

European networks observing the atmospheric boundary layer: Overview, access and impacts

Chapter: Overview of existing networks

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Introduction

This report provides a short overview of networks that observe the atmospheric boundary layer (ABL), their objectives, implementation and current status. Details of how to contact, join, or access data are also provided. The report concentrates on European-scale networks but also includes some national and international networks from across the globe.

E-PROFILE

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History & future

In 1997, a small European network of radar wind profilers was established under the name of CWINDE as a result of the COST-76 program. In 2003, VAD (velocity-azimuth-display) winds from weather radars during precipitation were added and the network was included as an observation programme of EUMETNET under the name of E-WINPROF. Since 2013, the scope of the programme was widened to include other remotely-sensed profiling observations and the name changed to E-PROFILE. A network of Automatic Lidars and Ceilometers (ALC) for aerosols and clouds became operational in 2016 with the calibration of the profiles of attenuated backscatter from these instruments being developed and optimised in subsequent years. Further developments have realised retrievals of extinction and aerosol mass profiles from these instruments. During the current programme phase lasting until the end of 2023 the setup of a fully operational network of microwave radiometers for humidity and temperature profiling and the addition of Doppler lidars is planned for inclusion within E-PROFILE.

Funding framework

E-PROFILE is a EUMETNET observation programme funded through European National Meteorological Services. Funding is only for network coordination and development. E-PROFILE does not own instruments but rather relies on partners sharing their data in exchange for services and processing by E-PROFILE. Funding occurs in programme phases of 5 years, with the current phase lasting until 31.12.2023 and coordinated by MeteoSwiss.

Network Objectives & Implementation

The aim is to provide observational data (in both dedicated NetCDF and BUFR formats) in near real-time on a 24/7 basis. The programme is based on distributed networks with instruments operated by different Meteorological Services, Environmental Protection or Research Institutes providing their data in native format (not for wind network) which is translated to a homogeneous format and distributed centrally. Daily monitoring and monthly quality checks using O-B statistics against the ECMWF IFS operational model or the CAMS model (for the ALC) are applied to the data.

E-PROFILE is composed of three sub-networks:

- A wind network based on radar wind profilers (40 instruments currently active) and wind profiles from precipitation radars (96 instruments). Upcoming integration of Doppler lidars is under way (2022 onward). This network is fully established. Data is assimilated by the leading NWP centres and regularly used by Meteorological Services. Impact studies have been performed and showed highly beneficial impact.

- Automatic Lidars and Ceilometers (ALC) for cloud and aerosol profiling. A network of 350 operational stations is established. Currently, work is concentrated on the improvement of data quality and derivation of advanced products (backscatter/extinction and mass retrieval, calibration, improvement of precipitation and cloud screening of aerosol data). The network contributes to research projects (e.g. ICOS PBL height) and field campaigns.
- An upcoming network of microwave radiometers for humidity and temperature profiling will begin implementation in 2021 and will be fully operational in 2023.

How to access data from the network

Data can be freely used for scientific applications. In case of publications E-PROFILE should be informed via e-profile@meteoswiss.ch in order to discuss co-authorship with E-PROFILE staff or instrument PIs. Data can be accessed in the following ways:

- Near real-time interactive visualisation: <https://e-profile.eu>
- data archive for ALC: <https://data.ceda.ac.uk/badc/eprofile/>
- data archive for wind profilers: <http://data.ceda.ac.uk/badc/ukmo-metdb/data/winpro>
- Near real-time data provision: BUFR over GTS and direct distribution of NetCDF via FTP upon request for important projects.

Becoming part of the network: possibility, conditions, benefits & obligations of membership

Modality for participation

E-PROFILE is happy to accommodate new instruments of the following type:

- Automatic lidars and ceilometers (ALC)
- Radar wind profilers
- Doppler wind lidars (starting from mid 2022)
- Microwave radiometers (starting from early 2022). Rapid network growth most welcome
- Wind data from weather radars is going to be directly provided by the central processing servers of the EUMETNET OPERA programme in the near future

Data can be supplied in native formats for the most common instrument types. In case of interest in participation please contact e-profile@meteoswiss.ch. We will then provide you a step by step guide for providing data from your instrument type.

Conditions

Data must be provided in near real-time (not more than a few minutes delay) via FTP/SFTP (or GTS in case of strong concerns against FTP/SFTP) and the instruments should target continuous operation. E-PROFILE provides daily monitoring and expects instrument operators to react to signalled issues on a best effort basis.

