Evaluation and advancement of the SKYNET Improved Langley Plot method in the Mediterranean area

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This presentation participates in OSPP

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Introduction

The Improved Langley plot method (ILP) is an on-site calibration method for calibrating the PREDE POM Sky radiometers. It was developed by Tanaka et al. (1986), Nakajima et al. (1996) and Campanelli et al. (2004) as an alternative to the Standard Langley plot (SLP) method. The ILP method was developed by modifying the SLP method: instead of assuming constant AOD over the measurement period at the site, AOD is treated as a variable. A least square fit is performed between the measured signal and the product of airmass and the scattering AOD. The calibration value is calculated from the y-axis intercept.

The calibration value obtained using this method is robust with small uncertainty: between 0.5-2.4 % at Tokyo and Rome (Campanelli et al., 2004; Nakajima et al., 2020). However, recent results from Karanikolas et al. (2024) and Campanelli et al. (2024) show some discrepancies in the ILP calibration values compared with the transfer from reference instruments such as PFR and CIMEL. The main aim of this study is to optimise the ILP method to reduce the involved uncertainties and increase the consistency.

Methodology

The ILP method uses an inversion algorithm to retrieve the scattering AOD, which is then used to calculate the calibration value as explained in Campanelli et al., (2004). Previously, Skyrad 4.2 (Nakajima et al., 1996) was used as an inversion algorithm, and the calibration values were obtained in a one-step process. In the current study, we replaced the Skyrad 4.2 with the latest Skyrad MRI v2 (Kudo et al., 2021) inversion algorithm. Additionally, we implemented an iterative approach which calculates the calibration value using multiple iterations, resulting in more accurate calibration values. Here we call this new calibration technique ILPU.

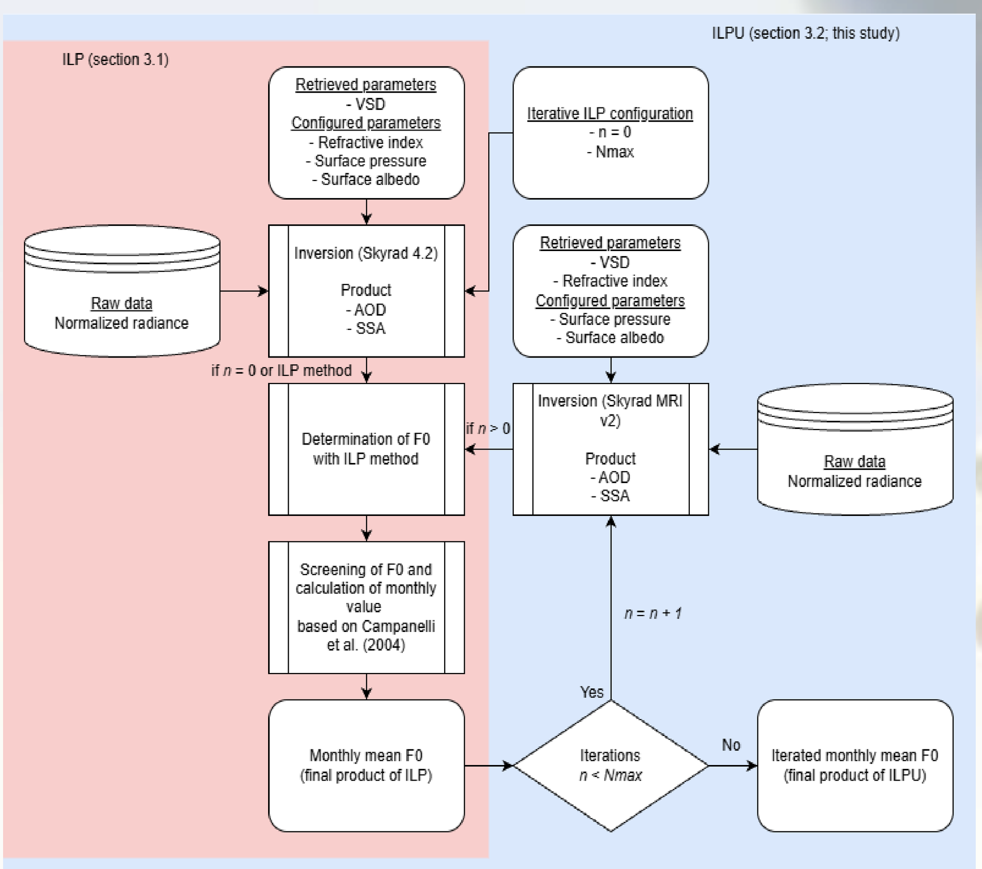

Figure 1: flowchart of the ILP and ILPU calibration technique

Sites

Figure 2: a) University of Sapienza, Rome, Italy b) University of Valencia, Burjassot, Spain

