Deliverable 2.1: Identification of opportunities for harmonised calibration and operation practices and data production software

Authors: Alfred Wiedensohler, Honey Alas, Kay Weinhold, Elisabeth Andrews, Olga Mayol-Bracero

Work package no	WP2
Deliverable no.	D2.1
Lead beneficiary	TROPOS
Deliverable type	X R (Document, report) ☐ DEC (Websites, patent filings, videos, etc.) ☐ OTHER: please specify ....
Dissemination level	X PU (public) ☐ CO (confidential, only for members of the Consortium, incl. Commission)
Estimated delivery date	M6
Actual delivery date	29/10/2024
Version	Final
Reviewed by	Tuukka Petäjä
Accepted by	Ewan O'Connor, Eija Juurola
Comments	This document contains only the in-situ part of the harmonisation activities. The complete deliverable, including the remote sensing component, is to be resubmitted by M18, i.e. August 2025, as agreed with the Project Officer.

CARGO-ACT (www.cargo-act.eu) is supported by the European Commission under the Horizon Europe (HORIZON) – Strengthening the international dimension of ESFRI and/or ERIC research infrastructures, HORIZON-INFRA-2023-DEV-01-07, Grant Agreement #: 101132093

Contents

CARGO-ACT (www.cargo-act.eu) is supported by the European Commission under the Horizon Europe (HORIZON) – Strengthening the international dimension of ESFRI and/or ERIC research infrastructures, HORIZON-INFRA-2023-DEV-01-07, Grant Agreement #: 101132093

1. Introduction

The main objective of CARGO-ACT is to pave the way for global interoperability that will ultimately lead to better harmonized global datasets of key atmospheric parameters, specifically for short-lived components such as aerosol particles, trace gases, and clouds. In this deliverable, we report on the results of CARGO-ACT's first activities towards achieving this goal. Building upon the Milestone #4 submitted during the M4 of this project (Documentation of standard operation procedures, calibration protocols, and processing), we assessed existing protocols (global, EU, and US) and identified opportunities for harmonization - ensuring measurement consistency across multi-network datasets employing different instruments and instrument methodologies.

As proof of concept, our activities here are focused on **8 microphysical and optical aerosol variables,** four for each branch and listed in their respective chapters. We have chosen these variables because they are the obligatory core aerosol measurements in ACTRIS.

The report proceeds as follows: the variables are grouped into the two branches, variables measured by in-situ (IS), and variables measured by remote sensing (RS) methods, which are distributed into two chapters. Please note that the chapter dedicated to RS protocols will be submitted in the second version of this deliverable. Here, we provide a summary of the state-of-the-art protocols of the relevant networks and report on which aspects can be further harmonized. Finally, we provide a brief overview of CARGO-ACT's activities for harmonization where possible.

This deliverable uses the following terminology:

- "variable" - microphysical and optical aerosol variable listed in Table 1;
- "observatory" - measurement station/site;
- "protocol" - collection of procedures;
- "network" – measurement observatories under one organization;
- "SOP" – on-site standard operating procedures

CARGO-ACT (www.cargo-act.eu) is supported by the European Commission under the Horizon Europe (HORIZON) – Strengthening the international dimension of ESFRI and/or ERIC research infrastructures, HORIZON-INFRA-2023-DEV-01-07, Grant Agreement #: 101132093

2. In Situ (IS) Variables

The harmonization activities of CARGO-ACT are centred on the four aerosol IS variables listed in Table 1. To achieve global harmonised datasets of aerosol variables, we focus our activities on four aerosol IS measurement networks which are briefly described below.

Table 1. List of IS microphysical and optical aerosol variables and relevant measurement principle/instrument.

IS Variables	measurement methods/instrumentation
particle number size distribution (10-800 nm) (PNSD)	mobility particle size spectrometers (MPSS)
particle number concentration Dp > 10 nm (PNC)	condensation particle counters (CPC)
particle light absorption coefficient (Abs)	absorption photometers (AP)
particle light scattering coefficient (Scat)	integrating nephelometers (IN)

Aerosol, Clouds and Trace Gases Research Infrastructure (ACTRIS - EU)

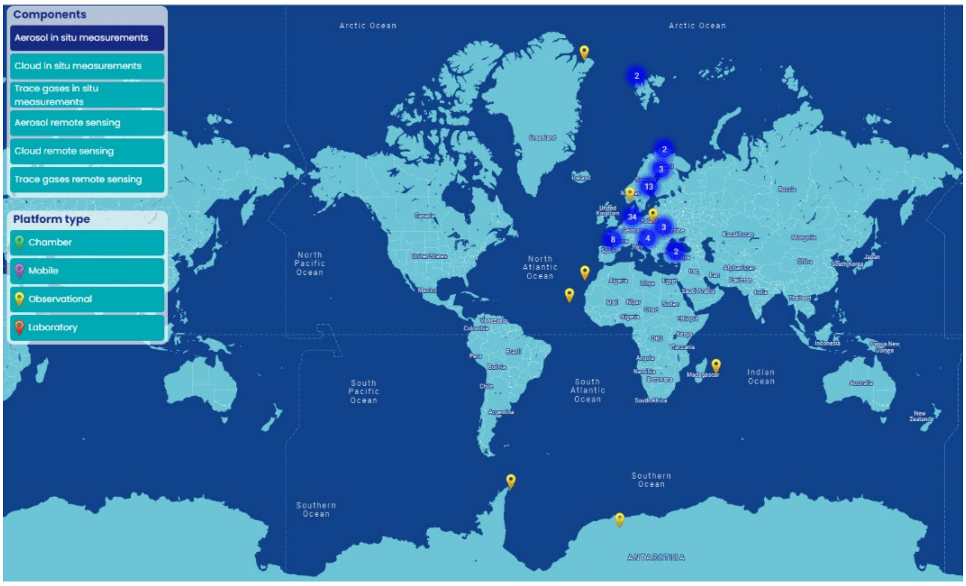

Figure 1 Map of ACTRIS sites for aerosol in situ measurements (source: https://www.actris.eu/facilities/national-facilities)

