HARMONIA
International network for harmonization of atmospheric aerosol retrievals from ground based photometers

HARMONIA CA21119

Deliverable 3.1b

Minutes of the 2nd Harmonia Workshop Aerosol data users and applications

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Harmonia Workshop on aerosol data users and applications

Meeting Agenda

Dates: 16th and 17th June, 2025

Hosted by: ERATOSTHENES Centre of Excellence

CUT Tassos Papadopoulos Building, Themidos 1, Limassol 3036, Cyprus

Agenda

Day 1	**16.06.2025 Harmonia COST Action Workshop day 1**	
9 - 9.10	Welcome and Harmonia Introduction	Rodanthi Mamouri and Stelios Kazadzis
9.10 - 9.30	Solar radiation/energy forecasting	Stelios Kazadzis
9.30 – 10	Solar resource and forecasting: the challenge of retrieving aerosol and cloud properties from all-sky imagers	Andreas Kazantzidis
10 - 10.20	Destination Earth / Renewable Energy case	Rizos Chadoulis
10.20 – 11	***break***	
11 - 11.30	Modeling dust mineralogy and radiative transfer in METAL-WRF	Stavros Solomos
11.30 -12	Satellite based dust climatologies	Antonis Gkikas
12 - 12.30	Dust observations in the thermal IR	Sophie Vandenbusche
12.30 – 14	***Lunch***	
14.00 - 14.30	WG3 objectives and goals	Harmonia WG3 leaders
14.30 - 16.30	in person and online WG3 discussions	Harmonia WG3 leaders
17-18	Visit at CARO Actris Station	

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Day 2	**17.06.2025 Atarri Theory and discussions**	
9 - 9.20	Solar measurements at ECoE	Georgia Charalambous
9.20 - 9.40	UV climatologies	Ilias Fountoulakis
9.40 – 10	Aerosol and radiation measurements at the Lampedusa Climate Observatory: from satellite validation to solar energy production	Daniela Meloni
10 - 10.30	The Dust Marie Curie Doctoral Network	Franco Marenco
10.30-10.40	Solar projects on Dust DN	Stelios Kazadzis
10.40 -11	Break	
11 - 11.45	PV applications	Miguel Brito
11.45 - 12.30	Learnings from e-shape H2020 on urban PV applications	Rodrigo Amaro
12.30 - 13.30	***Lunch***	
14.30 - 15.00	Earth Care validation aspects / Stelios Actris EG SAT objectives	Eleni Marinou & Stelios Kazadzis
15.00 - 15.15	The Thessaloniki campaign for Earth Care	Stelios Kazadzis
15.15 - 15.35	The P4Cv twining experience	Marinou Eleni
15.35 - 16.00	ECoE project on Earth Care validation	Rodanthi Mamouri
Break	Discussion on Earth Care potental involvement of ECoE	

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MINUTES OF THE HARMONIA WORKSHOP ON AEROSOL DATA USERS AND APPLICATIONS

Dates: 16–17 June 2025 (hybrid event)
Location: Limassol, Cyprus
Host: ERATOSTHENES Centre of Excellence

1. Introduction

The workshop was organized under the framework of COST Action CA21119 – HARMONIA, with a focus on enhancing end-user engagement, improving data quality, and advancing the integration of aerosol observations into applied sectors such as energy, climate modeling, satellite validation, etc. The workshop was conducted in a hybrid format, allowing for both in-person and remote participation.

On May 16 and 17 2025, 13 participants attended the workshop online (Teams) – Rodanthi Rlisavet Mamouri, Sophie Vadenbussche, Flori Toanca, Robert Tubbs, Anna Moustaka, Maja Kuzmanoski, Franco Marenco, Angelos Karanikolas, Kelly Voudouri, Ioanna Tsikoudi, Eleni Marinou, George Kotsias, Dimitra Kouklaki. A total of over 31 participants, including international experts, early-career researchers, and representatives from major European research infrastructures such as ACTRIS, AERONET, and satellite validation programs.

The two-day agenda included a series of expert presentations, technical discussions, collaborative planning for future deliverables, and a site visit to the CARO ACTRIS station. Day 1 focused on applications of aerosol data in forecasting, solar energy, dust modeling, and remote sensing innovations, while Day 2 featured UV climatology, campaign overviews, satellite validation discussions, and cross-sector collaboration opportunities.

Special attention was given to Working Group 3 (WG3) priorities, including the preparation of deliverables D3.1b, D3.2 (user requirements report) and D3.3 (white paper on photometric accuracy), both of which will be informed by the discussions and feedback gathered during the workshop.

2. Workshop Presentations – Day 1, June 16th, 2025

Welcome and Harmonia Introduction, SPEAKERS: RODANTHI MAMOURI (ERATOSTHENES CENTRE OF EXCELLENCE) AND STELIOS KAZADZIS (PMOD/WRC)

The workshop commenced with welcoming remarks from Dr. Rodanthi Mamouri (ERATOSTHENES Centre of Excellence) and Dr. Stelios Kazadzis (PMOD/WRC), who introduced the overarching objectives of the HARMONIA COST Action CA21119. They outlined the initiative's vision to strengthen collaboration across disciplines and institutions focused on aerosol research and applications.

PRESENTATION 1: SOLAR RADIATION/ENERGY FORECASTING, STELIOS KAZADZIS

Dr. Stelios Kazadzis opened the sessions of the 2nd Harmonia Workshop with a presentation on the critical role of solar energy forecasting in supporting climate goals and energy system efficiency. He explained that solar energy is inherently variable and weather-dependent, making accurate forecasting essential for reducing storage needs, optimizing the operation of solar power plants, and ensuring supply-demand balance in electricity grids. As he noted, reliable forecasts also contribute to minimizing infrastructure costs and enhancing energy market performance. Dr. Kazadzis outlined the main types of forecasting, distinguishing between short-term (minutes to hours) forecasts, which are vital for real-time PV grid management; medium-term (day-ahead) forecasts, used for market bidding and daily planning; and long-term (weeks to months) forecasts, which inform seasonal planning and capacity assessments. He emphasized that forecasting presents methodological challenges, particularly in modeling atmospheric components such as clouds and aerosols—key attenuators of solar radiation. The presentation stressed the importance of accurately quantifying Global Horizontal Irradiance (GHI) and Direct Normal Irradiance (DNI) for the deployment of technologies like photovoltaic systems and concentrated solar power. Dr. Kazadzis showcased tools developed under EU-funded projects such as NextSENSE and GEO-CRADLE, which enable real-time estimation and short-term forecasting of solar radiation using satellite and model data. These tools can process up to 1.5 million pixels in just two minutes, making them suitable for highly localized energy management. He highlighted the integration of aerosol data from CAMS (Copernicus Atmosphere Monitoring Service) and AERONET for improving forecast accuracy. In terms of model evaluation, Dr. Kazadzis emphasized the role of ground-based observations—such as those from BSRN stations—in validating model performance. He introduced metrics like the Cloud Modification Factor (CMF) and cloud motion vectors as essential tools for assessing forecast reliability. He also discussed ongoing improvements in aerosol forecasting for 1–2-day horizons through the fusion of AERONET observations, climatological data, and CAMS model output. Despite advancements, he acknowledged that aerosol attenuation remains one of the key uncertainties in solar radiation prediction.
Finally, Dr. Kazadzis pointed to the growing role of machine learning and probabilistic forecasting methods as promising directions to manage the spatial and temporal variability of atmospheric conditions. These tools, he concluded, are essential for delivering accurate and actionable forecasts that support both operational energy management and strategic planning.

***Question**:* What is the time consuming for the calculations? What is the granularity of the time?
Answer: The main problem is to transform solar radiation to actual energy. There is a tool for this.

