# CONSISTENCY OF THE SINGLE CALCULUS CHAIN FOR CLIMATOLOGICAL STUDIES USING LONG-TERM MEASUREMENTS FROM THESSALONIKI LIDAR STATION

**Nikolaos Siomos[1,*], Kalliopi A. Voudouri[1], Maria Filioglou[1,2], Eleni Giannakaki[2,5], Vasilis Amiridis[3], Giuseppe D'Amico[4] and Dimitris S. Balis[1]**

[1]*Laboratory of atmospheric physics, Physics Department, Aristotle University of Thessaloniki, Greece, *Email: nsiomos@physics.auth.gr*
[2]*Finnish Meteorological Institute, Atmospheric Research Centre of Eastern Finland, Kuopio, Finland*
[3]*Institute for Astronomy, Astrophysics, Space Applications and Remote Sensing, National Observatory of Athens, Athens, Greece*
[4]*Consiglio Nationale delle Ricerche, Instituto di Metodologie per l' Analisi Ambientale (CNR - IMAA), Tito Scalo, Potenza, Italy*
[5]*Department of Environmental Physics and Meteorology, Faculty of Physics, University of Athens, Greece*

## ABSTRACT

The long term analysis of 15 years of lidar data derived from a Raman lidar at Thessaloniki is presented here. All measurements have been processed with the latest version 4 of the EARLINET Single Calculus Chain algorithm and are compared with the results from the current operational retrieval algorithm. In this paper we investigate the consistency between the EARLINET database and SCC for the case of Thessaloniki and we identify the issues to be considered when switching from current operations to SCC.

## 1 INTRODUCTION

Thessaloniki lidar system (THELISYS), is operational for the detection of aerosol particles since 2000 in the framework of the European Aerosol Network EARLINET [1]. The primary setup of the lidar system included two elastic backscatter channels at 355nm and 532nm and a nitrogen Raman channel at 387nm. A second Raman channel at 607nm was added in 2008. In 2011, two channels for the measurement of the cross and parallel polarized signal at 532nm were added. Finally, a third elastic backscatter channel at 1064nm was added in 2012. All the measurements processed within the study period 2001-2015 have been uploaded in the EARLINET database (https://data.earlinet.org). The total number of uploaded files for the whole period is 1831. A number of 527 files correspond to the elastic backscatter profiles at 355nm, 723 files to the elastic backscatter profiles at 532nm, 182 files to the elastic backscatter profiles at 1064nm, 290 files to Raman extinction and backscatter profiles at 355nm and 109 files to Raman extinction and backscatter profiles at 532nm. All the raw data have been converted to the network's standard format in order to be reprocessed with the SCC v4.0 algorithm. The SCC structure is briefly described in section 2.

## 2 The Single Calculus Chain

An automated tool for the processing of lidar data from raw signals up to the final products was developed within EARLINET. The SCC algorithm [2] provides high quality standardized aerosol optical products in near real time along within the entire EARLINET network (Pappalardo et al. 2014 [1]). Briefly, the SCC consists of different modules and uses raw lidar data as input in a standard format (NetCDF). The raw lidar signals are initially processed by the Preprocessor module (ELPP: EARLINET Lidar PreProcessor). After the applied system-dependent corrections to the raw signals, the aerosol backscatter and extinction coefficient profiles are derived by the optical processing module (ELDA: EARLINET Lidar Data Analysis). Also, with the latest version of SCC the calculation of the particle linear depolarization ratio is possible, by the new module ELDEC (EARLINET Lidar Depolarization ratio). All these processes are monitored by the SCC daemon which runs continuously in the background. The software is installed on a centralized server and a web interface is available giving the possibility of uploading the data and selecting and modifying any of the input SCC parameters. The output data are also in the NetCDF format accepted by the EARLINET database.