The ACTRIS aerosol IS measurement network is part of an overarching long-term activity with more than 100 European partners engaged in building a single, pan-European, sustainable and distributed research infrastructure. The aerosol IS network consists of fixed stations mostly in Europe with a few stations in the

CARGO-ACT (www.cargo-act.eu) is supported by the European Commission under the Horizon Europe (HORIZON) – Strengthening the international dimension of ESFRI and/or ERIC research infrastructures, HORIZON-INFRA-2023-DEV-01-07, Grant Agreement #: 101132093

polar regions and around Africa all falling within the umbrella of the Centre for Aerosol In Situ – European Centre for Aerosol Calibration and Characterisation (CAIS-ECAC). A unique feature of the ACTRIS aerosol IS network is the World Calibration Centre for Aerosol Physics (WCCAP) which serves as a competence centre for IS physical and optical aerosol measurements and provides services for the traceability and quality assurance of these measurements, and station audits to improve infrastructures. WCCAP activities is also part of the world-wide Global Atmospheric Watch (GAW) program of the World Meteorological Organization (WMO).

National Oceanic and Atmospheric Administration - Federated Aerosol Network (NOAA NFAN - US) and Global Atmospheric Watch (GAW)

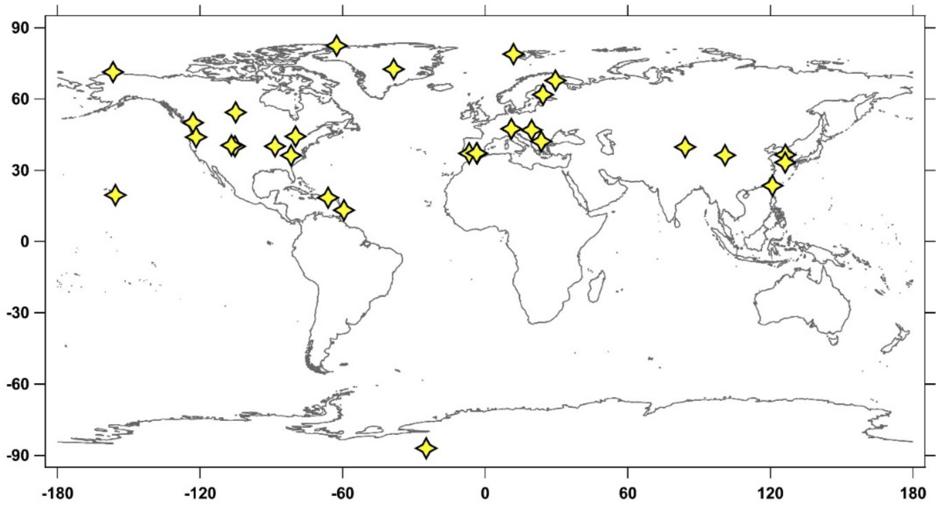

Figure 2 Map of NOAA NFAN stations (source: Elisabeth Andrews)

NOAA NFAN consists of NOAA Global Monitoring Laboratory (GML) operated stations and collaborations through the use of either, or both of, their facilities or logging software, and GAW stations (30 sites across 13 countries). Some of these stations overlap with the ACTRIS and ARM networks. These measurements are made both within the US and internationally and these networks provide their data to international archives as well as to NOAA databases. GML maintains calibration scales and provides calibration services to support the WMO GAW programs for a subset of their network measurements.

CARGO-ACT (www.cargo-act.eu) is supported by the European Commission under the Horizon Europe (HORIZON) – Strengthening the international dimension of ESFRI and/or ERIC research infrastructures, HORIZON-INFRA-2023-DEV-01-07, Grant Agreement #: 101132093

US Department of Energy - Atmospheric Radiation Measurement (DOE-ARM - US) fixed and mobile observatories

