Report on the outcomes of a Short-Term Scientific Mission[1]

Action number: CA21119

Grantee name: Lionel Doppler

Details of the STSM

Title: Harmonization of CAELIS product to a harmonized HARMONIA standard for a homogenised comparison.

Start and end date: 28/6/2026 to 4/7/2026

Description of the work carried out during the STSM

Description of the activities carried out during the STSM. Any deviations from the initial working plan shall also be described in this section.

This STSM focuses on the harmonization of AOD products, a main goal of HARMONIA, particularly WG1 and WG2, and on comparing AOD products from different networks and instruments (PFR, AERONET/Cimel, SKYNET/Prede). To this end, DWD has developed HARM (Harmonized AOD Retrieval Method) a harmonization algorithm currently applied to the Lindenberg dataset (2013–present) for PFR, AERONET/CIMEL, and SKYNET/Prede (see overview of DWD Lindenberg instrument set and AOD dataset in Figure 1). HARM reprocesses AOD products using the same processing equations (air masses, Rayleigh, …) and gas quantities.

[1] This report is submitted by the grantee to the Action MC for approval and for claiming payment of the awarded grant. The Grant Awarding Coordinator coordinates the evaluation of this report on behalf of the Action MC and instructs the GH for payment of the Grant.

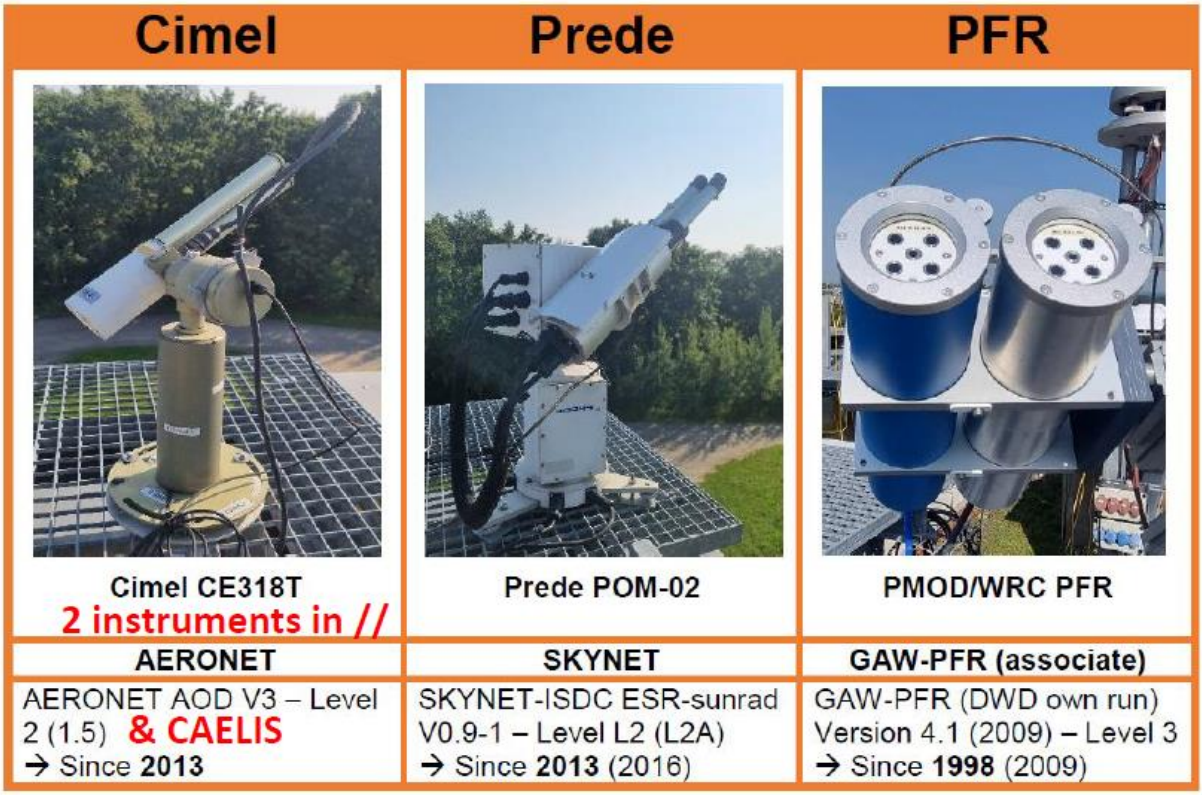

Figure 1. *DWD photometer setup for AOD retrieval in Lindenberg since 2013: CIMEL (AERONET and CAELIS datasets), Prede (SKYNET network), and PFR (associated with the GAW-PFR network), integrated into the DWD HARM algorithm in order to harmonize AOD retrievals from the different instruments, networks, and datasets for better intercomparison.*