## 3 METHODOLOGY

In the first part of the study, the SCCv.4 Raman extinction product at 355nm is evaluated for Thessaloniki. The evaluation procedure is based on a comparison of the aerosol optical depth (AOD) values derived by the SCCv.4 and the operational algorithm. AOD data from the Aerosol Robotic Network (AERONET) for Thessaloniki are also compared against the AOD of the two algorithms. The two lidar datasets include data from the period 2001-2015, processed by both the operational algorithm and the SCC. A common overlap correction was applied for the SCC Raman analysis. In the archived data Raman inversion, however, the applied overlap function is derived individually for each measurement [3]. Since the two algorithms don't always produce profiles with the same height range we use only the common part of the two profiles for the AOD integration. The values in the first point of the common height range are assumed to be constant down to the ground. The sunphotometer dataset includes the level 1.5 AOD at 340nm for Thessaloniki. This product is available for most of the period 2005-2015. Since the raman AOD is a nighttime product while the sunphotometer AOD is a day time product we use the closest sunphotometer measurement. In the second step, we examine the ability of the SCC algorithm to reproduce a seasonal climatology similar to the ones generated by the operational algorithm and the sunphotometer retrievals for the AOD at 355nm. Since a longer common period of measurements is important for a climatologic study, instead of using the sunphotometer AOD at 340nm, that is directly comparable with the lidar AOD at 355nm, we prefer to convert the sunphotometer's 440nm AOD using the angstrom 440-675nm that are available for the whole period 2003-2015. For the climatological comparison we preferred to use the daily mean AOD from the sunphotometer. We calculate and compare the seasonal averages, the annual cycle and the AOD trends for the three datasets.

## 4 RESULTS

The evaluation of the SCCv.4 Raman AOD at 355nm against the operational algorithm is presented in figure 1. A high correlation of 0.89 is derived with a least square fit slope at 0.78. The AOD seems to be underestimated by the SCC algorithm for the majority of the data points. In figure 2 and 3 the SCC AOD and the operational algorithm AOD are compared with the sunphotometer AOD. The results are similar for both lidar datasets. The correlation is close to 0.6 and the least square fit slope is the same for both comparisons. We have to mention here that figure 1 is not directly comparable with figures 2 and 3 since the sunphotometer data weren't available in the period 2001-2005. The annual cycle of the period is pre-

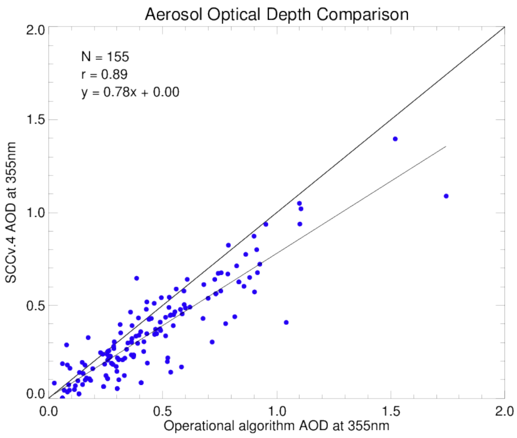


*Figure 1: Comparison of the SCC v.4 AOD at 355nm with the operational algorithm AOD at 355nm.*

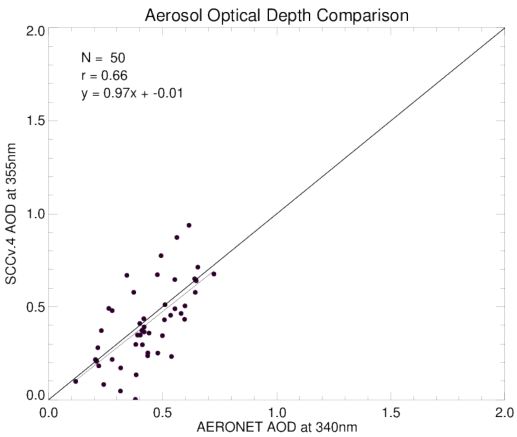


*Figure 2: Comparison of the SCC v.4 AOD at 355nm with the sunphotometer AOD at 340nm.*

sented in figure 4. The maximum values appear in summer and the minimum ones in winter in all datasets. The lidar AODs are usually underestimated compared to the sunphotometer AOD with the exception of the summer AOD of the operational algorithm. There is also an offset between the two lidar products

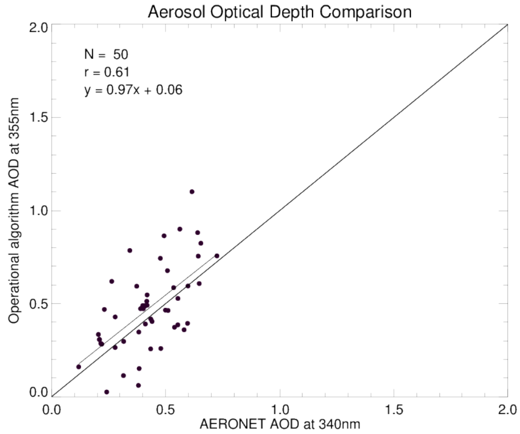


*Figure 3: Comparison of the operational algorithm AOD at 355nm with the sunphotometer AOD at 340nm.*

for all the seasons. Figure 5 contains the comparison of the AOD seasonal averages between the sunphotometer, the SCCv.4 and the operational algorithm datasets for the period 2003-2015. The least square fit line has been calculated for each timeseries. The sunphotometer values are considered as reference data. Both the operational algorithm and the SCCv.4 seasonal trends are similar to the sunphotometer one. There is a negative offset for both lidar