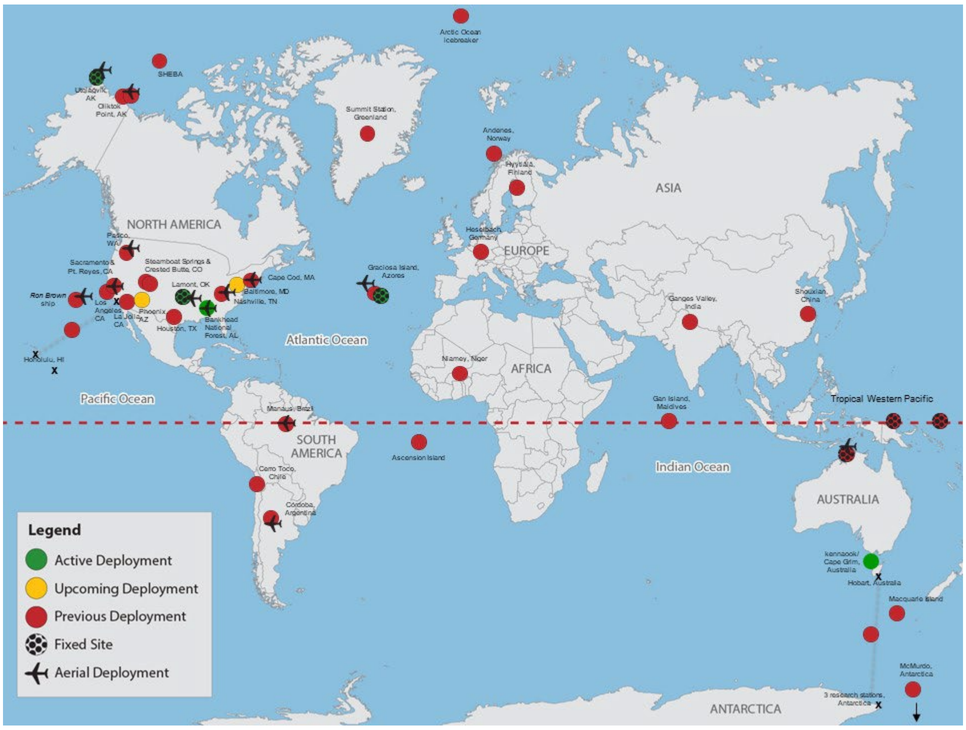

Figure 3 DOE ARM measurement network (source: Image courtesy of the U.S. DOE ARM user facility.)

The DOE ARM user facility operates a network of extensively instrumented long-term fixed-location observatories and mobile facilities deployed in various locations and periods providing measurements of atmospheric properties across the globe.

Atmospheric Science and Chemistry Measurement Network (ASCENT - US)

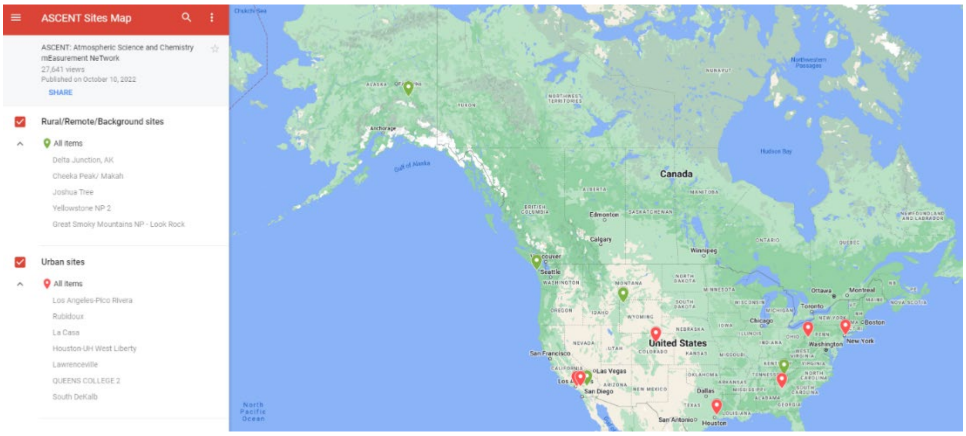

Figure 4 ASCENT measurement network (source: https://ascent.research.gatech.edu/measurement-sites)

CARGO-ACT (www.cargo-act.eu) is supported by the European Commission under the Horizon Europe (HORIZON) – Strengthening the international dimension of ESFRI and/or ERIC research infrastructures, HORIZON-INFRA-2023-DEV-01-07, Grant Agreement #: 101132093

ASCENT is a newly established comprehensive, high-time-resolution, long-term measurement network in the US focused on characterizing the chemical composition and physical properties of aerosols. The network consists of 12 long-term stations spread across rural, urban, and tribal sites in the US. Although not a partner, ASCENT is one of the main stakeholders of CARGO-ACT IS activities, attempting to incorporate harmonisation where possible as the network undergoes the implementation phase.

Atmospheric measurements across the globe can vary between and within measurement networks in terms of scientific goals and, therefore, the atmospheric variables covered. ACTRIS and ARM observatories measure all four of the ACTRIS core IS variables while NOAA does not measure PNSD and ASCENT doesn't measure the Scat. In this chapter, we describe the current protocols of the networks identifying what are common measurement and calibration procedures and what are the opportunities for harmonization of these for the core IS variables.

2.1 Summary of the state-of-the-art protocols

2.1.1 General protocols for aerosol sampling inlets and conditioning

Many aspects of the general recommendations or protocols stem from WMO-GAW report No. 227, and they are common among the observational networks assessed here. Protocols for aerosol sampling such as the configurations of the inlets depending on the target variables, use of laminar flow, if possible, types of pipes and tubing used, aerosol conditioning for controlling the relative humidity (RH), and a target data coverage of >90% are similar across networks.

2.1.2 Network-specific protocols for IS core instruments

In this section, we describe the current protocols at a network level such as minimum requirements for instrumentation and data processing software.

2.1.2.1 Instrument technical requirements

In the ACTRIS network, there are instrument design and technical specification criteria for each of the IS variables. Instruments which satisfy the ACTRIS criteria are then included in the ACTRIS list of compliant instruments, allowing them to be used in the ACTRIS observatories. For the ACTRIS core IS variables, this is done by the Centre for Aerosol In-situ - European Aerosol Centre for

CARGO-ACT (www.cargo-act.eu) is supported by the European Commission under the Horizon Europe (HORIZON) – Strengthening the international dimension of ESFRI and/or ERIC research infrastructures, HORIZON-INFRA-2023-DEV-01-07, Grant Agreement #: 101132093

Aerosol Calibration and Characterization (CAIS-ECAC) under the lead of the World Calibration Centre for Aerosol Physics (WCCAP).