PRESENTATION 2: SOLAR RESOURCE AND FORECASTING: ALL-SKY IMAGER CHALLENGES, ANDREAS KAZANTZIDIS

Dr. Andreas Kazantzidis presented innovative research on the use of All-Sky Imagers (ASIs) for solar resource assessment and short-term forecasting. He explained that ASIs provide rich visual information about sky conditions and are increasingly used to derive key atmospheric parameters such as Aerosol Optical Depth (AOD), cloud properties, and Direct Normal Irradiance (DNI). However, he noted that image-based measurements are inherently sensitive to calibration accuracy, environmental conditions, and the complexity of cloud formations. Dr. Kazantzidis introduced the "DeepSky" framework, a machine learning-based system designed to retrieve AOD at multiple wavelengths (440, 500, and 675 nm), the Ångström Exponent (AE), and DNI estimates. These retrievals were validated against AERONET data, demonstrating a high correlation, especially for DNI (R^2 = 0.90), under clear-sky conditions. The presentation also highlighted the development of a comprehensive dataset comprising over 7,000 annotated all-sky images, used to classify seven distinct cloud types through advanced computer vision techniques. The classification process involves segmenting the sky dome into 36 blocks and processing each individually, allowing for more granular and accurate identification of sky conditions. A prototype low-cost station was also presented, integrating commercial visible and infrared (IR) cameras. This system is capable of estimating cloud cover and types, retrieving Precipitable Water (PW) via thermal zenith temperature, and providing near-real-time estimates of DNI and Global Horizontal Irradiance (GHI). Dr. Kazantzidis emphasized that such systems could significantly reduce the costs associated with ground-based atmospheric measurements while maintaining reasonable accuracy. Another area of focus was the 3D reconstruction of cloud structures, aimed at improving the prediction of short-term fluctuations in irradiance, known as ramp events, which are critical for photovoltaic (PV) control systems. However, several technical challenges were identified. These include calibration drift in ASI sensors, limited generalization of models across different environments, distortion near the horizon (edge-of-field), the need for fast real-time image processing pipelines, and difficulty in handling mixed sky conditions with simultaneous cloud and aerosol presence. Looking ahead, Dr. Kazantzidis outlined promising future directions for the field. These include multimodal data fusion—combining ASI data with satellite, lidar, and numerical weather model outputs—alongside the adoption of advanced deep learning techniques, such as transitioning from traditional CNNs to Transformer-based models for improved temporal cloud behavior analysis. He also highlighted the potential of edge computing using compact AI hardware (e.g., NVIDIA Jetson) for on-site predictions, and transfer learning to adapt models to new locations with minimal training data. Finally, he stressed the importance of developing interpretable and probabilistic forecasting frameworks to support real-time decision-making.
In summary, Dr. Kazantzidis underscored that while challenges remain—particularly under mixed atmospheric conditions—All-Sky Imagers represent a scalable, cost-effective, and promising technology for ground-based solar radiation monitoring. Continued advances in machine learning, sensor integration, and operational deployment strategies are paving the way toward more accurate and standardized solar forecasting systems across diverse environments.

Question: Do you foresee any future developments regarding the participation of cloud formation in your research focus?
Answer: Yes, absolutely. A significant part of our future work will focus on understanding how urban environments influence cloud formation processes. Following established scientific guidelines, our aim is to identify which cloud types are most impacted by urban emissions and atmospheric conditions. This understanding is crucial for improving solar radiation forecasting, as cloud characteristics directly affect irradiance variability and the performance of forecasting models. Integrating cloud dynamics

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into our retrieval systems—particularly through machine learning and 3D cloud reconstruction—will enhance the accuracy and operational relevance of solar energy predictions in complex urban settings.

PRESENTATION 3: DESTINATION RENEWABLE ENERGY CASE, RIZOS CHADOULIS

Mr. Rizos Chadoulis presented a comprehensive case study on the transformation of tourist destinations through renewable energy integration, focusing on sustainability, stakeholder collaboration, and climate resilience. His presentation emphasized the systemic shift required to decarbonize energy systems in island or remote tourist locations while preserving the attractiveness and environmental quality of these destinations. The presentation began with an overview of key challenges facing tourism-dependent regions—such as energy insecurity, high CO_2 emissions, and seasonal demand peaks. Mr. Chadoulis framed these issues within the context of broader European Green Deal goals and the Fit for 55 package, which call for urgent reductions in fossil fuel dependence and integrated energy planning. He introduced the concept of Destination Renewable Energy (DRE) as a place-based strategy that combines renewable energy production, energy efficiency, smart grids, and sustainable mobility tailored to the unique needs of tourism regions. A core pillar of the approach is engaging local communities, municipalities, tourism operators, and energy agencies to co-develop feasible and scalable energy transition plans. Mr. Chadoulis presented a methodology combining Energy Transition Readiness Assessments, stakeholder mapping, and scenario modeling. This was illustrated through pilot projects in Mediterranean island regions, where tools such as geospatial solar mapping, rooftop PV analysis, and energy load profiling were used to design integrated solutions. Technologies deployed include solar PV, small-scale wind, storage, and digital monitoring systems that support real-time energy management. Key project examples included island-wide solar mapping with cadastre and land-use overlays to identify priority areas for PV deployment, the development of smart energy dashboards to inform municipal decision-making and tourism facility operators, and demand-response planning to address seasonal load spikes typical in tourism hotspots. Mr. Chadoulis also addressed policy and financing enablers, highlighting EU mechanisms like Just Transition Funds, LIFE, and regional development funding. He stressed the importance of integrating energy planning into destination branding and tourism quality standards, thus turning energy transition into a competitive advantage. In closing, he called for enhanced cross-sector cooperation between energy, tourism, and municipal governance, backed by robust data and participatory frameworks. The Destination Renewable Energy approach represents a replicable model for accelerating the energy transition in regions where climate goals, local identity, and economic resilience intersect.

PRESENTATION 4: MODELING DUST MINERALOGY AND RADIATIVE TRANSFER IN METAL-WRF, STAVROS SOLOMOS

Dr. Stavros Solomos presented his work on atmospheric dust modeling using the METAL-WRF system, a specialized adaptation of the WRF-Chem model. This version has been enhanced to simulate dust mineralogy and its interactions with radiation, clouds, and health-related parameters. Dr. Solomos emphasized that the strength of METAL-WRF lies in its integration of high-resolution geological, satellite, and in-situ datasets, enabling real-time prediction and evaluation of dust-related impacts across multiple sectors.

The presentation covered a wide range of key topics. In the area of dust emission and transport modeling, Dr. Solomos detailed how meteorological drivers such as Medicanes, Haboobs, and low-

level jets (LLJs) are incorporated into the simulations. A notable feature is the use of MODIS NDVI data to identify dynamic dust source regions—specifically, those with vegetation indices below 0.1. Changes in land use, particularly those resulting from conflict or agricultural shifts, were shown to significantly affect emission patterns. A unique strength of METAL-WRF is its mineral-specific radiative transfer capability. The model incorporates refractive indices for distinct minerals including illite, kaolinite, quartz, feldspar, and hematite, allowing simulations to resolve the radiative effects of dust at the mineral level. Online radiative transfer calculations provide high accuracy for evaluating the climate impact of different dust types. Dr. Solomos also presented several validation campaigns and case studies, including the Celia dust storm in London (2022), the ASKOS campaign in Cape Verde (2022), and the ongoing CHOPIN campaign at Mt. Helmos (2024–2025). Results indicate that METAL-WRF achieves improved performance when using dust source maps derived from NDVI data compared to standard model configurations. The interaction between dust, clouds, and radiation was another major focus. Simulations show that mineral dust can enhance cloud microphysical properties—producing stronger updrafts, higher cloud tops, and increased precipitation. Importantly, feldspar and quartz were implemented as ice-nucleating particles (INPs) within the Thompson microphysics scheme. These results have implications for aviation safety, as dust-induced cloud icing has been linked to engine failures and undetectable ice crystals on radar. In terms of health and environmental impact, Dr. Solomos highlighted findings from case studies like Tehran, where aerosol optical depth (AOD) was not always a reliable indicator of surface-level particulate matter, underscoring the need for vertical aerosol profiling in health assessments. The model also integrates well with satellite datasets, using information from NASA's EMIT mission and AERONET for validation and mineral abundance mapping. Online comparisons between modeled mineral fractions and observed data have been carried out in regions such as Cyprus and Izana, demonstrating the model's capacity to resolve spatial differences in dust composition. Finally, Dr. Solomos announced that METAL-WRF simulation outputs are publicly available through an online archive at forecast.uoc.gr/weather-forecast-archive. This accessibility supports broader scientific use and stakeholder engagement, from environmental agencies to renewable energy planners. In conclusion, the METAL-WRF system represents a significant advancement in dust mineralogy modeling, offering a comprehensive tool for studying the radiative, meteorological, and health impacts of airborne mineral dust. As it continues to evolve through the integration of satellite data and intensive field campaigns, METAL-WRF is poised to play a central role in both scientific research and operational forecasting efforts related to mineral dust.

