

Extended Report on the outcomes of a Virtual Mobility

Action number: CA21119

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Virtual Mobility Details

Title: **Overview of the Scientific Output of the HARMONIA COST Action Grants (2022–2026)**

Summary

Between 2022 and 2026, the HARMONIA COST Action (CA21119) implemented an extensive grant programme designed to support scientific collaboration, knowledge exchange, capacity building, networking and dissemination in the field of atmospheric aerosol retrievals. The grant portfolio comprises 108 grants across six schemes: Dissemination Conference, Inclusiveness Target Countries (ITC) Conference, Short-Term Scientific Mission (STSM), Virtual Mobility (VM), Virtual Networking Support (VNS), and Young Researcher and Innovator (YRI) Conference grants. The largest scheme is Virtual Mobility (51 grants), followed by STSM (18) and YRI Conference (19). The analysis of the identified outputs revealed 21 oral and 22 poster presentations across the grant portfolio, as well as 7 outreach videos and other dissemination and knowledge-transfer outputs.

The Scopus search of the funding information for “CA21119” or “COST Action HARMONIA” contains 45 records indexed between 2023 and 2026. Of these, 41 are classified as articles; the export also contains two reviews, one conference paper and one erratum. The records have accumulated 212 citations. These bibliometric results should be interpreted as evidence base for the scientific environment and outputs associated with the Action, rather than as proof that every publication was produced by a specific grant.

The grant reports demonstrate a broad spectrum of outcomes: development and testing of new retrieval algorithms, calibration and validation procedures, cloud-screening methods, radiative-transfer approaches, harmonized datasets and products, intercomparison activities, scientific deliverables, software-related developments and new measurement strategies, and training and

educational materials. They also facilitated collaborations between institutions and research groups working with complementary technologies and observations, contributed to conference presentations, and follow-up research. A recurring pattern is that grants acted as catalysts: a mission or virtual collaboration generated a methodological advance, dataset or comparison, which was then taken forward through conference contribution, deliverable, network activity, publication or subsequent collaboration.

The HARMONIA grant programme therefore acted not simply as a funding mechanism for individual mobility or conference attendance, but as a distributed scientific coordination mechanism, connecting researchers, instruments, methodologies, Working Groups and research communities.

1. Scope and methodology

The Virtual Mobility reported here covered the scientific outputs generated through the HARMONIA COST Action grant programme during the period 2022–2026. The analysis included the different grant schemes implemented within the Action, namely Short-Term Scientific Missions (STSMs), Virtual Mobilities (VMs), Young Researcher and Innovator (YRI) Conference Grants, Inclusiveness Target Countries (ITC) Conference Grants, Dissemination Conference Grants and Virtual Networking Support.

The methodology combined the systematic analysis of the documentation available within HARMONIA e-cost area, with an independent search for scientific outputs that could be associated with the grants. The main source of information was the HARMONIA database containing the reports submitted by grant holders. These reports were reviewed individually to identify and document the activities undertaken, scientific results, collaborations, presentations, publications, methodological developments, and other outputs arising from or associated with each grant. Where available, extended reports submitted by grant holders were also considered, as these frequently provided more detailed information on the activities and longer-term outcomes than the standard reports required by COST. To complement the information obtained from the grant reports, a systematic search was conducted in the Scopus database to identify scientific publications associated with HARMONIA COST Action. This additional source was particularly important for identifying scientific outputs that were not yet available, or were not explicitly reported, at the time the grant reports were submitted.

The information collected from the different sources was organised in a structured database, provided as a companion Excel spreadsheet to this report. The analysis also considered the nature and timing of the outputs, recognising that some grant schemes, particularly STSMs, Virtual Mobilities and Virtual Networking Support, may generate scientific and collaborative outcomes that become visible only after a certain time and are therefore not necessarily captured in the grant reports.

