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Milestone M7 (M1.8)

Requirements for the implementation of vertical profiling measurements in pilot sites

RI URBANS

RI-URBANS

Research Infrastructures Services Reinforcing Air Quality Monitoring Capacities in European Urban & Industrial AreaS (GA n. 101036245)

By

FZJ and CNR

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Milestone M7 (M1.8): Requirements for the implementation of vertical profiling measurements in pilot sites

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Work package (WP)	WP1: Novel AQ metrics and advanced source apportionment STs for PM and nanoparticles
Milestone	M7 (M1.8)
Lead beneficiary	FZJ
Means of verification	Requirements for the implementation of vertical profiling measurements in pilot sites. This will provide the procedures and the operational conditions to implement vertical profiling in the pilot studies
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Reviewed by	WP1 leaders
Accepted by	RI-URBANS Project Coordination Team
Comments	This document is elaborated as request from WP1, T1 provides an overview over the available measurement technics for vertical profiling and their corresponding data products. The basic requirements for the implementation of these measurement technics at pilot sites are summarized by means of the requirements to the site as well as technical and operational requirements. Based on these requirements three strategies for low, medium, and high complexity implementations are suggested.

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Table of Contents

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1. About this document

This report is elaborated as reply to the RI-URBANS objectives of WP1, T1.3 on developing products and methods for air quality (AQ) from profiling observations. In this way the T1.3. develops service tools (STs) for observations with vertical and/or horizontal scanning capability in and around urban environments from ACTRIS (Aerosol, Clouds and Trace Gases Research Infrastructure) and IAGOS (In-service Aircraft for a Global Observing System). Data on atmospheric boundary layer (ABL) height, 3-D wind profiles (Doppler LIDARs, LIght Detection And Ranging), profiles of aerosol levels and pattern by Raman LIDARs in synergy with sun/sky photometers; aircraft measurements and horizontal variability of trace gases (NO_2, SO_2, O_3, formaldehyde) based on MaxDOAS (Multi-Axes Differential Optical Absorption Spectroscopy) and Pandora measurements are being used. Measurement requirements are provided for the implementation in the pilots (WP4, T4.3). The data analysis techniques for the remote sensing are tailored for application in urban air quality issues, and experimental tools will be provided. Datasets will be used for characterization of urban dispersion (T3.1), pilots (T4.3-4.5) and upscaling (T5.1-T5.2).

This document provides an overview over the available measurement technics for vertical profiling and their corresponding data products. The basic requirements for the implementation of these measurement technics at the RI-URBANS pilot sites are summarized by means of the requirements to the site as well as technical and operational requirements. Based on these requirements three strategies for low, medium, and high complexity implementations are suggested.

This is a public document, available in the RI-URBANS website. The document will be distributed to all RI-URBANS partners for their use and submitted to European Commission as an RI-URBANS milestone M7 (M1.8). This document can be downloaded at https://riurbans.eu/work-package-1/#milestones-wp1

2. Available measurement technics

The measurement technics for vertical profiling and the corresponding air quality relevant data products available within the RI-URBANS project were identified and described in the RI-URBANS deliverable D6 (D1.6; “Observational methodologies for horizontal & vertical profiling for AQ purposes”).

Here the measurement technics were categorized into automatic lidars and ceilometers (ALC), high-power aerosol lidars, doppler and wind lidars, and IAGOS in-situ profiling. Table 1 shows the available data products for each of these different profiling measurement technics. Orange symbols represent limitations in measurement performance in comparison to other technics (ALCs and high-power aerosol lidars) or availability (IAGOS in-situ profiling) at the time of writing this document.

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Table 1: Available data products from the different profiling measurement technics. Orange symbols represent limitations in measurement performance or current availability.

	Automatic lidars and ceilometers	High-power aerosol lidars	IAGOS in-situ profiling	Doppler and wind lidars
Atmospheric boundary layer height	✓		✓	
Aerosol optical property profiles	(✓)	✓	(✓)	
Aerosol type profiles	(✓)	✓		
Aerosol mass concentration profiles	(✓)	✓	(✓)	
Gas concentration profiles			✓	
Wind and turbulence profiles				✓

3. Measurement requirements

The profiling technics listed in the Section 2 have quite different measurement requirements. Based on the standard operating procedures (SOPs) from ACTRIS and IAGOS, this Section provides a general overview over the requirements for the implementation of automatic lidars and ceilometers (ALCs), high-power aerosol lidars, doppler and wind lidars, and IAGOS in-situ profiling.