Question1: Could you please provide more detailed information about the graph that shows temperature and dust concentration, which was generated using the METAL-WRF model?
Answer1: This simulation was conducted in collaboration with the University of Crete. In addition to the graphical output, we have also extracted time series data for several locations, including Cyprus (with specific focus on Limassol, Nicosia, and Paphos), as well as Athens.

Question2: What is the spatial resolution?
Answer2: The spatial resolution of the simulation is 1 × 1 km, as shown in the graph depicting dust concentration and potential temperature (theta)**.** Please note that this is a scientific experimental tool**,** developed and used primarily for research purposes.

PRESENTATION 5: LONG-TERM VARIABILITY OF DUST BURDEN IN THE EASTERN MEDITERRANEAN: TRENDS AND DRIVING MECHANISMS, PRESENTER: ANTONIS GKIKAS

Dr. Antonis Gkikas delivered a comprehensive analysis of long-term dust trends in the Eastern Mediterranean and surrounding desert regions, based on the MIDAS (MODIS Dust Aerosol) dataset covering the period 2001–2023. His presentation focused on evaluating decadal trends in Dust Optical Depth (DOD) and identifying the underlying atmospheric and terrestrial factors driving observed changes. To construct the dataset, Dr. Gkikas merged data from MODIS Aqua and Terra satellites, enabling consistent dust monitoring across key regions: the Eastern Sahara (ES), the Mediterranean Sea (MS), and the Middle East (ME). Statistical analysis, including linear regression at 95% confidence and multi-linear regression (MLR), was applied to detect trends and link them to meteorological and environmental parameters. The results revealed that DOD has generally declined over the Eastern Sahara, with trends reaching $-0.008\ yr^{-1}$. In the Mediterranean Sea, a decreasing trend was evident, particularly in summer, although some regions showed a reversal to positive trends after 2012. The Middle East exhibited a dipole pattern, with both positive and negative trends varying by location and season. Dr. Gkikas highlighted several key drivers of dust variability, including near-surface wind speed, cyclonic activity, soil moisture, precipitation, and dust emissions. Dust anomalies were found to correlate positively with wind speed and emission intensity, and negatively with precipitation and soil moisture. To further understand atmospheric influences, factor and cluster analyses were applied to ERA5 reanalysis data (fields such as Z500, Z1000, and T850), identifying 11 dominant synoptic circulation clusters that explain seasonal dust behavior. Importantly, the analysis revealed strong anti-correlations between DOD anomalies and global teleconnection patterns, specifically ENSO (El Niño–Southern Oscillation) in the Middle East and the Dipole Mode Index (DMI) in the Mediterranean Sea. This work underscores the complex and non-stationary nature of dust burden trends, shaped by the interplay of climate variability, land surface changes, and atmospheric dynamics. Dr. Gkikas concluded that this type of analysis is essential not only for improving regional dust forecasting but also for enhancing climate model projections and supporting aerosol mitigation strategies across one of the world's most climatically sensitive regions.

Question: Could you clarify the trends shown in the slide titled "MIDAS Regional DOD Trends (2001–2023)"? Recent literature appears to indicate positive trends, while your graphs suggest negative ones. Could you explain this discrepancy?
Answer: Sure, I can share the original plot and the results depends on which data you are using.

PRESENTATION 6: DUST OBSERVATIONS IN THE THERMAL IR, SOPHIE VANDENBUSCHE

Dr. Sophie Vandenbussche presented an in-depth overview of dust observation using thermal infrared (TIR) satellite measurements, with a particular focus on data derived from the IASI instrument onboard the MetOp satellites. She highlighted the unique capabilities and limitations of using TIR channels for mineral dust detection and profiling. The IASI instrument covers the 3.6 to 15.5 µm spectral range, making it suitable for observing thermal emission, absorption, and scattering by aerosols. A key advantage of TIR observations is that they do not rely on sunlight, enabling day and night monitoring. Unlike visible and near-infrared (VIS/NIR) channels, TIR primarily detects coarse-mode particles, such as mineral dust and volcanic ash, due to their distinctive thermal emission signatures.
Dr. Vandenbussche introduced the MAPIR algorithm (Mineral Aerosol Profiling from Infrared Radiances), which retrieves vertical dust profiles using optimal estimation methods and radiative transfer modeling (RTTOV). The algorithm resolves dust concentration in vertical layers (0.5–9.5 km) and provides Averaging Kernels and Degrees of Freedom for Signal (DOFs), reaching up to 2.5 under ideal conditions. Notable case studies included retrievals during the Godzilla dust storm (June 2020) and examples from Ilorin (Nigeria) and Dakar (Senegal), demonstrating MAPIR's ability to distinguish distinct dust layers. Validation of TIR-based dust products remains a significant challenge. There is

currently no direct TIR reference dataset for dust AOD, which limits quantitative evaluation. As a workaround, comparisons are made with VIS-based observations (e.g., MODIS), though this is complicated by differing sensitivities, spectral characteristics, and altitude responses. VIS instruments can capture both fine and coarse-mode aerosols, whereas TIR is primarily sensitive to coarse particles at specific altitudes.
Dr. Vandenbussche also discussed the limitations in comparing VIS and TIR products, particularly regarding aerosol mixtures, altitude sensitivity, and non-sphericity of particles. She emphasized the need for new methodologies to convert and harmonize AOD across spectral domains and encouraged caution in interpreting cross-domain comparisons.
In conclusion, the presentation highlighted the distinct value of TIR observations in characterizing coarse-mode mineral aerosols, particularly under cloud-free conditions and during nighttime, where traditional VIS/NIR approaches are limited. The integration of IASI-derived products like MAPIR into multi-sensor frameworks offers promising pathways for better dust characterization and modeling, though significant work remains in validation and intercomparison.

Question1: I wanted to follow up on the part of the conversation where you mentioned using optical properties to convert from the visible to the infrared. Could you clarify which specific optical properties are required and where you obtain them? Are these properties derived from satellite data?
Answer1: The optical properties presented here come directly from the retrieval itself. To perform the retrieval, we need to model dust absorption and scattering. For this, we use a dust model that includes the refractive index and the particle size distribution, specifically characterized by a geometric mean diameter at 2 microns.

Question2: What about validation? Is it possible to validate the results using lidar or ceilometer data?
Answer2: Yes, there are teams working on this in Thessaloniki. Ongoing efforts are currently focused on validating the vertical dust profile.

Question3: Could you explain how a microwave or infrared radiometer could be used for validation purposes?
Answer3: I need more details in order to have an answer.

WG3 DISCUSSIONS AND OUTCOMES

The overarching mission of Working Group 3 (WG3) is to bridge the gap between aerosol science and its real-world applications by fostering stronger engagement with end-users. The group aims to maximize the value of aerosol photometric measurements by aligning them with the operational needs of sectors such as climate science, energy, health, and aviation. A central objective is to link the accuracy and uncertainty of aerosol data products with user-specific requirements, ensuring the scientific output is both relevant and actionable. To achieve this, WG3 promotes cross-sector coordination involving academia, research infrastructures, operational agencies, and industry stakeholders.
In support of these goals, WG3 is responsible for delivering three key documents:

- D3.1b: The current deliverable, summarizing the outcomes of the 2nd Harmonia Workshop.
- D3.2: A comprehensive report on user requirements, due by Month 36.
- D3.3: A white paper on the accuracy of sun-photometric aerosol observations, due by Month 48.