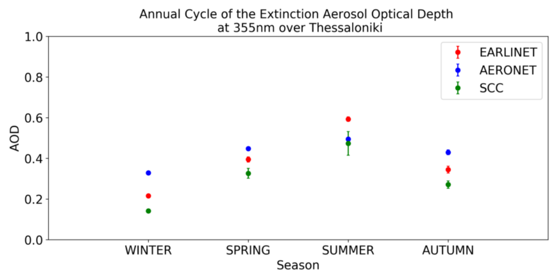


*Figure 4: Comparison of the annual cycle calculated with the three datasets.*

products which is larger for the SCC. Overall the SCC lidar AODs tend to be underestimated compared to the sunphotometer and the operational algorithm. This is compatible with figure 1 where the SCC AOD seems underestimated for most data points. It is important to mention

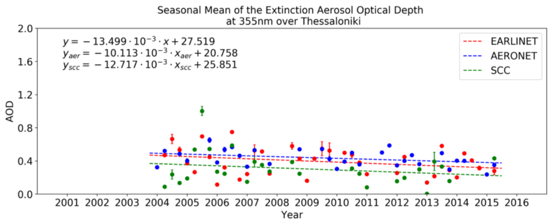


*Figure 5: Comparison of the seasonal averages calculated with the three datasets.*

though that the AOD is calculated in different ways between figures 1,2,3 and figure 4,5 (see section 3). This behavior could be attributed to the fact that each algorithm applies the overlap function in a different way and this affects the AOD calculation [4] (section 3).

## 5 CONCLUSIONS

The SCCv.4 algorithm has been evaluated for the AOD at 355nm for Thessaloniki. The agreement with the standard algorithm seems promising with a correlation of 0.89. The comparison with the sunphotometer gives similar results for the two algorithms. In both cases the correlation is close to 0.6 and the least square fit slopes are the same. The seasonal variability of the AOD at 355nm in the period 2003 to 2015 is reproduced adequately by the lidar products despite the fact that the data availability for the lidar is quite lower than the sunphotometer. The trends are similar and the minimum and maximum values in the annual cycle occur in the same seasons. The overall underestimation of the SCCv.4 results is mostly connected to differences in the overlap function that is applied in each algorithm. In the future additional optimizations in the SCC products, such as the addition of radiosonde data for each measurement are going to be implemented and the effect of the overlap function in the climatological results will be further examined.

## ACKNOWLEDGEMENTS

This work has been conducted in the framework of EARLINET (EVR1 CT1999-40003), EARLINET-ASOS (RICA-025991) and ACTRIS-2 funded by the European Commission. This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654109.

## References

[1] G. Pappalardo, A. Amodeo, A. Apituley, A. Comeron, V. Freudenthaler, H. Linné, A. Ansmann, J. Bösenberg, G. D'Amico, I. Mattis, L. Mona, U. Wandinger, V. Amiridis, L. Alados-Arboledas, D. Nicolae, and M. Wiegner. Earlinet: towards an advanced sustainable european aerosol lidar network. *Atmospheric Measurement Techniques*, 7(8):2389–2409, 2014.

[2] G. D'Amico, A. Amodeo, H. Baars, I. Binietoglou, V. Freudenthaler, I. Mattis, U. Wandinger, and G. Pappalardo. Earlinet single calculus chain – overview on methodology and strategy. *Atmospheric Measurement Techniques*, 8(11):4891–4916, 2015.

[3] Ulla Wandinger and Albert Ansmann. Experimental determination of the lidar overlap profile with raman lidar. *Appl. Opt.*, 41(3):511–514, Jan 2002.

[4] Voudouri, K., Siomos, N., Giannakaki, E., Amiridis, V., d'Amico, G., and Balis, D. S. Comparison of aerosol backscatter and extinction profiles based on the earlinet database and the single calculus chain for thessaloniki greece (2001–2014). *EPJ Web of Conferences*, 119:23024, 2016.