As foreseen in the Plan for Participation, the work was conducted in close collaboration with Prof. Pavla Dagsson-Waldhauserova, who coordinates the HARMONIA grant-awarding activities and provided valuable knowledge of the grant programme and access to the relevant Action records. The objectives and methodology were discussed, followed by a systematic review of the available information for the identification and classification of outputs. Further exchanges throughout the VM were used to clarify information, validate the results, and discuss the interpretation of the outputs identified.

2. HARMONIA grant portfolio

The grant portfolio comprises 108 awarded grants. Virtual Mobility is the dominant scheme (51 grants; 47.2% of the portfolio), followed by YRI Conference (19; 17.6%) and STSM (18; 16.7%). ITC Conference grants account for 16 (14.8%), while Dissemination Conference and Virtual Networking Support account for 2 grants each.

The temporal distribution of HARMONIA grants presented in Figure 1, demonstrates a sustained and increasingly intensive use of HARMONIA's grant mechanisms throughout its implementation period. The number of grants increased from 22 in 2023 to 26 in 2024, before reaching 36 in 2026. Virtual Mobility grants constitute the dominant grant mechanism throughout the period, highlighting the importance of virtual scientific collaboration, knowledge exchange and methodological learning. Conference-oriented schemes, particularly YRI and ITC grants, also became increasingly prominent in the later years, supporting the dissemination of HARMONIA-related research and strengthening the participation of young researchers and researchers from Inclusiveness Target Countries (ITC). The pronounced increase in 2026 is particularly noteworthy and indicates an intensification of grant-supported activities during the final year of HARMONIA, when dissemination, networking and consolidation of scientific outputs became increasingly important. Overall, the pattern demonstrates that the HARMONIA grant programme was not only a mechanism for individual mobility, but an important instrument for building scientific capacity, promoting collaboration and accelerating the dissemination and consolidation of the Action's results.

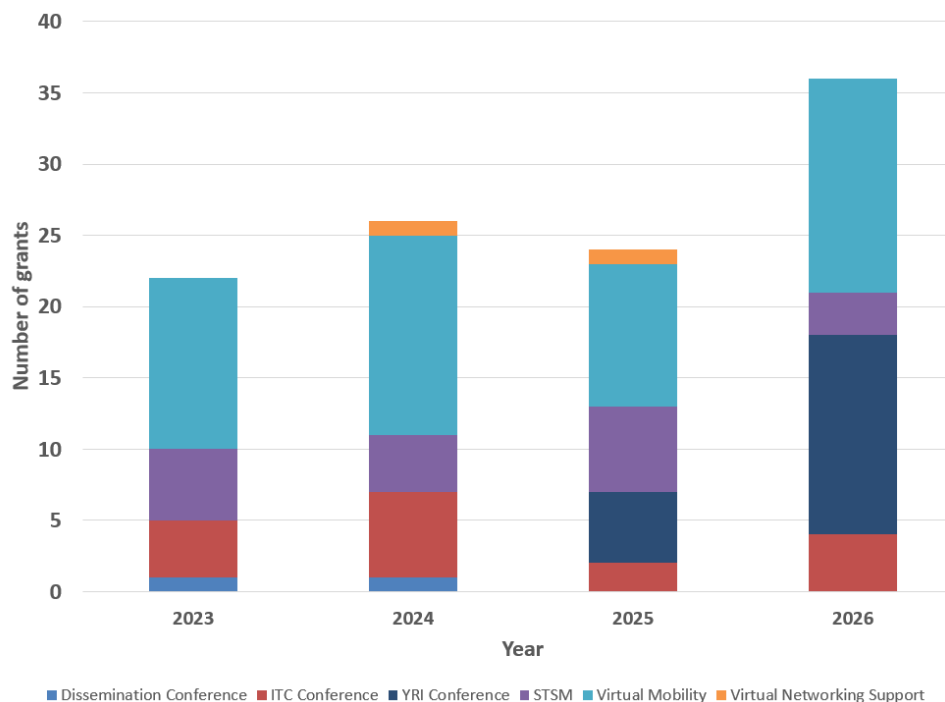


Figure 1 – HARMONIA grants by year and scheme.