Below is an overview of the criteria for each instrument.

CPC:

- EN 16976:2024 compliant with certification from a calibration facility
- full flow CPC
- capability to provide pulse output (primary output of the photodetector)
- working fluid is n-butanol
- lower detection efficiency diameter, Dp50, of 10 nm
- minimum PNC range up to 50,000 cm-3
- model-specific calibration factor between 1 to 10%
- model-specific coincidence correction equation

MPSS:

- CEN/TS 17434 compliant with certification from a calibration facility
- full flow CPC
- particle size range: 10 - 800 nm
- aerosol to sheath flow ratio between 1:10 and 1:4
- bipolar diffusion charger either Krypton 85 or Nickel 63
- use of a positive (preferred) high voltage power supply for the differential mobility analyser (DMA) with possibility to measure the voltage output independently
- capable of performing up and down scans with high resolution, especially for the size calibration
- particle size resolution of 16 -32 bins per decade
- time resolution of 5 - 10 minutes.

AP:

- ACTRIS compliant with a certification from a calibration facility and using a harmonization factor
- the sample flow through the filter must be controlled

CARGO-ACT (www.cargo-act.eu) is supported by the European Commission under the Horizon Europe (HORIZON) – Strengthening the international dimension of ESFRI and/or ERIC research infrastructures, HORIZON-INFRA-2023-DEV-01-07, Grant Agreement #: 101132093

- the attenuation or transmission of light must be recorded
- when exceeding an instrument specific maximum attenuation, the filter must be changed either automatically or manually
- the filter type must have been calibrated for use in that instrument with calibration factors provided for data evaluation

IN:

- ACTRIS compliant with a certification from a calibration facility
- multi-wavelength
- capability of calibration with two gases
- automatic measurement of the baseline at regular intervals with particle free air
- truncation error scheme should be provided
- response time of < 5 minutes
- time resolution of 0-level data should be >= 1 minute
- sampling flow rate of 5L/min

It is mandatory for all of these instruments to undergo biannual intercomparison and calibration workshop at the CAIS-ECAC calibration facility. These calibrations are science and capacity building-related and go beyond the maintenance procedures of the instrument manufacturers.

The other measurement networks do not require any instrument design and technical specification to be allowed to operate in their observatories. They use different kinds of instrument models from different manufacturers. Some of the instruments at the other networks are also on the ACTRIS list of compliant instruments.

These specifications are not required in NOAA-operated observatories where water-based CPCs are used as the replacement instrument for the 30-year-old n-butanol pulse output instruments. For quality assurance, they intercompare their CPCs against a reference CPC calibrated at the WCCAP. Similarly, they use different AP models which includes the AE33 (ACTRIS compliant). In addition, only approved filter types are used, for instance, only Pall e70-2075w filters or Azumi filters are allowed to be used in the NOAA continuous light absorption photometer (CLAP). Finally, NOAA uses INs which are on the list of ACTRIS compliant instruments (TSI and Aurora).

CARGO-ACT (www.cargo-act.eu) is supported by the European Commission under the Horizon Europe (HORIZON) – Strengthening the international dimension of ESFRI and/or ERIC research infrastructures, HORIZON-INFRA-2023-DEV-01-07, Grant Agreement #: 101132093

At the ARM observatories, the PNSD measurements are done by different MPSS models with different combinations of their integral parts (CPC, DMA, and particle chargers). For Abs measurements, they mainly use the particle soot absorption photometer (PSAPs), which are not ACTRIS compliant. ARM only operates the TSI 3563 IN in their network.

ASCENT uses the new "wide-range" TSI MPSS, satisfying ACTRIS compliance except for the CPC component. ASCENT uses a water-based CPC in their MPSS. Similarly, they also use an AE33 in their network which is ACTRIS compliant.

2.1.2.2 Data production software

Each measurement network employs their own data production software. Both NOAA and ACTRIS submit data to the NILU EBAS database, and therefore, the data provided comply with the requirements of EBAS (corrections and data format). The ARM network provides data to the ARM Data Discovery database.

In ACTRIS, a newly developed near-real-time (NRT) data reporting software is currently being implemented at the National Facilities (observatories). The NRT software supports different types of ACTRIS compliant instruments for each variable, INs, APs, CPCs, and MPSS. In ACTRIS, a harmonization factor is applied to the AE33 data while the truncation error correction is applied to the IN data same as in the NOAA software and ARM data processing. For the CLAP and PSAP in the NOAA network the standard corrections (Bond et al., 1999, Ogren, 2010) including for flow rate, spot size, scattering artifact and filter type are made. For the PSAP data, ARM applies an improved gain calibration and a scattering correction to the data from PSAP. For ASCENT, the data infrastructure is currently under development, which will include automated data quality assurance and will be uploaded into their own database.

For the last 22 years NOAA has used a Linux-based software package developed in-house. The software is used in different configurations for both data acquisition and data visualization/quality control. Because of the wide number of instruments used in the NFAN network it is capable of logging data from multiple PNC, AP, and IN, system housekeeping parameters (temperature, RH, pressure, flow, etc), as well as a variety of other instruments not discussed here. The software includes the capability of sending NRT raw data to EBAS (and other entities - for example DOE gets NRT raw aerosol data from one of the NFAN stations).