Benefits

- Daily monitoring and notification in case of instrument errors or problems with data quality
- Monthly data quality and O-B monitoring
- Central data processing (calibration for ALC, centralised retrieval of temperature, humidity and forecast indices for microwave radiometers) · near real-time interactive visualisation of the observation data on <https://e-profile.eu> (access can be restricted upon request)
- Knowledge exchange with experts and the community
- BUFR distribution via GTS
- NetCDF distribution via FTP upon request
- Visibility within the meteorological and scientific community

Urban networks

As cities are key to both climate change mitigation and adaptation, advanced observations of the urban atmosphere are urgently needed to support informed decision making. Ground-based remote sensing profilers are hence increasingly deployed across urban areas such as Berlin, Beijing, or Bucharest to monitor the Urban Boundary Layer (UBL) dynamics with implications for a range of applications, including air quality, human thermal comfort, weather, greenhouse gas assessment, and urban air mobility. It is the goal of the PROBE WG1 subgroup on urban environments to get an overview of the various activities. Further information will be available soon.

GRUAN: The Global Climate Observing System (GCOS) Reference Upper-Air Network

GRUAN Lead Centre:

Lindenberg Meteorological Observatory
German Meteorological Service (DWD)
Am Observatorium 12
D-15848 Tauche OT Lindenberg
GERMANY



Contacts:

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fax: +49 69 8062 5710
email: gruan.lc@dwd.de

History & future:

Since the early 1990s, the climate research community has been calling for a ground-based reference observing system for measuring upper-air changes (Seidel et al., 2009 and references therein). The key aspects of GRUAN have been developed through three workshops (Boulder, 2005; Washington, 2006; Lindenberg, 2008). These workshops reached decisions on issues related to instrumentation, observing protocols, management, and relationships between GRUAN and other programs and organizations, all of which are needed to initiate the program (GCOS-112).

Since then, the GRUAN community has made significant advances toward achieving the goal of a global reference-quality upper-air climate observing system (Bodeker et al., 2016). While GRUAN remains committed to meeting the needs of the global climate community, fulfilling those needs will require resourcing by a wide range of national and international agencies.

Funding framework:

GRUAN is jointly overseen by the Global Climate Observing System (GCOS) and World Meteorological Organization (WMO), under the Atmospheric Observation Panel for Climate (AOPC) of GCOS. The GRUAN Lead Centre at the Lindenberg Meteorological Observatory/ Richard-Assmann-Observatory (MOL-RAO), Germany, is funded by DWD and responsible for the monitoring of GRUAN, including development of GCOS needs for station operation, coordination among stations, and ensuring archival and dissemination of GRUAN data. The GRUAN overall structure is pictured here: <https://www.gruan.org/network/about-gruan/structure-of-gruan>

Parent organisations:

- UNEP: United Nations Environment Programme
- IOC: UNESCO's Intergovernmental Oceanographic Commission
- ICSU: International Council for Science
- WMO: The World Meteorological Organisation with its Commission for Instruments and Methods of Observations (CI MO), Commission for Basic Systems (CBS), Commission for Atmospheric Sciences (CAS), Commission on Climatology (CCL).
- WCRP: The World Climate Research Programme

Other funding partners are:

- National contributors: National meteorological services and research/monitoring organizations providing development and operations of GRUAN sites
- Other observational networks: NDACC, ARM, GAW, BSRN, GUAN, GSN, ACTRIS, AERLINET, AERONET
- GSICS: The Global Space-based Inter-calibration System
- SCOPE-CM: The Sustained, Coordinated Processing of Environmental Satellite Data for Climate Monitoring Initiative

Network objectives & implementation

GRUAN is an international reference observing network, designed to provide long-term, high-quality climate data records from the surface, through the troposphere, and into the stratosphere. These will be used to determine trends, constrain and calibrate data from more spatially-comprehensive observing systems (including satellites and radiosonde networks), and provide appropriate data for studying atmospheric processes.

Reference quality observation for GRUAN means:

- It is traceable to a SI unit or an internationally accepted standard;
- It provides comprehensive uncertainty analysis;
- It is documented in accessible literature;
- It is validated (e.g. by inter-comparison with complementary measurement systems);
- It includes complete metadata description.