3. Scientific outputs and contribution to HARMONIA

The grant reports reveal a multi-dimensional output profile. The most recurrent scientific outputs are methodological developments (including aerosol retrieval algorithms, cloud screening, calibration and validation methods), data products and datasets, software or scripts, scientific reports and contribution to Action deliverables. Conference presentations are a major dissemination channel, while several reports explicitly describe manuscripts or papers in preparation or publications arising from the work. Representative examples include: development and validation of lunar aerosol optical depth (AOD) retrieval for PREDE/Skyenet instruments; CIMEL repair, calibration and preparation for AERONET participation; testing of GRASP-AOD retrievals from PFR measurements; assessment of automated cloud screening across Davos and Izaña; harmonisation of sun, star and lunar photometer observations in the Arctic; integration of Brewer UV-B AOD products into EUBREWNET; EarthCARE validation activities at multiple sites; and work linking photometry, satellite products, radiative transfer, machine learning and aerosol microphysical retrievals.

Table 1 presents the grants awarded within HARMONIA by scheme and indicates the outputs identified directly from the reports submitted for each grant. It should be noted that a substantial number of grants resulted in more than one report: in addition to the standard report required by the COST Association, many grantees provided an extended report containing further details of their activities and results, specifically contributing to the objectives of HARMONIA. Therefore, the number of reports indicated in Table 1 represents a minimum and is lower than the actual number of reports produced.

Table 1 – Grants attributed by type and outputs identified.

Grant type	Number of grants	Oral presentations	Poster presentations	Reports (at least)	Manual/Guide	Video
Dissemination Conference	2	2		2		
ITC Conference	16	11	6	16		
STSM	18			18		
Virtual Mobility	51	3	1	51	1	7
Virtual Networking Support	2			2		
YRI Conference	19	5	15	19		
Total	108	21	22	108	1	

For STSM, Virtual Mobility (VM) and Virtual Networking Support (VNS) grants, the reports did not always document immediate or readily quantifiable outputs. This is particularly relevant for these grant schemes, as their outcomes may require additional time to materialize and may emerge subsequently in the form of scientific publications, training activities, educational materials, methodological developments, new collaborations, or other scientific and networking outputs. Consequently, the outputs presented in Table 1 should be understood as those directly identifiable from the available grant reports at the time of submission, shortly after completion of the respective grants, rather than as a comprehensive measure of their longer-term impact.

Conference participation represents a central pathway through which HARMONIA research results were disseminated, discussed and further developed within the scientific community. The grant summary records 43 presentations across four grant schemes, comprising 21 oral and 22 poster presentations, as shown in Table 1 and illustrated in Figure 2. Conference dissemination increased in importance towards the later years of the HARMONIA Action. Figure 2 shows that conference presentations were supported primarily through ITC and YRI Conference Grants, with ITC grants generating oral contributions throughout the 2023–2026 period and YRI grants introduced in 2025 and 2026. Poster presentations also increased markedly in 2026, driven predominantly by YRI-supported participation. Overall, the pattern demonstrates the complementary role of the different grant schemes in increasing scientific visibility, supporting participation of researchers at different career stages and from different geographical contexts, and providing pathways for grant-supported research activities to reach the wider scientific community. The concentration of presentations in 2026 is particularly relevant to the Action's final phase, reflecting the increasing emphasis on dissemination and consolidation of HARMONIA's scientific results.

Grant reports document participation in major international scientific meetings, including the EGU General Assembly, International Laser Radar Conference (ILRC), European Meteorological Society (EMS) and other specialist conferences. Beyond increasing the visibility of HARMONIA and its scientific results, conference participation provided opportunities for researchers to receive feedback on methodologies and preliminary findings, establish new scientific contacts and identify potential collaborations. Several reports also indicate that these interactions contributed to the development of follow-up research activities and provided pathways towards scientific publications, new projects and longer-term collaborations. Conference grants therefore functioned not only as dissemination mechanisms, but also as an important component of HARMONIA's strategy for scientific exchange, networking, capacity building and the development of future research opportunities.