This STSM addressed Deliverable D1.3 of WG1 in the HARMONIA project, which focuses on harmonized AOD retrievals and the intercomparison of different photometer systems and networks. The aim of this STSM is to extend the algorithm to the Cimel photometer CAELIS AOD products. CAELIS is the database system used by GOA to manage data from CIMEL photometers, which are calibrated at its own AERONET calibration facility, RIMA. Therefore, the applicant visited the GOA group (Group of Atmospheric Physics) at the University of Valladolid (UVa) to gain information, meet GOA experts, and adapt HARM to the CAELIS dataset.

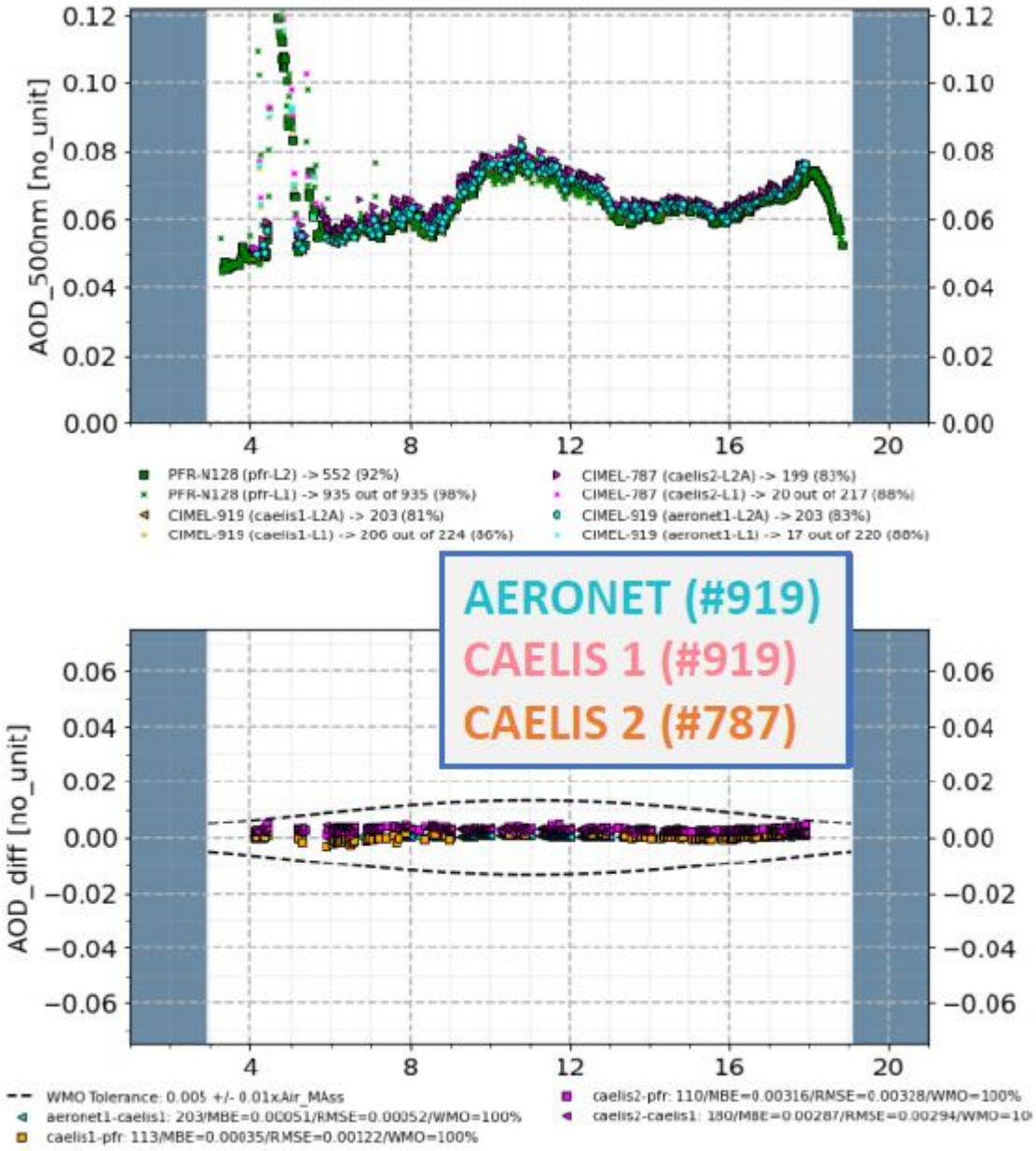

Figure 2. *Example of 25 May 2026: daily graph comparing PFR and CIMEL instruments #787 and #919. Top: AOD values. Bottom: AOD differences. For the CIMEL instrument, turquoise denotes the AERONET product for instrument #919, magenta denotes the CAELIS product for instrument #919, and orange denotes the CAELIS product for instrument #787.*