As an example of reference quality, GRUAN processing of radiosonde data corrects the measured profiles for known errors and biases. The correction algorithms are based on effects previously reported in literature and on sensor characterisation using laboratory and field experiments (Dirksen et al., 2014). The correction algorithms provide the best possible estimate of the associated measurement uncertainty. The vertically resolved measurement uncertainty is included in the data product. Other data streams are currently available (GNSS) and others are under development (e.g., lidar, MWR).

The current GRUAN Implementation Plan consists of high-level objectives and leaves specific action items to achieve these to the annual Implementation and Coordination mechanism. The current GRUAN Implementation Plan is available here (to be renewed in 2021): <https://www.gruan.org/documentation/gcos-wmo/gcos-205>

Network status, i.e. current and planned set-up

GRUAN is envisaged as a global network of eventually 30-40 sites that, to the extent possible, builds on existing observational networks and capabilities. The site map and the network status are pictured here: <https://www.gruan.org/network/sites>. As at August 2020, GRUAN comprises of 30 sites, 12 of which have been GRUAN certified.

How to access networks: data & platforms

All GRUAN data products are served without restriction for use by researchers. A GRUAN data product is a set of measurements from a given instrument system that have been undertaken in a sufficiently similar manner across all contributing sites to be intercomparable. Measurements are taken in such a manner as to be traceable to SI or community accepted standards with fully quantified uncertainty budgets. The use of measurements with robust uncertainty estimates has many potential applications, and users are strongly encouraged to provide constructive feedback on GRUAN products as they are developed and deployed. The file archive is hosted by the U.S. NOAA and National Centers for Environmental Information (NCEI).

GRUAN Data are accessible through: <https://www.gruan.org/data>

The GRUAN data policy suggests good practice of acknowledging the site for providing data or offering co-authorship to site managers: <https://www.gruan.org/data/data-policy>

Becoming part of the network: possibility, conditions, benefits & obligations of membership

Possibility

National Meteorological Services and sites interested in joining GRUAN should contact the Lead Centre to initiate discussions and to become informed on requirements. Instrument experts are always welcome to provide insights on the development, assessment, and improvement of GRUAN data streams and to contribute to the work of the GRUAN task teams.

Conditions

GRUAN has minimum requirements for a site and these are detailed in the GRUAN Manual (GCOS-170) and Guide to Operations (GCOS-171). The Working Group on GRUAN (WG-GRUAN), when assessing the application for a new site, focusses on the added value that the site would bring to the network as a whole. A new site in a currently data-sparse region of the globe would be assessed more favourably than an equally well instrumented and resourced site in a region where many other GRUAN sites are already in operation. Sites in data sparse regions may bring enough added value to the network that they could be certified as a GRUAN site without, in the short-term, meeting the minimum requirements. The WG-GRUAN would then work with the site to apply for additional funding to bring the site to the stated minimum requirements. GRUAN cannot provide funding to support sites and therefore recognizes that it will be necessary to work with sites to achieve its goals. GRUAN is not a command and control organisation.

Benefits

Given the high profile of GCOS, GRUAN endorsement of the quality of a site's measurement programmes has been shown to be attractive to funding agencies.

The GRUAN lead centre provides information on the processing performance of each data stream delivered, including statistics for the same data stream for other sites. As well as requiring long-term homogeneity of measurements at specific sites within the network, GRUAN also emphasizes network-wide homogeneity of its data products. Measurements at a site are anchored to a reference network that provides traceability to internationally recognized measurement standards. By making measurements that are directly comparable to those made at numerous other global sites, users benefit from access to those additional data at no extra direct cost. GRUAN has established a number of Task Teams to entrain skills and expertise from across the international community in measurement sciences. Sites joining GRUAN have access to this pool of expertise. GRUAN has developed and implemented a state-of-the-art data delivery service through the NOAA's National Climate Data Center. Raw measurements made at GRUAN sites are processed at a centralised data processing facility and are provided to a wide range of data users. Therefore, organizations hosting a GRUAN site do not need to commit resources to this activity. Observations from GRUAN sites are used in global climate monitoring and research, with potential participation by site scientists.

Obligations

Organizations hosting a GRUAN site are recognized as maintaining and operating a state-of-the-art measurement programme, supporting the core goals of GCOS, for measuring essential climate variables in the upper atmosphere. Each candidate site should go under a certification procedure to become a GRUAN-certified site. Certification update is required periodically.