Data

Data type	Place	Site/Campaign	Duration (months)	Period
Radiance + direct Irradiance data	Rome (Italy)	Campaign (QUATRAM3)	1	Sep-21
Radiance + direct Irradiance data	Davos (Switzerland)	Campaign (QUATRAM2)	5	May - Sept 2019
Radiance + direct Irradiance data	Valencia (Spain)	Burjassot, Spain	12	Jan - Dec 2023

Table 1: - Datasets used in this study.

Results

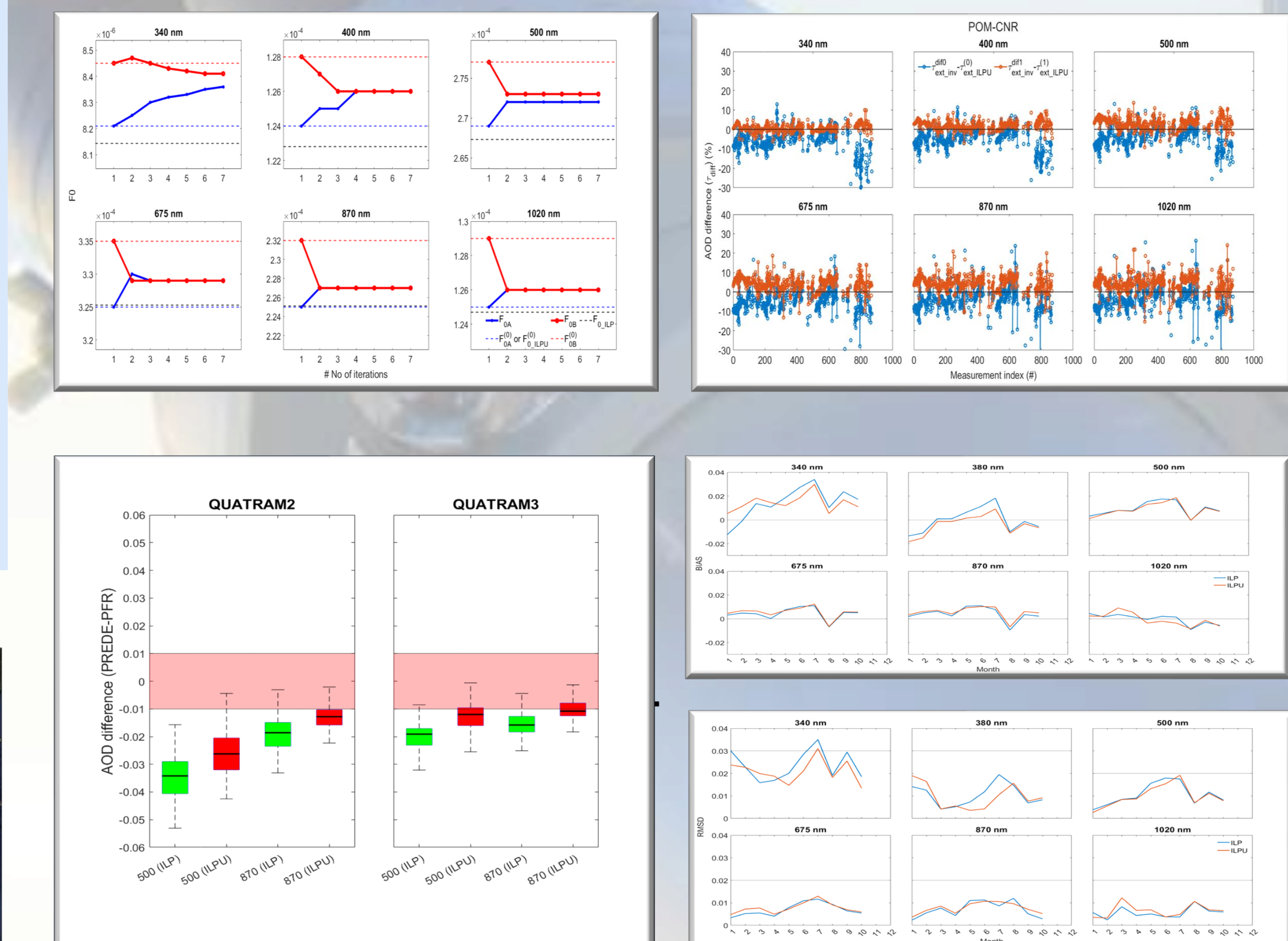

Figure 3: a) Convergence of the ILPU calibration after six iterations b) Consistency of the extinction AOD at the two stages: extinction AOD retrieved through inversion during the ILP and full inversion using the same ILPU calibration values. c) Comparison of the direct AOD between PFR and PREDE during QUATRAM 2 and 3 campaigns using ILP and ILPU calibration values. d) Monthly Bias and e) RMSD in Burjassot, at six common channels, namely 340, 380, 500, 675, 870 and 1020 nm.

Campaign	Year	Duration	No of data points	Points within WMO limits (%) (ILP)		Points within WMO limits (%) (ILPU)	
				500 nm	870 nm	500 nm	870 nm
QUATRAM II	2019	5 months	3806	0	11.7	2.5	41
QUATRAM III	2021	1 month	1221	2.3	14.7	43.5	58.5

Instrument	RMSD			MBD (AERONET-PREDE)			R^2			Calibration method
	675 nm	870 nm	1020 nm	675 nm	870 nm	1020 nm	675 nm	870 nm	1020 nm	
POM-CNR	0.0054	0.0037	0.0031	0.0042	0.0029	0.0025	0.99	0.99	0.99	ILP
POM-CNR	0.0035	0.0024	0.0019	-0.0002	0.0000	0.0003	0.99	0.99	0.99	ILPU
POM-UV	0.0045	0.0033	0.0029	0.0015	0.0009	0.0008	0.99	0.98	0.98	ILP
POM-UV	0.0044	0.0033	0.0028	-0.0007	-0.0006	-0.0003	0.99	0.98	0.98	ILPU

Wavelength	No of data points	Points within WMO limits (%) (ILP)	Points within WMO limits (%) (ILPU)
340	788	26	40
380	788	51	64
500	788	64	66
675	788	88	82
870	788	91	89
1020	787	90	89

Table 1: - a) Amount of PREDE data within the WMO limits for QUATRAM 2 and 3 campaigns when compared to PFR. b) Statistics of the comparison of the PREDE inversion extinction AOD and AERONET level 2 inversion extinction AOD. c) Amount of PREDE data within the WMO limits in Burjassot after the comparison with the AERONET level 2 extinction AOD.

Summary

