



## AEROSOLS, CLOUDS, AND TRACE GASES RESEARCH INFRASTRUCTURE

### 10 QUESTIONS AND ANSWERS TOWARDS THE ESFRI ROADMAP

Strengthening the ground-based component of the Earth Observing System for key atmospheric variables has been unambiguously asserted in the IPCC Fourth Assessment Report and the EU Thematic Strategy on air pollution. Key climate variables not only concern CO<sub>2</sub> and other greenhouse gases but also the short-lived components driving the interaction between solar radiation and the atmosphere, aerosols and clouds. Their radiative impact and the understanding of their evolution in gas-aerosol-cloud-interactions constitute the main uncertainty in predicting future air quality and climate change. Over the last 15 years, Europe has built a unique infrastructure for the coordination of aerosol, cloud, and trace-gas observations essential to a large community of users for applications such as process studies of physical phenomena in the atmosphere, validation, evaluation, and improvement of climate and numerical weather prediction models, validation and improvement of data products from ground-based, airborne, and space-borne sensors or assimilation of data into numerical weather prediction and air-quality models. Continuation of observations and services provided by this infrastructure requires the establishment of a framework that will organize in the long-term this essential support to research activities of the atmospheric science community.

#### Q1: What is ACTRIS?

**A1:** The Research Infrastructure ACTRIS is the pan-European initiative that consolidates strategies amongst European partners for observation of aerosols, clouds, and trace gases. ACTRIS focuses on producing high-quality observations of clouds and short-lived climate-forcing pollutants (SLCPs). Short-lived atmospheric components have a residence time in the atmosphere from hours to few weeks, which differentiates them from long-lived greenhouse gases. The short lifetimes make their

concentrations highly variable in time and space and involve fast processes. The infrastructure is unique in providing the 4D-variability of reactive trace gases, clouds and of the physical, optical and chemical properties of short-lived atmospheric species. ACTRIS is a distributed infrastructure consisting of National (observing stations) and Central Facilities (Calibration Centres, Data Centre, Head Office) that serve a vast community of users working on models, satellite retrievals, and analysis and forecast systems. Atmospheric predictions of all kinds use complex models that are underpinned by observations. Without high-quality observation data to constrain predictive models any forecasts

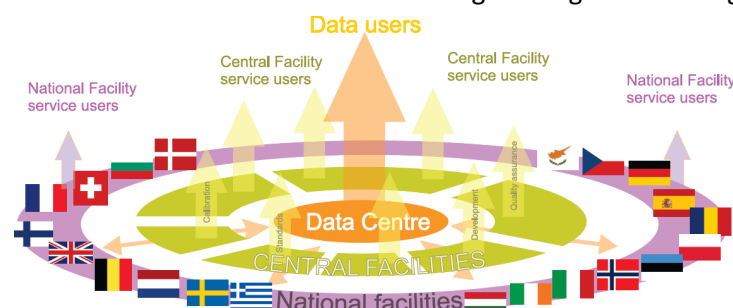


Figure 1: The ACTRIS concept with National and Central facilities

of the atmosphere are highly unreliable. Without a ground-truth capability, satellite sensors cannot be accurately validated.

## Q2: How is ACTRIS linked to European and international networks?

**A2:** Several networks operate in Europe and in the world to produce information on atmospheric composition changes.

- In Europe, the European Monitoring and Evaluation Programme (EMEP) is a science-based and policy-driven programme under the Convention on Long-range Transboundary Air Pollution (CLRTAP) for international co-operation to solve trans-boundary air pollution problems. EMEP coordinates monitoring activities from about 180 sites in Europe and includes a research observation component organized at so-called EMEP supersites (level-2 and level-3 sites). Level-3 activities are research-oriented to improve the scientific understanding of the relevant physico-chemical processes in relation to regional air pollution and its control. ACTRIS is the proposed funding scheme to ensure long-term sustainability of level-3 activities within EMEP, and is central in harmonizing efforts of level-2 sites ensuring the required quality and development.
- In the world, the Global Climate Observing System (GCOS) is a long-term, user-driven operational system capable of providing the comprehensive observations required for monitoring the climate system, detecting and attributing climate change. For the atmospheric domain, Aerosol Robotic Network (AERONET), GRUAN (Global Reference Upper Air Network), NDACC (Network for the Detection of Atmospheric Composition Change) and GAW (Global Atmosphere Watch) are four major components of that system. All networks operate advanced instrumentation, calibration centers and data centers essentially under national funding schemes. ACTRIS is the proposed funding scheme for long-term support of the European component contributing to AERONET, GRUAN, NDACC and GAW, for the relevant essential climate variables. ACTRIS includes support to the World Data Center (WDC) and World Calibration Centers (WCC) located in Europe, and contributes to operation at supersites relevant to those networks.