References

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ACTRIS: European Research Infrastructure for Aerosol, Cloud and Trace Gases

ACTRIS Head Office:

Finnish Meteorological Institute
Erik Palménin aukio 1
FI-00560 Helsinki
FINLAND



Contacts:

website: <https://www.actris.eu/contact>

History & future:

ACTRIS is the result of 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), with a heritage leading back more than 20 years. ACTRIS is now being implemented as an European Research Infrastructure due to be fully operational by 2025 and is now integrating the short-lived components of NDACC (Network for the Detection of Atmospheric Composition Change), and large simulation chambers which have been operating within the EUROCHAMP projects.

Funding framework:

ACTRIS results from more than 15 years of consistent development funded by both Member States and the European Commission through the Research Infrastructure programme. As a Research Infrastructure, ACTRIS operations are now funded by its member and observer countries, together with EU and national funding projects supporting the implementation of the research infrastructure.

Network objectives & implementation

ACTRIS is the pan-European research infrastructure producing high-quality data and information on short-lived atmospheric constituents and on the processes leading to the variability of these constituents in natural and controlled atmospheres. ACTRIS is a distributed ground-based network, providing long-term high-quality data from both in-situ instruments operated at the surface and vertical profiles from remote-sensing instruments.

Network status, i.e. current and planned set-up

ACTRIS incorporates a European-wide community comprising more than 100 research performing organisations with at least 22 countries being committed at organisational or state level.

How to access networks: data & platforms

ACTRIS provides access to a large variety of high-quality services to a wide range of users and needs, for scientific, technological and innovation-oriented usage. These include digital, innovation, training, research, technical and tailored services. All data products are available according to the FAIR principles and have undergone the data quality control procedures detailed by the ACTRIS standard operating procedures. The ACTRIS Data Centre is a distributed archive and ACTRIS data are accessible through the ACTRIS data portal: <https://actris.nilu.no> and the ACTRIS data policy is available here: <http://actris.nilu.no/Content/Documents/DataPolicy.pdf>

Becoming part of the network: possibility, conditions, benefits & obligations of membership

Possibility

Sites interested in joining ACTRIS should contact their national representative in order to begin the labelling process required to become an ACTRIS site. This may require a national representative joining the ACTRIS council as an observer.

Conditions

ACTRIS has mandatory requirements for operating a site which are detailed in the Standard Operating Procedures for Exploratory and Observational Platforms. These can include instrument specifications, a minimum

list of instruments operating together, and instrument operating parameters. National/organisational funding commitments are necessary for operating a site as ACTRIS does not fund their operation.

Benefits

ACTRIS uses a centralised processing service, together with state-of-the-art calibration centres, to provide high quality data products harmonised across a wide variety of platforms and environments. Network data quality is ensured through strict adherence to measurement protocols and calibration procedures designed by ACTRIS scientists. With data products being comparable across the network, this provides immediate benefits to the data provider. ACTRIS sites also benefit from the access to the expertise within the ACTRIS community.

Obligations

Organizations hosting an ACTRIS site are recognized as maintaining and operating a state-of-the-art measurement programme. Every candidate site will undertake a labelling procedure to become an ACTRIS-certified site.

ICOS: Integrated Carbon Observing System

ICOS Head Office:

Finnish Meteorological Institute
Erik Palménin aukio 1
FI-00560 Helsinki
FINLAND



Contacts:

website: <https://www.icos-cp.eu/about/contact>
email: [info \(at\) icos-ri.eu](mailto:info@icos-ri.eu)

History & future:

European national networks have been measuring greenhouse gases for many years, and plans to combine and harmonise the research and instrumentation across Europe had already begun in the 1990s. ICOS itself was initiated in 2006, and became a European Research Infrastructure in 2015.

Funding framework:

As a Research Infrastructure, ICOS operations are funded by its member and observer countries, together with EU and national funding projects supporting new developments and innovations.

Network objectives & implementation

ICOS is a pan-European distributed Research Infrastructure conducting standardised, high-precision and long-term observations of greenhouse gases in order to understand the carbon cycle. ICOS-based knowledge supports policy- and decision-making to combat climate change and its impacts. To this end, ICOS integrates terrestrial, atmospheric and oceanic measurements, together with the fluxes between these components.

Network status, i.e. current and planned set-up

Currently, the ICOS station network consists of 140 measurement stations from 13 European countries. Of these, nearly 40 stations are dedicated to atmospheric measurements and over 80 stations are concerned with ecosystem measurements (exchange between ecosystem and the atmosphere). For atmospheric measurement stations, one important variable to observe is the boundary layer height as this is required for generating some of the elaborated products.