3.1 Automatic lidars and ceilometers (ALC)

Site requirements:

- Operation area (environment surrounding the instrument): Secure, stable, levelled surface (e.g., concrete base). Open view to the sky (e.g., no tree branches).
- It is recommended (not mandatory) to install ALC pointing northward and 3° off zenith. This is to minimize solar background radiation and specular reflection from ice clouds.
- Reliability of internet (stable) connection and power (uninterruptible) supply are required.
- Compliance with local safety and security rules: ALCs operate eye-safe lasers that do not require specific security clearance in most cases. Regulations applicable for the specific measurement location must be checked.

Operational requirements:

- ALCs operate continuously (24/7) and automated.
- Recommendations to maximize good working order of the instrument: clean the window when window condition (housekeeping data) is less than ideal. Ensure most appropriate firmware is in use.
- Monitoring of system parameters: keep all housekeeping data and check them regularly. Take warning messages and especially error messages seriously. The housekeeping data threshold and available variability in depending on the ALC manufacturer.
- No on-site calibration. Absolute calibration of attenuated backscatter is performed in post-processing.

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- Measurement uncertainties depend on optical overlap in the near range and signal-to-noise ratio in higher ranges. Also, range-dependent signal distortion has been detected for some sensors which may require correction during post-processing. Both depend on instrument specifics and can even be affected by the firmware version.
- A failing laser can cause deterioration of signal. Laser power housekeeping data should hence be monitored continuously.
- Preventive maintenance: clean the window when the window condition (housekeeping data) is less than ideal. ALC of Lufft GmbH requires replacement of drying agent.
- Component replacements: lifespan of lasers can vary (in order of ~ 5-8 years).
- Software issues, software upgrades: ensure firmware is appropriate for specific hardware. Always follow ACTRIS CCRES (Centre for Cloud Remote Sensing) firmware update recommendations.

Further and more detailed requirements for the implementation of ALCs can be found in the ACTRIS ALC standard operating procedures (https://www.actris.eu/topical-centre/ccres/automatic-low-power-lidar-and-ceilometer).

3.2 High-power aerosol lidars

Site requirements:

- A high-power aerosol lidar should be operated together with an automatic sun/sky/lunar photometer. These instruments should be collocated, i.e., situated in the same mixed layer in order to measure the same atmosphere. The maximum allowed horizontal distance is 1 km.
- The automatic sun/sky/lunar photometer requires clear field of view with a maximum 10° elevation mask in all the directions is requested. South ways not obstructed.
- Reliability of internet (stable) connection and power (uninterruptible) supply are required.
- Compliance with local safety and security rules: high power aerosol lidar typically need specific security clearance because lasers are not eye safe. Regulations applicable for the specific measurement location should be checked.

Technical/operational requirements:

- Minimum setup: Aerosol remote-sensing station consists of a one-wavelength Raman with polarization discrimination capability and a sun/sky photometer. The photometer must be set up for automatic operation.
- Optimum setup: Aerosol remote-sensing station consists of a three-wavelength Raman or high spectral resolution lidar with polarization discrimination capability and an automatic sun/sky and moon photometer (optionally also polarized) according to ACTRIS/AERONET (Aerosol Robotic NETwork) standards, both operating continuously.
- Measurements of aerosol extinction, backscatter and depolarization-ratio profiles are to be performed, at least, at one wavelength, either 355 or 532 nm.
- Technical system parameters such as laser power, telescope aperture, receiver bandwidth and data acquisition system must be chosen such that profiles can be acquired throughout the troposphere up to the lower stratosphere with the required accuracy and temporal and spatial resolution. A separate near range receiving system is recommended for observations in the lower planetary boundary layer. Configurations may vary to account for climatic circumstances, e.g., the typical height of the boundary layer for the location.
- It is recommended to operate the aerosol high-power lidar and the sun/sky/lunar photometer continuously, weather permitting.
- The Photometers are fully automatic and follow standard measurement protocols.