CARGO-ACT (www.cargo-act.eu) is supported by the European Commission under the Horizon Europe (HORIZON) – Strengthening the international dimension of ESFRI and/or ERIC research infrastructures, HORIZON-INFRA-2023-DEV-01-07, Grant Agreement #: 101132093

ARM currently uses a suite of internally developed LabView-based software applications to acquire data from deployed instruments. These applications provide near real time visualization of raw data along with instrument operating parameters. Data is stored in a plain-text format and sent to ARM data servers for further processing, where it is converted to NetCDF format and corrections/quality control checks are applied. There is currently interest in exploring alternative options to modernize this software to further improve performance, maintainability, and reliability.

2.1.3 Calibration procedure for core IS instruments

As mentioned above, in ACTRIS, the core IS instruments are required to participate in biannually intercomparison and calibration workshop. If they pass, they are issued either a CEN certificate (for MPSS and CPC) or an ACTRIS Calibration Certificate (for AP and IN).

In this section, we briefly describe the setup of the calibration facilities of WCCAP and its calibration workshop program which will then be adapted by Center for Aerosol Measurement Science (CAMS) within CARGO-ACT. The full detail of this knowledge transfer and capacity building will be reported in D2.5 - Strategy plan for the harmonization of regional aerosol in-situ calibration center in the US with the ACTRIS Central Facility for aerosols IS measurements by project month 17.

Calibration Facility Setup and Calibration Procedures

In ACTRIS (WCCAP), CPC and MPSS instruments are calibrated in separate laboratories for IS microphysical instruments, while the APs and INs are calibrated in the same laboratory for optical IS instruments.

The WCCAP **CPC calibration laboratory** is equipped with a Faraday cup aerosol electrometer (FCAE) which serves as a traceable primary standard for particle number concentration. The FCAE is regularly calibrated by the German National Metrology Institute. A "master" CPC serves as a secondary standard. WCCAP uses silver particles for calibration (EU Norm), which are formed by silver vapor after a tube furnace operated at a temperature range between 900 and 1200°C under pure nitrogen. The generated silver aerosol is then sintered in a second tube furnace at 700°C to obtain quasi spherical particles. Finally, monodisperse silver particles in the range from 3 to 40 nm are obtained using a size selection rack equipped with a Nano-DMA This set-up is based on the ISO 27891:2015 and modified for the calibration of several CPCs at the same

CARGO-ACT (www.cargo-act.eu) is supported by the European Commission under the Horizon Europe (HORIZON) – Strengthening the international dimension of ESFRI and/or ERIC research infrastructures, HORIZON-INFRA-2023-DEV-01-07, Grant Agreement #: 101132093

time. The CPC calibration follows the procedures criteria detailed in EN 16976:2024 assuming all other technical specifications are already met:

- leak (zero) checks;
- flow rate;
- detection efficiency at 40 nm;
- detection efficiency at 20 nm;
- detection efficiency iat 10 nm;
- detection efficiency curve from 7 to 40 nm;
- concentration response and linearity compared against the FCAE.

The WCCAP **MPSS calibration laboratory** is equipped with a reference MPSS and a reference stand-alone CPC both serving as secondary standards with the stand-alone CPC calibrated against the primary standard FCAE. This allows a quality-assurance by an intercomparison between the total PNC and the integrated PNC obtained from the PNSD. For the MPSS, the following basic checks are performed:

- flow condition;
- flow rate;
- leak (zero) checks;
- particle size calibration accuracy test using nebulized 203 nm PSL particles;
- high voltage (HV) calibration if possible;
- check of the accuracy of the integrated number concentration measurement (compared against the reference stand-alone CPC);
- the accuracy of the PNSD (compared against the reference MPSS).

Like the CPC calibration, CEN and ACTRIS standard compliant MPSS instruments are issued a CEN certificate, otherwise a calibration report is provided.

The WCCAP set-up in the laboratory for the calibration of **absorption photometers** includes a secondary standard absorption photometer with the extinction-minus-scattering (EMS) method as the primary standard, using integrating nephelometers and extinction monitors at the different wavelengths. Soot and graphite are generated as standard materials for the intercomparison. The following tests are performed:

- zero baseline measurement;
- accuracy against the reference method (EMS) and secondary standard;

CARGO-ACT (www.cargo-act.eu) is supported by the European Commission under the Horizon Europe (HORIZON) – Strengthening the international dimension of ESFRI and/or ERIC research infrastructures, HORIZON-INFRA-2023-DEV-01-07, Grant Agreement #: 101132093

- flow re-calibration when necessary.

For the characterization of **integrating nephelometers**, the set-up uses the scattering of CO_2 gas as a primary standard with a reference IN as a secondary standard. An ammonium sulfate aerosol is additionally used to calibrate the particle scattering coefficient. The following tests are performed:

- zero baseline measurement;
- span gas check with CO_2;
- accuracy of the IN against optical reference using ammonium sulfate.

The NOAA measurement network, as briefly mentioned above, has two laboratory reference CPCs, one of which is ideally regularly calibrated at the WCCAP. This reference CPC is then used to intercompare other CPCs prior to deployment and after in-house repairs/maintenance. During the intercomparison, leak (zero) and flow rate checks are performed, and the CPCs sample laboratory and ambient air to get three orders of magnitude of number concentration. For the APs and INs, calibrations like ACTRIS procedures are performed on-site with the exception of the accuracy check against a reference method or a primary or secondary standard reference instrument.