How to access networks: data & platforms

ICOS provides access to a large variety of services, including tools for visualisation, footprint and air mass analysis, ready-made virtual research environments, and metrology and calibration. ICOS data products are accessed through the ICOS data portal <https://data.icos-cp.eu/portal/> under the ICOS data policy and licence: <https://data.icos-cp.eu/licence>

Becoming part of the network: possibility, conditions, benefits & obligations of membership

Possibility

Sites interested in joining ICOS should contact their national representative in order to begin the labelling process required to become an ICOS site. This may require a national representative joining the ICOS council as an observer.

Conditions

ICOS has mandatory requirements for operating a site which are detailed in the quality-assurance programme known as Station Labelling. Compliance with these standards is necessary in order to maintain the high network data quality. Stations may meet the standards for the full set of ICOS variables or a pre-defined subset of ICOS variables. National/organisational funding commitments are necessary for operating a site as ICOS does not fund their operation.

Benefits

ICOS uses a centralised processing service, together with state-of-the-art calibration centres, to provide high quality data products harmonised across the network. Network data quality is ensured through strict adherence to measurement protocols and calibration procedures designed by ICOS scientists. With data products being comparable across the network, this provides immediate benefits to the data provider through enhanced global visibility. ICOS stations benefit from the latest developments in greenhouse gas measurements and technical support for station operations.

Obligations

Organizations hosting an ICOS site are recognized as maintaining and operating a state-of-the-art measurement programme. Every candidate site will undertake a labelling procedure to become an ICOS-certified site.

MPLNET: The NASA Micro-Pulse Lidar Network

Contacts:

website: <https://mplnet.gsfc.nasa.gov/about-us.cgi?>

MPLNET PI: Ellworth J. Welton



History and Scope

The NASA Micro-Pulse Lidar Network (MPLNET) is a federated network of Micro-Pulse Lidar (MPL) systems, a single-wavelength lidar designed to measure aerosol and cloud vertical structure, and boundary layer heights. All sites in MPLNET currently use the Micro Pulse Lidar (MPL), which was developed at NASA Goddard Space Flight Center (GSFC) in the early 1990s. The MPL was patented and subsequently licensed to industry for commercial sales beginning in the mid 1990s. Established in 1999, the network collects data continuously, day and night, over long time periods from more than 20+ sites around the world, deployed at all latitudes, from polar regions, equator and mid-latitude. Most MPLNET sites are co-located with sites in the NASA Aerosol Robotic Network (AERONET).

Network Objectives

MPLNET is a contributing network to the World Meteorological Organization (WMO) Global Atmospheric Watch (GAW) Aerosol Lidar Observation Network, GALION. MPLNET data have contributed to many studies and applications. Key focus areas for MPLNET include:

- Aerosol and cloud research
- Climate change and air quality studies
- Support for NASA satellite and sub-orbital missions
- Aerosol modelling and forecasting

MPLNET is composed of NASA sites and others run by, or with help from, partners from around the world. Principal investigators for individual network sites may be from NASA, other US government agencies, universities, or foreign institutions.

Funding

MPLNET core activities and the NASA staff are funded by the NASA Radiation Sciences Program and the NASA Earth Observing System (EOS). Many individual network sites also have their own funding support.

Data Access

All the different data products are freely available from NASA MPLNET website. All project operations, calibrations, and data processing are coordinated by MPLNET staff at NASA. The PI(s) has priority use of the data collected at the site(s). The PI(s) is entitled to be informed of any other use of the data. MPLNET data products follow the modified EOS convention originated by AERONET: Level 1, Level 1.5, and Level 2. Contrary to standard EOS conventions, MPLNET Level 1 data contain both calibrated-measured and retrieved variables. MPLNET product levels are abbreviated as L1, L15, and L2. L1 and L15 are all available in near real time (NRT).

Joining the network

Applicant proposals are evaluated on singular basis, i.e., site relevance for aerosol, cloud and precipitation studies, fund availability, instrument owned (or not). Once accepted, the designed Principal Investigator(s) (PI) will be responsible for deployment, maintenance, and data collection.

MPLCAN: Micro Pulse Lidar network in Canada

Website: <http://www.uwo.co/sci/mplcan>



Network objectives

The objective of MPLCAN is to develop:

- A Canadian Smoke and Particulate tracking network, to help with forest fires, air quality, and emergency management.
- Assessment of the impact of profiling measurements on surface total column measurements.
- Profiling measurements to improve modelling of cloud, and fog development.

