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

Action number: CA21119

Grantee name: Simone Pulimeno

Details of the STSM

Title: **Sun-photometers intercomparison campaign**

Start and end date: 06/05/2024 to 20/05/2024

Description of the work carried out during the STSM

During my arrival in Valladolid, and throughout the month of May, we were quite unlucky with the weather. Temperatures were below the average monthly value, and the cloud cover was persistent. Therefore, the photometer was deployed on the roof of the Science Faculty building of the University of Valladolid (41.66N, 4.70W, 710 m. asl), along with a CIMEL CE318 from the GOA and a PFR from the PMOD group, as planned. Originally, we used a NUC PC for the acquisition with the new version of the PREDE's software for Windows10, Skyradiometer2013Pro. However, after a few days of acquisition, despite the days not being ideal for solar photometry observations due to the presence of clouds, the raw signals registered by the instrument appeared strange in magnitude. Hoping to solve the problem, we decided to use a proven acquisition system used by the CNR in Italy with the PREDE, which uses a Lattepanda PC with a virtual machine running Windows XP and the older version of the software Skyradiometer_v4.11.

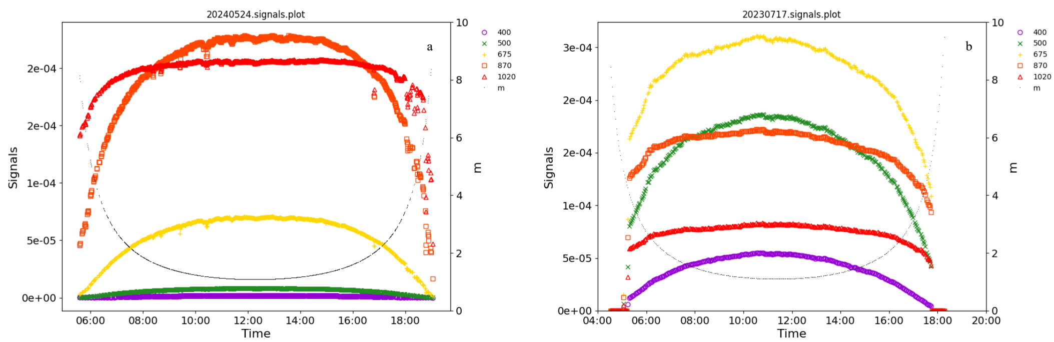

Figure 1 Raw signals measured by the PREDE POM02 at 5 wavelengths. The left panel shows signals at Valladolid on May 24th, 2024; the right panel shows signals recorded at Bologna (Italy) during a field campaign on July 17th, 2023. Black dots labeled as *m* in the legend represent the air mass.

[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.

We could not determine if the problem was due to the acquisition system or some mechanical components of the instrument, mainly because we did not have a clear sky day until the end of May. The first clear sky day was the 24th of May, with the signals shown in Figure 1a; it shows a comparison of raw signals between Valladolid 2024 and Bologna 2023 for the same wavelengths. Despite the different locations, with different coordinates and altitudes, we expected the signals to be of the same order of magnitude. Although the signals seem very different, it stands out that the channels at 400 and 500 nm appeared very flat due to the loss of 2 orders of magnitude, from 1e-04 to 1e-06. The channel at 675 nm also registered a loss of 1 order of magnitude, whereas the signals at 870 and 1020 nm seem greater than those acquired by the same channels in 2023.

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

The very first thing I tried to understand was if the signals at 400 and 500 nm were really flat or if they appeared so in Figure 1a because of the y-axis scale used for plotting. Therefore, I plotted the signals at the same 5 wavelengths using a log scale for the y-axis.

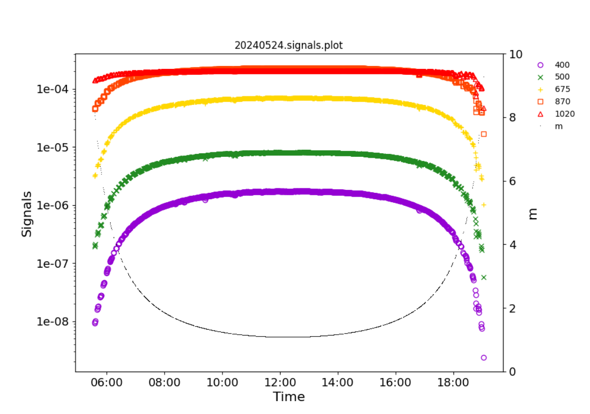

Figure 2 Raw signals recorded the 24th of May 2024 in Valladolid plotted using a log-scale on y-axis.

