# Deliverable D5.6 : Final report on cooperation between ACTRIS and other European and international RIs, networks and programmes

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There is a great potential for improving the integration of observations across the various international networks engaged in systematic atmospheric long-term observations. International collaboration and establishment of joint procedures and standards is therefore essential to ensure implementation of common strategies for international networks. Further, there is a need to develop cost-efficient monitoring capacity in regions currently inadequately covered. The specific task is to improve comparability of data, work towards more uniform data quality standards, share QA/QC approaches in relation to ACTRIS calibration facilities, increase synergy of measurements and prevent unnecessary duplication and, finally, promote the ACTRIS concept outside Europe. This will be done in the international framework of GAW and GCOS. This includes also the transfer of standards and methodologies to more operational networks (e.g. those covered by the EU Met Services in EUMETNET, EMEP, whenever possible). The second aspect within task 5.4 is to ensure proper representation of ACTRIS and adoption of ACTRIS standards, when applicable, in international initiatives such as COOPEUS, RDA, PEEX, ILEAPS, IGAC, etc.

## 1. ACTRIS as a global Research Infrastructure

Grand research and societal challenges addressed by ACTRIS are of international dimension by nature and require not only a pan-European approach but also a global effort to consolidate partnerships in science and technology, to enhance exchange of information and interoperability, and ensure advanced training goals are proposed to a worldwide community of users. Ambition in ACTRIS is to solidify its leadership as a global distributed research infrastructures in the field of climate and air quality sciences, to intensify its cooperation with the corresponding partners in other World regions and with the relevant international institutions. This ambition is achieved if ACTRIS is recognized as a Global Research Infrastructure, i.e. 1) a RI influencing the global strategy for in-situ Earth Observation of aerosol, clouds and trace gases and 2) a RI with consolidated partnerships in Europe and worldwide, to ensure alignment of policies with the relevant international initiatives and to contribute to strategies for enhancing uptake of ACTRIS data, data-products and services by user communities.

One key element in this consolidation is that ACTRIS should be promoted in the international framework as an important player for influencing methodologies and standards for Earth observation of short-lived atmospheric compounds from the ground.

## 2. Use of ACTRIS standards operating procedures beyond the RI

Almost 100 different atmospheric variables are measured within ACTRIS complying with well-described measurement guidelines and standard operating procedures (SOPs), defined by the ACTRIS Topical Centers. Comparable data from different observational platforms and sites are crucial, but only possible with SOPs and detailed description of procedures and recommendations. The ACTRIS Data Centre offers access to all ACTRIS measurement guidelines and SOPs used for aerosol remote observations, and aerosol and trace in situ measurements within ACTRIS. It is clear that standard operating procedures are not yet fully defined as the measurements in ACTRIS are continuously evolving. Compiled ACTRIS SOPs and guidelines for aerosol, cloud and trace gases measurements: http://actris.nilu.no/Content/SOP

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→ Standard Operating Procedures and Measurement Guidelines for ACTRIS Aerosol column and profile variables. Below is a list of measurement guidelines and the standard operating procedures (SOPs) used for aerosol profile and column measurements within ACTRIS. The SOPs provide guidelines for good measurement practice.

| Component | Category | Description | Access to documents and reports |
|---|---|---|---|
| AOD | Measurement guidelines | WMO/GAW Aerosol Measurement procedures, guidelines and recommendations, including a chapter on measuring the profile of aerosol backscatter and extinction by lidar. (This report supersedes GAW report No. 153). | GAW Report No. 227 |
| AOD | Measurement guidelines | PFR manual, containing description of data analysis and quality assurance. | Precision Filter Radiometer Documentation |
| Profile of Aerosol Backscattering and Extinction | Measurement guidelines | WMO/GAW Aerosol Measurement procedures, guidelines and recommendations, including a chapter on measuring the profile of aerosol backscatter and extinction by lidar. (This report supersedes GAW report No. 153). | GAW Report No. 227 |
| Profile of Aerosol Backscattering and Extinction | Check-up procedures | Lidar internal checkup procedures: telecover measurements, Rayleigh fit, dark and zero-bin measurements, data submission format. | Lidar quality-assurance internal checkups |
| Profile of Aerosol Backscattering and Extinction | Check-up procedures | Procedure for assessing the effects of polarising optics on the signal of typcial lidar systems and for measuring calibrated linear depolarization ratios | Depolarization measurements and calibration, V. Freudenthaler AMT (2016) and supplement |
| Profile of Aerosol Backscattering and Extinction | Check-up procedures | Single Calculus Chain procedure for automatic cloud detection, aerosol layer detection, and calculation of uncertainties in aerosol optical products derived from raw lidar signals. | Assessment of lidar calculus subsystems |

