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Outstanding Student & PhD candidate Presentation contest

ANALYSIS OF SKYNET DERIVED AOD DURING THE FRC-VI CAMPAIGN IN DAVOS, AND VALIDATION OF IMPROVED DATA PROCESSING AND CALIBRATION ALGORITHMS

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Introduction

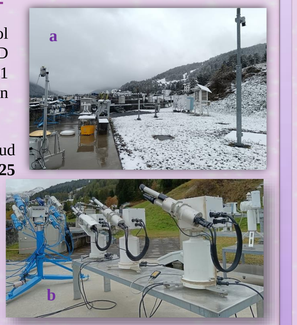
The 6th Filter Radiometer Comparison (FRC-VI) campaign took place in Davos (Switzerland) from 20th September to 10th October 2025 (although it was extended to 17th October). This event, organised by the PMOD/WRC with the support of the World Meteorological Organisation, aims to ensure harmonisation and traceability of ground-based aerosol optical depth (AOD) measurements to the WMO reference scale, given by the PMOD/WRC reference Precision Filter Radiometers (PFRs). Several sun-photometers belonging to different sites from the main global networks (e.g. SKYNET and AERONET) participated. Another advantage that these kind of campaign offer is that measurements are performed at almost the same time and place, so discrepancies in the retrievals would be attributed to the instrumentation, processing algorithms or calibration. Hence, this dataset can be used to understand the limitations of existing methods and develop possible improvements.

In the present work, data from Prede, Cimel and PFR collected during this campaign are analysed. First of all, a validation of the SUNRAD algorithm, which is adopted by the SKYNET network to obtain AOD, Ångström Exponent (AE) and columnar water vapor (CWV) from direct sun measurements (Estellés et al. 2012), has been carried out. For this purpose, the dataset provided by AERONET from the Cimel #1144 has been taken as reference, and thus compared with AOD retrievals obtained by running SUNRAD for three cases: Cimel #1144 raw data and calibration, raw Prede data but calibration transferred from Cimel #1144, and raw Prede data with Improved Langley Plot (ILP) calibration based on MRI (Kudo et al. 2021). Results overall confirm the agreement of SUNRAD algorithm with the standard procedure used in AERONET. However, discrepancies in the 1020 nm channel in the case of Prede data with ILP calibration are found and have been hypothesised as temperature or calibration effects, although further examination is required. Furthermore, AOD comparison between Cimel-PFR, Prede-PFR and two Prede instruments have been analysed. Cases involving the PFR are related to a reasonably good agreement taking into account that the corresponding dataset does not belong to the reference triad and is not definitive (see Kouremeti et al. 2026 for a stricter PFR comparison). Nevertheless, from the Prede-Prede comparison, it is concluded that the CNR Prede had some problem that have yet to be analysed, since unexpectedly larger AOD are found. Finally, the influence of the calibration method in the retrievals has been studied by comparing the AOD for Prede (based on SUNRAD) with the obtained from the Cimel #1144. It has been found that the ILP calibration based on MRI is the one which provides the best agreement between these two instruments.

Measurements and methods

The FRC-VI campaign:

- Several sun-photometers from different aerosol observation networks attended: 11 PFR + triad for AOD reference, 4 Cimel, 2 CW193 and 3 Prede POM (POM-01 from CNR and UVEG and POM-02 from Japan Meteorological Agency).
- Unfavourable weather conditions (rain, snow and cloud coverage) → best days for observation were **28-29/09/2025** and **2-3/10/2025**, so we have focused on these 4 days.



Measurement area for the FRC-VI campaign (coord.: 46.81° N, 9.84 ° E, 1588 m.a.s.l.). Picture a shows the instrumentation under snow coverage, and picture b depicts the three Prede (JMA, UVEG and CNR from left to right), some PFR and a CW193 (bottom right) measuring under cloud coverage conditions.

SUNRAD algorithm:

- The SUNRAD algorithm was elaborated in the context of the European Skynet Radiometers network (ESR) to perform synergistic analyses between instruments from different aerosol measurement networks (Estellés et al. 2012).
- It consists of two modules: **dsform,** which adapts raw data files to the SUNRAD specific format (for the moment, the algorithm can deal with Prede and Cimel data, although the adaptation to PFR is planned); and **dsproc**, which retrieves AOD, AE and CWV from the formatted data files.
- Meteorological parameters can be specified in a separated file. In this work, NO_2, O_3, CWV and Temperature for each measurement day have been taken from AERONET retrievals. However, for the Pressure, values computed by SUNRAD are chosen instead.
- For the SUNRAD validation, AOD is obtained through this algorithm and then compared with AERONET V3 retrievals for Cimel #1144.

