ATMO ACCESS
Access to Atmospheric Research Facilities

Activity report of the TNA to ATMO-ACCESS research infrastructures

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TNA title and acronym: Lidar data in a Radiative Transfer model for dust direct radiative effect estimation and evaluation against solar measurements (LiRTaSoM)

Facility/ies accessed: EVASO

This work has received funding from the European Union's Horizon 2020 research and innovation programme through the ATMO-ACCESS Integrating Activity under grant agreement No 101008004

Is the information provided in the report confidential and should not be made available on the ACTRIS website?

✖ No, the information can be made public.

Yes, the information should not be made public and access should be restricted to the TNA Team, the ATMO-ACCESS access providers, the reviewers concerned and the ATMO-ACCESS Strategic TNA Board.

Table of Contents

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1. Short executive summary (can be made available to reviewers and EU experts)

The project's main objective is to acquire expertise in implementing continuous polarised Micro-Pulse Lidar (P-MPL) measurements into the Radiative Transfer model LibRadTran for dust Direct Radiative Effect (DRE) estimation. In order to validate the input scheme introduced in the model, the derived downward radiation outputs were compared against EVASO solar measurements for two study cases: clean conditions (with rather low aerosol content in the atmosphere) and dusty conditions (during a Saharan dust outbreak over the station). Thus, simultaneous INTA P-MPL and EVASO solar radiation measurements were performed for one week.

In light of the outcomes, the training was completed successfully, allowing the implementation of the LibRadTRan model (by using the P-MPL measurements as one of the inputs) at the institution of the user.

2. User group

Complete the table with details of the user group members who actually accessed the Facility. Duplicate the table below for each member of the user group.

Information on the User group members	
Member # 1	
First and last name	María Ángeles López Cayuela
Gender	✖ Female Male Prefer not to say
Nationality	Spanish
Profile	Undergraduate ✖ Postgraduate Expert scientist Engineer, Technician Other:
Field of activity	✖ ENV-ATMO - Earth and environmental sciences/Atmospheric domain ENV-HYDRO - Earth and environmental sciences/Hydrosphere domain ENV-LITHO - Earth and environmental sciences/Lithosphere ENV-ECOBIO - Earth and environmental sciences/Eco-biosphere PHY - Physics astronomy, astrophysics and mathematics CHEM - Chemistry and material sciences BIO-MED - Biological, medical sciences and biotechnology ENG-TECH - Engineering and technology EGY - Energy ART - Humanities and arts ISC - Information science and communication SOC - Social sciences
Are you a new user?	✖ Yes

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	No	
Institution name (employer)	Instituto Nacional de Técnica Aeroespacial (INTA)	
Institution legal status (employer)	✖ Public research (including international research organizations and private research organization controlled by a public authority) University and higher education Public authority Small Medium Enterprise (SME) Other industrial and/or profit private organization Other	
Address (employer)	Torrejón de Ardoz, 28850 Madrid	**Country** Spain
Email address	lopezcma@inta.es	
Access start date	11/07/2022	**Access end date** 17/07/2022

3. Scientific objectives

In the climate change context, atmospheric aerosol particles play a significant role due to their optical and microphysics properties and spatial distribution. Mineral dust is the most abundant aerosol in the atmosphere and its climatic implications are widely investigated, but large uncertainties in estimating both the dust direct and indirect radiative forcings remain. The dust direct radiative effect (DRE) has been investigated in both short- and long-wave spectral ranges, underestimating the radiative contribution of the fine mode of dust particles (DF) within the dust outbreaks. Moreover, the vertical impact of dust particles is also an added value in the DRE estimation by considering the vertical contributions of fine and coarse (DC) modes separately, and it is worth performing a deeper study, as only a few works have focused on this topic to date (e.g., Sicard et al., 2014; Córdoba-Jabonero et al., 2021; Sicard et al., 2022).

The Spanish Institute for Aerospace Technology (INTA) manages the atmospheric station El Arenosillo at Huelva (ARN, SW Spain), an AERONET/MPLNET site which participates in ACTRIS projects. Due to their exceptional situation for the first Saharan dust detection over the Iberian Peninsula, one of the main scientific fields performed is the vertical impact of aerosol particles and clouds in the atmosphere, especially on the study of mineral dust and its radiative effect. The polarized Micro-Pulse lidar (P-MPL) as deployed at ARN is an elastic system that includes polarisation capabilities.

The main objective of this TNA is to acquire expertise in the use of the LibRadTran Radiative Transfer (RT) model (Mayer and Kylling, 2005), by using the P-MPL measurements as one of the inputs of the model. The radiative outputs obtained could be compared with the short-wave (SW) solar radiation instrumentation deployed at the facility.