→ Standard Operating Procedures and Measurement Guidelines for ACTRIS in situ aerosol particle variables. Below is a list of measurement guidelines and standard operating procedures (SOPs) used for aerosol in situ measurements within ACTRIS.

| Component | Category | Description | Access to documents and reports |
|---|---|---|---|
| All, or most | General guidelines | Guidelines on inlet design for different ambient environments and station settings. | GAW-WCCAP recommendations for aerosol inlets and sampling |
| All, or most | General guidelines | The station audit check list highlights the points most critical for station operation concerning data quality assurance. | Station audit check list for atmospheric aerosol property observations |
| All, or most | General guidelines | Guidelines on conditioning and drying the aerosol sample depending on ambient temperature. | GAW - WCCAP recommendation for aerosol drying |
| All, or most | General guidelines | Relevant for most aerosol variables, current WMO/GAW Aerosol Measurement procedures, guidelines and recommendations published in 2016. | GAW report No. 227 |
| **Cloud condensation nuclei** number concentration | SOP | Standard operating procedure for operating ACTRIS cloud condensation nucleus counters | ACTRIS protocol and measurement guidelines on cloud condensation nuclei number concentration |

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→ Standard Operating Procedures and Measurement Guidelines for ACTRIS in situ trace gases. Below is a list of measurement guidelines and standard operating procedures (SOPs) used for trace gas in situ measurements within ACTRIS.

| Component | Category | Description | Access to documents and reports |
|---|---|---|---|
| $NO_x$ | Measurement guidelines | The ACTRIS measurement guidelines for submission of NOx data under ACTRIS contains many helpful features to check the quality of the data. | ACTRIS measurement guidelines on NOx |
| $NO_x$ | Measurement guidelines | A WMO/GAW Expert Workshop on Global Long-Term Measurements of NOx. Description of the state-of-the art NOx measurements of GAW sites. | GAW report No. 195. |
| VOC | Measurement guidelines | The ACTRIS measurement guidelines for submission of VOC data under ACTRIS contains many helpful features to check the quality of the data. | ACTRIS measurement guidelines on VOC |
| VOC | Measurement guidelines | Measurement guidelines for air sampling in stainless steel canisters for non-methane hydrocarbon analysis. | GAW-Report No. 204. |
| VOC | Measurement guidelines | A WMO/GAW Expert Workshop on Global Long-Term Measurements of VOCs Description of the state-of-the art VOC measurements of GAW sites. | GAW report No. 171. |
| VOC | SOP | EMEP standard procedure for offline measurements of OVOC by DNPH cartridges are described in Chapter 3.8 in the EMEP manual | EMEP Manual for Sampling and Analysis |
| Ozone | Measurement guidelines | MO/GAW guidelines for continuous measurements of tropospheric ozone. This variable is needed for corrections and recommended with the NOx guidelines. | Guidelines for Continuous Measurements of Ozone in the Troposphere |
| $NO_x$ | SOP | CEN standard describing the procedure for measuring the concentration of NO and NO2 with online chemiluminescence instruments. | Ambient air. Standard method for the measurement of the concentration of nitrogen dioxide and nitrogen monoxide by chemiluminescence |

It is easy to see, in the last column, that methodologies, guidelines and SOPs in ACTRIS are also recommended within EMEP, whenever applicable and GAW. This is a key feature in ACTRIS that ensured that SOPs are widely adopted to international networks in Europe and outside.