ACTRIS provides the proper level of coordination and commitment to make the European contribution to GCOS better recognized.

## Q3: What are the ACTRIS National Facilities?

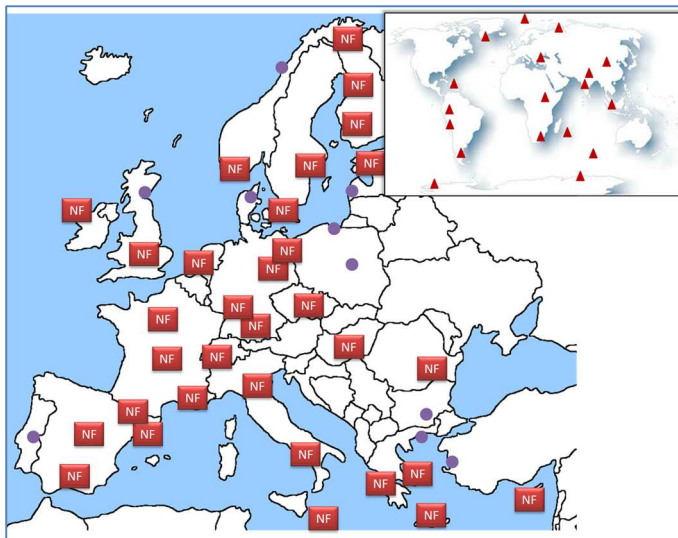


Figure 2: A view of the envisaged ACTRIS stations based on past delivery to ACTRIS DC, including potential contributing stations (circle). Stations operated by ACTRIS partners outside Europe geographical boundaries are also indicated (GAW/NDACC). Selection of ACTRIS platforms will be made at a later stage.

**A3:** The main body of ACTRIS is the distributed observation platform, consisting of observation stations strategically located in diverse climate regimes in Europe and outside Europe, and operated (or co-operated) by ACTRIS partners. Many observation stations belong to one or several European and international networks, such as EMEP, NDACC, GRUAN, or GAW, and are possibly partly shared with other environmental infrastructures, such as ICOS, SIOS, or ANAEE. A typical ACTRIS National Facility is equipped with state-of-the-art instrumentation for the measurement of variables governing the atmospheric radiation balance above Europe. Measurements of all relevant components are obtained via a

combination of *in situ* and remote-sensing systems and include: i) near-surface measurements of aerosols and short-lived trace gases; ii) vertically resolved measurements of aerosols; iii) vertically resolved measurements of clouds and precipitation; iv) profile and column observations of short-lived trace gases; and v) measurements of a variety of supplementary meteorological and radiation quantities. Besides observation platforms, ACTRIS also includes exploratory platforms at the national level. This category includes laboratories, but also the ability to perform exploratory research in connection with the observational platforms. ACTRIS National Facilities are essentially funded by the member states.

#### Q4: What are the ACTRIS Central Facilities?

**A4:** Production of harmonized, reliable, and documented observational data in ACTRIS relies on appropriate Central Facilities (Calibration Centres, Data Centre) that ensure compliance with standard operating procedures and/or quality protocols. Calibration Centres include the existing European WDC and WCC components of GAW and the European component of the AERONET calibration facility and complement CCs already operating within other RIs (ICOS) or networks (NDACC) in Europe. The quality-assurance objectives are therefore compliant to international standards. Five Calibration Centres are currently in operation in ACTRIS, each one organized as one consortium with two or three nodes (additional facilities (or nodes) may complete this landscape at a later stage):

- The Lidar Calibration Facility (nodes: Romania, Italy, Germany);
- The AERONET-Europe Calibration Facility for sun/sky photometers (nodes: France, Spain);
- The European Centre for Aerosol Calibration that includes the GAW World Calibration Center for Aerosol Physics (WCC-AP) (nodes: Germany, France, and Czech Republic);
- The European Calibration Facility for reactive gases that comprises the GAW WCC for Volatile Organic Compounds (WCC-VOC) and for Nitrogen Oxides (WCC-NOx) (nodes: Germany, Finland, Switzerland);
- The Calibration Facility for Cloud Radars (nodes: The Netherlands, United Kingdom, France).