At ARM, aside from factory calibration every two years, the ARM calibration procedure for their MPSS systems have three Tiers which includes the CPC calibration:

1. Tier 1 - screening of instruments
   a. flow rate
   b. zero count rate (leak check)
   c. sizing accuracy check with 4 PSL sizes (between 100 - 400 nm)
2. Tier 2 - evaluation of the MPSS CPC
   a. flow and zero checks;
   b. intercomparison of CPC against a “master” CPC (which has been factory calibrated annually) through collocation and sampling ambient air
   c. determination of size resolved biases, particularly at 15 - 100 nm using ammonium sulfate concentrations between 1000 and 10,000 particles cm-3.
3. Tier 3 - detection efficiency of the MPSS CPC
   a. Intercomparison against an FCAE (annual factory calibration) using ammonium sulfate as standard material
4. Tier 4 - Closure validation of the MPSS

a. check of the accuracy of the integrated PNC measurement (compared against the reference stand-alone CPC) and the accuracy of the PNSD (compared against the reference MPSS when available)

Similarly, for the APs and INs, calibrations similar to ACTRIS procedures are performed on-site with the exception of the accuracy check against a reference method or a primary or secondary standard reference instrument.

The ASCENT network is implementing ACTRIS standards with their MPSS and AE33 with the exception of the water-based CPCs.

2.1.4 SOP at the observatory

This section describes the observatory SOPs of the networks for each of the core IS instruments. NOAA and ARM provide detailed and documented SOPs for their users while ACTRIS currently provide only general standard procedures. Detailed documents of observatory SOPs are under development.

PNC - CPCs

For the observatory SOPs, the following checks are common across all three networks (although the frequency of checks may vary):

- zero (HEPA filter at the instrument inlet)
- aerosol flow rate
- liquid level

Because NOAA and ACTRIS sites submit PNC data to EBAS database, the data processing and reporting procedures are the same for these two networks.

PNSD - MPSS

Several of the SOPs for the MPSS are common between the ACTRIS and ARM observatories, such as regular checks of:

- zero (scan with HEPA filter at the instrument inlet);
- aerosol flow rate;
- closure of the integrated particle number concentration with a stand-alone CPC;
- checking of diagnostic parameters such as RH.

CARGO-ACT (www.cargo-act.eu) is supported by the European Commission under the Horizon Europe (HORIZON) – Strengthening the international dimension of ESFRI and/or ERIC research infrastructures, HORIZON-INFRA-2023-DEV-01-07, Grant Agreement #: 101132093

On-site calibration procedures for an MPSS measuring PNSD can differ between makes and models and can vary in complexity. This can also depend on the MPSS design criteria of the station or of the network. An important calibration procedure which can be done on-site is the calibration of the sizing accuracy of the system using certified monodisperse polystyrene latex (PSL) particles (ISO 15900). The ACTRIS observatories follow the procedure outlined in CEN/TS 17434, which is also employed by the ASCENT network. The procedure for the ARM observatories is similar: they use PSL spheres between 100-400 nm while the ACTRIS (CEN) recommendation is to choose a particle size between 100 and 300 nm (normally the PSL particle size of 203 nm is used).

Abs - APs

Commercially available APs employed in all three networks are relatively easy and straightforward to handle with SOPs provided in the user manuals. Therefore, most SOPs request the following checks:

- the aerosol flow rate;
- zero (HEPA filter at the instrument inlet).

These checks are already common (for common instruments such as the AE33) across these three networks. The AE33 is utilized in all of the 4 (ARM uses one AE33 in one of their mobile facilities) networks, and the manufacturer recommended flow calibration procedure is, therefore, the same across the networks, albeit with differences in the frequency. Because NOAA and ACTRIS sites submit Abs data to EBAS database (although NOAA typically does not submit AE33 data), the data processing and reporting procedures are the same for these two networks.

Scat - IN

ACTRIS, and the US measurement networks use common calibration procedures for the INs:

- zero calibration;
- span check with CO_2.

Therefore, aside from differing details such as frequency of calibrations, etc., the calibration procedures of INs are already harmonized at least in observatories operated by ACTRIS, NOAA, and ARM. Because NOAA and ACTRIS sites submit Scat data to EBAS database, the data processing and reporting procedures are the same for these two networks.

CARGO-ACT (www.cargo-act.eu) is supported by the European Commission under the Horizon Europe (HORIZON) – Strengthening the international dimension of ESFRI and/or ERIC research infrastructures, HORIZON-INFRA-2023-DEV-01-07, Grant Agreement #: 101132093

2.2 Opportunities for harmonization

2.2.1 General protocols for aerosol sampling inlets and conditioning

As mentioned in 2.1.1, specifications of the aerosol sampling and conditioning are common across networks. The differences can stem from the needs of the wide range of instruments in operation. An opportunity for harmonization is to share information between networks of ways to improve sampling systems when accommodating new instrumentation (such as the MPSS). For high quality measurements, the following criteria needs to be met:

- (ideally) laminar flow in the aerosol inlet;
- and/or the inlet is well characterized in terms of particles losses;
- the aerosol must have a RH <40% at the inlet of the microphysical or optical IS aerosol instrument.

2.2.2 Network-specific protocols for IS core instruments

To achieve a high level of interoperability within a network, it is essential to establish network-specific protocols including instrument design and technical specification requirements, and a universal data production software. Harmonizing instrument design and data production software is understandably a huge undertaking and should be supported by robust research.