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- Use of centralize ACTRIS ARES (Aerosol Remote Center) processing is required for aerosol mass concentration profiles.

Further and more detailed requirements for the implementation of high-power aerosol lidars can be found in the guidelines and standard operating procedures of the ACTRIS Centre for Aerosol Remote Sensing (CARS; https://www.actris.eu/topical-centre/cars/announcements-resources/documents).

3.3 Doppler and wind lidars

Site requirements:

- Operation area (environment surrounding the instrument): Open view within a cone of specified elevation angle from zenith necessary to obtain a wind profile, and preferably open view to horizon to enable low-elevation scans.
- Uninterruptible power supply: Keep the instrument powered. This ensures permanent temperature stabilization.

Operational requirements:

- Doppler and wind lidars operate continuously (24/7) and automated.
- Ancillary measurements to be performed: Co-located ceilometer for an extended period to determine telescope focus function (if use of attenuated backscatter profile required).
- Calibration schedule: Automatic processing for signal-to-noise (SNR) ratio and velocity uncertainty. Cloud calibration updated every event. Telescope focus can be continuous or periodic depending on co-located ceilometer availability.
- Detecting systematic errors during instrument operation: Hard target velocity calibration and pointing angle (target and/or horizontal winds). Monitor instrument stability (background, telescope focus, cloud calibration).
- Preventive maintenance: Occasional cleaning of the telescope. Leosphere systems need regular change of desiccant to prevent lens fogging.
- Component replacements: Amplifiers can degrade. Usually this is very rapid.

Further and more detailed requirements for the implementation of doppler and wind lidars can be found in the ACTRIS standard operating procedures for doppler lidar (https://www.actris.eu/topical-centre/ccres/doppler-lidar).

3.4 IAGOS in-situ profiling

Site requirements:

- The urban area of interest must be located close to an international airport, that is functioning as a hub for or is regularly served by an airline which is participating in IAGOS.

Operational requirements:

- Instruments must be operated fully automated.
- Certification of the instrumentation by the European Union Aviation Safety Agency (EASA) for operation on commercial aircraft is required.
- An instrument exchange is scheduled in intervals of three to six months or on demand if required due to insufficient instruments performance.
- Time and frequency of the profiling is depending on the airlines flight schedule.

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Further and more detailed requirements for the implementation of IAGOS in-situ profiling can be found in the standard operating procedures for the different IAGOS instruments (https://www.iagos.org/iagos-core-instruments

4. Implementation strategies for pilot sites

The requirements to the measurement site as well as technical and operational requirements for the implementation of the discussed vertical profiling technics have quite different level of complexity. This section provides three strategies for an implementation of vertical profiling activities to the pilot sites with low, medium, and high complexity. Table 2 summarises the suggested profiling measurement technics for the three implementation strategy complexities.

Table 2: Summary table for low, medium, and high complexity implementation strategies for pilot sites.

	Low complexity implementation	Medium complexity implementation	High complexity implementation
Automatic lidars and ceilometers	✓	✓	✓
Doppler and wind lidars	(optional)	✓	✓
High-power aerosol lidars		✓	✓
IAGOS in-situ profiling			✓

4.1 low complexity implementation

For a low complexity implementation of vertical profiling to a pilot site automatic lidars and ceilometers (ALCs) with an option to add Doppler and wind lidars are recommended.

This setup can provide measurements of the atmospheric boundary layer height as well as wind and turbulence profiles. The ALCs can also measure vertical profiles of aerosol optical properties, type, and mass. Even though these measurements are limited in resolution and uncertainty compared with the high-power aerosol lidars, they can still add valuable information about the air quality.

4.2 medium complexity implementation

An improvement in the vertical profiling performance of aerosol optical properties, type, and mass measurements can be achieved by combining the ALCs, doppler and wind lidars with high-power aerosol lidars.

4.3 high complexity implementation

The measurement of atmospheric boundary layer height, wind and turbulence profiles, vertical profiles of aerosol optical properties, aerosol type and mass, as well as trace gas concentration requires the highest complexity implementation. This strategy would include the full available profiling suite as a combination of automatic lidars and ceilometers, high-power aerosol lidars, doppler and wind lidars, and IAGOS in-situ profiling.

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