}$) and a thorough bibliographic review of dual-polarization measurements for relevant aerosol types. A relation for the spectral conversion of δ_{linear}^{part} is proposed.

Results and discussion

Relevant results were obtained regarding the bibliographic review. A modest, but significant, dataset of dual-polarization measurements is obtained for different aerosol types, including mineral dust (fresh, aged, mixed), marine, mixed anthropogenic, smoke, volcanic and bioaerosol particles. For these aerosol types a linear fit is applied to estimate $\delta_{linear,355}^{part}$ from $\delta_{linear,532}^{part}$ though a factor K_δ, called the depolarization spectral conversion factor (Table 1). However, mainly mineral dust, marine and mixed anthropogenic particles are detected during Aeolus selected overpasses, so the factor $K_\delta = 0.82 \pm 0.02$ is implemented in the calculation of the Aeolus-like profiles. Additionally, bibliographic results are endorsed with analogous measurements from Barcelona (Table 1) at dust and non-dust (a mixture of marine and anthropogenic particles) conditions. The derived K_δ aims to serve as a look-up table for other stations where a depolarization channel is available only at 532 nm, which is a frequent handicap worldwide. A further explanation of the dataset used is given by Abril-Gago et al. (2021).

The statistical validation of the satellite products showed that Aeolus SCAmb retrievals presented lower RMSE values than the SCA with respect to ground-based measurements (Figure 1). SCAmb RMSE profiles are fairly similar for the three stations, providing consistency to the results. Additionally, Aeolus measurements presented a critical surface-related effect that caused the satellite to drastically overestimate the co-polar backscatter coefficients in the lowermost range. This effect was more present in the SCA retrievals than in the SCAmb. Depending on the station and the orography of the region, this effect could extend to higher altitudes.

Aeolus quality flags (QF) application entailed a strong reduction of the number of measurements available. Approximately 20 % of all the data is flagged as valid, which affected the statistical significance of the results. In addition, the statistical intercomparison was not improved after the QF application, e.g. the surface effect was not mitigated and a RMSE increase (between 40 and 65 %) was observed. Finally, SCA tends to retrieve negative and meaningless backscatter coefficient values in the free troposphere, where the concentration of aerosol is expected to be low. These negative values are avoided with the quality flag filtering.

The statistical results show the ability of the satellite to detect and characterize aerosol layers under cloud free conditions. However, a case study presented by Abril-Gago et al. (2021) shows that Aeolus is able to characterize thin cirrus clouds with an acceptable agreement. Despite the distance between the stations and the overpasses, and the fact that the products are generated by averaging horizontally over 87 km, a good agreement was found between Aeolus retrievals and ground-based lidar measurements, demonstrating its potential for the characterization of the aerosol distributions.

Challenges

A further exploration of K_δ is encouraged, as a greater dataset of dual-polarization measurements will entaill interesting and usefull results.

Regarding Aeolus cal/val activities, more stations should join in order to achieve a fully operational version of Aeolus products. In addition, Aeolus products could be improved via the quality flags application, although the surface-related effect seems to be unavoidable.

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References

Abril-Gago, J., Guerrero-Rascado, J. L., Costa, M. J., Bravo-Aranda, J. A., Sicard, M., Bermejo-Pantaleón, D., Bortoli, D., Granados-Muñoz, M. J., Rodríguez-Gómez, A., Muñoz-Porcar, C., Comerón, A., Ortiz-Amezcua, P., Salgueiro, V., Jiménez-Martín, M. M., and Alados-Arboledas, L.: Statistical validation of Aeolus L2A particle backscatter coefficient retrievals over ACTRIS/EARLINET stations in the Iberian Peninsula, Atmos. Chem. Phys. Discuss. [preprint], https://doi.org/10.5194/acp-2021-388, in review, 2021.

Flamant, P. H., Lever, V., Martinet, P., Flament, T., Cuesta, J., Dabas, A., Olivier, M., and Huber, D.: ADM-Aeolus L2A Algorithm Theoretical Baseline Document Particle spin-off products, ESA, reference: AE-TN-IPSL-GS-001, 2020.

Table 1. Factor K_δ for the different aerosol types and their Pearson correlation coefficient R

Aerosol type	K_δ	R
mineral dust, marine and mixed anthrop.	0.82 ± 0.02	0.99
biomass	1.36 ± 0.08	0.97
volcanic	0.82 ± 0.13	0.98
bioaerosol	0.46 ± 0.13	0.91
Barcelona dust and non-dust	0.76 ± 0.01	0.99

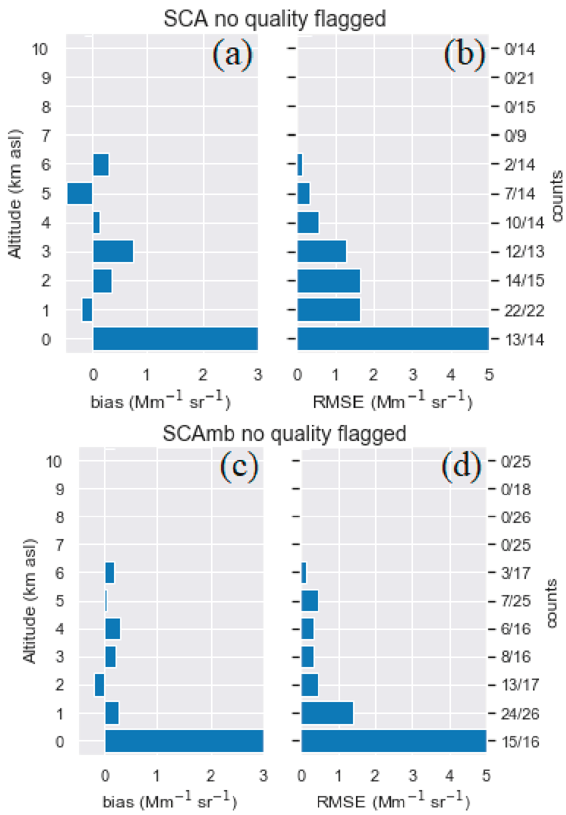

Figure 1. Statistical results for the intercomparison of Aeolus SCA and SCAmb with Barcelona ground-based measurements. The right-hand axis indicates the number of available data points included in each vertical range out of the total number of measures within that vertical range. (a) and (c) present the bias profiles calculated as $bias = \beta^{part}_{Aeolus,355} - \beta^{part}_{Aeolus\ like,355}$. (b) and (d) present the RMSE profiles. No quality flags are considered in these figures.