2.2.2.1 Data production software

The data production of NOAA, ACTRIS, ARM, and ASCENT is an interesting and important aspect of harmonization to explore. For instance, there are harmonization factors for the AE33 data (depending on filter type) to make it comparable to MAAP (generally considered as reference absorption photometer) based on the ACTRIS guidelines for Manual QC of AE33. Since NOAA and ARM do not apply these harmonization factors to the AE33 data, this offers an opportunity to investigate how these harmonization factors will impact their data. We also emphasize here the opportunity to harmonize the data obtained from other absorption photometers employed such as the PSAP, CLAP and the 3-wavelength absorption photometer (TAP) by deriving harmonization factors for each type employed in the observatories. This investigation falls in T3.1 of WP3 (Cross-network intercomparison of instrument data acquisition and automated processing tools) where we will be able to experimentally identify detailed similarities and differences between the different data production software and find opportunities for harmonization.

2.2.3 Calibration procedure for core IS instruments

The most significant opportunity for harmonization of calibration and operation practices for the core IS variables is the establishment of regional calibration facilities in the US and other parts of the world patterned on the WCCAP in Europe. Currently, for the US networks, some instruments are sent to manufacturer for maintenance and calibration. Factory calibration has its advantages, although, with several manufacturers in the market, the calibration procedure (beside the technical maintenance) not only may vary greatly but may also be not entirely transparent to the customers. A traceable, standardized and transparent calibration routine serviced by an independent facility would ensure harmonized quality assurance and comparability across instruments of different manufacturers and models. In addition, the establishment of a regional calibration facility would provide support closer to the measurement network and would minimize data loss from shipping instruments to and from Europe for routine calibration. Furthermore, having a calibration facility in the same country could mean simpler processes for transporting hazardous material type shipments (for example, an MPSS along with its own radioactive bipolar charger) - allowing the system as a whole to undergo a quality-check as well.

As part of CARGO-ACT, BNL and WCCAP (TROPOS) are collaborating to establish a calibration centre at BNL, New York, USA, called the Center for Aerosol Measurement Science (CAMS). This activity falls under T2.3 of WP2. In the first months of the project, BNL scientists visited the WCCAP twice: first as an introduction and second for a calibration workshop for their own secondary reference instruments for PNC and PNSD variables. Considering this, the calibration procedures may become more harmonized and occur more frequently in the future.

The setup of the calibration facilities of WCCAP and its calibration workshop program for the MPSS and CPC described in Chapter 2.1.3 will be adapted by CAMS within CARGO-ACT. The full detail of this knowledge transfer and capacity building will be reported in D2.5 - "Strategy plan for the harmonization of regional aerosol in-situ calibration centre in the US (CAMS) with the ACTRIS Central Facility for aerosols IS measurements" by project month 17.

2.2.4 SOP at the observatory

An important aspect in harmonizing SOP at the observatory is the complete documentation of observatory and instrument specific SOPs for the users (technicians, station managers, etc.). Both NOAA and ARM provide handbooks with detailed SOPs for their observatories while ACTRIS provides currently only general standard procedures online. ACTRIS is currently in the implementation phase and their activities

CARGO-ACT (www.cargo-act.eu) is supported by the European Commission under the Horizon Europe (HORIZON) – Strengthening the international dimension of ESFRI and/or ERIC research infrastructures, HORIZON-INFRA-2023-DEV-01-07, Grant Agreement #: 101132093

here in CARGO-ACT provide an opportunity for ACTRIS to learn from the handbooks of NOAA and ARM as they develop their own. This also presents a chance to compare the handbooks in detail and discover more opportunities for harmonization across networks. ACTRIS could develop harmonized observatory SOPs for the core variables.

PNC - CPC

SOPs for CPC operation at the observatory are basic and should be performed regularly such as:

- aerosol rate check;
- liquid-level check for CPCs;
- visual check of diagnostic parameters;
- zero/leak check.

Unlike the other instruments, calibration of CPCs is better done in a dedicated facility such as a calibration centre (see Chapter 2.1.3). With the establishment of CAMS, this can be harmonized in the future.

PNSD - MPSS

PNSD measurements of fine and ultrafine particles require specific flow conditions to avoid particle losses. It might be necessary to improve this infrastructure when adding an MPSS in a measurement station.

The basic checks and calibrations must be performed regularly (frequency depends on station needs and available manpower). Therefore, we highlight the opportunity to harmonize the level of complexity of these calibration procedures:

- aerosol rate check;
- liquid-level check for CPCs;
- visual check of diagnostic parameters;
- sizing check: One approach is by settling for a simple yet harmonized procedure of the sizing accuracy check and leave the sheath air flow rate adjustment in the DMA for the calibration centre;
- zero check: zero filter in front of the instrument. If the CPC reading is zero, then it means there is no leak;
- offset and laminarity check with the high voltage power supply off - if the CPC reading is zero, then it means there is no turbulence in the DMA.

Abs - AP

One important check which must be done is the zero-check using a HEPA filter in from of the instrument to identify the noise level of the absorption.

Since most SOPs, especially for the AE33, are already similar across networks, details such as frequency of the calibration procedures and checks may be further harmonized.

Scat - IN

Since most SOPs for the INs are already similar across networks, details such as frequency of the calibration procedures and checks may be further harmonized:

- span check with CO_2 -- done at least monthly at NOAA, once or twice a year at ARM, and every two to three months at ACTRIS observatories;
- automatic zero checks – are done daily at ARM and ACTRIS while hourly at NOAA.

The harmonization of the frequency of these routines is not simple. INs at observatories in areas with lower particle concentrations may require more frequent zero calibrations. This is because of a daily variability of the molecular scattering. An incorrect molecular scattering may cause a larger error for the particle scattering if this is in the same range or smaller than the molecular scattering. We identify an opportunity here to investigate and determine the best frequency of calibration with respect to the aerosol load of each observatory type (urban, background, rural, remote) while keeping the desired data coverage.