4. Reasons for choosing the Facility/ies

The EVASO-TNA, managed by the Institute of Earth Sciences/Evora University (ICT-UE) in Portugal, was selected not only for their high-qualified expertise in active/passive remote sensing techniques (EARLINET lidar, photometers, radiometers) and skills in RT modelling; but also, for its participation in numerous research campaigns and national/international projects on the study of Saharan dust and its radiative effect. Both EVASO and El Arenosillo are similarly influenced by the arrival of Saharan dust intrusions, sharing similar atmospheric conditions. Hence, results obtained in both stations could be comparable.

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5. Activities during the TNA (research, training, events, ...)

Training about the LibRadTran Radiative Transfer model was performed, in terms of: 1) configuration of the model inputs by the implementation of the P-MPL measurements into the model; and 2) application to relevant cases (clean and dusty conditions) both historical and measured during the TNA activity. In addition, a discussion of the results was performed.

6. Method and set-up of research

The P-MPL lidar was deployed at EVASO regarding a two-fold exercise: 1) collecting measurements simultaneously with EVASO SW solar radiation instrumentation, and 2) performing the implementation of those lidar measurements into the LibRadTRan model as input data, and evaluating its radiative outputs with the SW radiation measurements of the facility.

Both Klett-Fernald retrievals (Fernald, 1984; Klett, 1985) and POLIPHON (Polarisation Lidar PHOtometer Networking; Mamouri and Ansmann, 2014, 2017) methods were used in combination with the P-MPL measurements to derive the elastic extinction coefficient. More details about this methodology can be found in Córdoba-Jabonero et al. (2021). Those coefficients, together with AERONET L1.5 asymmetry factor, single scattering albedo, Angström exponent, water content and ozone concentration were used as inputs of the model.

On one hand, to validate the SW downward irradiance given by the model with those given by the EVASO radiometer, 2 case studies were chosen:

a) ***Clean conditions***. During the TNA activity, no clean conditions were found. Thus, the day of 20 February 2022 was chosen, with a daily-mean aerosol optical depth at 500 nm ($\overline{AOD^{500}}$) of 0.04. As no P-MPL measurements were available, only AERONET L1.5 values were used as input for the model.
b) ***Dusty conditions***. During the TNA activity, a dust outbreak over EVASO was observed. The cloudy conditions prevented most of the lidar retrievals, thus the clear days 10 and 11 July 2022 were chosen as a case study, with $\overline{AOD^{500}}$ of 0.28.

On the other hand, the DRE of the dust outbreak was obtained, and calculated at a given height level L, as:

$$\mathrm{DRE(L)} = \left[\mathrm{F_d^{\downarrow}(L)} - \mathrm{F_d^{\uparrow}(L)}\right] - \left[\mathrm{F_0^{\downarrow}(L)} - \mathrm{F_0^{\uparrow}(L)}\right], \quad [1]$$

where F_d and F_0 are the radiative flux values with and without dust, and the ↓ and ↑ arrows indicate whether the fluxes are downward or upward, respectively. The dust contribution in the atmospheric column is quantified by the atmospheric (ATM) radiative effect defined as follows:

$$\mathrm{DRE(ATM)} = \mathrm{DRE(TOA)} - \mathrm{DRE(BOA)}, \quad [2]$$

where TOA and BOA refer to the top and bottom of the atmosphere, respectively.

7. Preliminary project results and conclusions

Figure 1 shows the comparison between hourly-averaged downward irradiance measurements and simulated values for clean (Fig. 1a) and dusty cases (Fig. 1b). Under both conditions, the slope and the correlation coefficients are near to one; however, the LibRadtran model slightly overestimates the experimental irradiance measurements. The mean values of the relative differences are ∼1% and ∼2% for the clean and dusty cases, respectively. Those differences could be related to either uncertainty in the input

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values given to the model or experimental errors in the instrumentation used. It can be concluded that the outputs of the model are reliable, by using the methodology applied (see Sect. 6).

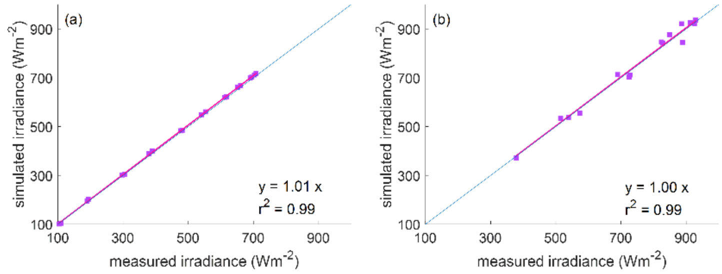

Figure 1. Comparison of the irradiance measured by an EVASO radiometer against the irradiance simulated by LibRadTran in (a) clean conditions and (b) dusty conditions.