During the 2nd Harmonia Workshop, WG3 discussions focused on refining user engagement and identifying practical use cases. Key outcomes and user needs are summarized in Table 1 of this report. The WG3 session also referenced several ongoing studies and initiatives that inform the development of deliverables D3.2 and D3.3:

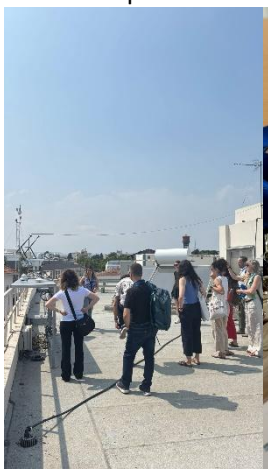
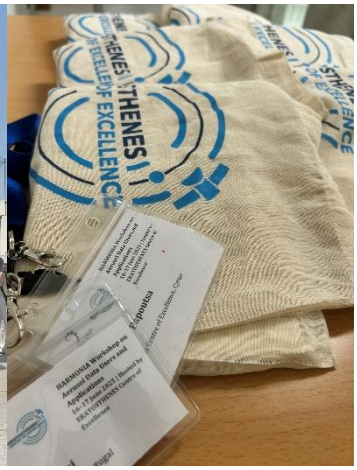
- The Berlin School highlighted the use of AERONET data and METAL-WRF simulations to analyze the origin and impact of dust events.
- The Izana School presented radiative transfer simulations (using libRadtran and MYSTIC) that incorporate aerosol input to validate satellite missions such as EarthCARE.
- Efforts are underway to consolidate findings from the VM, EMS, Berlin, and Izana programs into the structure of the upcoming deliverables.

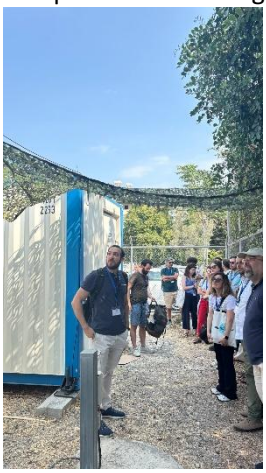
Planning is also advancing for the WG3 white paper, provisionally titled: "Radiometric Measurements of Aerosol Optical Properties: Applications, Current State, and Needs." Chapters are being developed around major application domains, with the following initial authors and themes: Solar Energy: Ilias Fountoulakis, Stelios Kazadzis, Modeling and Data Assimilation: Stavros Solomos, Satellite Validation: Sophie Vandenbussche, Health, Agriculture, Climate, Aviation: Additional contributors to be determined. WG3 continues to play a key role in aligning aerosol science with operational relevance, ensuring that measurement networks and modeling systems are directly informed by end-user needs and supported by robust, validated datasets.

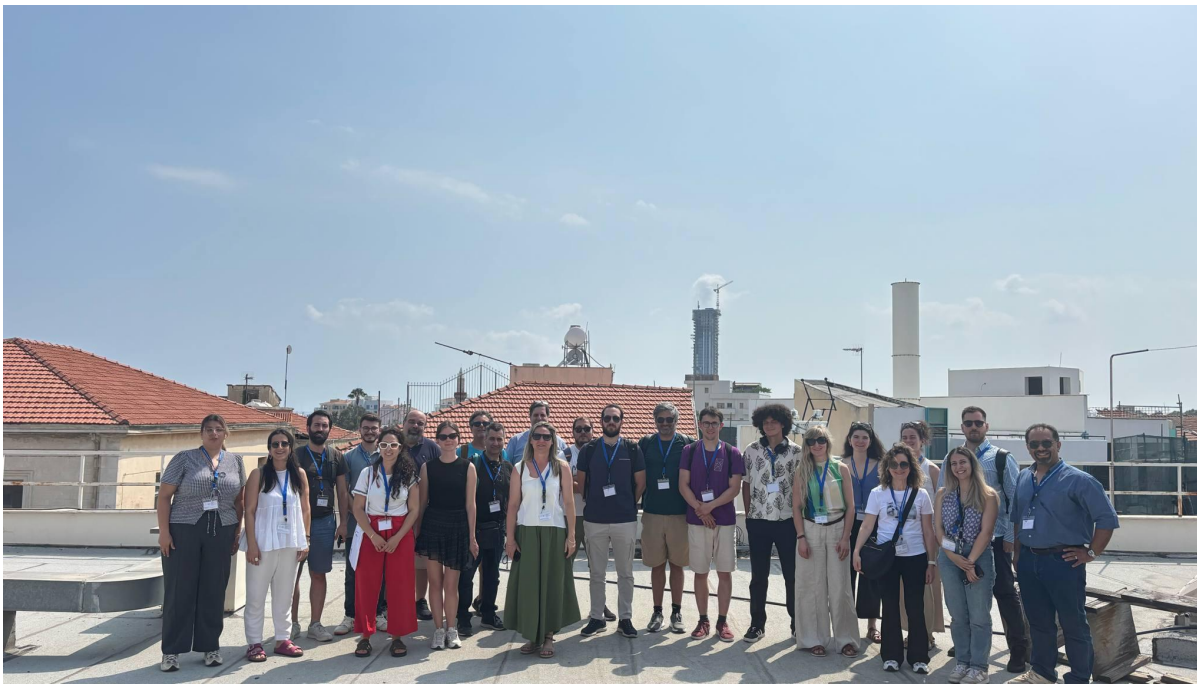
VISIT AT CARO ACTRIS STATION

Participants of the Harmonia Workshop concluded the first day with a site visit to the CARO ACTRIS station, a key infrastructure of the ERATOSTHENES Centre of Excellence and a certified ACTRIS (Aerosol, Clouds and Trace gases Research Infrastructure) facility. The station plays a vital role in the continuous monitoring of atmospheric components over the Eastern Mediterranean. During the visit, attendees were introduced to: Ground-based instruments for aerosol, cloud, and solar radiation measurements Sun photometers, lidar systems, and pyranometers used for ACTRIS-compliant data acquisition The integration of CARO data into European-wide research networks and satellite validation efforts

The visit allowed participants to better understand the instrumentation standards, data quality protocols, and the operational role of CARO in both scientific research and regional atmospheric monitoring.





3. Workshop Presentations – Day 2, June 17th, 2025

PRESENTATION 1: SOLAR MEASUREMENTS AT ERATOSTHENES CENTRE OF EXCELLENCE, GEORGIA CHARALAMBOUS

Georgia Charalampous presented recent advancements in solar radiation and ultraviolet (UV) monitoring carried out at the Eratosthenes Centre of Excellence in Cyprus. Since late 2023, the Centre has established a growing network of regional monitoring stations across the island, providing high-resolution, one-minute data on solar and UV radiation. This observational infrastructure plays a vital role in both applied research and operational forecasting. The monitoring network spans multiple locations, including Kyperounta (Limassol district), Athalassa (Nicosia), Polis Chrysochou (Pafos), Frenaros (Larnaca), and a dedicated urban site in Limassol. Stations are equipped with a range of high-quality instruments: MS-80 pyranometers (EKO Instruments) for Global Horizontal Irradiance (GHI), SUV-E erythemal UV actinometers (Kipp & Zonen), spectroradiometers for the 290–600 nm spectral range, and all-sky cameras capturing cloud coverage at one-minute intervals. These instruments enable simultaneous measurement of global, direct normal, and diffuse horizontal irradiance, erythemal UV irradiance (converted into UV Index), and spectral irradiance values, which support assessments of vitamin D potential, DNA damage risks, and blue light exposure—with applications in agriculture and public health. To ensure high data reliability, the Centre has implemented Libinsitu protocols for quality assurance and quality control (QA/QC) and continues routine spectroradiometer calibration to maintain measurement accuracy. Dr. Charalampous also highlighted several recent research initiatives utilizing this dataset. These include the preliminary evaluation of the Cyprus UV Forecasting System under various sky conditions (Charalampous et al., 2025), next-day solar radiation forecasting using measured and modeled GHI values (Fragkos et al., 2024), and analysis of dust radiative effects during episodes in Limassol throughout 2024 (Charalampous et al., COMECAP2025).