The ACTRIS SOP are also integrated into the WMO Commission for Instruments and Methods of Observation (CIMO). The mission of CIMO is to promote and facilitate international standardisation and compatibility of instruments and methods of observation used by Members, in particular within the WMO Global Observing System, to improve quality of products and services of Members and meet requirements and the Report of the President to Cg-XV (2007)). Having ACTRIS procedures included in the report ensures the widest application of SOPs outside of ACTRIS.

A similar strategy applied to e-infrastructure dimension of ACTRIS. In ACTRIS-2, we developed a strategy to facilitate direct uptake of data and data products by users, reaching larger communities also unrelated to the Atmosphere and Climate science by ensuring full compliance to international data standards, and with the WMO Information System. ACTRIS addressed the value of joint activities with other RIs, with particular focus on the atmospheric domain within the framework of the ENVRI projects. This resulted in successful funding of the ENVRI FAIR project, where RI from the atmospheric domain are sharing resources towards raising the FAIR level of each RI. The work within the atmospheric RIS is to demonstrate the new interoperability-based atmospheric services, to perform an assessment and to provide recommendations for the future strategy.

## 3. Strategies for developing new standards

It is essential that ACTRIS jointly works with NMIs for improving standardization of ACTRIS procedures and, in parallel, ensures that the recommended ACTRIS procedures are accepted and used by a large body of users, in Europe and beyond. ACTRIS-2 developed very strong links with the National Metrology Institutes (NMIs) in different EU countries through the European Metrology Programme for Innovation

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and Research (EMPIR) that coordinates research projects to address grand challenges, while supporting and developing the SI system of measurement units. The EMPIR programme enables European metrology institutes and academia to collaborate on a wide variety of joint research projects within specified fields including environment. Four main projects were co-organized between NMIs and ACTRIS partners, fully relevant to ACTRIS :

- European Metrology project 16ENV02 Black Carbon Metrology for light absorption by atmospheric aerosols( July 2017 – July 2020) : The objective of the project is, for the first time, to bring SI traceability to field of black carbon measurements, so that their accuracy and value is greatly increased. The specific objectives are 1) 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. 2) To develop and characterise a black carbon standard reference material (SRM), as a near-black carbon source that is highly relevant for atmospheric aerosols, together with methods for using it to calibrate field black carbon monitors. 3) To develop a traceable, primary method for determining aerosol absorption coefficients at specific wavelengths that are to be defined for the benefit of users. The method should have defined uncertainties and a quantified lowest detection limit. 4) 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 absorption photometers.
- Metrology for VOC indicators in air pollution and climate change KEY-VOCs (October 2014 September 2017). KEY-VOCs aims at improving the measurement infrastructure for key Volatile Organic Compounds (VOCs) in air by providing traceable and comparable reference gas standards and by validating new measurement systems (sensors-based) in support to the air monitoring networks. KEY-VOCS focuses on the VOC key compounds (indicators) that are regulated by the European legislation, that are relevant for indoor air monitoring and for air quality and climate monitoring programmes and are those relevant in ACTRIS-2. The requirements for establishing variability and trends of those compounds have set challenging data quality objectives (DQOs) for the atmospheric monitoring programmes. The evidence is that for priority classes of VOCs traceable and stable gas standards are still lacking and specifically for oxygenated-VOCs (OVOC), oxidation products from anthropogenic and biogenic origin and to terpenes, biogenic aerosol precursors. ACTRIS-2 partners, together with key NMIs in Europe aim at developing fit-for-purpose gas standards based on novel passivation chemistries to guarantee mixture stability and improved preparation methods. KEY-VOCs also addresses the need to develop standards for reactive VOCs that are not sufficiently stable in high-pressure gas cylinders. To achieve this, novel dynamic generation techniques will be designed and constructed taking into account the VOCs' behaviour to adsorb and react on contact with material surfaces.
- Metrology for climate relevant volatile organic compounds (MetClimVOC), starting 2019. The objectives of the work will be to advance the research required to develop an SI-traceable measurement infrastructure for climate relevant volatile organic compounds identified by the WMO, by research infrastructure (GAW-VOC network, GAW-greenhouse gases network, ACTRIS, AGAGE [1, 2]) and regulated under European and International legislation (e.g. Kyoto and Montreal protocols). The work aims at 1) developing traceable reference standards of priority VOCs (oxy-VOCs and terpenes) at atmospherically relevant amount fractions (1 nmol/mol – 1 µmol/mol) with uncertainties that support global monitoring of background levels (< 5 %); 2) Developing working standard and metrological support to ensure comparability of field

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measurements and to ensure dissemination of traceability to the field at monitoring stations.