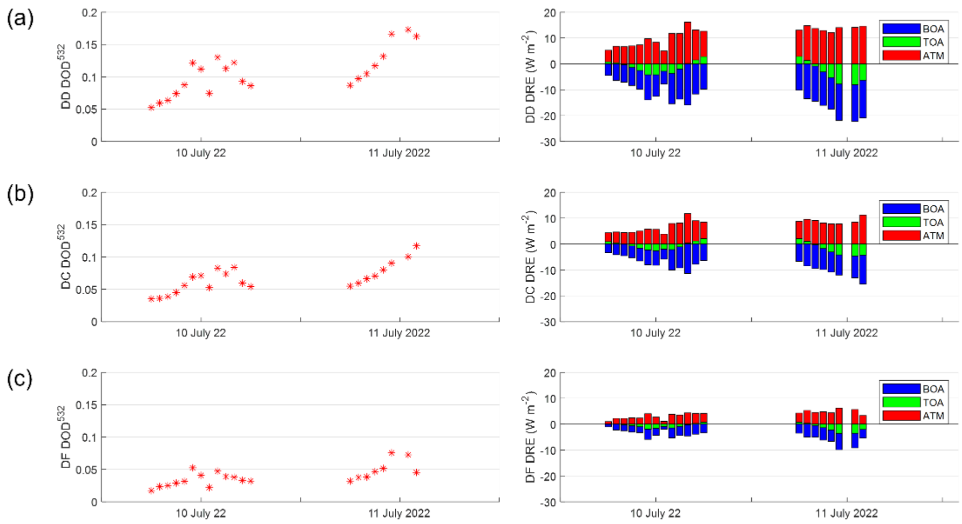

Figure 2. (Left) Hourly-mean dust aerosol optical depth at 532 nm (DOD^{532}) together with (Right) dust direct radiative effects (DRE) on the surface (BOA) (blue), TOA (green), and in the atmosphere (red) for (a) the total dust (DD), (b) dust coarse (DC) and (c) dust fine (DF) on 10 and 11 July 2022.

Figure 2 shows the hourly-averaged total dust (DD), DC and DF dust optical depth at 532 nm ($\overline{DOD^{532}}$) for the dusty cases, together with the DRE at the BOA, TOA and ATM. The $\overline{DOD^{532}}$ was low at the beginning of the dust outbreak (10 July 2022), with values ranging from 0.05 to 0.13, increasing to 0.18 on 11 July 2022. It should be noted that, on average, DF particles represented 40% of the DD particles. As expected, the dust produces a warming in the atmosphere (red bars are positive) and a cooling effect on the BOA and TOA. On average, DD, DC and DF DRE(ATM) show values of $10.9 \pm 3.5\ Wm^{-2}, 7.3 \pm 2.3\ Wm^{-2}$ and $3.7 \pm 1.4\ Wm^{-2}$, respectively. Regarding the BOA, DD, DC and DF DRE(BOA) values of $-13.0 \pm 5.0\ Wm^{-2}, -8.4 \pm 3.1\ Wm^{-2}$ and $-4.6 \pm 2.2\ Wm^{-2}$ were computed, respectively, being those found at the TOA almost 85% lower in comparison.

8. Outcomes and future studies

This TNA was an opportunity to strengthen bonds between INTA and EVASO with the consequent collaboration in future studies. Moreover, this training was useful in the frame of my PhD studies, which are related to the characterization of the optical/microphysical properties and radiative impact of mineral dust in planetary atmospheres using active and passive remote sensing observations.

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Before the TNA stay, a work about an intense dust outbreak over the Iberian Peninsula was performed (López-Cayuela et al., 2022; in revision), regarding their optical and microphysical properties. Thanks to this training in the LibRadTran model, that study could be extended to calculate the DRE of dust particles by considering the vertical contributions of fine and coarse modes separately.

9. Plans for publications

The results are planned to be disseminated in ACTRIS meetings (e.g. ACTRIS Week) and Cost Actions meetings such as PROBE, HARMONIA and CLEAN FOREST. Other international conferences considered are EAC2023, ELC2023, WLMLA2023, EMS2023 and ISAARS2023.

On the other hand, the final results from this project are expected to be published at least in a scientific article (Q1 JCR, such as Atmospheric Chemistry and Physics or Science of the Total Environment).

10. References

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