

HARMONIA CA21119

Deliverable 5.3d

Annual review of progress/achievements towards deliverables during MC meetings

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1. Introduction

It is the overall objective of the WG5 to establish mechanisms to disseminate the outcomes of the HARMONIA COST Action (CA21119) WG1-4 activities towards measurement improvement, new techniques and measurement approaches to aerosol scientists and instrument users (inside and outside the HARMONIA consortium). The main targets are:

- Present HARMONIA results to various structures dealing with aerosol measurements, including aspects of the entire processing chain; from measurement to end-user products.
- Disseminate and communicate scientific results and end user aerosol related activities towards different audiences (scientists, public, industry, government bodies).
- Exchange and combine software and hardware user tools among partners towards retrieval improvements.
- Publish scientific results of HARMONIA collaboration to peer reviewed journals, conferences, and reports.

This deliverable describes the progress, the achievements and all the networking activities towards the eight deliverables of the third year of the action, based on the discussions during the MC and the corresponding WG meetings. The eight deliverables of the fourth year of the Harmonia action come from all working groups and are respectively:

D1.3 Harmonised AOD Retrievals & AOD Comparisons

D1.4 Spectral AOD and AOD in the UV

D1.5 Photometry from day to night in Europe: solar, lunar and stellar. Historical approach new methods and synergies

D2.4: Report on uncertainties for optimized and homogenized products and suggestions for improving already existing products.

D3.3: Publish a white paper on sun-photometric aerosol accuracy and uncertainty for different applications.

D4.1b: Share the recordings and the presentations of two Workshops that will be organized, with industrial users related with: technological needs and innovation actions. The deliverable D4.1a concerns the report for the first of the two workshops in Davos and it was transferred at the end of the third year of the COST action.

D4.2: Report on hardware and software evolution needs according to WG3 results.

D5.4: Report on the dissemination of HARMONIA results to major stakeholder conferences.

In the Memorandum of Understanding (MoU), WG1 originally had a single deliverable for this period, D1.3 ("Report on the cross validation experiments of synergies with co-located solar, lunar and stellar photometers on white and review papers"). On the proposal of the WG1 leaders, it was split into the three deliverables D1.3, D1.4 and D1.5 listed above.

2. Annual review for 4th year deliverables

2.1 Deliverables D1.3, D1.4, D1.5 (-initially D1.3)

The main objective of the WG1 is the homogenization and harmonization of global aerosol measurements and retrievals. To achieve this goal networking is a key aspect since different instruments/networks and related algorithms have to be unified. The cooperation and the knowledge exchange inside the HARMONIA and specifically inside the WG1 aims to create a scientific roadmap on worldwide homogenization of aerosol properties' measurements including calibration, standard operation, quality assurance and control procedures and post processing.

As decided during the third year, D1.3 was moved to the fourth year and split into three deliverables:

Deliverable D1.3: "Harmonised AOD Retrievals & AOD Comparisons"

Deliverable D1.4: "Spectral AOD and AOD in the UV"

Deliverable D1.5: "Photometry from day to night in Europe: solar, lunar and stellar. Historical approach new methods and synergies"

A joint online WG1–WG2 meeting was held on 12 December 2025 to discuss the deliverables of both WGs and their common topics. For WG1, the focus was on D1.3 and D1.4

At the HARMONIA workshop in Astypalea, Greece (6-7/7/2026), it was announced that two Virtual Mobility (VM) grants would be requested for D1.3 and D1.4, for Angelos Karanikolas and Lionel Doppler, to speed up their preparation. The links to the shared online working documents were circulated and the content of each deliverable was discussed.

For D1.5 (solar/lunar/stellar synergy), the initial idea was to provide an overview of all studies combining stellar and lunar, or solar and lunar, photometry. As this is already largely covered by WG2 Deliverable D2.2, "List of possible improvements on the quality of solar, lunar and stellar photometry" (123 pages), it was proposed to

extend D1.5 to recent work on AOD retrievals from all-sky cameras, also carried out by members of the HARMONIA core group and WGs.

At the Helsinki MC meeting, the WG1 leaders (now including Angelos Karanikolas) said work on D1.3, D1.4 and D1.5 was progressing very actively. The VM grants for Angelos Karanikolas and Lionel Doppler were still pending, the content so far was presented, and members were invited to contribute.

2.2 Deliverable D2.4

The objective of the WG2 is to improve aerosol measurements using solar-, lunar- and star photometry, breaking new grounds for aerosol retrieval techniques including calibration improvement (via S.I. traceable related standardization results), hardware and software improvement actions. The exchange of knowledge and experience among manufacturers, calibration and data processing related scientists and users by establishing a network through HARMONIA, are the foundations for those improvements. The exploitation of existing measurement experimental data for different aerosol environments is one of the main sources of information for investigating and suggesting improvements of aerosol photometry measurement. The fourth deliverable of the WG2 is:

Deliverable D2.4: “Report on uncertainties for optimized and homogenized products and suggestions for improving already existing products.”

The joint online WG1–WG2 meeting of 12 December 2025 discussed the topics feeding the deliverables of both WGs, some of which are common.

At the Astypalea workshop, the D2.4 template was shared as an online document with a suggested structure for the content, and members were invited to add their contributions. Work related to D2.4 was also presented during the meeting.

At the Helsinki MC meeting the D2.4 document in progress was presented and members were again invited to add contributions. Work for D2.4 was also presented, along with results from two recent VMs that will be part of the deliverable.