As seen in Figure 2, all the channels maintain their typical bell shape for the irradiances measured by directly pointing at the Sun. Since the Aerosol Optical Depth (AOD) recorded on May 24th in Valladolid appears fairly constant throughout the day, I decided to evaluate the solar calibration coefficients using the Langley method. I then compared these V_0 coefficients with those used in the 2023 campaign in Bologna (Table 1).

wl (nm)	Bol_23	Val_24	Val_corr_24
400	1.40e-04	4.16e-06	1.31e-04
500	3.58e-04	1.52e-05	3.15e-04
675	4.32e-04	1.18e-04	4.26e-04
870	2.80e-04	3.02e-04	2.00e-04
1020	1.99e-04	2.27e-04	2.28e-05

Table 1 Calibration coefficients retrieved by applying the Langley method for the 2023 campaign in Bologna (Bol_23), the Valladolid campaign using raw signals (Val_24), and the Valladolid campaign with amplification applied to all wavelengths (Val_corr_2024).

As seen in Table 1, the calibration coefficients measured in Valladolid (Val_2024) are significantly different from those retrieved in Bologna in 2023. The most notable variations affect the 400, 500, and 675 nm channels, and could be an indication of some fast filter's degradation process. On the other hand, the calibration coefficients at 870 and 1020 nm seem to be quite in line with those from 2023. Due to this notable dissimilarity in the other wavelengths, I decided to apply an amplification factor to the irradiance measurements recorded by the instrument.

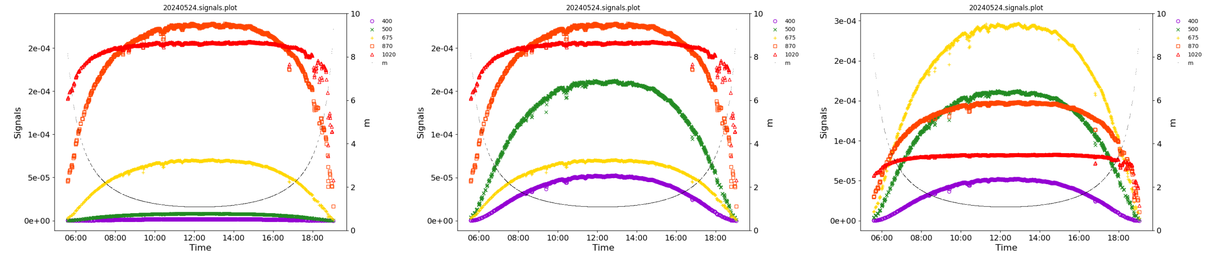

Figure 3 Signals recorded by the PREDE; left panel - raw signals measured the 24th of May 2024 in Valladolid with no modifications; central panel - amplification factor applied at 400 and 500 nm; right panel – amplification factor applied to all wavelengths to respect the expected magnitude of the signals.

To produce the central image in Figure 3, correction factors were applied only to the 400 and 500 nm channels, respectively 3e+01 and 2e+01. In an attempt to bring the magnitude of the signals back to the expected values, I also applied correction factors to the other channels: raw signals at 675 nm were multiplied by 0.35e+01, at 870 nm by 6.5e-01, and at 1020 nm by 1e-01. With these modifications, the magnitude of the signals appears closer to the expected values for the various wavelengths, making the last image in Figure 3 more similar to the image in Figure 1b. I then recalculated the calibration coefficients and added them to Table 1 (Val_corr_24), which now seem closer to those of the 2023 campaign.

Then, I investigate if it is still possible to calculate AOD using raw irradiances without any changes. I applied a personalized algorithm for evaluating AOD and Angstrom Exponent (AE), following the recommendations of WMO experts for intercomparison campaigns. Specifically, I retrieved AOD at 500 and 870 nm, using these channels to also evaluate AE, as they are largely free from absorption effects due to gases such as nitrogen dioxide and ozone. In this algorithm, the Rayleigh optical depth is calculated using the Bodhaine et al. (1999) formula, and the Rayleigh air mass factor is derived from Kasten and Young (1989), such as the other air masses for gases (H_2O, NO_2 and O_3). The absorption of ozone and nitrogen dioxide at various wavelengths is obtained from the US Standard Atmosphere 1976 textbook, with their concentrations provided by the TROPOMI sensor on Sentinel-5P satellite. These concentrations are compared with the outputs from the Global Modelling and Assimilation Office Composition Forecasts (GEOS-CF), which produces global 3D distributions of atmospheric composition with a spatial resolution of 25 km (see Figure 4).