Results

SUNRAD Validation

Raw data from Cimel + Cimel #1144 calibration

Effect:
- Algorithm

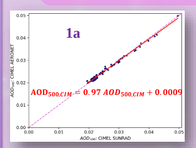
Effect:
- Algorithm
- Instrument

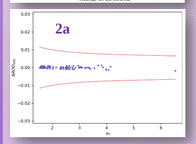
Raw data from Prede + Cimel #1144 calibration (transference)

AERONET lv. 1.5 data for CIMEL #1144

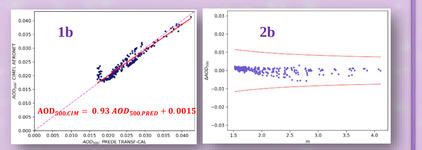
Effect:
- Algorithm
- Calibration
- Instrument

Raw data from Prede + Prede calibration



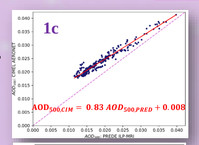


Comparison of AOD_{500} retrieved by AERONET with the obtained from SUNRAD (figures 1) and AOD_{500} differences as a function of the optical air mass, with upper and lower WMO limits (figures 2). SUNRAD has been run using raw CIMEL #1144 data (letters a) and raw PREDE data with CIMEL transferred calibration (letters b) or ILP MRI calibration (letters c).



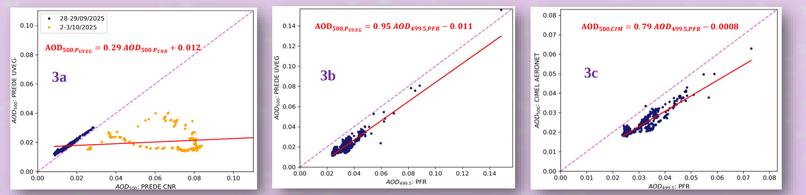
Statistical parameters applied to the comparison of the AOD at different channels for the validation of the SUNRAD algorithm: Root-Mean-Square-Error (RMSE), Standard Deviation of the differences (DIFF STD), Mean Bias Deviation (MBD), 90th percentile (P90), correlation coefficient R^2 and ratio of points within the WMO limits.

		RMSE	DIFF STD	MBD	P90	R^2	% WMO
AOD_{500}	Cimel raw (Cimel cal.)	0.0006	0.0004	0.00002	0.0008	0.9908	100
	POM raw (Cimel cal.)	0.0015	0.0009	0.0002	0.0017	0.9135	100
	POM raw (ILP MRI cal.)	0.0052	0.0014	-0.0050	-0.0030	0.9486	98.4
AOD_{675}	Cimel raw (Cimel cal.)	0.0002	0.0001	-0.0001	0.0001	0.9988	100
	POM raw (Cimel cal.)	0.0009	0.0006	0.0001	0.0011	0.9138	100
	POM raw (ILP MRI cal.)	0.0015	0.0008	0.0011	0.0022	0.8898	100
AOD_{870}	Cimel raw (Cimel cal.)	0.0004	0.0001	-0.0004	-0.0003	0.9998	100
	POM raw (Cimel cal.)	0.0016	0.0009	-0.0003	0.0015	0.5759	100
	POM raw (ILP MRI cal.)	0.0077	0.0018	-0.0075	-0.0047	0.7278	71.8
AOD_{1020}	Cimel raw (Cimel cal.)	0.0011	0.0004	0.0010	0.0018	0.9904	98.9
	POM raw (Cimel cal.)	0.0039	0.0022	0.0022	0.0062	0.4998	99.6
	POM raw (ILP MRI cal.)	0.0254	0.0057	0.0248	0.0323	0.0038	0



- For Cimel raw data, **excellent agreement** between AERONET and SUNRAD retrievals.
- Good agreement when Prede data and Cimel transferred calibration are used, but higher discrepancies found at 1020 *nm* channel.
- For Prede raw data and calibration, the agreement is also good except at 1020 *nm*, which may be affected by **temperature**.

Comparison of *AOD*



Comparison of AOD_{500} between some of the instruments from the main aerosol observation networks at FRC-VI: 3a, Prede UVEG-CNR (AOD from SUNRAD); 3b Prede UVEG-PFR, and 3c, Cimel-PFR. Dataset from Cimel is provided by AERONET. For PFR, belonging to the Swedish Meteorological and Hydrological Institute, preliminary data were downloaded.

Statistical parameters applied to the comparison of AOD between the different instruments.