2.3 Deliverable D3.3

The objective of the WG3 is to increase the applicability for aerosol optical properties for different scientific fields. HARMONIA network and specifically WG3 aims to link the accuracy and uncertainty of aerosol optical properties to the objectives and needs of the climate and atmospheric related scientific community and relevant structures (e.g. WMO, GCOS, satellite related missions) and to create interacting mechanisms with users (Climate scientists, air quality, solar energy, aviation and others). The expertise of diverse groups in HARMONIA (ground-based aerosol monitoring, satellite monitoring, atmospheric modelling, etc.) and the networking activities are essential in fulfilling those objectives. The third deliverable of the WG3 is:

D3.3: " Publish a white paper on sun-photometric aerosol accuracy and uncertainty for different applications."

After the MC meeting in February 2026, the WG3 leaders e-mailed the HARMONIA WG members asking for contributions to D3.3. As experts in different topics related to the use of radiometric aerosol measurements, members were asked to contribute a couple of paragraphs each, following an indicative assignment in a shared online document. They were also invited to correct the assignments where needed, to recommend people who could help with specific sections or sub-sections, and to involve colleagues. The main goals of the white paper are to:

- a) demonstrate the current state of the art of AOD measurements from ground-based instruments, satellites and models (e.g. CAMS, MERRA-2);
- b) describe and demonstrate, through a literature review, the use of AOD and other aerosol properties by different communities and applications;
- c) identify needs and gaps.

The online document was continuously updated until the final MC meeting in Helsinki (September 2026).

At the final MC meeting in Helsinki (3–4 September 2026), the WG3 leaders presented the status of the white paper. Sections 1 (Introduction) and 2 (Current capabilities) were nearly complete, and most sub-sections of Section 3 (User requirements across disciplines) had been drafted. The following actions remained pending:

- **Section 2 – Current capabilities:** further revision, moving part of the material to a supplement.

- **Section 3 – User requirements across disciplines:**
 - review of Sections 3.1 (Aerosol impacts on solar irradiance) and 3.6 (Aviation);
 - possible shortening of Section 3.2 (Solar energy) and shortening of Section 3.5 (Health);
 - additional contributions to Section 3.3 (Atmospheric composition and climate), particularly on machine-learning techniques, and to Section 3.5 (Health), on complementing PM monitoring;
 - volunteers to draft Section 3.7 (Agriculture, ecosystems and other emerging needs), drawing on material already available in D4.2;
 - upload of a new version and invitation of further contributors and reviewers for specific sections.
- **Section 4 – Gaps and challenges:** to be drafted, reusing material from D4.2 and moving related text from Section 3. Possible topics include geographical coverage (e.g. oceanic and polar regions, developing countries), temporal resolution and diurnal sampling, instrument harmonization and calibration, UV/IR measurements, data latency and dissemination, uncertainty quantification and documentation, and social and geopolitical issues and their impacts.
- **Way forward:** to be added as a short paragraph in Section 4 rather than as a separate section.
- **Overall:** complete the missing information, review the full text and shorten selected sections.

The agreed timeline was:

- **20 September 2026:** finalize Sections 1–3;
- **5 October 2026:** finalize Section 4;
- **15 October 2026:** submit the revised version of the report.

2.4 Deliverable D4.1b

WG4 addresses the challenge: how can scientists improve aerosol measurement quality and future measurement capabilities, including low-cost sensors? Its approach (Objective 4) is to establish an interdisciplinary team of scientists dealing

with aerosol measurements and their use, together with industrial instrument developers, in order to report on the current status of measurement uncertainty and on future technical needs, and to suggest innovative ideas for the future of aerosol remote sensing sensors and retrieval methods.

The second deliverable of WG4 relates to the second WG4 workshop:

D4.1b: "Share the recordings and the presentations of two Workshops that will be organized, with industrial users related with: technological needs and innovation actions."

The second WG4 workshop was held on 30 June 2026 at the Group of Atmospheric Optics of the University of Valladolid (GOA-UVA), Spain, with 18 participants, all attending in person. It focused on low-cost instrumentation and on covering complex regions without measurements. Further details are documented in Deliverable D4.1b.

2.5 Deliverable D4.2

The third deliverable of WG4 is:

D4.2: "Report on hardware and software evolution needs according to WG3 results."

D4.2 was completed (https://harmonia-cost.eu/wp-content/uploads/2026/09/Harmonia_D42.pdf) ahead of the final MC meeting in Helsinki, where the WG4 leaders presented its key points: the highest-priority hardware and software investments, the remaining gaps and strategic recommendations. Its main conclusion is that a measurement ecosystem is needed that combines reference instruments, validated complementary sensors and satellite data.

2.6 Deliverable D5.4

The objective of the WG5 is to increase the dissemination of the produced outcomes of the WG1-4 activities of the HARMONIA COST Action, to aerosol scientists, instrument users and other HARMONIA participants inside and outside the HARMONIA consortium, towards measurement improvement, new techniques and

measurement approaches, sharing of protocols etc. thus contributing to the objectives of the Action.

A lot of dissemination activities took place in the 4 years of HARMONIA Cost Action which are reported in the following deliverable:

D5.4: "Report on the dissemination of HARMONIA results to major stakeholder conferences.

Many dissemination activities took place during the four years of the HARMONIA COST Action; they are reported in D5.4. The deliverable was prepared by Anca Nemuc, WG5 leader, with contributions from the core group and will be published on the website of HARMONIA