Report on the outcomes of a Virtual Mobility[1]

Action number: CA21119 HARMONIA

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Virtual Mobility Details

Title: Assessing satellite-based PBL dust PM trends on the basis of ground-based PhotoMeter measurements over Megacity areas for Air Quality (PMs4AQ).

Start and end date: 20/09/2024 to 10/10/2024.

Description of the work carried out during the VM

Description of the virtual collaboration and activities carried out during the VM, with focus on the work carried out by the grantee. Any deviations from the initial working plan shall also be described in this section.

(max. 500 words)

Among the aerosol species, dust plays a key role in the Earth's climate system, affecting anthropogenic activities as well as human health. More specifically, according to recent epidemiological studies airborne dust is related to several negative disorders induced on human health, ranging from mild skin irritation, to allergic responses, cardiovascular and respiratory diseases, even to pandemic outbreaks.

Recently Proestakis et al. (2024) established on the basis of satellite Earth Observations (EO) the four-dimensional structure of the sub-micrometer and super-micrometer components of atmospheric dust. The established EO-based Climate Data Record (CDR) includes monthly-mean profiles of extinction coefficient at 532 nm and mass concentration profiles for the two modes at $1^{o}x1^{o}$ spatial resolution at a near-global scale. On the basis of the established EO-based fine-mode and coarse-mode dust products, the VM approached the scientific question to what extent satellite-based observations can be employed in order to assess PBL dust AOD/PM1 changes over megacities of the Earth and whether it is feasible to identify robust trends.

Towards addressing the aforementioned VM scientific question, validation/evaluation activities are of paramount importance to be carried out, in order to ensure the reliability, accuracy, and credibility of the outcomes and

[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.

conclusions. Towards this objective, in the framework of the VM AERONET $AOT_{coarse\text{-}mode}$ and $AOT_{fine\text{-}mode}$ at 500 nm products were employed as reference. More specifically, intercomparison between AERONET as reference and EO-based products was performed, aiming to assess and enhance the reliability of EO-based $DOD_{coarse\text{-}mode}$ and $DOD_{fine\text{-}mode}$ and PBL $MC_{coarse\text{-}mode}$ and PBL $MC_{fine\text{-}mode}$ products and time-series. The intercomparison and the establishment of the methodology was performed for the study-case of Beijing - China megacity.

Towards this intercomparison several intermediate actions were undertaken. More specifically, the originally established by Proestakis et al. (2024) fine-mode and coarse-mode CDR was provided on averaged monthly-mean profiles of backscatter coefficient at 532 nm, extinction coefficient at 532 nm, and mass concentration profiles of $1^o x 1^o$ deg^2 grid spatial resolution, based on CALIPSO V4.2 aerosol profiles between 06/2006 and 12/2021. In the framework of the VM the CDR was updated to CALIPSO V4.5. In addition, the spatial and temporal resolutions of the original CDR in Proestakis et al. (2024) were modified. More specifically, all CALIPSO overpasses in the proximity of the Beijing megacity area, within radius of 100 km and for the period 06/2006-07/2023 were processed and mean dust, fine-mode dust, and coarse-mode dust mass concentration profiles were established in seasonal-mean temporal resolution.

Following the performed intercomparison between the time-series of the EO-based based $DOD_{coarse\text{-}mode}$ and $DOD_{fine\text{-}mode}$ and PBL $MC_{coarse\text{-}mode}$ and PBL $MC_{fine\text{-}mode}$ products and AERONET $AOT_{coarse\text{-}mode}$ and $AOT_{fine\text{-}mode}$ at 500 nm products as reference for the study-case of the megacity of Beijing-China, all products despite the inherited differences related to the sensors and techniques, demonstrated similar trends and significance, enhancing the reliability of the conclusions. As such, the VM provided a solid basis to expand the approach to the megacities of the Earth, aiming to address and better understand the dust related induced disorders on human.

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

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

(max. 500 words)

In terms of degradation of Air Quality (AQ), crucial determining factor related to induced negative health effects in humans is the concentration of airborne particulate matter (PM). PM is typically categorized into three classes: PM_{10} (coarse), $PM_{2.5}$ or PM_1 (fine), and $PM_{0.1}$ (ultrafine classes), which correspond to particles with aerodynamic diameters of ≤10 μm, ≤2.5 μm or ≤1.0 μm, and ≤0.1 μm, respectively (WHO Air Quality Guidelines). Several epidemiological research studies have established a strong correlation between elevated concentrations of airborne dust and negative health disorders. Generally, the health risks associated with coarse-sized mineral particles, around 10 μm or larger, are considered low, primarily resulting in mild skin irritation or allergic reactions, even in cases of high dust concentration and prolonged exposure. In contrast, PM_1 particles, due to their small size, can penetrate deeply into the lungs and alveoli, leading to allergic responses, cardiovascular issues, respiratory diseases, cancer, even to meningitis pandemic outbreaks. In the context of mineral dust, extensive experimental studies utilizing airborne in-situ instrumentation have characterized dust particle size distributions (PSD), reporting spanning from 0.1 μm to over 100 μm in diameter.