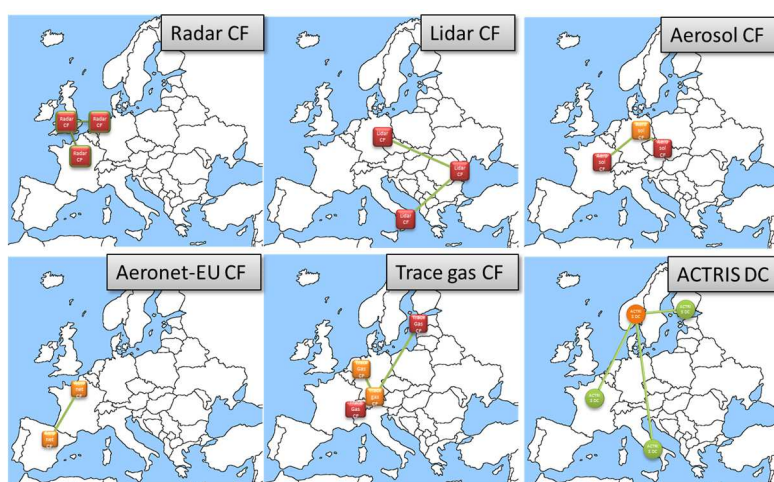


Figure 3: ACTRIS Central Facilities currently operating in the context of ACTRIS-2 – World Calibration Centers of WMO-GAW (WCC, WDC) and other international networks (AERONET) are indicated in orange.

Finland and France. ACTRIS DC is shared with EMEP and GAW World Data Centre for Aerosols (WDCA), and is linked to the WDC for Remote Sensing of the Atmosphere as well as with NDACC Data Centre. The architecture of the ACTRIS Data Centre is compliant to international frameworks such as the WMO Information System (WIS) and the Global Climate Observing System (GCOS).

The data curation and storage services, including data management and necessary development work on, e.g., workflow documentation, metadata issues, etc., is handled by a dedicated Central Facility, the ACTRIS Data Centre (ACTRIS DC). ACTRIS follows the open research data initiative of the commission. ACTRIS data and products are interoperable to specific quality standards and free of charge. The ACTRIS Data Centre consists of contributing scientifically based topic facilities in Norway, Italy,

### Q5: What is the history of ACTRIS?

**A5:** ACTRIS results from a construction effort of more than 15-yr engaged by both member states and the European commission through the Research Infrastructure programme. ACTRIS was initiated as an Integrated Initiative in 2011 building on three historical European research collaborations: **EARLINET** (European Aerosol Research Lidar Network, EU-FP5 and FP6 projects), **EUSAAR** (European Supersites for Atmospheric Aerosol Research, EU-FP6 project), **CREATE** (Construction, use and delivery of an European aerosol database, EU-FP5 project) and **CLOUDnet** (started as an EU-FP5 project for observing cloud profiles), to which a new integration of long-term **trace-gas** observatories was then added. The operations will be pursued as part of ACTRIS-2 funded as a new IA programme by the European commission in H2020. The short-lived components of **NDACC** (Network for the Detection of Atmospheric Composition Change) will be incorporated in the Research Infrastructure ACTRIS also building on advances made in the NORS program. Many of the observatories in ACTRIS are collocated with EMEP, GAW and GRUAN sites, and in many cases started observations prior to the mentioned EU projects in quasi-independent initiatives. In addition, a few facilities, such as large simulation chambers are proposed as National Facilities, and have been operating for years within the **EUROCHAMP** projects.