Network status

London, Toronto, and Sherbrooke operational. Eureka: install is in progress for October 2021 operation. Halifax: pending Transport Canada approval to operate. We recently received funding to install MPLs at the Canadian High Arctic Research Station (Cambridge Bay) and at ECCC's Iqaluit site, both planned for installation in summer 2022.

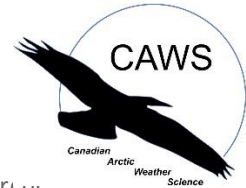
Data access

Data from the Purple Air sensors, CIMELs, and MPLs are available to all in near-real time:

<https://www.uwo.ca/sci/mplcan/data/index.html>

Canadian Arctic Weather Science (CAWS) Project

Website: <https://obrs.ca/>



Network objectives

- Test new remote sensing technologies and their applications in the Canadian Arctic
- Provide recommendations on the optimal meteorological observing system for the Canadian Arctic
- Provide enhanced meteorological observations during WMO's Year Of Polar Prediction (YOPP) for NWP model evaluations, intercomparisons, and process studies

Network status

- (1) Iqaluit, NU (2015-current; site outage since 202104 requiring repairs - nearly completed),
- (2) Whitehorse, YT (201711-202111, planned decommissioning)
- (3) Squamish, BC (2016-current).

Data access

Products available in near-real time via obrs.ca. Raw data files during YOPP are available via obrs.ca. All other raw data files are available via the Gov of Canada Open Data Portal and via zen.mariani@ec.gc.ca

New York State Mesonet (NYSM)

Website: http://nysmesonet.org/networks/profiler#stid=prof_alba



Network objectives

The NYSM profiler network serves as a national testbed to facilitate the research, development and evaluation of ground-based profiling technologies and applications. It fills a critical gap in the nation's observing system with the potential to improve analysis and prediction for many weather-sensitive sectors, such as aviation, ground transportation, health, and wind energy.

Network status

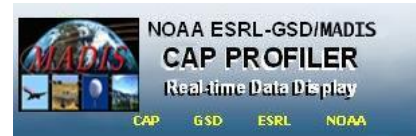
Operational since 1 April 2018.

Data access

<http://nysmesonet.org/weather/requestdata>

Cooperation Agency Profilers (CAP)

Website: <https://madis-data.ncep.noaa.gov/cap/profiler.jsp>



Network objectives

Cooperative Agency Profilers (CAP) is a cooperative venture between GSD (formerly FSL) and many participating agencies enabling GSD to; acquire profiler and RASS data in near real-time, apply GSD's data quality control algorithms, and make these value-added data available on the web and to the National Weather Service. At this time, data from approximately 100 CAP sites from over 35 different agencies from around the world are being acquired by GSD. The majority of CAP systems are 915 MHz Boundary Layer Profilers, there are also several 449 MHz and 50 MHz profilers in the CAP network. <https://madis-data.ncep.noaa.gov/cap/>

Network status

<https://madis-data.ncep.noaa.gov/cap/sysStatus.jsp>

Data access

<https://madis-data.ncep.noaa.gov/cap/data.jsp>

Atmospheric Radiation Measurement program (ARM)

Website: <https://www.arm.gov/>



Network objectives

The Atmospheric Radiation Measurement (ARM) program is a US Department of Energy funded user facility managed by the Office of Biological and Environmental Research and provides the research community with strategically located in situ and remote-sensing observatories measuring clouds, aerosol and radiation. These measurements are used to improve process-level understanding, their interactions and coupling with the surface, and for improving their representation in climate and earth system models.

Instrumentation profiling the atmosphere includes: Doppler cloud radars (vertically-pointing and scanning), radar wind profilers, automatic lidar ceilometers (Vaisala and MPL), Doppler lidars, Raman lidar and HSRL, profiling microwave radiometers, and radiosondes.

Network status

The observatory network comprises core stations operating continuously and campaign sites that typically operate for 6-18 months. Some core stations have operated for almost 30 years.