2.3 Summary

Understanding the role of aerosol particles in atmospheric processes, particularly for climate and air quality studies - both of which impact the globe is a key objective of all the networks in this project. Therefore, the measurement of key atmospheric variables needs to reach a high level of convergence across networks on a global scale. As a proof of concept, CARGO-ACT aims to pave the way for the harmonization of large measurement networks starting with eight microphysical and optical aerosol variables; four in-situ (IS) and four remote sensing (RS) variables. This deliverable reports on the common practices, and more importantly, on the opportunities for harmonization across networks in terms of calibration, operation practices, and data production software relevant to the eight targeted variables.

CARGO-ACT (www.cargo-act.eu) is supported by the European Commission under the Horizon Europe (HORIZON) – Strengthening the international dimension of ESFRI and/or ERIC research infrastructures, HORIZON-INFRA-2023-DEV-01-07, Grant Agreement #: 101132093

For the IS variables, we focused on the observatories within the ACTRIS, NOAA, ARM, and ASCENT (not a partner in CARGO-ACT) networks. It must be noted that these networks operate with different scientific goals and hence, some do not measure all four IS variables: e.g., NOAA does not measure PNSD and ASCENT does not measure Scat. Nevertheless, since the existing protocols for all these networks largely stem from the GAW Report no. 227, many protocols are, to some extent, already harmonized - particularly the general observatory set-up and requirements, SOPs and calibration procedures, and data production for commercially available instruments. This is particularly true for the most used instruments: the absorption photometers AE33 and MAAP, and the TSI and Aurora nephelometers. Some instrument design requirements are also common across networks measuring PNSD with an MPSS.

The opportunities for harmonization that we have identified apply to the range of instrumentation used to measure the same IS variable and to the specific way the same procedures are done. For instance, some networks use CPCs with different working fluids and different lower detection efficiency particle diameters for their MPSS, which will influence the reported PNSD and the total or integrated PNC values. The same is true for the several types of APs used. Because of differences in filter type and instrument specific corrections or harmonization factors, the AP measurements need to be harmonized to ensure data comparability between observatories and networks. As for the IN, although most of the procedures are already common, the frequency of the calibrations differs from one network to another. The frequency of IN calibrations is a balance between the aerosol conditions at the observatory and manpower and resources. Recommendations on this must consider these two aspects.

Since the publication of the GAW report in 227 in 2016, several protocols have evolved resulting in the current standards being implemented today in the ACTRIS observatories such as the European standards for determining PNSD using an MPSS (CEN/TS 17434:2020) and determining PNC with a CPC (EN 16976:2024). These standards have paved the way for harmonizing PNSD and PNC measurements within the ACTRIS network. This brings us to the most significant opportunity for harmonizing the IS variables: the establishment of an independent calibration facility in the US, servicing the measurement networks there with traceable, standardized procedures as in ACTRIS in the EU. As part of CARGO-ACT, the Center for Aerosol Measurement Science (CAMS) is currently in planning with the goal of serving as a calibration facility for MPSS and CPC, (with the intention of extending to AP and IN in the future) in the US, including intercomparison workshops and personnel training and capacity building. The WCCAP will be working together with BNL to build up CAMS in the same way the Prague Aerosol Calibration Centre (PACC) was established in Prague for ACTRIS. These activities are part of task T2.3 (capacity building) and will be running parallel to T2.2 activities.

The outlook for WP2 following Milestone 4 (Documentation of protocols) and this deliverable (assessment of protocols) is as follows:

1. WP2 will be hosting a joint workshop with network coordinators and international stakeholders as a project milestone. In this workshop, we will gather the insights of the stakeholder in terms of the harmonization of the IS variables.
2. From here, identified opportunities for harmonisation in this deliverable will be deliberated between the participating IS networks.
3. This deliberation will be part of Task T2.2 starting with the creation of a common vocabulary (D2.2).
4. Based on D2.1, the insights of the stakeholder, and utilizing D2.2, we will draft a recommendation for common calibration and operation procedures (D2.3).
5. This will be followed by recommendations on common approach in measurement uncertainties (D2.4).
6. All this will be the basis of the strategy plan for the capacity building for CAMS (D2.5) done as part of T2.3 which is running in parallel to T2.2.

CARGO-ACT (www.cargo-act.eu) is supported by the European Commission under the Horizon Europe (HORIZON) – Strengthening the international dimension of ESFRI and/or ERIC research infrastructures, HORIZON-INFRA-2023-DEV-01-07, Grant Agreement #: 101132093

References

Bond, T. C., Anderson, T. L., & Campbell, D. (1999). Calibration and Intercomparison of Filter-Based Measurements of Visible Light Absorption by Aerosols. Aerosol Science and Technology, 30(6), 582–600. https://doi.org/10.1080/027868299304435

Ogren, J. A. (2010) Comment on "Calibration and Intercomparison of Filter-Based Measurements of Visible Light Absorption by Aerosols", Aerosol Science and Technology, 44:8, 589-591. https://doi.org/10.1080/02786826.2010.482111

CARGO-ACT (www.cargo-act.eu) is supported by the European Commission under the Horizon Europe (HORIZON) – Strengthening the international dimension of ESFRI and/or ERIC research infrastructures, HORIZON-INFRA-2023-DEV-01-07, Grant Agreement #: 101132093