In the present study, we successfully demonstrated that upgrading to the latest inversion algorithm, along with the new iterative technique, helps to increase the accuracy of the ILP calibration values.

- The stability of the calibration value was checked by doing a convergence test, where the calibration values obtained after six iterations showed convergence for all the wavelengths.
- The consistency of the extinction AOD was checked at two stages: during the inversion, during the ILPU calibration, and during a full inversion using the ILPU calibration values.
- The results showed the reduction in the standard deviation of the difference of the two extinction AODs.
- The discrepancies between the ILPU and transfer calibration were reduced by up to 1.3 %, lower than the discrepancy between ILP and transfer calibration in the previous studies.
- The comparison of the inversion AOD did not show many effects. Although there were tiny improvements in reduced MBD and RMSD, overall, the agreement between the PREDE and the AERONET level 2 data was very good and the R^2 was mostly 1 in both cases.
- We saw a significant improvement for both the QUATRAM campaign and the Burjassot direct AOD data. The median difference of the PREDE and PFR direct AOD was reduced, and the number of points within the WMO limits increased for both QUATRAM 2 and QUATRAM 3 data.
- The comparison of the AERONET level 2 direct AOD and PREDE at Burjassot also showed improvement. However , the improvement was pronounced for the shorter wavelengths, especially for wavelengths smaller than 500 nm. Although the RMSD and the MBD revealed a similar pattern, the number of points within the WMO limits rose by more than 10 per cent for both 340 and 380 nm

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Acknowledgements

The current analysis has been done in the frame of the COST Action CA21119 HARMONIA, supported by COST (European Cooperation in Science and Technology). The Spanish Ministry of Economy and Competitiveness also funded the research through project PID2022-138730OB-I00. The participation of Gaurav Kumar has been supported by the Santiago Grisolia program fellowship GRISOLIAP/2021/048. We thank AERONET, PHOTONS and SKYNET for their scientific and technical Support.