Milestone MS4.4: Final report on standard-making process.

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Purpose of the document

This document outlines standard-making processes for technologies relevant to ACTRIS observations in cooperation with specific SMEs and national, European and, when applicable, international centres for normalization and standards.
This task is devoted to maintain and further develop standard-making processes for technologies relevant to ACTRIS observations in cooperation with specific SMEs and national, European and, when applicable, international centres for normalization and standards.

General information on the standard making activities within ACTRIS

Since the overall objective of this activity is to enhance and promote cooperation with the private sector and in particular with European SMEs, the development of pending and new standard-making procedures is of most importance for the ACTRIS community. For this purpose, a progress report on standard-making process relevant to ACTRIS, designed to collect and centralize all ongoing efforts on standardization, is required to channel future standard making activities within the ACTRIS community.
The activities carried out during the implementation of ACTRIS cover involvement in several CEN or ISO initiatives but also cover the development of internal measurement and calibration procedures for different instruments and techniques relevant to the consortium.

Several reports on standardization and data submission protocols have been delivered in ACTRIS-2:

- D 3.3: Standardization and data submission protocol for aerosol particle mass spectroscopy measurements containing recommendations for standardization and data submission for aerosol particle mass spectroscopy measurements (M16).
- D 3.4: Standardization and data submission protocol for coarse mode particle number size distribution measurements that contains recommendations for standardization and data submission for coarse mode particle number size distribution measurements (M15).
- D 3.12: Standardization and data submission protocol for PVM measurements containing recommendations for standard operating procedures of PVM and protocols for data submission (M31).
- D 3.15: Standard Operating Procedures (SOPs) for the targeted set of OA tracers, containing recommendations for operating procedures for the OA selected tracers (M36 delayed to M47).
- D 2.3: Documentation on radar calibration and standardization concepts which describes the state of the art of radar calibration, outlines the concepts and field studies including planning issues; linked to task 2.2.2 (Calibration and standardization of cloud radars, KNMI, CNRS, UNIVLEEDS), M6.
- D 2.12: Recommendations on radar calibration and standardization at Cloudnet stations which is an extended report on the performed radar calibration studies, conclusions, recommendations and established standards. It is related to MS2.3 (First radar calibration field study, KNMI, M18), MS2.9 (Second radar calibration field study, KNMI, M36) and linked to task 2.2.2 (Calibration and standardization of cloud radars, KNMI, CNRS, UNIVLEEDS), M43.

In M46 will be released D11.5: Final report on the validity assessment of vertical absorption coefficient and SSA profiles by remote sensing, with Preparation of Standard Operating Procedures containing information on combining remote sensing with in-situ aerosol profiling and preparation of Standard Operating Procedures based on the different methodologies used and validated in previous steps.

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A report on tests for a new light-weight aethalometer for airborne measurements of the light absorption coefficient at several wavelengths has also been submitted:

- D 11.1: Report on validity tests of new light-weight aethalometer for airborne measurements of the light absorption coefficient at several wavelengths for a new light-weight aethalometer prototype for airborne measurements of the light absorption coefficient at several wavelengths that was compared and validated against existing methods that provide the absorption coefficient (M12).

A retrieval algorithm for aerosol absorption coefficient and SSA profiling based on the combination of multiwavelength elastic lidar and sun photometers (daytime) and lunar/star photometers (night time), including different sets of input variables has been submitted:

- D 11.2: Optimized inversion algorithms for the determination of absorption coefficient and SSA vertical profiles suited for day and night operation, to be tested in Task 3, (M24).

A report to combine remote sensing with in-situ aerosol profiling to harmonize and validate the different methodologies and reduce absorption uncertainties has been submitted:

- D 11.3: Intermediate report on the validity assessment of vertical absorption coefficient and SSA profiles by remote sensing, with recommendations for improvements (M24).

A report for the determination of the black carbon (BC) concentration as well as the light absorption coefficient with different methods and containing also an assessment of the mass absorption coefficient (light absorption per unit mass of BC) as well as its variability in the atmosphere has been submitted:

- D 11.4: Report on closure results between the measurements of absorption coefficient and black carbon concentration (M42).