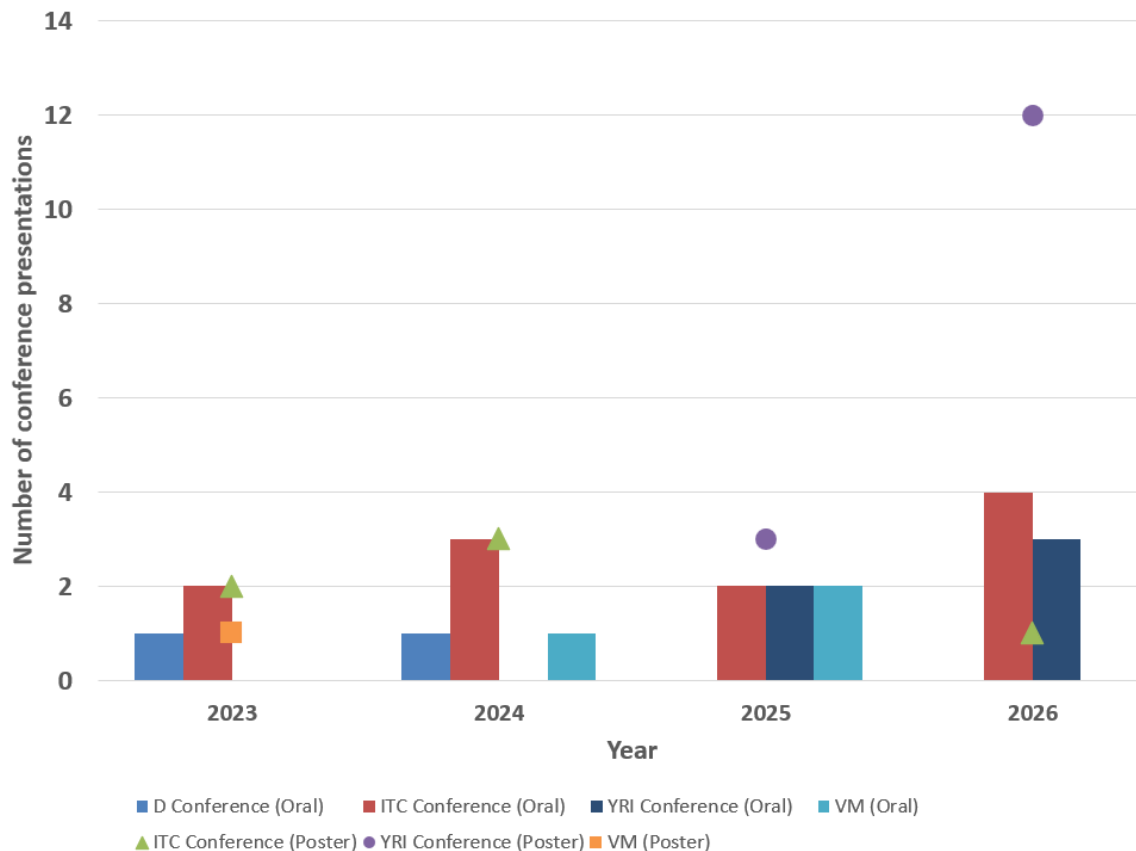


Figure 2 – Conference presentation outputs by year and grant type.

The analysis of the grant reports allowed for identifying six main scientific and capacity-building themes that demonstrate their contribution to the development, harmonisation and application of ground-based aerosol observations:

- Measurement, calibration and harmonisation

A substantial proportion of the STSM and VM activities addressed the improvement, comparison and harmonisation of aerosol measurement systems. These included CIMEL instrument repair and calibration, Improved Langley methods, Brewer retrievals, CAELIS harmonisation, error-propagation analyses, and the integration of sun, star and lunar photometry. These activities directly contributed to improving the consistency, quality and comparability of aerosol measurements across instruments, networks and geographical regions.