Data access

<https://www.arm.gov/data/>

The UK Met Office Raman dual polarization lidar network



Network objectives

The Met Office is operating a ground-based network of nine 3-channel lidars (UV (355nm, parallel and perpendicular), Raman (387nm), Raymetrics model LR111-D300) at fixed locations each accompanied by a sun photometer (polarized model). One lidar fitted into a mobile trailer is currently located in Exeter (UK) and used for research and development. The main purpose of this network is to provide quantitative monitoring of volcanic ash over the UK for the London Volcanic Ash Advisory Centre. The network is funded by the Civil Aviation Authority and Department for Transport.

Network status

The following stations are part of the network in the UK with hyperlink to the sun photometer AERONET station (including station information on the webpage):

[Camborne](#), [East Malling](#), [Lerwick](#), [Stornoway](#), [Watnall](#), [Rhyl](#), [Loftus](#), [Glasgow](#), [Portglenone](#)

Data access

Data can be accessed and downloaded through the CEDA Archive:
<https://catalogue.ceda.ac.uk/?q=Met+Office+Raymetrics+lidar>

Finnish Meteorological Institute lidar networks



Website: <https://ceilometer.fmi.fi/>

Network objectives

The lidar networks of the Finnish Meteorological Institute deliver both operational services and enable the testing of new remote sensing instruments and applications. The Finnish Meteorological Institute operates a profiling ceilometer network producing quality-controlled real-time quicklooks for forecasters. Many of the stations also report to E-PROFILE. Embedded within the ceilometer network are: a Doppler lidar network of six Halo Photonics Doppler lidars with depolarisation capability (4 full hemispheric scanning, 2 scanning within a cone 20 degrees from vertical) operating at 1.5 um to provide winds, turbulence and particle typing; five depolarisation ceilometers (Vaisala CL61D) providing particle typing; and a reference multiwavelength Raman PollyXT lidar. A selection of ceilometers and Doppler lidar stations are used for icing hazard potential monitoring and contribute to an icing alert service.

Network status

All lidar networks are operational, with new services including icing and fog alerts being implemented. Ceilometer network status: <https://ceilometer.fmi.fi/>

Data access

Data is available on request from ewan.oconnor@fmi.fi.

Hidden networks - the survey

In the framework of PROBE, a survey was conducted to find hidden networks, that is, networks of boundary layer profiling devices which are not yet known to the PROBE community. Whereas some survey participants were aware of PROBE, none are currently contributing to PROBE. In total, we received 45 answers to the survey from 34 countries, among those, 22 European countries.

Specific questions were asked about four ground-based remote sensing instrument types commonly used in the PROBE community: automatic lidars and ceilometers (ALC), microwave radiometers (MWR), Doppler wind lidars (DWL), and cloud radars (CR). In Table 1, the number of responses is given per instrument type, and number of instruments. The number of responses from European institutions is given in parentheses. The total number of institutions with at least one of the four instruments was 33 (26 in Europe).

There was an additional question to specify other devices used for profiling of the boundary layer, with the following options (and the number of responses; multiple answers were possible):

1. Tower observations (13)
2. Sensors on unmanned aerial vehicles (11)
3. Tethered balloons (5)
4. Radio sondes (5)
5. None (17)
6. Other (6)

In the following, we focus on European institutions with more than one instrument of either of the four types, further referred to as networks. There were in total 15 institutions, of which three had networks of both ALC and DWL. ALC networks are mostly used for air quality and climate studies, fundamental research, and aviation safety. The primary purposes of DWL networks are in the majority wind field assessment, wind engineering, or replacement for met masts. One MWR network is mostly used for air quality and climate studies. There were no CR networks among the institutions that participated in the survey.

Five of the hidden European networks contribute to or participate in other existing European networks: ICOS, FLUXNET, ACTRIS, and E-Profile. Dissemination of the work of the PROBE community among those networks will help integrating the hidden networks into PROBE.

This survey revealed networks of boundary layer profiling devices operated by institutions that are not currently linked to PROBE or any other network described in this document. All of the responding institutions were interested in joining PROBE and most were willing to share data from their boundary layer profiling sensors. This is a starting point for a more inclusive and diverse PROBE community.

Table 1: Number of instruments per institution participating in the survey (from Europe in parentheses). There were four options to specify the number of instruments: None, one, between two and ten, and more than 10.

Number of devices	0	1	2-10	10+
ALC	33	2 (2)	8 (5)	2 (2)
MWR	39	5 (5)	1 (1)	0
DWL	31	2 (1)	7 (5)	5 (5)
CR	44	1 (0)	0	0
other devices	17	28*		

* yes/no option, number of devices was not asked for