

Milestone M19 (M4.3)

Aerosol number size distribution measurements



RI-URBANS

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

**By
UHEL, UoB & CSIC**



UNIVERSITY OF HELSINKI



UNIVERSITY OF
BIRMINGHAM



CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

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Milestone M19 (M4.3): Aerosol number size distribution measurements

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1. About this document

This is a document describing measurements of aerosol particle number size distribution Milestone 19 (M4.3) in the RI-URBANS project. The milestone builds towards Near Real Time data delivery by first ensuring that the measurements are harmonized to the ACTRIS and CEN standards.

This is a public document that will be distributed to all RI-URBANS partners for their use and submitted to European Commission as the RI-URBANS Milestone M19 (M4.3). This document can be downloaded at <https://riurbans.eu/work-package-4/#milestones-wp4>.

2. Aerosol number size distribution measurements

The aim of Pilot #2 within RI-URBANS WP4 (Task 4.2) is to provide near-real time (NRT) particle number size distribution (PNSD) data from different city environments in Europe. **The NRT measurements of aerosol PNSD have started** in each of the three pilot cities (**Barcelona, Spain; Birmingham, UK and Helsinki, Finland**) and work towards ensuring ACTRIS (The Aerosol, Clouds and Trace Gases Research Infrastructure) compatibility and the NRT data delivery is ongoing. The measurement site and setup are described below, and some preliminary examples of PNSD data are given.

2.1. BARCELONA

2.1.1. Site description

The city of Barcelona has 1.6 million inhabitants (3.6 million is within its metropolitan area), and it is located in a coastal area in the western Mediterranean region (Figure 1). It is a densely populated area, also characterized by a high density of motor vehicles and by a compact architecture hampering dispersion of atmospheric pollutants. The Barcelona Ring Roads Low Emission Zone was implemented in January 2020; so, that the RI-URBANS' Pilot #2 will supply fundamental information for the evaluation of this plan.

Air quality (AQ) in Barcelona city is affected by industrial emissions in nearby areas. Moreover, Barcelona harbour, one of the main harbours in the Mediterranean, is located in the city centre and the airport, second largest airport in Spain, is 10 km away from the measurement site. Barcelona is one of the most polluted cities in Europe, with NO₂ frequently exceeding EU AQ air quality guidelines.

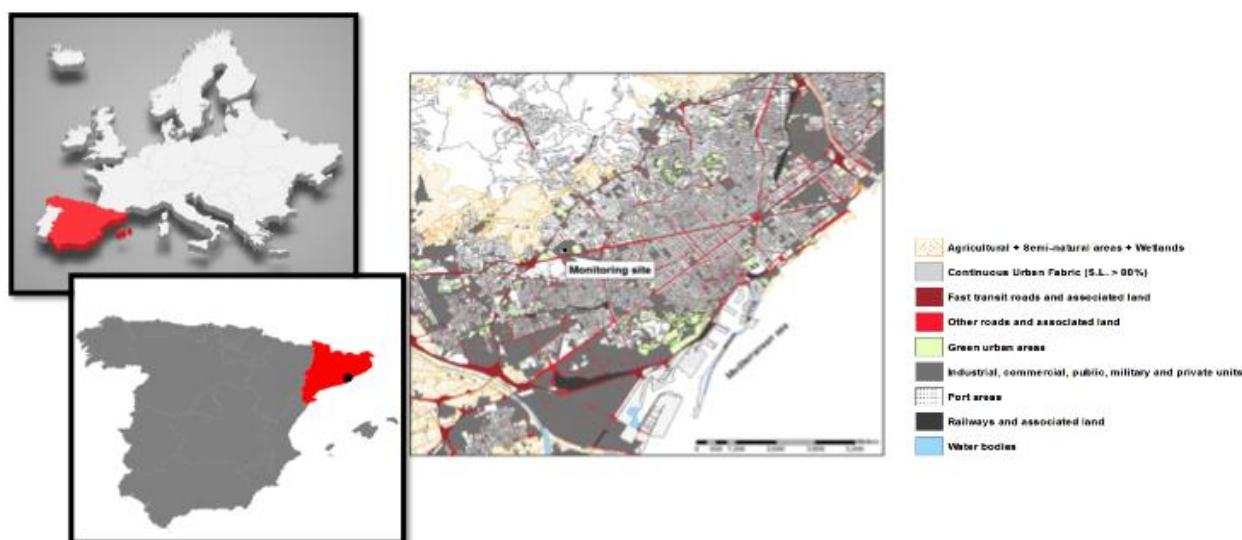


Figure 1. Barcelona monitoring station / supersite (BCN, urban background). Upper panel: Overview of the geographical positioning of Barcelona and land-cover/use of the area. Lower panel: monitoring site and instrumentation for ultrafine particle (UFP) measurements.