		RMSE	DIFF STD	MBD	P90	R^2	% WMO
AOD_{400}	Prede CNR/UVEG	0.0279	0.0177	0.0181	0.0508	0.3233	37.9
AOD_{500}	PFR/Prede UVEG	0.0130	0.0033	0.0125	0.0180	0.8278	22.6
	Prede CNR/UVEG	0.0305	0.0197	0.0219	0.0543	0.2338	31.8
	PFR/Cimel #1144	0.0080	0.0029	0.0075	0.0124	0.8113	76.4
AOD_{675}	Prede CNR/UVEG	0.0314	0.0199	0.0225	0.0557	0.1536	30.5
AOD_{870}	PFR/Prede UVEG	0.0069	0.0025	0.0064	0.0087	0.8944	72.7
	Prede CNR/UVEG	0.0401	0.0230	0.0329	0.0656	0.2203	27.2
	PFR/Cimel #1144	0.0019	0.0009	-0.0013	0.0001	0.9001	99.8
AOD_{1020}	Prede CNR/UVEG	0.1077	0.0326	0.1026	0.1488	0.2845	0.0

- The CNR Prede shows an unexpected behaviour on 2-3/10/2025, as higher AOD than expected are found (yellow points in Figure 3a). Further examination is required to assess the cause of these discrepancies.
- Cimel-PFR differences are smaller than the AOD uncertainty, 0.01.
- For Prede-PFR, the agreement is better when $AOD > 0.15$ are excluded.

However, PFR dataset used is preliminary.

Effect of the ILP calibration

Four calibration methods have been applied and the AOD obtained using SUNRAD have been compared to AERONET retrievals from Cimel #1144

- ILP including 340 *nm*
- ILP without 340 *nm*
- **ILP without 340 *nm* using MRI → best agreement with AERONET**
- ILP with new computed Solid View Angle (using data from 28/09)

The 340 *nm* filter has been found to be degraded, and thus affected the determination of the other calibration coefficients

Statistical parameters applied to the comparison of AOD obtained using SUNRAD with different calibration methods.

		RMSE	DIFF STD	MBD	P90	R^2	
AOD_{340}		0.2794	0.0682	0.2710	0.3423	0.1849	0.0
	ILP new SVA	0.0413	0.0154	0.0383	0.0554	0.0032	5.7
AOD_{500}		0.0325	0.0080	0.0315	0.0406	0.0034	0.0
	ILP new SVA	0.0090	0.0020	-0.0088	-0.0055	0.9363	89.4
AOD_{675}		0.0113	0.0024	-0.0111	-0.0073	0.9229	22.5
	ILP new SVA	0.0156	0.0036	0.0152	0.0194	0.0665	2.4
AOD_{870}		0.0032	0.0011	-0.0029	-0.0012	0.9106	100.0
	ILP new SVA	0.0053	0.0015	-0.0051	-0.0030	0.9012	100.0
AOD_{1020}		0.0025	0.0015	-0.0020	-0.0004	0.6486	100.0
	ILP new SVA	0.0083	0.0020	-0.0080	-0.0054	0.6567	45.3
		0.0099	0.0018	-0.0097	-0.0072	0.6476	6.1
		0.0251	0.0056	0.0244	0.0317	0.0034	0.0
		0.0226	0.0052	0.0220	0.0288	0.0169	42.3
	ILP new SVA	0.0223	0.0051	0.0217	0.0285	0.0201	0.0

Conclusions

The datasets collected by the different types of sun-photometers that attended the FRC-VI campaign have been useful for suggesting improvements of the SUNRAD algorithm. In particular, the 1020 *nm* Prede channel should be regarded, requiring better temperature management. AOD comparisons involving UVEG Prede and Cimel #1144 retrievals yielded successful results, except for the aforementioned channel. On the other hand, the CNR-UVEG Prede comparison suggested that the CNR Prede dataset must be thoroughly examined, since AOD from days 2-3/10 significantly differ from the UVEG Prede. The agreements involving the PFR instrument were reasonably good, taking into account that the data used was not definitive and also did not belong to a PFR from the reference triad. Finally, by comparing the AOD of the UVEG Prede based on different calibration methods with the retrievals from Cimel #1144, it has been found that the degradation of the 340 *nm* channel affected the value of the other coefficients. Hence, the best agreement in AOD was found when this channel was excluded and the ILP method based on MRI was applied.

ACKNOWLEDGEMENTS:

This presentation is based upon work from COST Action HARMONIA, supported by European Cooperation in Science and Technology. The participation of M. Garcia-Suñer has been supported by the grant PREP2022-000658, associated to the Project ISLA (PID2022-138730OB-I00), and funded by the Spanish Science and Innovation Ministry. We also thank AERONET staff for their scientific and technical support.

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