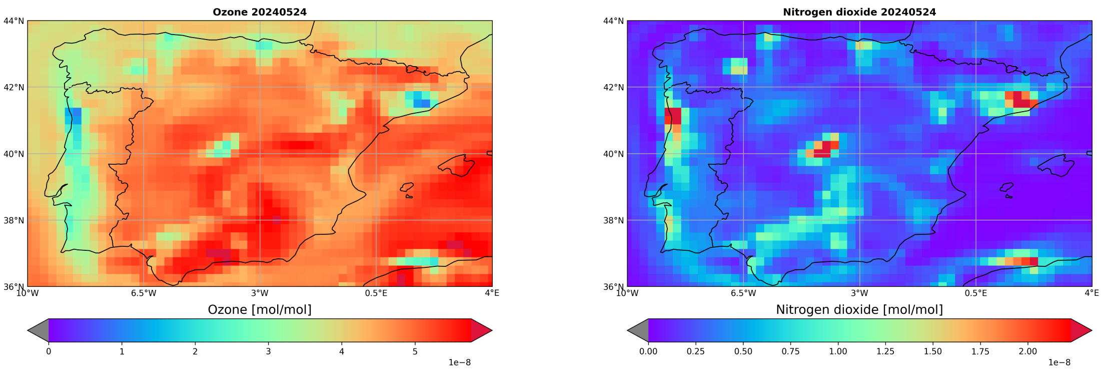

Figure 4 Ozone and Nitrogen dioxide concentration in the Iberian Peninsula on the 24th of May 2024 by using the GEOS-CF model (https://gmao.gsfc.nasa.gov/whether_prediction/).

Some channels (400, 500, and 675 nm) appear to have lost a significant amount of strength, but they still display the typical bell shape. However, the AODs retrieved from these raw signals were more than six times higher than those from AERONET (Figure 5). Specifically, the average AOD at 500 and 870 nm from AERONET was 0.068 and 0.033, respectively, with a standard deviation of 0.014 and 0.006. In contrast, the average AOD at the same wavelengths from PREDE was 0.429 and 0.229, respectively, with a standard deviation of 0.028 and 0.019.

I attempted to retrieve AODs using the calibration constants (Val_corr_24, Table 1) found by applying the Langley method to corrected raw signals. Unfortunately, these V0s proved to be unsuitable for this process.

The next step in this work involves transferring the calibration constants from CIMEL master instruments to PREDE following Campanelli et al. (2023). With these new V0s, we will attempt to retrieve aerosol optical thickness again. Simultaneously, visual checks will be conducted on the instrument during the acquisition phase to identify any issues with the filter wheel. Given the challenges encountered during the campaign, the primary focus of this STSM will shift towards another objective: determining whether it is still feasible to obtain high-quality AODs using signals acquired by the instrument after the transmissivity of filters has dropped significantly, aligning with the objectives of WG2.

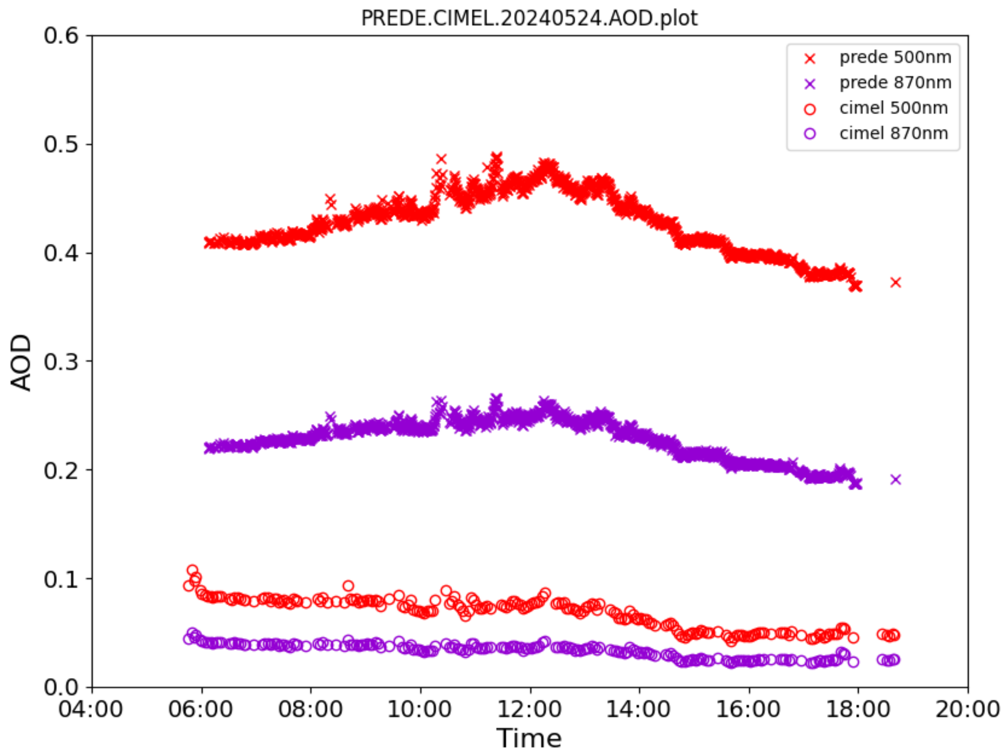

Figure 5 Comparison between AODs retrieved by AERONET for CIMEL and by our algorithm for PREDE, both at 500 and 870 nm, on the 24th of May 2024 in Valladolid (Spain).