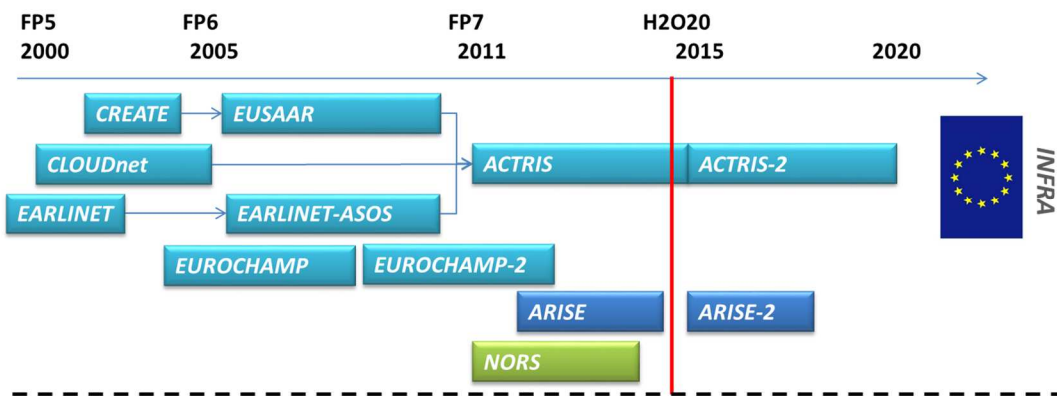


Figure 4: The ACTRIS construction history starting more than 15 year ago

Amongst the achievements of the 15-yr construction plan is the complex data-stream from data collected through the routine operations of the National Facilities, their quality assurance and their use in higher level data products distributed through the Data Centre, featuring search engines, multi-pass data selection, graphical views of data and data products, some of them in near real-time. It is also the very high quality data provided that facilitated research of a very large community of users worldwide.

### Q6: How is ACTRIS complementary to other Research Infrastructures?

**A6:** ACTRIS strongly supports research on direct effects of aerosols and the cloud feedback to global warming that form the major uncertainty in predicting climate change. Part of this research is the interaction of reactive gases, aerosols and cloud hydrometeors which is fundamental to the understanding of the evolution of aerosol and cloud particles. The observational basis to assess and understand these processes is not

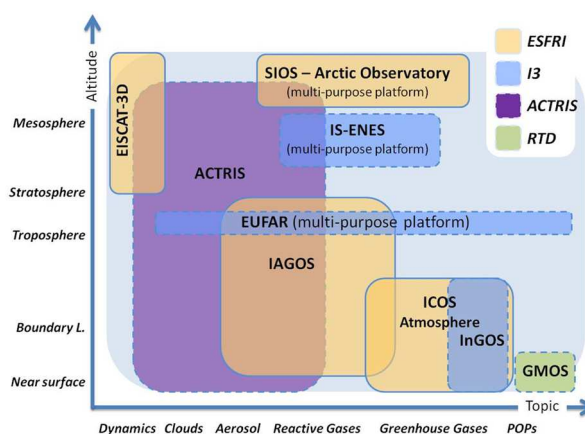


Figure 5: The European landscape for atmospheric observations.

within the scope of ICOS (Integrated Carbon Observation System) and IAGOS (In-service Aircraft for a Global Observing System), the two infrastructures including an atmospheric component currently on the ESFRI roadmap. ICOS focuses on the observation of carbon dioxide and other greenhouse gases in Europe. IAGOS is a fleet of commercial airliners equipped with instrumentation to measure the atmospheric state along the fixed trajectories of the aircraft. Understanding the future developments of the climate system requires observations of the forcers of climate change such as greenhouse gases and aerosols as well as the response of the climate system to the effects of these forcers. ACTRIS will complement IAGOS by providing the required spatial and temporal dimension by measuring *vertical profiles* of the physical properties of the atmosphere. Several ACTRIS National Facilities are collocated with ICOS facilities. Interoperability amongst research infrastructures is essential for the user community. This is ensured by the ENVRI<sup>plus</sup> project, which is an EC funded project to provide common environmental RI solutions for science and society in where ACTRIS, ICOS and IAGOS are partners.

#### **Q7: Who will use the ACTRIS infrastructure or its products and services?**

**A7:** The infrastructure will produce data and data products essential to a wide range of communities:

- Climate and air quality research communities worldwide;
- Universities and research institutions for training of researchers and young scientists;
- Space agencies for validation and the development of new satellite missions;
- Legislation-based monitoring networks of atmospheric compositional change;
- Sensor industries for testing, prototyping and demonstrations;
- Air quality agencies for validation of air pollution models;
- Numerical weather prediction centres for model validation;
- Institutes for eco-system studies of the interaction of atmosphere and biosphere.