The final report on combining remote sensing with in-situ aerosol profiling and preparation of Standard Operating Procedures based on the different methodologies used and validated in previous steps was submitted:

- D 11.5: Final report on the validity assessment of vertical absorption coefficient and SSA profiles by remote sensing, with preparation of Standard Operating Procedures (M46).

An evaluation of the link between light absorption and black carbon concentration at different sites, connecting it to different air masses was released:

- D 11.6: Report on source-specific light absorption characteristics of different anthropogenic and natural aerosol types (M48).

Several actions are pending for the development of CEN/ISO standards:

- Development of CEN standard FprCEN/TS 16976 for ambient particle number concentration measurements (CPC).
  The technical committee for the standard development consisted mainly of ACTRIS and manufacturer members. ACTRIS sampling recommendation played a major role for the development of technical documents required for the standardization process.
- Ongoing CEN standardization for ambient particle number size distribution measurements (MPSS) [1]
- Funded project on metrology for light absorption by atmospheric aerosols - 16ENV02 Black Carbon – start date 01 July 2017, aiming to:

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  - To establish a set of well-defined physical parameters, such as aerosol light absorption coefficients and mass absorption coefficients, which together can be used to quantify black carbon mass concentrations with traceability to primary standards.
  - To develop and characterise a black carbon standard reference material (SRM), that has a high content of elemental carbon, as a near-black carbon source and is highly relevant for atmospheric aerosols.
  - To develop a traceable, primary method for determining aerosol absorption coefficients, using particulate black carbon (BC), at specific wavelengths. The method should have defined uncertainties and be quantified down to its lowest limit.
  - To develop a validated transfer standard for the traceable in-field calibration of established absorption photometers such as multi angle absorption photometers, aethalometers and particle black carbon/absorption photometers. The transfer standard should make use of the black carbon SRM (developed in objective 2) and associated portable instrumentation characterised by the primary method (from objective 3).
  - To facilitate the take up of the technology and measurement infrastructure developed in the project by standards developing organisations (CEN, ISO) and end users (e.g. Environmental Protection Agency (EPA), European Environment Agency (EEA), World Meteorological Organization-Global Atmosphere Watch (WMO-GAW), the ACTRIS (Aerosols, Clouds, and Trace gases Research InfraStructure Network) project.
- ISO/TC 146/SC 5 Air quality -- Environmental meteorology: two lidar related standards are under development under this working group → Visual range lidar and Doppler Lidar.

The development of ACTRIS procedures to perform quality check (QC) on both lidar raw data and products already started within previous projects like ACTRIS and Earlinet-ASOS. During the implementation of ACTRIS-2, these QC procedures have been updated to the current developments of the lidar community:

- Rayleigh Fit test gives information about the quality of the signals in the far range. This test is mostly used for analog signals that tend to show distortions in this range [6]
- Telecover test
  Gives information about the alignment of laser and optics and can be used to give information about the distance of full overlap for a biaxial lidar instrument [5] ,[4]
- Trigger delay / Zero bin measurement
  A mandatory test procedure to determine the lidar error in the trigger delay between the real laser output and the start signal for the detection system. This test is designed to correct any range related errors given by the instrument electronics
- Dark measurement
  It is a mandatory measurement procedure for analog detection within Actris. It makes use of an extended lidar measurement with a fully covered telescope or with covered detectors. The test shows all stray pick-ups and distortions that do not stem from the atmospheric backscatter but from the lidar instrument itself.
- Calibration of the depolarization channels for polarisation sensitive lidar systems [7], [8], [9]
  Continuous efforts are made to develop standard procedures for the calibration of lidar depolarization channels. The depolarization calibration is already a mandatory QA test required for each lidar station in Actris-2 [2], [3], [9]. New SCC modules designed to process the depolarization calibration data are already implemented. A dedicated LiCalTrain workshop based on the new features of SCC (depolarization and GUI) took place on 27th of February - 3rd of March 2017.