Proestakis et al. (2024) established on the basis of satellite Earth Observations (EO) the four-dimensional structure of the sub-micrometer and super-micrometer components of atmospheric dust. On the basis of the established EO-based fine-mode and coarse-mode dust products, the VM approached the scientific question to what extent satellite-based observations can be employed in order to assess PBL dust AOD/PM_1 changes over megacities of the Earth and whether it is feasible to identify robust trends.

The main outcomes of this VM grant are the following two:

1) Updated and upgraded CDR of the fine-mode and coarse-mode dust aerosol components, allowing the database to be utilized in the framework of assessing the inhalable component of dust in megacities areas and assessing the corresponding AQ degradation.

More specifically, the originally established by Proestakis et al. (2024) fine-mode and coarse-mode CDR provides averaged monthly-mean profiles of backscatter coefficient at 532 nm, extinction coefficient at 532 nm, and mass concentration at $1^{o}x1^{o}$ deg^2 grid spatial resolution, based on CALIPSO V4.2 aerosol profiles between 06/2006 and 12/2021. In the framework of the VM the CDR was updated to CALIPSO V4.5. In addition, the spatial and temporal resolutions of the original CDR in Proestakis et al. (2024) were modified. More specifically, all CALIPSO overpasses in the proximity of the Beijing megacity area, within radius of 100 km and for the period 06/2006-07/2023 were processed and mean dust, fine-mode dust, and coarse-mode dust extinction coefficient at 532 nm and mass concentration profiles were established in seasonal-mean temporal resolution.

2) Establishment of an evaluation approach to the scientific question to what extent satellite-based observations can be employed in order to assess PBL dust AOD/PM_1 changes over megacities of the Earth and whether it is feasible to identify robust trends.

More specifically, intercomparison between AERONET observations as reference and EO-based products was performed, aiming to assess and enhance the reliability of EO-based $DOD_{coarse\text{-}mode}$ and $DOD_{fine\text{-}mode}$ and PBL $MC_{coarse\text{-}mode}$ and PBL $MC_{fine\text{-}mode}$ products and time-series. The intercomparison was performed for the study-case of Beijing - China megacity. The carried-out evaluation activities and results established the accuracy and credibility of the outcomes. Following the performed intercomparison for the study-case of the megacity of Beijing-China, all products despite the inherited differences related to the sensors and techniques, demonstrated similar trends and significance, enhancing the reliability of the conclusions. As such, the VM provided a solid basis to expand the approach to the megacities of the Earth, aiming to address and better understand the dust related induced disorders on human health.

Overall, "PMs4AQ" is fully aligned with the COST HARMONIA WG3 - "End user engagement towards maximizing aerosol measurement use" objectives. More specifically, "PMs4AQ", through the extensive implementation of sunphotometer measurements and products facilitates improvements on the capacity of Earth Observations (WG3-T3.1) to translate observations into geoinformation, and more specifically in the field of Air Quality (WG3-T3.2). Moreover, the present work investigated and reported on the uncertainties of the present EO-based CDR products (WG3-T3.3). "PMs4AQ" through the intercomparison between EO-based and sunphotometer products assessed the uncertainty of the intercompatibility of aerosols data sets, directly affecting satellite-based applications with respect to aerosols and impact on health and air quality. The VM supported communication and networking between the ground based-measurement photometry community and the satellite aerosol scientific community through enhancing the link among scientists dealing with surface-based and satellite-based aerosol properties. In addition, the VM created added value through enhancing existing and ongoing projects (e.g. ESA-LIVAS and AXA-EO4AQ-DustFM) and further supporting developments and novel applications, such in the case of the "PMs4AQ" the relation between aerosols and degradation of Air Quality. VM has facilitated better knowledge on the aerosol amounts in terms of dust residing into PBL over the Beijing megacity with the methodology feasible to be extrapolated to other study cases, thus satellite data are made more valuable thanks to photometry, since photometry is a validation base for the EO based products.

Upon implementation of the established evaluation methodology on the outcomes of addressing the scientific question related to what extent satellite-based observations can be employed in order to assess PBL dust AOD/PM_1 changes over the Beijing-China megacity and addressing whether it is feasible to identify robust trends, the outcomes will be expanded to cover more megacities of the Earth. The conclusions will be disseminated in a form of a scientific publication in a peer review journal. Moreover, the VM outputs will be presented and disseminated to the broader scientific community in a specialized conference (e.g. EGU2025, COMECAP) in order to increase the activity's outreach.