Furthermore, the Centre actively contributed to the EarthCARE campaign in Thessaloniki (April–May 2025), deploying pyranometers, all-sky cameras, and a Microtrops II sun photometer in collaboration with the Solar Radiation and Atmospheric Clusters. These efforts underscore the Eratosthenes Centre's growing role in regional and European research networks. In conclusion, the Eratosthenes Centre of Excellence has established a robust and versatile observational platform that supports a wide range of applications—from solar energy optimization and UV health risk assessment to satellite validation. Its high-resolution measurements are proving critical for the improvement of forecasting models and for strengthening aerosol and radiation research across the Eastern Mediterranean.

PRESENTATION 2: UV CLIMATOLOGIES, ILIAS FOUNTOULAKIS

Dr. Ilias Fountoulakis delivered an in-depth presentation on the variability and trends of surface-level solar UV radiation, with a particular focus on the influence of aerosols in the Eastern Mediterranean region. His talk explored both the health-related and environmental implications of UV radiation, emphasizing the dual biological significance of UV exposure—from promoting Vitamin D synthesis to contributing to skin cancer risk and ecological stress. He highlighted the importance of defining optimal sun exposure thresholds and stressed the critical need for continuous, high-accuracy monitoring of biologically effective UV doses. The presentation examined the atmospheric factors that modulate UV transmission, including stratospheric ozone, cloud coverage, aerosol loading, and surface albedo. Dr. Fountoulakis explained how even subtle changes in these parameters—particularly ozone concentrations and aerosol optical properties—can significantly alter UV radiation levels reaching the surface. He presented results from UV climatological analyses for both Greece and Cyprus, based on satellite-derived data and ground-based measurements. In Cyprus, summer UV index values often reach levels between 8 and 10, with occasional peaks above 11, classified as extreme. Trends over the 2004–2024 period reveal an increase in UV radiation in Greece—particularly during winter and autumn—linked primarily to declining aerosol concentrations. In contrast, Cyprus exhibited a modest decrease in UV levels during autumn, attributed to increasing total ozone. Dr. Fountoulakis also discussed the uncertainties in aerosol optical properties, especially the Single Scattering Albedo (SSA) in the UV-B range, which he identified as a major source of error in UV forecasts. He explained that SSA varies widely by aerosol type—such as dust or brown carbon—and that extrapolating values from the visible spectrum often leads to inaccuracies in UV modeling. In comparing satellite-derived UV products with ground-based observations, he pointed out consistent discrepancies that could largely be explained by simplifications in aerosol modeling—particularly those embedded in global products like CAMS. He called for a stronger integration of ground-truth data with satellite systems to refine radiative transfer simulations and forecast accuracy. In conclusion, Dr. Fountoulakis underscored the importance of maintaining long-term UV and aerosol datasets, improving model representations of aerosol optical characteristics, and increasing attention to UV-B absorbing aerosols, such as mineral dust and brown carbon, particularly under cloud-free conditions. His presentation reinforced the role of UV research not only in public health and environmental risk assessment but also in solar energy modeling and policy-making related to atmospheric monitoring.

PRESENTATION 3: AEROSOL AND RADIATION MEASUREMENTS AT THE LAMPEDUSA CLIMATE OBSERVATORY: FROM SATELLITE VALIDATION TO SOLAR ENERGY PRODUCTION, PRESENTER: DANIELA MELONI (ENEA)

Dr. Daniela Meloni presented the ongoing long-term monitoring activities at the Lampedusa Climate Observatory, with a focus on aerosol and solar radiation measurements and their applications in

satellite validation and solar energy production. The observatory plays a crucial role in supporting the ESA–JAXA EarthCARE mission through the validation of aerosol optical depth (AOD) using high-precision ground-based observations and stringent spatial and temporal matching protocols.
One of the central findings presented was the significant overestimation of satellite-derived solar irradiance during desert dust events, with observed biases reaching up to 8% under cloud-free conditions. This discrepancy highlights the importance of incorporating aerosol corrections into satellite algorithms, especially in dust-prone regions. Dr. Meloni elaborated on the use of EUMETSAT CM SAF SARAH-3 data derived from SEVIRI to evaluate global shortwave irradiance. Compared to surface-based observations, the satellite-derived values showed a mean bias of −3.6 ± 10.2 W/m², or approximately −1.2 ± 7.1%, with more pronounced errors during dusty episodes. In terms of EarthCARE mission support, the Lampedusa Observatory has developed comprehensive validation protocols for products from ATLID (Atmospheric Lidar) and MSI (Multi-Spectral Imager). AOD retrievals at 355 nm, 670 nm, and 875 nm are assessed using quality flags (Q_ALD status 0–4) to determine data usability. However, Dr. Meloni noted a limited number of successful satellite-ground coincidences between January and May 2025, due to constraints in overpass timing and atmospheric conditions. To address these challenges, a homogeneity-based satellite data selection method was introduced. This method enhances the reliability of satellite-ground comparisons by accounting for temporal tolerance (±1 hour) and spatial overlap (e.g., ±12 MSI pixels), while also considering swath width and track geometry.
The observatory also conducts applied research on photovoltaic (PV) performance degradation due to aerosol soiling. Two key instruments were highlighted: DustIQ (Kipp & Zonen), which measures transmission losses from dust accumulation on PV panels.
CR-PVS1 (Campbell Scientific), which quantifies short-circuit current loss, offering insight into actual irradiance loss caused by particulate deposition. These measurements are used to compare effective irradiance on clean versus soiled panels (G_eff,Ref vs G_eff,Test) and inform both solar yield projections and operational decision-making. Dr. Meloni emphasized that the Lampedusa Climate Observatory is a model facility, with similar instrumentation and validation strategies now being replicated at two other Mediterranean sites. This expansion strengthens regional capabilities in aerosol monitoring and solar energy optimization.
In conclusion, Dr. Meloni affirmed that the Lampedusa Observatory fulfills a dual function: as a validation hub for advanced satellite missions like EarthCARE and as a practical resource for optimizing solar power systems under dusty conditions. Her presentation highlighted the importance of integrating ground-based measurements with satellite observations, not only to enhance climate model accuracy but also to support sustainable energy planning in aerosol-affected environments.

PRESENTATION 4: THE DUST MARIE CURIE DOCTORAL NETWORK, FRANCO MARENCO

Dr. Franco Marenco presented the Dust-DN (Dust Doctoral Network), a Marie Skłodowska-Curie doctoral training initiative dedicated to advancing the scientific understanding of mineral dust—its physical properties, sources, atmospheric transport, and societal impacts. The network adopts an interdisciplinary approach, integrating remote sensing, modeling, and experimental techniques to address long-standing gaps in dust research and application. Dr. Marenco began by outlining the motivation behind Dust-DN. Despite its importance, mineral dust remains poorly constrained in global models, particularly in terms of microphysical and optical properties. Observational data near dust source regions is often sparse, which hinders accurate assessments of dust's effects on climate systems, renewable energy, health, and transportation. The network was established to bridge this gap, offering cutting-edge research opportunities and infrastructure access to a new generation of scientists. The consortium includes 6 EU beneficiaries, led by the Cyprus Institute (CyI) and supported