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The LiCoTest installation provides services for testing optical components and lidar modules. Based on the requests and feedback of the lidar community, LiCoTest started to develop measurement procedures designed to fully describe laboratory setups, error treatment and reporting for several services provided by the installation. These activities will also be supported by national efforts – proposal POC/78/1/2/ "Consolidating the involvement of ACTRIS-RO to the pan-European research infrastructure ACTRIS"

- Measurement of the transfer coefficients for parallel and cross light components for polarization sensitive lidar components
  Based on the user requests, LiCoTest started to develop measurement and data processing schemes to retrieve polarization sensitive parameters used by the lidar community to correct and calibrate lidar data.
- Assessing the spatial homogeneity for optical transmission functions at predefined wavelengths (1064nm, 532nm and 355nm)
- Laser beam parameterization: polarization purity, rotation of the plane of horizontal-linear polarisation of the laser around the z axis

All these procedures will be made available on the LiCal website (lical.inoe.ro) and will include laboratory optical setup description, theoretical support, error assessment and example measurements (including reports).

Software developments

A new version of the EARLINET Single Calculus chain (SCC, D'Amico, 2015) have been released allowing to produce high-resolution pre-processed lidar products in a common format for any type of lidar (see D2.8 - Implementation of the lidar quicklook database). These new products provide particle-like backscatter coefficient, calibrated attenuated backscatter, and depolarization ratio. Particular attention has been paid for the calibration of the high resolution products: an automatic calibration procedure using the SCC-retrieved particle backscatter and extinction coefficients have been implemented together with an improved error characterization (see Task WP2.1). A dedicated school based on the new SCC version took place on 4-6 December 2018 in Potenza, Italy.

National efforts for standard making process

- In the autumn of 2016, the German standard "Partikelrückstreulidar" (Particle backscatter lidar) has been completed and is now in a review process. The contents list is freely available at: https://www.vdi.de/uploads/tx_vdirili/pdf/2572801.pdf. Further on, the German standard "Partikelrückstreulidar" (Particle backscatter lidar) will be taken by an ISO working group for international standardization. The name of this working group is "Bodengebundene Fernmessung meteorologischer Größen" (surface-based remote sensing of meteorological quantities) and the frame of this group is the VDI/DIN-Kommission Reinhaltung der Luft (KRdL) - Normenausschuss (https://www.vdi.de/technik/fachthemen/reinhaltung-der-luft/wir-ueber-uns/).
- Under the supervision of Bernhard Pospichal and Ulrich Löhnert, the Research Centre Jülich has established standards for ground-based microwave radiometer operation and calibration. These activities shall be included in the planned Radar Calibration Centre within ACTRIS at the JOYCE site (http://joyce.cloud) operated by the University of Cologne.

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General information on the standard making activities relevant to ACTRIS

Several publications on measurement guidelines, operating procedures, and inter-comparisons that are relevant to ACTRIS are available:

- General Guidelines on Aerosol Sampling, Instrument Setup, and Station Operation
  - GAW report No. 153
    WMO/GAW Aerosol Measurement procedures, guidelines and recommendations
  - GAW-WCCAP recommendations for aerosol inlets and sampling
    Guidelines on inlet design for different ambient environments and station settings.
  - GAW - WCCAP recommendation for aerosol drying
    Guidelines on conditioning and drying the aerosol sample depending on ambient temperature.
- Measurements of Particle Number Concentration
  - GAW report No. 153
    WMO/GAW Aerosol Measurement procedures, guidelines and recommendations, including a chapter on measuring particle number concentration.
  - Particle counting efficiencies of new TSI condensation particle counters
    Hermann, M., et al., J. Aerosol Sci. 38, 674 – 682.
    A detailed characterisation of the latest generation butanol- and water-based TSI condensation particle counters.
- Measurements of Particle Number Size Distribution (fine mode)
  - GAW report No. 153
    WMO/GAW Aerosol Measurement procedures, guidelines and recommendations, including an introduction chapter on measuring the particle number size distribution.
  - GAW - WCCAP recommendation mobility particle size spectrometer: Part I recommended instrument set-up
    How to design an instrument for measuring the electrical mobility particle number size distribution.
  - GAW - WCCAP recommendation mobility particle size spectrometers - Part II recommended particle loss correction
    How to correct for diffusion losses when analysing data from particle mobility size spectrometers.
  - GAW – WCCAP recommendation mobility particle size spectrometers - Part III Standard Operation Procedure
    Essential aspects for assuring the continued data quality when operating a mobility size spectrometer.
  - GAW – WCCAP recommendation mobility particle size spectrometers - Part IV Constants and Relevant Equations
    The theory behind particle mobility size spectrometers.
  - Mobility particle size spectrometers: harmonization of technical standards and data structure to facilitate high quality long-term observations of atmospheric particle number size distributions
    Wiedensohler et al., Atmos. Meas. Tech. 5, 657-685
    The most authoritative peer-reviewed resource on design, sampling, operation, and data reporting for particle mobility size spectrometers.