- Aerosol retrieval algorithms and value-added products

The grants supported the development, testing and application of retrieval methodologies for AOD, aerosol size distributions, effective radius, aerosol concentration, volume-to-extinction parameters and other aerosol properties. Examples include GRASP-based retrieval approaches

and the development of lunar aerosol retrievals. These activities contributed to transforming primary observations into more advanced and scientifically useful aerosol products, thereby increasing the value of existing measurement networks.

- Cloud screening and quality assurance

Improving data quality was another important topic. In particular, the clustering-based cloud-screening work applied to PFR measurements illustrates the effort to improve the identification of cloud-contaminated observations while preserving short-term aerosol variability, including dust events. The analyses conducted for Davos and Izaña not only assessed the performance of existing approaches but also identified limitations and directions for further methodological development. Such work is fundamental to producing reliable and harmonised long-term aerosol datasets.

- Synergies between satellite and ground-based observations

Several grants promoted the integration of complementary observing systems. EarthCARE validation activities, A-Train satellite analyses, CAMS-related studies, and comparisons between satellite products and photometer and lidar observations demonstrate how HARMONIA grants contributed to strengthening links between ground-based observations, satellite remote sensing and atmospheric modelling. These activities enhance the potential of harmonised ground-based observations to support satellite validation and Earth-system monitoring.

- Climate, radiation and applications

The scientific activities extended beyond measurement methodology to address the broader implications and applications of aerosol observations. Several grants connected aerosol measurements with solar radiation, photovoltaic energy production, climate projections, radiative forcing and air quality. This demonstrates the relevance of HARMONIA outputs to wider scientific and societal challenges and illustrates how improved aerosol observations can support applications in climate research, renewable energy and environmental monitoring.

- Capacity building, young researcher development and networking

The grants also made an important contribution to the development of scientific capacity and the strengthening of the HARMONIA research community. Conference grants and mobility schemes enabled young researchers to present their work, receive scientific feedback, establish new contacts and develop follow-up collaborations. In parallel, grant-management VMs contributed to improving the Action's internal procedures for evaluation, reporting and dissemination. Thus, the grant programme supported not only scientific outputs but also the development of the human and collaborative infrastructure required to sustain HARMONIA's scientific objectives.

4. Scopus bibliometric overview

Regarding publications and scientific recognition, a Scopus analysis was undertaken using the funding information fields to identify records associated with “CA21119” or “COST Action HARMONIA”. The data was obtained from Scopus on 23 August 2026. A total of 45 Scopus-indexed records published between 2023 and 2026 were identified, with their annual evolution and associated citation counts presented in Figure 3. The analysis indicates a sustained level of scientific publication throughout the HARMONIA Action, with the annual number of publications remaining relatively stable, ranging from 10 to 12 publications per year. In contrast, citations increased steadily over the period, accumulated 212 citations in the period, indicating growing visibility and uptake of the scientific work associated with the Action. However, the citation levels of the most recent publications, particularly those published in 2026, should be interpreted with caution, as these publications have had substantially less time to accumulate citations. Their citation counts are therefore expected to increase as these publications remain available and are progressively cited by the scientific community. Furthermore, the number of scientific publications emerging from HARMONIA is also expected to increase, as several manuscripts resulting from the activities are currently in preparation or under review. Consequently, the publication and citation figures presented here should be regarded as a snapshot of the Action's scientific output at the time of the analysis, rather than as a final measure of its publication legacy.