by partners such as BSC, NOA, KIT, University of Évora, and TUDa. It also involves 2 associated employers (funded by UKRI and SERI), and 15 additional partners, including PMOD/WRC, ETH Zurich, GRASP-SAS, the WMO, and private-sector stakeholders like EY. In total, the network spans 9 countries and connects both academic and non-academic institutions, providing a robust foundation for interdisciplinary collaboration.
The scientific work is structured into several core work packages, including: WP2: Dust microphysical properties, WP3: Source region influence, WP4: Socioeconomic impacts (health, aviation, energy), WP5: Dust in the global climate system.
Dr. Marenco also highlighted three exemplary doctoral projects: DC15 (PMOD/WRC & ETH Zurich): Investigating how dust from various regions affects spectral solar irradiance, aiming to reduce uncertainty in aerosol radiative forcing; DC6 (UÉvora, CIEMAT/PSA, EY): Focused on parameterizing DNI and CSNI under high dust conditions to improve solar energy forecasts; DC7 (University of Reading & UÉvora): Studying super-coarse dust particles and their radiative properties using campaign data and radiative transfer simulations. The Dust-DN initiative benefits from close integration with major international missions and platforms, such as EarthCARE and NASA's EMIT, and has access to state-of-the-art resources like the Marenostrum5 supercomputer at BSC. Its objectives are aligned with HARMONIA WG3, particularly in terms of photometric accuracy, end-user engagement, and validation of aerosol measurements. The network is also linked to WMO-led global aerosol validation activities, further reinforcing its operational relevance.
The training program supports 17 PhD students, providing tailored research, joint supervision, inter-sectoral secondments, and capacity-building events, including seasonal schools, workshops, and virtual exchanges. The project officially began on 1 November 2024, with six doctoral candidates already in place by June 2025, and the remaining 11 expected to start by September 2025. In conclusion, Dr. Marenco emphasized that Dust-DN represents a transformative educational and scientific platform, uniquely positioned to advance dust observation techniques, enhance climate and energy modeling, and prepare future leaders in aerosol-related research. The initiative strongly complements HARMONIA's mission to connect data accuracy with societal needs.

Presentation 5: Solar projects on Dust DN, Stelios Kazadzis

Dr. Stelios Kazadzis focused on the influence of dust source-region variability on the optical, microphysical, and mineralogical properties of airborne mineral dust. The collaborative effort aims to enhance the representation of dust in climate and solar radiation models by integrating observational data and regional-scale modeling techniques. The study supports key objectives of HARMONIA WG3, particularly in linking aerosol data accuracy with practical applications in climate and energy systems. The core aim of the initiative is to investigate how different dust source regions—such as the Sahara, Sahel, and Middle Eastern deserts—affect a range of dust-related parameters. These include optical properties like aerosol optical depth (AOD) and single scattering albedo (SSA), microphysical characteristics such as particle size distribution, spectral attenuation of solar radiation, and mineralogical composition. Understanding these variations is essential for improving the accuracy of radiative forcing estimates and for assessing the broader impacts of dust on climate and renewable energy systems. To achieve this, the project combines sun-photometric, in situ, and profiling measurements with modeling tools and satellite observations. Key data sources include ground-based field campaigns (e.g., DC13 and DC15), satellite instruments like NASA's EMIT, AERONET photometers, and regional modeling tools such as the BSC MINERALOGY-WRF system. These resources are used to link observed dust properties to specific source regions, enabling more targeted analysis and model tuning. Methodologically, the project includes the identification and retrospective analysis of major

dust events over the past decade across the Mediterranean, Eastern Atlantic, and North Africa. Mineralogical and optical characterization is carried out through sample analysis during campaign deployments, while EMIT-derived mineral maps are being used to implement spatially explicit mineralogy in regional models. Size distribution assumptions are refined to better reflect real-world measurements, especially for super-coarse particles. Model outputs are evaluated against in situ data, lidar profiles, and satellite retrievals from institutions such as PMOD/WRC, KIT, and BSC, ensuring cross-validation across independent platforms and techniques. The expected outcomes include improved regional and global dust model accuracy, better quantification of dust-related radiative forcing, and an enhanced ability to simulate the climate sensitivity of dust-affected regions in Europe, North Africa, and the Middle East. In conclusion, the initiative highlights the critical importance of source attribution in dust research and modeling. By integrating diverse datasets and mineral-specific modeling approaches, the project strengthens the scientific foundation for incorporating dust variability into climate and energy system models—one of the core goals of HARMONIA WG3.

PRESENTATION 6: PV APPLICATIONS, MIGUEL BRITO

Dr. Rodrigo Brito presented an overview of the current landscape and emerging challenges of photovoltaic (PV) integration in Cyprus and similar high-irradiance regions. He noted that over 90% of Cypriot households already rely on solar thermal systems, and emphasized that PV can further contribute to the energy transition. However, increased PV penetration brings specific challenges—particularly grid curtailment during periods of low demand, which now frequently affects renewable energy systems (RES). Dr. Brito highlighted the need for flexible storage, grid interconnections, and demand-side management to mitigate these constraints. His talk explored innovative PV deployment strategies to address land use conflicts and infrastructure limitations. Building-Integrated PV (BIPV) systems, where PV is integrated into rooftops or facades, offer aesthetic and functional synergy with urban architecture, though cost and performance trade-offs—such as shading and panel orientation—must be carefully managed. Vehicle-Integrated PV (VIPV) represents another frontier, with modeling results showing that solar panels could supply up to 93% of an electric vehicle's annual charging needs in cities like Lisbon, significantly reducing grid dependence and emissions. Further, Dr. Brito discussed AgriPV and Floating PV systems as promising dual-use solutions for agriculture and water management. These approaches can reduce land competition, moderate local temperatures, cut irrigation demand, and enhance energy-water synergies, making them especially relevant for Mediterranean regions facing resource pressures. In conclusion, Dr. Brito emphasized that PV is now globally cost-competitive, but realizing its full potential—especially in urban, transport, and agricultural applications—requires innovative system design, cross-sector integration, and targeted policy support.

PRESENTATION 8: EARTH CARE VALIDATION ASPECTS / STELIOS ACTRIS EG SAT OBJECTIVES, ELENI MARINOU & STELIOS KAZADZIS

Dr. Stelios Kazadzis presented the goals, methodology, and preliminary insights from the RACE-ECV (Radiation Closure Experiments for Essential Climate Variables) campaign—an ambitious initiative designed to support and validate products from ESA's EarthCARE satellite mission. Funded by Swiss institutions and conducted in collaboration with multiple European partners, the campaign focused on assessing the accuracy of aerosol and cloud retrievals, while simultaneously exploring aerosol radiative effects through comprehensive ground-based observations and modeling. The campaign took place in Thessaloniki, Greece, between April 18 and May 22, 2025, with critical EarthCARE

overpasses occurring on April 25 and May 20. The participant consortium included PMOD/WRC, University of Zurich, Aristotle University of Thessaloniki, University of Patras, National Observatory of Athens, the ERATOSTHENES Centre of Excellence, and several other institutions, combining expertise in remote sensing, radiation measurements, and atmospheric modeling.

The main objectives of RACE-ECV were to: Validate EarthCARE aerosol and cloud optical thickness (COT) retrievals from the Multi-Spectral Imager (MSI) and Broadband Radiometer (BBR) instruments.; Perform radiative closure experiments by comparing measured surface irradiance with outputs from radiative transfer models; Produce a rich dataset encompassing spectral irradiance, aerosol optical depth (AOD), cloud microphysics, and trace gases under a variety of sky conditions. The observational strategy involved an extensive suite of ground-based instrumentation, including AERONET sun photometers, multi-wavelength lidars (e.g., Thelisis), broadband and spectral pyranometers, all-sky and stereo cloud cameras, FTIR and Pandora spectrometers, and low-cost sensor platforms for cross-validation and calibration. Key scientific areas of focus included spatiotemporal validation, where AOD and spectral radiation were measured across several sites in the Thessaloniki area and compared with EarthCARE MSI and BBR products. These measurements were cross-referenced with lidar data and satellite overpasses to evaluate consistency and identify retrieval limitations. In the area of 3D cloud reconstruction, stereo camera systems were used to map cloud structures in three dimensions, enabling researchers to study how cloud morphology influences irradiance variability and sensor detection capabilities.