- Aerosol metrology for atmospheric science and air quality (Short Name: AEROMET, Project Number: 16ENV07). Measurements of aerosol particles are vital for enforcing EU air quality regulations to protect human health, and for research on climate change effects. Although metrics such as the mass concentration of airborne particulate matter (PM) including PM10 (inhalable particles with diameters of 10 micrometres and smaller) and PM2.5 (fine inhalable particles, with diameters of 2.5 micrometres and smaller) are currently in use the level of uncertainty is too high and the traceability is insufficient. Therefore this project aims to improve the uncertainty of particle mass, size and number concentration measurements and the characterisation of regulated components in airborne particles as needed by EU air quality monitoring networks. Regulatory bodies, air quality networks and atmospheric instrument manufacturers all require the improvement of air quality monitoring, however there is currently a lack of traceable calibration standards and harmonised calibration procedures for measuring airborne PM. In addition, methods measuring PM10 and PM2.5 (particle mass concentration) within the EU Air Quality Directive 2008/50/EC need improving in order to ensure the comparability of local data measured by instruments relying on different working principles (e.g. gravimetric vs. optical measurements). Therefore, reference methods for measuring PM10 and PM2.5 and calibration methods for the instruments used for such measurement are needed. The chemistry of aerosols (elemental composition analysis) is also part of existing regulation and necessary to understand their origins, behaviour, environmental fate and impacts (e.g. effects on health and climate). However, current methods for the quantification of regulated aerosol components (e.g. Elemental Carbon and Organic Carbon (EC/OC), metals, anions, and cations) are notoriously inflexible in terms of time and spatial resolution and are inaccurate. In addition, they do not meet requirements concerning detection sensitivity and flexibility for monitoring the temporal and spatial variability of air pollution. Therefore, validated methods for the determination of major components of PM are needed as well as reliable procedures for Mobility Particle Size Spectrometers (MPSS) and Condensation Particle Counters (CPC). Modern x-ray analytical techniques could also be used to improve the chemical analysis of airborne particles directly at their emission sources, therefore new SI-traceable X-ray techniques need to be developed.

The ACTRIS strategy to develop standards together with the NMIs gave a very strong visibility to many actions, in particular for the relationship with the private sector. Capacity to ensure that ACTRIS SOPs are based on a very solid metrology grounds and that they may be adopted as CEN or ISO standards in the future. This is why ACTRIS may seek a specific role as a stakeholder within the next European Metrology Networks" (EMN) on Essential Climate Variable which has recently been established by a pool of National Metrology Institutes.

## 4. Strategies to enhance the impact of ACTRIS in relation to SOPs

The ACTRIS strategy to become a Global Research Initiative through its integration in the
ACTRIS must also engage in developing stronger liaison with the international initiatives, consolidating its position in the relevant international networks and actively liaise with relevant communities in developing/emerging countries where the demand for capacity building is high and the need for provision of reliable atmospheric information a scientific necessity.

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In ACTRIS-2, all actions were taken to ensure proper alignment of policies (governance, access, policies, standards, and protocols) with the relevant international initiative data hubs, identify potential conflict in data policies and initiate discussion to seek harmonisation. ACTRIS is the European contribution of several networks for the observation of the atmospheric composition and properties related to aerosol, cloud and trace gases, such as AERONET, NDACC, GAW, EMEP. There networks are also operated under other umbrella by other research performing organisations such as NASA or under global or European initiatives such as GEO, GCOS, or COPERNICUS, which in turn define their standards and requirements such as in GEOSS, WIGOS or other data hubs. ACTRIS is managing well to be a well-identified contribution to international networks by 1) providing observation data, 2) defining the SOPs and operating as the network calibration center(s), 3) operating the network data center or any combination of the three.