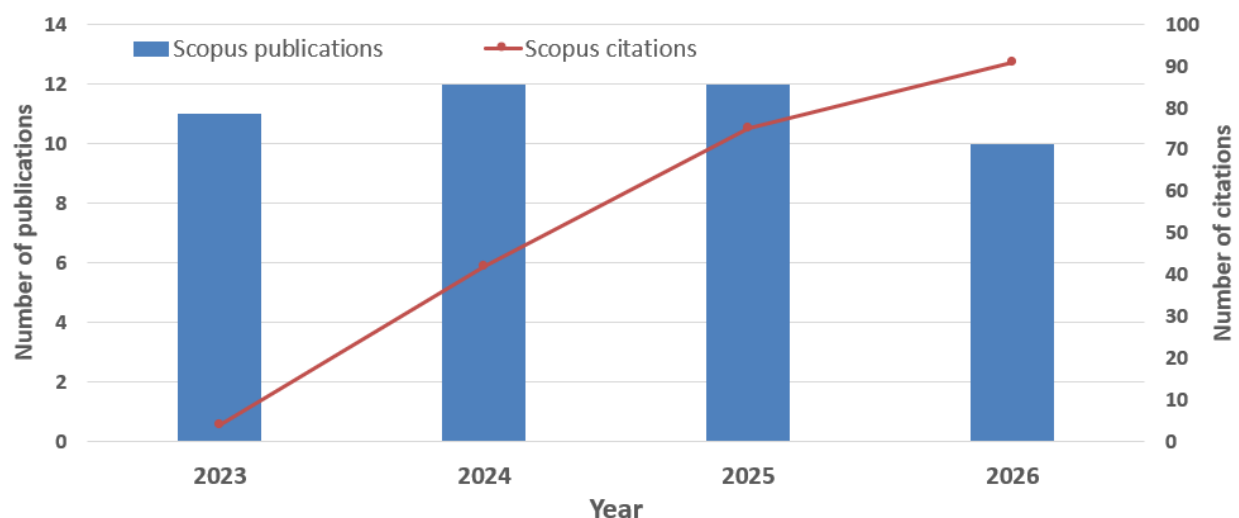


Figure 3 – Evolution of Scopus-indexed HARMONIA publications and cumulative citations, 2023–2026 (source: Scopus on 23 August 2026). Bars represent the number of publications indexed in Scopus for each year, while the line represents the cumulative number of citations recorded for the corresponding publication portfolio.

Table 2 summarises the distribution of the Scopus-indexed HARMONIA documents by journal and publication type. The journal distribution is strongly concentrated in Atmospheric Measurement Techniques (16 records) and Atmospheric Chemistry and Physics (9), followed by Remote Sensing (5). Together, these journals account for 67% of the 45 publications. The remaining publications are distributed across a broader range of journals, reflecting the wider applicability of HARMONIA research into areas such as atmospheric science, climate, radiation, energy and environmental applications. This distribution is also consistent with an important indicator of HARMONIA's scientific legacy: the joint inter-journal special issue, “Sun-photometric measurements of aerosols: harmonization, comparisons, synergies, effects, and applications”, organised across Atmospheric Measurement Techniques (AMT) and Atmospheric Chemistry and Physics (ACP) (https://acp.copernicus.org/articles/special_issue400_1356.html; last accessed 23 August 2026). The special issue is explicitly framed within HARMONIA and addresses key scientific areas of the COST Action, including improved surface-based aerosol measurements, harmonisation of products across networks, aerosol trend analysis and satellite validation, synergies with *in situ* and lidar measurements and modelling, aerosol–cloud–radiation interactions, and applications in solar energy, aviation, health, climate and air quality. As noted above, the number of publications associated with the special issue and other HARMONIA-related publications is expected to increase further before the end of the Action, as several manuscripts are currently in preparation or under review.

Table 2 – Distribution of the Scopus-indexed HARMONIA documents by journal and publication type.