ACTRIS is part of the data provision scheme of Copernicus Atmosphere Service. As such, improved climate models will result in better climate scenarios, which is relevant to a wide range of parties, e.g.:

- (Local) governments, who can adapt their policy to improved climate scenarios;
- Water boards to improve water management strategies;
- Insurance companies for the optimization of the risk-benefit analysis;
- Companies with a long-term (multi-decadal) strategy (e.g., the food and energy industry).

#### **Q8: Will ACTRIS have any impact on innovation and technology transfer to SMEs?**

**A8:** Worldwide, the mitigation of and adaptation to climate change require a dedicated monitoring capacity, leading to a potentially large market for cost-effective and innovative cloud, aerosol, and gas monitoring instrumentation. Industrial production applications are expected to grow with the international air pollution, climate, and weather monitoring market. The innovation potential of ACTRIS is well illustrated by the large number of products and software currently available on the market directly achieved within ACTRIS I3 activities or previous related INFRA projects. Because ACTRIS has a leading role in defining technical recommendations for future standardization, it will reinforce the capacity of European SME's to respond to the evolution of standardized protocols for monitoring the atmosphere. ACTRIS contributes to improving standard operating procedures and developing standardization through CEN and ISO procedures. ACTRIS establishes the platform for exchange of expertise and information with the private sector to further develop the innovation potential and the readiness transfer level of prototype instruments in close association with private companies that are clearly interested in the technological innovation potential brought by the ACTRIS partnership. Overall, it is expected that ACTRIS research infrastructure will provide highly skilled employment opportunities in the private sector.



**Q9: What is the proposed governance for ACTRIS and how much would ACTRIS research infrastructure cost?**

**A9:** ACTRIS consists of more than 50 different national level facilities (observation and exploratory facilities) in 21 countries and 7 European level central facilities (Head Office, Data Centre, 5 Calibration Centres) distributed across Europe. Until now, ACTRIS has been supported through short-term EC-funded projects. In March 2015, ACTRIS is applying for an ESFRI roadmap status and with the support of ACTRIS countries - and hopefully with the EC-funded preparatory phase project - will start the preparation towards common European level governance and its own entity (as a legal model ERIC - European Research Infrastructure Consortium). The steps towards ERIC are described in Table 1.

Table 1. The contractual agreements and the decision structure of ACTRIS in its different phases towards legal entity ERIC.

	<b>Decisive Planning Phase (incl. Preparatory Phase Project)</b>	<b>Implementation phase (decisive construction phase and testing of the operations)</b>	<b>1<sup>st</sup> Operational phase (first five years of operations)</b>
<b>Legal form</b>	Project consortium	MoU	ERIC
<b>Decision body</b>	Interim Council of ACTRIS	Interim Council of ACTRIS	ERIC General Assembly
<b>External advisory bodies</b>	Scientific and implementation board for ACTRIS PPP	Interim Scientific and implementation Advisory Board	Advisory Board Science and Innovation
		Interim Ethical Board	Ethical Board
<b>Leader</b>	ACTRIS coordinator	Interim director	Director General
<b>Internal boards</b>	Executive Board	Interim RI committee	RI committee
<b>National scientific contact</b>	National ACTRIS focal point	National ACTRIS focal point	National ACTRIS coordinator
<b>RI actors (content and service provision)</b>	PPP General Assembly, PPP project partners,	Central Facility reps and national facility PIs	Central Facility leaders, and Facility Assemblies

Investment costs for a completely new fully equipped gas/aerosol/cloud supersite can amount up to 20 M€, depending on instrumentation and supporting infrastructure. ACTRIS, however, will not start from scratch. The European countries have already invested more than 270 M€ in ACTRIS type research facilities over the last decades, and those will be the ACTRIS National Facilities. The annual cost of running these facilities is roughly 24 M€. Beyond this there is the need for upgrading at some National Facilities to meet the ACTRIS quality objectives, which will cost 20-25 M€ during the construction phase of ACTRIS (years 2015-2019). Roughly 70% of these costs are already secured by existing commitments, accepted projects and in-kind contributions from the research performing organizations. The ACTRIS National Facilities will be funded 100% nationally, both during the construction and operational phases of ACTRIS.