For low-cost sensor evaluation, RACE-ECV assessed the calibration stability and performance of affordable sensors by comparing them with standard instruments such as pyranometers and lidars, supporting the scalable deployment of atmospheric monitoring tools across regions. Cloud Optical Thickness (COT) retrievals were conducted using both ground-based and satellite observations (MSG/MTG) to derive COT values and analyze the impact of cloud presence on surface radiative fluxes, with important implications for climate and energy modeling. Lastly, advanced radiative modeling involved radiative transfer calculations using both 1D (DISORT) and 3D (MYSTIC) solvers to investigate the Direct Radiative Effects (DRE) of aerosols under both clear-sky and partially cloudy conditions. This work helped quantify potential biases resulting from simplified assumptions in satellite-derived products. In conclusion, Dr. Kazadzis emphasized that the RACE-ECV campaign provides a critical validation framework for EarthCARE, contributing to the accurate interpretation of aerosol-cloud-radiation interactions. The initiative also reinforces the importance of high-resolution surface observations and 3D radiative modeling as complementary tools to satellite-based systems, furthering the overarching goals of climate monitoring, satellite validation, and energy system modeling under the umbrella of HARMONIA WG3.

Dr. Eleni Marinou presented the outcomes and future perspectives of the P4CV (Photometric Calibration and Validation for Climate Variables) Twinning initiative. The project aims to strengthen research excellence in satellite validation and radiometric calibration by fostering collaboration between emerging institutions and established European research centers.

Her presentation began by outlining the primary goals of P4CV: Enhance institutional capacity in Earth observation calibration and validation (Cal/Val), Promote the adoption of ACTRIS-compliant photometric measurement standards, Build human capital through targeted training, staff exchange, and workshops. Dr. Marinou highlighted the central role of fiducial reference measurements (FRM) in the validation of satellite missions such as ESA's EarthCARE, and emphasized how P4CV contributes to this process by: Supporting the harmonization of sun-photometer networks across Mediterranean sites, Coordinating joint Cal/Val campaigns in collaboration with ACTRIS EG-SAT, Developing protocols for uncertainty quantification in aerosol optical depth (AOD) measurements. She detailed the work

plan of P4CV, which includes intensive collaboration with PMOD/WRC, NOA, and BIRA, alongside on-site deployments at CARO (Cyprus), Thessaloniki, and other ACTRIS-affiliated stations. These deployments focus on: Cross-instrument calibration (e.g., AERONET vs low-cost sensors), Temporal collocation with satellite overpasses, Development of best practices for spectral irradiance measurements. A significant portion of the talk was dedicated to capacity building: summer schools, lab training, and e-learning platforms were created to ensure long-term knowledge transfer to early-career researchers and technical staff. Dr. Marinou stressed the importance of gender balance, inclusivity, and multi-disciplinary collaboration as key values embedded in the project.
The presentation concluded with a roadmap for P4CV's integration into broader European efforts, including: Contributions to the WG3 white paper on photometric accuracy, Providing standardized datasets for satellite algorithm developers, Aligning with ESA/EUMETSAT needs for pre-operational validation frameworks. In summary, Dr. Marinou's presentation emphasized the importance of coordination, standardization, and knowledge-sharing in advancing satellite validation infrastructure. P4CV serves as a strong enabler for bridging scientific excellence across European institutions and directly supports the strategic objectives of HARMONIA WG3.

PRESENTATION 9: THE THESSALONIKI CAMPAIGN FOR EARTH CARE, STELIOS KAZADZIS

Dr. Stelios Kazadzis presented an overview of the ACTRIS Expert Group on Satellite Calibration and Validation (EG-Sat), a recently established initiative that serves as the formal interface between ACTRIS and European satellite agencies such as ESA and EUMETSAT. The group's mission is to ensure that ACTRIS provides fiducial reference measurements (FRMs) and expert input in support of satellite missions focused on aerosols, clouds, and atmospheric composition, including EarthCARE, Sentinel-4/5, and Aeolus. Formally established in 2024, EG-Sat is composed of representatives from ACTRIS Central Facilities, national research platforms, and campaign leaders. It provides strategic recommendations to the ACTRIS Director General and broader community on matters of satellite validation. In its role, the group also receives mandates to participate directly in the design, planning, and execution of satellite calibration and validation (Cal/Val) activities, ensuring a seamless link between ACTRIS ground-based expertise and satellite mission requirements. Dr. Kazadzis detailed several recent and ongoing key contributions of EG-Sat. Validation campaigns have included the validation of GOME-2 absorbing aerosol height retrievals using EARLINET lidar profiles from 13 ACTRIS stations, as well as the assessment of Aeolus Level-2A wind product performance based on multi-year lidar data collected between 2019 and 2023. EG-Sat has also been actively involved in validation activities for CALIPSO, CATS, and EarthCARE through both dedicated field campaigns and collaborative research projects. Under the ATMO-ACCESS pilot initiatives, EG-Sat developed customized aerosol and cloud products tailored to the needs of ESA and EUMETSAT missions, reprocessed historical lidar datasets to align with satellite data specifications, and improved fast-track access to quality-assured ACTRIS datasets, thereby enhancing preparedness for EarthCARE and future satellite missions. Looking ahead, Dr. Kazadzis shared the group's strategic vision for long-term collaboration with satellite operators. A formal Memorandum of Understanding (MoU) between ACTRIS and EUMETSAT is planned for mid-2025. Potential areas of cooperation under this agreement include ACTRIS contributing quality-assured validation datasets and providing technical consultation on satellite algorithm development and product definitions. EUMETSAT, in turn, may support ACTRIS by funding validation campaigns, contributing to research and development for next-generation instruments, and

offering PhD fellowships focused on calibration and validation (Cal/Val) activities using ACTRIS infrastructure. In conclusion, Dr. Kazadzis emphasized that ACTRIS is increasingly recognized as a central European infrastructure for satellite atmospheric mission validation. Through standardized, quality-controlled observations and a robust partnership with ESA and EUMETSAT, EG-Sat is helping ensure that satellite aerosol and cloud products are rigorously validated, continuously improved, and fully integrated with the ground-based observational community. This initiative strongly supports the objectives of HARMONIA WG3, particularly in aligning photometric accuracy with user-focused satellite applications.

PRESENTATION 10: THE P4CV TWINING EXPERIENCE, MARINOU ELENI

Dr. Eleni Marinou presented the objectives and results of the P4CV Twinning project**,** a collaborative initiative aimed at strengthening the photometric calibration and validation capacity of the Eratosthenes Centre of Excellence (ECoE) through joint actions with three leading European institutions: PMOD/WRC (Switzerland), NOA (Greece), and BIRA-IASB (Belgium). The presentation outlined the project's strategic focus on advancing scientific excellence in radiometric and aerosol measurements, supporting the validation of the ESA EarthCARE satellite, and building long-term capacity through knowledge transfer, instrumentation training, and field campaigns. Dr. Marinou emphasized the integration of ECoE into key European networks such as ACTRIS and AERONET, which play a crucial role in ensuring standardized and traceable aerosol and radiation data. Through joint field campaigns and methodological workshops, the P4CV consortium concentrated on improving spectral irradiance measurements, AOD retrieval techniques, and data uncertainty quantification and inter-comparability. The project's core pillars included twinning and training, with activities such as hosting early-career researchers and delivering intensive courses on radiative transfer and instrument calibration; scientific excellence, demonstrated through co-located measurements conducted during EarthCARE Cal/Val campaigns; and open science, with efforts focused on developing protocols and datasets that are compatible with European research infrastructures.Dr. Marinou also highlighted key project milestones, including the deployment of low-cost sensors alongside reference instruments for performance benchmarking, contributions to the EG-SAT group within ACTRIS to strengthen the satellite validation pipeline, and the preparation of standard operating procedures intended for adoption across the network. In conclusion, she positioned P4CV as a vital enabler of long-term collaboration and excellence in satellite calibration, aligning with the strategic vision of HARMONIA WG3. The initiative has established ECoE as a credible node within Europe's aerosol validation ecosystem, supporting the broader objective of harmonizing ground-based observations with satellite-derived climate variables.