Journal	Number of publications	Type
Atmospheric Measurement Techniques	16	Article
Atmospheric Chemistry and Physics	9	Article
Remote Sensing	5	Article
Solar Energy	3	Article
Atmosphere	2	Article (1), Review (1)
Atmospheric Environment	2	Article (1), Erratum (1)
Advances in Science Technology and Innovation	1	Conference paper
Allergy European Journal of Allergy and Clinical Immunology	1	Review
Astronomy and Astrophysics	1	Article
Atmospheric Research	1	Article
Energies	1	Article
Geoscientific Model Development	1	Article
Journal of Geophysical Research Atmospheres	1	Article
Remote Sensing of Environment	1	Article
Total	45	

5. Success stories

Several success stories have been identified among the HARMONIA grants, three of which are presented below. They illustrate how the grants contributed to strengthening research collaboration, supporting coordinated scientific activities, generating new datasets, and creating opportunities for further analysis and future scientific outputs. Importantly, the impact of HARMONIA extends beyond individual outputs, reflecting the cumulative contribution of multiple grants to shared scientific objectives and the development of sustained collaborative activities.

Harmonisation of aerosol observations

One of the central achievements of the HARMONIA grant programme was to advance the harmonisation of aerosol observations across different instruments, networks and retrieval approaches. The grants brought together researchers working with CIMEL/AERONET, PFR/GAW-PFR and PREDE/SKYNET measurements and enabled the development, testing and application of common approaches for AOD retrieval and quality control.

A particularly clear example is the extension of the HARM (Harmonized AOD Retrieval Method) developed by the German Weather Service (DWD) to CAELIS products generated by the University of Valladolid. The STSM enabled researchers from DWD and the University of Valladolid to work jointly on adapting HARM to the CAELIS dataset. This made it possible to compare two CIMEL instruments operating in parallel using the same retrieval methodology and to separate instrumental differences from differences caused by the retrieval/data-processing system. The analysis also identified previously unrecognised inhomogeneities between AERONET and CAELIS products and allowed to establish follow-up plans, thereby facilitating future intercomparisons and reducing dataset inhomogeneities. The same harmonisation challenge was addressed from other complementary perspectives. HARMONIA grants supported the evaluation of cloud-screening approaches across CIMEL and PFR observations, including measurements from different sites and aerosol regimes. This work demonstrated that apparently comparable observations can be affected by differences in measurement frequency, temporal resolution and cloud-screening methodology, highlighting the need for harmonised quality-control procedures. Other grants extended the harmonisation effort to lunar and night-time observations, to additional photometer networks, and to value-added retrievals such as GRASP. In parallel, HARMONIA activities addressed calibration, metadata, retrieval uncertainties and operational data processing, contributing to the Action's objective of homogenising aerosol optical properties across networks.

This helped transform a fragmented landscape of aerosol observations into a more interoperable measurement system, by enabling researchers from different networks and institutions to work together on common retrieval methodologies, calibration, quality control and intercomparison procedures. The importance of this achievement is that harmonisation is not simply about making datasets numerically similar. It means understanding why different observations differ, whether because of the instrument, calibration, retrieval algorithm, atmospheric assumptions, cloud screening or data processing, and developing common procedures that allow the resulting measurements to be meaningfully compared.

EarthCARE validation network

A sequence of HARMONIA VM Grants supported coordinated ground-based observations for the validation of the EarthCARE satellite mission, contributing to a distributed measurement network linked to the mission's Cal/Val activities. The grants enabled researchers to coordinate measurements with EarthCARE satellite overpasses, combining complementary observations from instruments such as sun-photometers, lidars, pyranometers, pyrhemometers and all-sky cameras. This provided coincident measurements of aerosol optical properties, surface solar irradiance and cloud conditions under a range of atmospheric situations. The resulting datasets are being quality-controlled and calibrated for comparison with EarthCARE products and will contribute to the assessment of aerosol and radiative-flux retrievals. The observations also provide a basis for further analyses, including comparisons with ground-based aerosol products and, in subsequent work, the reconstruction of three-dimensional cloud fields and their integration into radiative-transfer modelling.