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- Measurements of the Aerosol Particle Scattering Coefficient
  - GAW report No. 153
    WMO/GAW Aerosol Measurement procedures, guidelines and recommendations, including an introduction on measuring the aerosol particle scattering coefficient.
  - GAW report No. 200
    WMO/GAW report containing one chapter each on operation procedures, quality assurance, and data handling for the TSI 3563 and ECOTECH M9003 integrating nephelometers.
  - Performance Characteristics of a High-Sensitivity, Three-Wavelength, Total Scatter/Backscatter Nephelometer
    Anderson et al., J. Atmos. Oceanic Technol. 13, 967–986.
    Peer-reviewed standard Operating Procedure for TSI 3563 integrating nephelometer.
  - Determining Aerosol Radiative Properties Using the TSI 3563 Integrating Nephelometer
    Anderson and Ogren, Aerosol Sci. Tech. 29(1), 57-69.
    Standard Operating Procedure for TSI 3563 integrating nephelometer, part 2, including formulas for correcting instrument artefacts through angular truncation.
  - Design and performance of a three-wavelength LED-based total scatter and backscatter integrating nephelometer
    Müller et al., Atmos. Meas.Tech. 4, 1291-1303.
    Performance comparison between the ECOTECH Aurora 3000 and the TSI 3563 integrating nephelometers, including a procedure for correcting instrument artefacts through angular truncation for the ECOTECH Aurora 3000.
  - IMPROVE Standard Operating Protocols, Optical Monitoring
    Webpage linking to the Standard Operating Procedures for monitoring aerosol optical properties used in the U.S. IMPROVE network.
  - Intercomparisons and Aerosol Calibrations of 12 Commercial Integrating Nephelometers of Three Manufacturers
    Heintzenberg, J., et al., J. Atmos. Oceanic Technol. 23, 902–914.
    Early intercomparison exercise for integrating nephelometers.
  - Angular Illumination and Truncation of Three Different Integrating Nephelometers: Implications for Empirical, Size-Based Corrections
    Müller, T., et al., Aerosol Sci. Tech. 43(6), 581–586.
    Another intercomparison exercise for integrating nephelometers.

- Measurements of the Aerosol Particle Absorption Coefficient
  - GAW report No. 153
    WMO/GAW Aerosol Measurement procedures, guidelines and recommendations, including an introdution on measuring the aerosol particle absorption coefficient.
  - GAW report No. 200
    WMO/GAW report containing one chapter each on operation procedures, quality assurance, and data handling for the Radiance Research Particle Soot Absorption Photometer (PSAP) and the Thermo 5012 Multi-Angle Absorption Photometer (MAAP).
  - Calibration and Intercomparison of Filter-Based Measurements of Visible Light Absorption by Aerosols
    Bond, T.C. et al., Aerosol Sci. Tech. 30(6), 582-600.
    Reference publication for data processing and corrections for cross-sensitivity to particle scattering for the Radiance Research Particle Soot Absorption Photometer

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(PSAP). The information in this article needs to be used together with the update given in the article below.