The work carried out in the context of this STSM is as follows:

1) Preliminary work:

Extension of the DWD HARM algorithm to CAELIS products and testing of HARM on the Lindenberg dataset. For each day, a graphic is produced with the AOD values obtained from each system and dataset in the upper panel, and the comparison between systems (e.g. CIMEL #787 vs CIMEL #919) or between datasets (e.g. AERONET vs CAELIS) in the lower panel, as shown in Figure 2 for PFR and CIMEL AERONET and CIMEL CAELIS for both CIMEL systems #787 and #919. Graphics were produced for each year and for the full ten-year dataset, using various statistical parameters (daily Mean Bias Error,

MBE; bias error at a given solar zenith angle, SZA, e.g. 70°, 55°, 40°, etc.). Statistical tables of the comparisons are shown in Figure 3.

	n_days	Mean(BE70)	Mean(abs(BE70))
CIMEL (A) – PFR	870	+0.000045	0.005926
CIMEL_919 (C) – PFR	615	+0.002418	0.007013 ✪
CIMEL_787 (C) – PFR	401	+0.005340	0.011043 ✪
PREDE(L2) – PFR	470	+0.000725	0.018848
PREDE(L4) – PFR	196	-0.000351	+0.01803
CIMEL_787 (C) – CIMEL_919 (C)	166	+0.002992	0.010094 ✪

WMO tolerance criterion: Bias (SZA=70°) = 0.0085

Figure 3. *Statistics of the comparisons between the four datasets for the three systems: AERONET and CAELIS (for CIMEL photometers #787 and #919), SKYNET (for Prede), and the GAW-PFR network for PFR. The parameter compared is the difference in AOD at 500 nm for measurements at a solar zenith angle (SZA) of 70° for every possible day in the ten-year dataset. The statistical parameters are the mean Bias Error (BE) and its absolute value (right column). For the CIMEL instrument, the bracketed label is (A) for the AERONET dataset and (C) for the CAELIS dataset. In the right column, a star indicates that the CAELIS dataset was necessary for the comparison..*

2) During the visit

2a) Exchanges and joint work with GOA (University of Valladolid) experts responsible for the CAELIS products, and improvement of the algorithm: presentation of all comparison graphics and statistical tables, followed by joint interpretation.

2b) Determination of a database strategy: defining possible improvements to the CAELIS dataset, the HARM algorithm, and the comparison method.

2c) Determination of a publication strategy for a joint peer-reviewed paper (in the HARMONIA special issue of AMT) and for the presentation of these results in the next HARMONIA WG1 deliverable, D1.3.

2d) Exchanges and joint work with GOA experts on the feasibility of extending the DWD "HARM" algorithm to other instruments and products, such as CIMEL lunar AOD and possibly star-photometer products, as well as to other stations belonging to the CAELIS community.

Description of the STSM main achievements and planned follow-up activities

Description and assessment of whether the STSM achieved its planned goals and expected outcomes, including specific contribution to Action objective and deliverables, or publications resulting from the STSM. Agreed plans for future follow-up collaborations shall also be described in this section.

Achievements: The following achievements were obtained during this STSM:

1) Extension of the HARM algorithm to the CAELIS dataset for CIMEL #787 and #919

This extension was crucial, as it made it possible to compare AOD measurements from two instruments (CIMEL #787 and #919) retrieved with the same algorithm (CAELIS), which was not possible with the

AERONET dataset, where only one “priority instrument” is provided. This makes the redundant measurements from two CIMEL instruments operated in parallel valuable and allows us to identify differences that are purely due to the instrumentation (CAELIS dataset: CIMEL #787 vs CIMEL #919).

2) Statistical analysis of the AOD differences for different systems, networks, and datasets

We produced and analysed many graphics at daily scale (example in Figure 1), annually, and for the full ten-year dataset (Figure 4), using various statistical parameters. The most relevant parameter is the bias error at a given solar zenith angle (SZA), e.g. BE70 for SZA = 70°. For this parameter, the statistical means are shown in the table in Figure 3. We found that the purely instrumental differences (CAELIS dataset: CIMEL #787 vs CIMEL #919) lead to a mean absolute difference of 0.010, which is of the same order of magnitude as the WMO tolerance criterion (0.0085), and slightly larger than or comparable to the differences obtained when comparing measurements from different systems (CIMEL vs PFR) and networks (CAELIS vs GAW-PFR, or AERONET vs GAW-PFR) simultaneously (0.0006; 0.007; 0.011), as shown in Figure 3.