Beyond the observational results, the distributed approach strengthened collaboration among HARMONIA researchers and connected complementary expertise and measurements across institutions and countries. It also linked local observational activities to the broader objectives of the HARMONIA CA concerning aerosol measurement accuracy, retrieval uncertainty and satellite validation. Overall, these VMs helped transform geographically distributed measurement activities into a coordinated contribution to an international satellite validation effort. They generated new observational datasets, strengthened cross-institutional and international collaboration, and created opportunities for joint analyses, further research and future scientific publications, demonstrating the capacity of COST networking instruments to rapidly mobilise complementary research activities around a major scientific mission.

Lunar AOD retrieval and network capability

A couple of HARMONIA STSMs supported the development, validation and implementation of a method for retrieving night-time AOD from PREDE instruments operating within the European SKYNET Radiometer network.

The initial STSM focused on adapting an existing lunar-AOD methodology and modifying the existing processing system to account for lunar reflectance, calibration and the specific characteristics of PREDE measurements. New scripts were developed, including an automated processing chain. The resulting night-time AOD retrievals showed very good agreement with AERONET observations.

The work was subsequently extended through a further STSM, which moved beyond the initial proof of concept. The retrieval system was implemented in two sites to automatically process observations and update calibration values, with plans to expand in the future to more sites. The work resulted in two data products and enabled automatic inversion of nocturnal observations across the operational lunar POM sites of the European SKYNET Radiometer network.

HARMONIA networking enabled the technique to be adapted, tested, validated, automated and subsequently extended to a wider observational network. The work also generated a clear pathway towards further scientific exploitation, including additional validation, comparisons between different networks and preparation of a peer-reviewed publication. This sequence of STSMs transformed knowledge exchange between researchers into a new observational capability for the SKYNET network, extending aerosol measurements into the nighttime and strengthening the harmonization of lunar AOD observations.

6. Conclusions

The evidence reviewed through this Virtual Mobility demonstrates that the HARMONIA COST Action grant programme generated a substantial and diverse scientific legacy during the period 2022–2026. The contribution of the grant programme cannot be fully captured by publication or presentation counts alone. Rather, the analysis reveals a broader chain of effects through which the grants supported scientific and technological development, knowledge exchange and the establishment of longer-term collaborations.

The grants created mobility and collaboration opportunities that would have been difficult to achieve through the central Action meetings alone. By enabling researchers to visit other institutions, access specialised expertise and infrastructure, participate in scientific events and establish direct interactions with colleagues from across the HARMONIA network, the different grant schemes substantially extended the collaborative dimension of the Action.

The analysis also demonstrates the scientific breadth and complementarity of the grant portfolio. The activities supported by the grants covered different stages of the atmospheric observation and remote-sensing research chain, including instrument calibration, algorithm development, data quality assessment, validation and harmonisation, satellite validation, dataset and product generation, and applications addressing the needs of scientific and end-user communities. This demonstrates that the grants contributed not only to individual research activities but also to the integration of different expertise and methodological approaches within the HARMONIA network.

The conference grant schemes, in particular YRI and ITC Conference Grants, provided an important bridge between scientific production and dissemination. They enabled researchers, including early-career researchers, to present their work to the wider scientific community, receive feedback and establish new scientific contacts. These activities contributed simultaneously to scientific dissemination, professional development and the integration of researchers into the wider HARMONIA network.

The analysis also highlights the importance of recognising time-dependent outputs. Not all scientific outcomes are immediately visible in grant reports. This is particularly relevant for STSMs, Virtual Mobilities and Virtual Networking Support, where the immediate outcome may be the establishment of a collaboration, development of a methodology, exchange of expertise or preparation of research activities, with publications, datasets, software or other scientific products emerging at a later stage. The complementary analysis of Scopus records therefore provided evidence of outputs extending beyond those directly documented in the original grant reports.

Overall, the evidence demonstrates the added value of COST networking instruments in transforming relatively short-duration mobility, collaboration and dissemination activities into longer-term scientific interactions and outputs. The impact of the HARMONIA grant programme can therefore be summarised as a progression from networking to collaboration, from collaboration to scientific output, and from scientific output to longer-term impact.