PRESENTATION 11: ECOE PROJECT ON EARTH CARE VALIDATION, RODANTHI MAMOURI

Dr. Rodanthi Mamouri presented the contribution of the ERATOSTHENES Centre of Excellence (CoE) to the validation of ESA's EarthCARE satellite mission through a series of coordinated ground-based observations at the Cyprus Atmospheric Remote Sensing Observatory (CARO)—an ACTRIS-labeled National Facility located in Limassol, Cyprus. The CARO site plays a strategic role in EarthCARE's validation network, providing multi-instrumental measurements of aerosols, clouds, and solar radiation in a region characterized by complex atmospheric conditions, including dust, pollution, smoke, and marine influences. The CARO facility, located just under 2 km from the Mediterranean coastline, was initially launched in October 2020 with a focus on aerosol profiling and was fully expanded by July 2024 to include cloud and radiation sensing capabilities. It now operates three main

observational platforms: aerosol remote sensing, which is equipped with PollyXT lidar, Doppler lidar, and an AERONET sun photometer; cloud remote sensing, which includes a ceilometer, microwave radiometer, and MIRA 35 GHz cloud radar; and solar radiation monitoring, featuring broadband and spectral radiation sensors as part of the Cyprus Solar Station, operational since December 2023. Between the beginning of 2024 and mid-2025, 48 EarthCARE satellite overpasses occurred within 100 km of the Limassol site. Dr. Mamouri highlighted two representative cases: on 4–5 March 2025, a dust event was observed during EarthCARE's overpass at approximately 106–116 km, where the PollyXT lidar provided valuable aerosol layering data before and after the satellite pass, capturing detailed structural information that supported model and retrieval evaluations; and on 3 June 2025, a smoke-dominated episode influenced by long-range transport from Canadian wildfires was recorded, with ground-based lidar revealing polluted, cloud-free layers that were compared to satellite profiles for validation. Results from the campaign showed good agreement between EarthCARE and PollyXT data in aerosol and cloud vertical structures. However, spatial and temporal mismatches of up to 34–40 km were observed due to wind drift, highlighting the importance of careful co-location and timing analysis. Manual processing of PollyXT lidar data enabled classification of complex aerosol types, including dusty smoke, ice clouds, and continental pollution. Additionally, the team employed the EC-VALTOOL framework to validate EarthCARE ATLID Level 2 products using high-quality RAMAN and depolarization lidar data. These advanced capabilities were instrumental in resolving vertically stratified aerosol mixtures, demonstrating the CARO site's potential as a key reference validation hub in the region. Looking ahead, Dr. Mamouri outlined several next steps, including continuing long-term co-located measurements with lidar and radar to support extended EarthCARE operations, validating EarthCARE CPR (Cloud Profiling Radar) data using the MIRA cloud radar, broadening analysis to include different aerosol regimes such as biomass burning, urban pollution, and natural dust, collaborating with the RACE-ECV and ACROSS campaigns for enhanced regional calibration and validation coverage, and integrating CARO datasets with CLOUDNET to support comprehensive studies of aerosol-cloud-radiation interactions. In conclusion, the CARO National Facility has emerged as a critical node in the EarthCARE validation network, offering high-resolution, ACTRIS-compliant measurements in the Eastern Mediterranean. The site's capabilities directly support the scientific goals of ESA missions and HARMONIA WG3, particularly in satellite validation, photometric accuracy, and regional climate research.

Discussion on Earth Care potental involvement of ECoE

During the Harmonia Workshop, a dedicated discussion took place on the potential for expanding the involvement of the Eratosthenes Centre of Excellence (ECoE) in the EarthCARE satellite validation framework. Given ECoE's existing infrastructure at the CARO National Facility—equipped with advanced aerosol, cloud, and solar radiation sensors—it was recognized as a strategically valuable site for long-term EarthCARE data validation in the Eastern Mediterranean region. The Centre's recent contributions, including the capture of complex aerosol and cloud layering during satellite overpass events, highlight its capability to support multi-instrument, high-resolution ground-based observations aligned with EarthCARE product requirements.

4. Conclusions

The 2nd Harmonia Workshop successfully advanced WG3 objectives, highlighting the importance of aerosol observations for climate applications, energy systems, and satellite validation. Through expert presentations and interdisciplinary discussions, participants identified practical use cases, outlined user needs, and explored emerging tools and techniques. The workshop also reinforced the value of

coordinated field campaigns, like EarthCARE validation efforts, and promoted cross-sector collaboration. Outcomes from this workshop will directly inform Deliverables D3.1b (second workshop), D3.2 (user requirements) and D3.3 (white paper on photometric accuracy).

User Group	**Identified Needs**	**Related Applications**	**Linked Presentations**
Modeling Community	• Harmonized and validated aerosol data • Real-time data access • Vertical aerosol profiles	Data assimilation, weather & climate models	S. Solomos (METAL-WRF), S. Vandenbussche (IASI/MAPIR), S. Kazadzis (RACE-ECV, EG-SAT)
Energy Sector	• High-resolution urban aerosol data • All-sky camera imagery • Improved AOD-based solar forecasts	Solar energy production and forecasting	S. Kazadzis (Forecasting), A. Kazantzidis (All-sky Imaging), M. Brito & R. Amaro (PV use)
Aviation Sector	• Frequent vertical aerosol profiles near airports • Volcanic ash and dust detection • Integration with forecasts	Air traffic safety and route planning	S. Solomos (Dust-Cloud Interaction), F. Marenco (Dust DN), S. Kazadzis (ACTRIS EG-SAT)
Health & Public Safety	• Ground-level aerosol concentration and speciation • Temporal trends • UV radiation and exposure metrics	Air quality advisories, health risk assessments	I. Fountoulakis (UV Climatology), S. Solomos (Tehran case), G. Charalampous (UV network)
Agriculture	• Aerosol impact on solar irradiance and crop health • UV radiation monitoring	Precision agriculture, crop modeling	I. Fountoulakis, G. Charalampous (UV health/agriculture links)
Satellite Validation Teams	• Coincident sun-photometer, lidar, and radiometric measurements • Cloud optical	EarthCARE, MODIS, TROPOMI validation	D. Meloni (Lampedusa), S. Kazadzis (RACE-ECV), E. Marinou (EG-SAT), WG3 Campaign inputs

	properties • Spectral AOD data		
Urban Planners	• Solar cadastre and rooftop PV analysis tools • Accurate irradiance data in built environments	Urban PV deployment, energy infrastructure	M. Brito & R. Amaro (Urban PV and e-shape tools)

The main takeaways from the discussions can be summarized as:

- The workshop successfully advanced the core objectives of WG3, reinforcing the importance of aerosol observations for a range of sectors, including climate research, energy systems, aviation safety, and satellite validation.
- User-specific requirements were identified across multiple domains through expert presentations, interdisciplinary panels, and interactive sessions.
- Emphasis was placed on the need for real-time, high-resolution aerosol data—especially in urban, coastal, and high-aerosol-load regions.
- Vertical aerosol profiling emerged as a recurring priority, particularly for modeling, aviation safety, and satellite validation use cases
- The role of harmonized, uncertainty-qualified datasets was highlighted for atmospheric modeling and data assimilation efforts (e.g., METAL-WRF, CAMS, RACE-ECV).
- Energy sector stakeholders stressed the need for improved AOD-based solar forecasts and site-specific irradiance data to optimize photovoltaic system performance
- Presentations demonstrated the utility of all-sky cameras and urban photometric networks for solar energy and urban planning applications (e.g., solar cadastre).
- The aviation community called for increased deployment of lidar and photometer systems near airports for dust and ash detection, and real-time integration with hazard alert systems
- Public health experts highlighted the importance of UV monitoring and fine-scale aerosol concentration data for exposure risk assessment and urban air quality services.
- The agricultural community outlined the importance of UV radiation and aerosol impacts on crop health, with a need for seasonal data and biologically effective irradiance estimates.
- Satellite validation experts emphasized the critical need for coincident ground-based measurements (sun photometers, lidars, sky radiometers) for validating missions like EarthCARE, MODIS, and TROPOMI.
- The value of coordinated field campaigns (e.g., EarthCARE validation) was broadly acknowledged, along with the need for multi-instrument synergies and temporal co-location.
- The workshop promoted cross-sector collaboration, linking modeling, instrumentation, and application communities to enhance data usability and interoperability.
- The outcomes of the 2nd workshop will directly inform Deliverables D3.1b (Minutes), D3.2 (User Requirements Report), and D3.3 (White Paper on Photometric Accuracy).