The level of trust developed with users gives ACTRIS a key role in the landscape as the unique atmospheric RI capable of providing large scale services to large initiatives such as the COST projects for observation E-PROFILE. E-PROFILE is part of the EUMETNET Composite Observing System, EUCOS, managing the European networks of Radar/Lidar wind profilers and automatic lidars and ceilometers (ALC) for the monitoring of vertical profiles of wind and aerosols including volcanic ash. E-PROFILE recommends that its members implement standard operating procedures for all the instruments involved. ACTRIS is proposing standard operating procedures for ALCs, and methods to perform preprocessing and to calibrate the ALCs. Several types of ALCs were compared and their performance evaluated during the CeiLinEx 2015 field experiment carried out in the framework of the TOPROF COST action. This type of service will be continued in the framework of the ACTRIS centre for aerosol remote sensing. ACTRIS is also proposing standard operating procedures, quality control methods and calibration methods for Microwave radiometers and Doppler Lidars. This service will be provided in the framework of the ACTRIS centre for cloud remote sensing. As Microwave radiometers and Doppler Lidars join the E-PROFILE network, E-PROFILE members will be able to access a large range of ACTRIS services.

The future of ACTRIS in the international context will be clearer if better integrated into GEO (Group on Earth Observations). GEO is an intergovernmental partnership that improves the availability, access and use of Earth observations promoting open, coordinated and sustained data sharing in support of global priority engagement areas, including the UN 2030 Agenda for Sustainable Development, the Paris Agreement, and the Sendai Framework for Disaster Risk Reduction. GEO develops the effective policy responses for climate change adaptation, mitigation and leads national, regional and global efforts to enhance global observation systems. Better integration of ACTRIS in the GEO framework will require the establishment of a GEO initiative on short-lived climate species, of which ACTRIS will be the European node. The initiative will part of ACTRIS strategy towards delivery of data and data products to the climate impacts, adaptation and vulnerability research community for the Intergovernmental Panel on Climate Change (IPCC) assessment reports. ACTRIS must be looking for an active relationship with GEO to enhance its impact worldwide through the establishment of a GEO initiative. In order to strengthen the GEO application process, ACTRIS, with key partners worldwide, will first strengthened its connection with the Global Climate Observing System (GCOS). In a second step, will liaise with stakeholders in different World regions to propose a joint GEO initiative on short-lived climate species, of which ACTRIS will be the European node.

## 5. Cooperation with other Research Infrastructures

ACTRIS is the research infrastructure for the study of short-lived atmospheric components which are relevant for both climate and air quality research. ACTRIS provides access to high-quality data and also physical access to large facilities and laboratories, including simulation chambers, to conduct excellence

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research in the atmospheric domain. In this respect, ACTRIS is unique not only because provides unique information, not covered by any other European RI, but also because it is the only RI in the atmospheric domain offering physical access to advanced facilities and laboratories. Because of this specificity, ACTRIS is organized into a concept that fundamentally differs from other RIs.
However, ACTRIS is fully integrated in the European Landscape of Atmospheric Research Infrastructures together with IAGOS, ICOS-Atmosphere, ARISE and EISCAT-3D, such as:

- ACTRIS complements the area of ICOS-Atmosphere (greenhouse gases) with the provision of information on short-lived pollutants including short-lived climate forcers. In fact, ACTRIS is currently unique in providing both long time series of essential climate variables as recognised in the recent IPCC report and short-term information on significant atmospheric processes.
- ACTRIS completes information provided by IAGOS both temporally by adding the required continuity of the time series and spatially by offering 3-D information across Europe on parameters measured by both RIs. Because ACTRIS is not limited in payload, it can deploy the heavy instrumentation required to relate cloud, aerosol, and trace-gas observations to climate and chemistry-transport model development and evaluation.
- ACTRIS investigates the atmosphere from surface to stratosphere and therefore complements ARISE and EISCAT-3D mostly focusing on upper atmosphere dynamics, a region and a domain not covered in ACTRIS

Upon establishing ACTRIS-ERIC in the future, there will a need to better formalize the partnership with the other RIs, in the atmospheric domain to ensure that all elements of ACTRIS, from the governance to access, are compliant with the participation and role in the international network and ensure a representation of ACTRIS in the long-term. The work engaged in ENVRI FAIR will be key to develop a fully interoperable e-framework to the benefit of the users.

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