3) Identification of inhomogeneities between the AERONET and CAELIS datasets

We identified some inhomogeneities between the AERONET and CAELIS datasets (for example, the red circle in Figure 4) that are exceptional, since normally the differences in AOD between CAELIS and AERONET retrievals for the same system, i.e. the same measurement, are below 0.0001. This led to very interesting discussions with the GOA experts working on CAELIS and provided an opportunity to improve the CAELIS dataset.

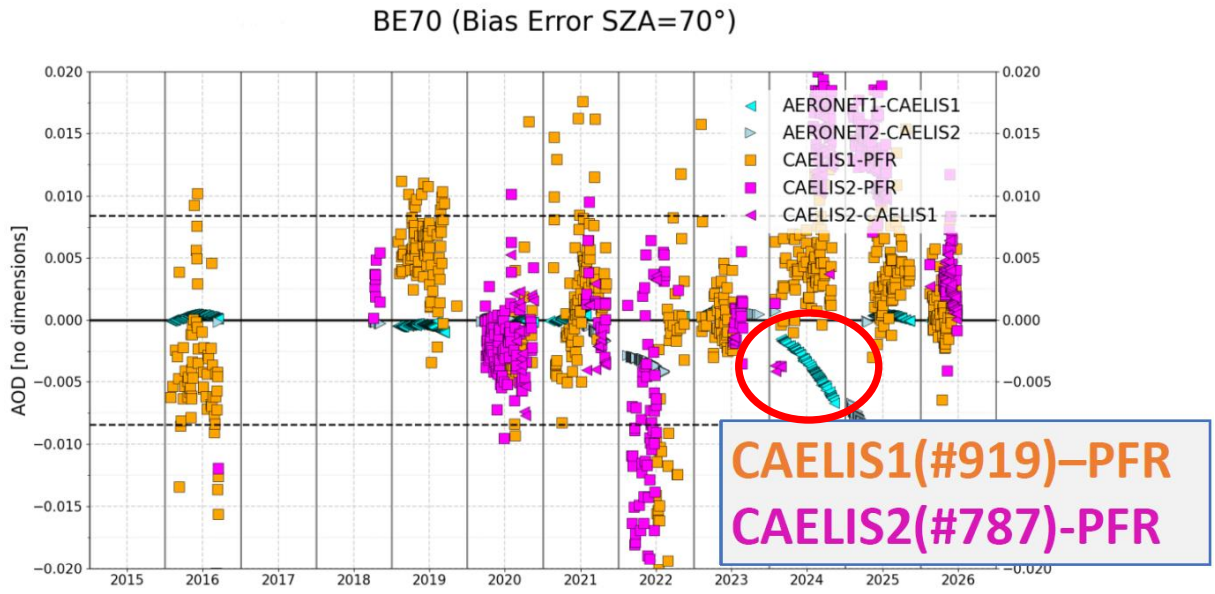

Figure 4. *Comparison over ten years of PFR and CIMEL AOD at 500 nm for an SZA of 70°. In cyan and grey: comparison of AERONET versus CAELIS for the same CIMEL instrument. In orange and magenta: comparison of CIMEL (CAELIS product) versus PFR. The red circle around the cyan triangles (AERONET versus CAELIS for CIMEL #919) highlights an exceptional inhomogeneity between the AERONET and CAELIS datasets, an issue that will be improved in the future thanks to this STSM.*

Follow-up: This STSM allows us to define the following tasks and goals:

1) For the CAELIS dataset: to deliver a Level 2 CAELIS product that follows the same methodology in terms of calibration coefficients and data flagging as AERONET, in order to facilitate intercomparisons and avoid the inhomogeneities mentioned above.

2) To improve the comparison strategy by focusing on the same solar zenith angles when computing statistical parameters and comparing data at the same level, once the CAELIS Level 2 product has been processed.

3) To define a publication strategy for both a peer-reviewed article in the HARMONIA special issue of AMT and the next HARMONIA WG1 deliverable (Deliverable D1.3).

Acronyms:

DWD = Deutscher Wetterdienst (German Meteorological Service)

GOA = Grupo de Óptica Atmosférica (Group of Atmospheric Optics) of UVa who hosted this STSM

HARM = Harmonised AOD Retrieval Method (DWD algorithm)

SZA = Solar Zenith Angle

UVa = University of Valladolid, Valladolid, Spain.