  - Comment on "Calibration and Intercomparison of Filter-Based Measurements of Visible Light Absorption by Aerosols"
    Ogren, J.A., Aerosol Sci. Tech. 44(8), 589-591.
    Comment on the above reference publication for the Radiance Research Particle Soot Absorption Photometer (PSAP). The article includes an important update to the correction for cross-sensitivity to particle scattering.
  - Multi-angle absorption photometry—a new method for the measurement of aerosol light absorption and atmospheric black carbon
    Petzold and Schönlinner, J. Aerosol Sci. 35(4), 421-441.
    Reference publication for data processing and quality assurance for the Thermo 5012 Multi-Angle Absorption Photometer (MAAP), including instructions on how to convert the equivalent black carbon concentration reported by the instrument to the property actually measured, the aerosol absorption coefficient.
  - Characterization and intercomparison of aerosol absorption photometers: result of two intercomparison workshops
    Müller, T., et al., Atmos. Meas tech. 4, 245-268.
    Results from 2 intercomparison workshops on instruments measuring the aerosol absorption coefficient, including the Radiance Research Particle Soot Absorption Photometer (PSAP), the Thermo 5012 Multi-Angle Absorption Photometer (MAAP), and the Magee Scientific Aethalometer.

- Measurements of Aerosol Particle Mass Concentration
  - GAW report No. 200
    WMO/GAW report containing chapters on conducting, quality assuring, and reporting: 1) offline gravimetric measurements of the particle mass concentration following North American protocols; 2) online measurements of the particle mass concentration using attenuation of beta-radiation with the Met One Instruments BAM-1020 beta attenuation monitor.
  - EMEP manual for sampling and chemical analysis
    Operating procedure and quality assurance manual of the European Monitoring and Evaluation Programme (EMEP), including sections on offline gravimetric measurements of the particle mass concentration following European protocols.

- Measurements of Aerosol Particle Inorganic Chemical Composition
  - EMEP manual for sampling and chemical analysis
    Operating procedure and quality assurance manual of the European Monitoring and Evaluation Programme (EMEP), including sections on offline measurements of particle-phase inorganic composition following European protocols.
  - GAW report No. 200
    WMO/GAW report containing a chapter on conducting, quality assuring, and reporting offline measurements of particle-phase inorganic composition.

- Measurements of Particulate OC / EC concentrations
  - Toward a standardised thermal-optical protocol for measuring atmospheric organic and elemental carbon: the EUSAAR protocol
    Cavalli et al., Atmos. Meas. Tech. 3, 79-89.
    Guidelines on taking and analysing aerosol samples for measuring the particulate

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organic (OC) and elemental carbon (EC) concentrations by thermal-optical analysis using the European EUSAAR protocol.

- Measurements of Cloud Condensation Nucleus Concentration
  - GAW report No. 153
    WMO/GAW Aerosol Measurement procedures, guidelines and recommendations, including a chapter on measuring the cloud condensation nucleus concentration as a function of water vapour supersaturation.

- Measurements of Aerosol Optical Depth
  - GAW report No. 153
    WMO/GAW Aerosol Measurement procedures, guidelines and recommendations, including a chapter on measuring the aerosol optical depth by filter radiometer.
  - Manual of the Precision Filter Radiometer
    PFR manual, containing description of data analysis and quality assurance.

- Measurements of Profile of Aerosol Backscattering and Extinction
  - GAW report No. 153
    WMO/GAW Aerosol Measurement procedures, guidelines and recommendations, including a chapter on measuring the profile of aerosol backscatter and extinction by lidar.

The current involvement of ACTRIS in CEN and ISO initiatives will be further maintained and reinforced. Considering the increasing demand for technologies like black-carbon and visual range lidars, further efforts are foreseen for the standardization of these technologies. Taking into consideration the increasing role on the market of the end-user services and products emerging from ACTRIS activities, a strategy to improve and harmonize the operation activities of the infrastructure is under development (e.g. standardization of techniques and procedures for data quality assurance – calibration of the lidar depolarization channels, automation of data collection – new SCC user interface, processing and transfer – NetCDF conversion tools, LiCal internal standardization development – LiCoTest measurements standards).

Reference documents:

[1] Wiedensohler et al. (2012). Mobility Particle Size Spectrometers: Harmonization of Technical Standards and Data Structure to Facilitate High Quality Long-term Observations of Atmospheric Particle Number Size Distributions. AMT 5, 657–685.
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[6] Freudenthaler, V.: Rayleigh scattering coefficients and linear depolarization ratios at several EARLINET lidar wavelengths, 2013.
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[9] Freudenthaler, V.: About the effects of polarising optics on lidar signals and the Δ90 calibration, Atmos. Meas. Tech., 9(9), 4181–4255, doi:10.5194/amt-9-4181-2016, 2016.

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