We estimate that constructing the ACTRIS Central Facilities will cost 29 M€ during years 2015-2019, of which also 70% is covered by the current level of secured funding. These costs will include both investments in instrumentation and operational costs during the construction period. Once ACTRIS is operational (in 2020) the operation costs of the ACTRIS Central Facilities will be 6 M€/year. During the construction phase of ACTRIS these will be funded 100% nationally by the hosting countries, and during the operational phase of ACTRIS the Central Facilities will be funded 80% by the hosting country and 20% by ACTRIS ERIC.

**Q10: What is the added-value of ACTRIS?**

**A10:** Securing the pan-European coordination of ACTRIS in the long-term will first ensure optimized and cost-efficient use of resources invested by member states (in particular the Central Facilities) and the right level of collaboration, technology and data sharing with other RIs in the atmospheric domain. It will maintain European atmospheric science in the leading position globally, in particular enhancing its impact and involvement in WMO/GAW and other global programme activities. It will create new scientific knowledge for better understanding of the climate system and its complex climate-chemistry feedback mechanisms from surface to stratosphere. The specific features of ACTRIS (station footprint on regional or global scales, 4-D multi-instrumental observation system, high quality and standardization, secured data flow) are unique and will be used to support Copernicus towards implementation of the Atmospheric Monitoring services and future Climate services. It will complement the actual landscape of European infrastructure with a component that is crucially missing.

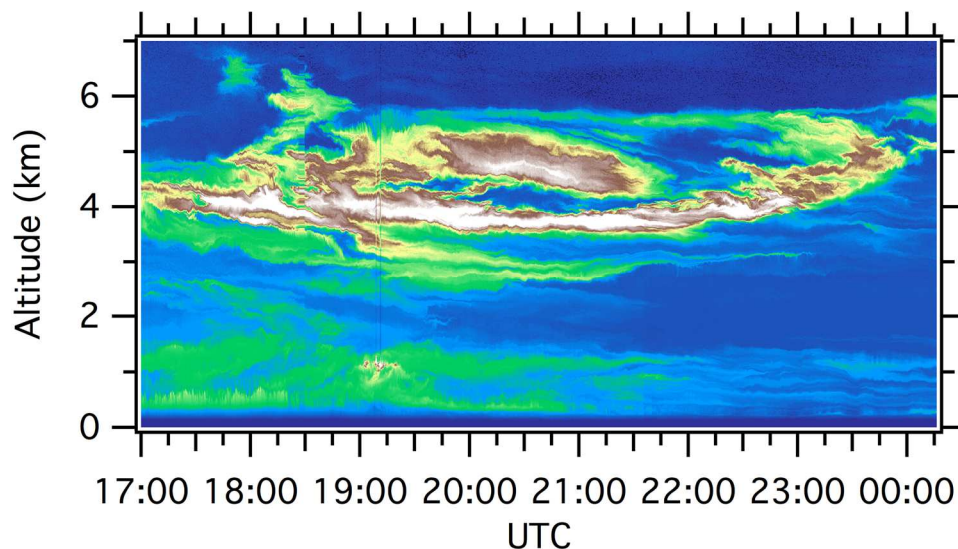


Figure 6: An ACTRIS lidar profile detecting the volcanic ash of Eyjafjallajökull eruption over Cabauw on 17 May 2010 between 4 and 6 km altitude. A small cloud appears at 1 km at about 19 UTC (colours are arbitrary units).

Securing the ACTRIS infrastructure in the long-term is required to go beyond the current state of services. The step towards pre-operational and operational use in atmospheric services can only be reached with a secured pan-European Research Infrastructure that will guarantee the return on investments. Expectations are high that ACTRIS products, once assimilated into models, will significantly improve prediction systems both at the global and the regional scales. Once implemented, ACTRIS will provide policy makers with new tools for validating the impact of regulation strategies or emission abatement policies by direct evaluation of atmospheric trends at regional/European scale. It will contribute to service development related to natural and anthropogenic hazards. Natural and man-made atmospheric hazards include, for instance, forest fires, sand-storms, dispersion of volcanic ash, etc. The role of Atmospheric Research Infrastructures during the 2010 volcanic crisis in Europe has been recognized at all levels. Since then, ACTRIS has established operational links with agencies in the various countries for atmospheric crisis management.