2.1.2. Instrumentation & data

Barcelona supersite (BCN) is reference for AQ management authorities and AQ research in Spain. This site is operated by CSIC in collaboration with the Catalan Government (GENCAT).

Since 2009, the BCN site is a complete cutting-edge supersite integrated in AQ monitoring network (AQMN), measuring a high number of variables and pollutants, comprising regulated pollutants (SO₂, NO_x, PM₁₀, PM_{2.5}), sub-micron aerosol PNSDs, black carbon (BC) and aerosol chemical measurements, using offline (PM₁, PM_{2.5} and PM₁₀ sizes), and online (ACSM, sub-micron) techniques. This approach has enabled studies on an extensive range of topics to be carried out, including temporal and spatial variation of ultrafine particles (UFP), sources of total number particle concentrations (PNC) and particle number size distribution (PNSD) modes resolved by cluster and receptor modelling, trends in primary and secondary particle number concentrations, PM_x chemistry and source apportionment, as well as quantification of African dust contributions using both offline and online multi-wavelengths particle absorption measurements. Online measurements of volatile organic compounds (VOCs), combining different techniques (support from GENCAT), are currently being launched, while implementation of

reactive oxygen species (ROS) measurements is also planned. It should be highlighted that the BCN supersite is a pilot in ACTRIS – CAMS (Copernicus Atmosphere Monitoring Service) system software, designed to report data in NRT.

On the other hand, intensive collaboration between the RI-URBANS Partners CSIC and ISGlobal has allowed gathering understanding on effects of pollutants, including non-regulated variables, such as UFP and BC, and PM source contributions on morbidity, mortality, hospitalizations, and cognitive development. Citizen science has also been explored in our team (e.g., H2020 CAPTOR; H2020 CiteS-Health), based on a citizen network of low-cost sensors and passive dosimeters.

Average concentrations measured at BCN site are in the range of those typically measured at an urban environment in southern Europe: O₃ 50 µg/m³; NO 7.6 µg/m³; NO₂ 29 µg/m³; SO₂ 2.1 µg/m³; BC 1,500 ng/m³; PM_{2.5} 13 µg/m³; PM₁₀ 20 µg/m³; PNC 11,200 #/cm³

In the case of PNSDs, the measurements started in 2013. The Scanning Mobility Particle Sizer (SMPS) comprised of a TSI 3080 classifier, operated with a TSI 3081 Differential Mobility Analyzer (DMA) and a TSI 3772 Condensation Particle Counter (CPC). The SMPS was operated in conjunction with a stand-alone TSI 3785/3787 WCPC. These instruments were connected to a sampling system consisting of a PM₁₀ inlet, with a total flow rate of 38.3 l/min.

In the framework of RI-URBANS, we have recently upgraded the SMPS system and stand-alone CPC to ACTRIS and CEN (European Committee for Standardization) standards. The BCN site is now running a TSI3938 SMPS comprising of a TSI 3082 classifier, a wide range DMA TSI 3083 (10-800 nm) and a TSI 3750 CPC. Our classifier has been upgraded to be able to work with positive voltage. The stand-alone CPC has been replaced with a TSI 3750 CPC and this instrument has been upgraded to meet ACTRIS standards. Therefore, the lower detection efficiency diameter (DP50) has been changed from 7 to 10 nm.

We have recently added a UCPC (TSI 3756) for parallel particle concentration measurements from 3 nm.

We are using a BGI PM_{2.5} inlet, exclusively dedicated to UFP measurements. The aerosol is dried before the splitter using a TROPOS (Leibniz Institute for Tropospheric Research) Nafion dryer operated with a compressor and a membrane dryer, which dries aerosol to less than 40% relative humidity, RH<40%.

The TSI software has been upgraded to the latest TSI AIM11 (monitoring version). In addition, we are exporting data continuously from our station using the CAMS system.

A year-to-year (for 2013-2022) variability of averaged size distributions of the most frequently detected particles measured at the Barcelona supersite can be found in Figure 2.

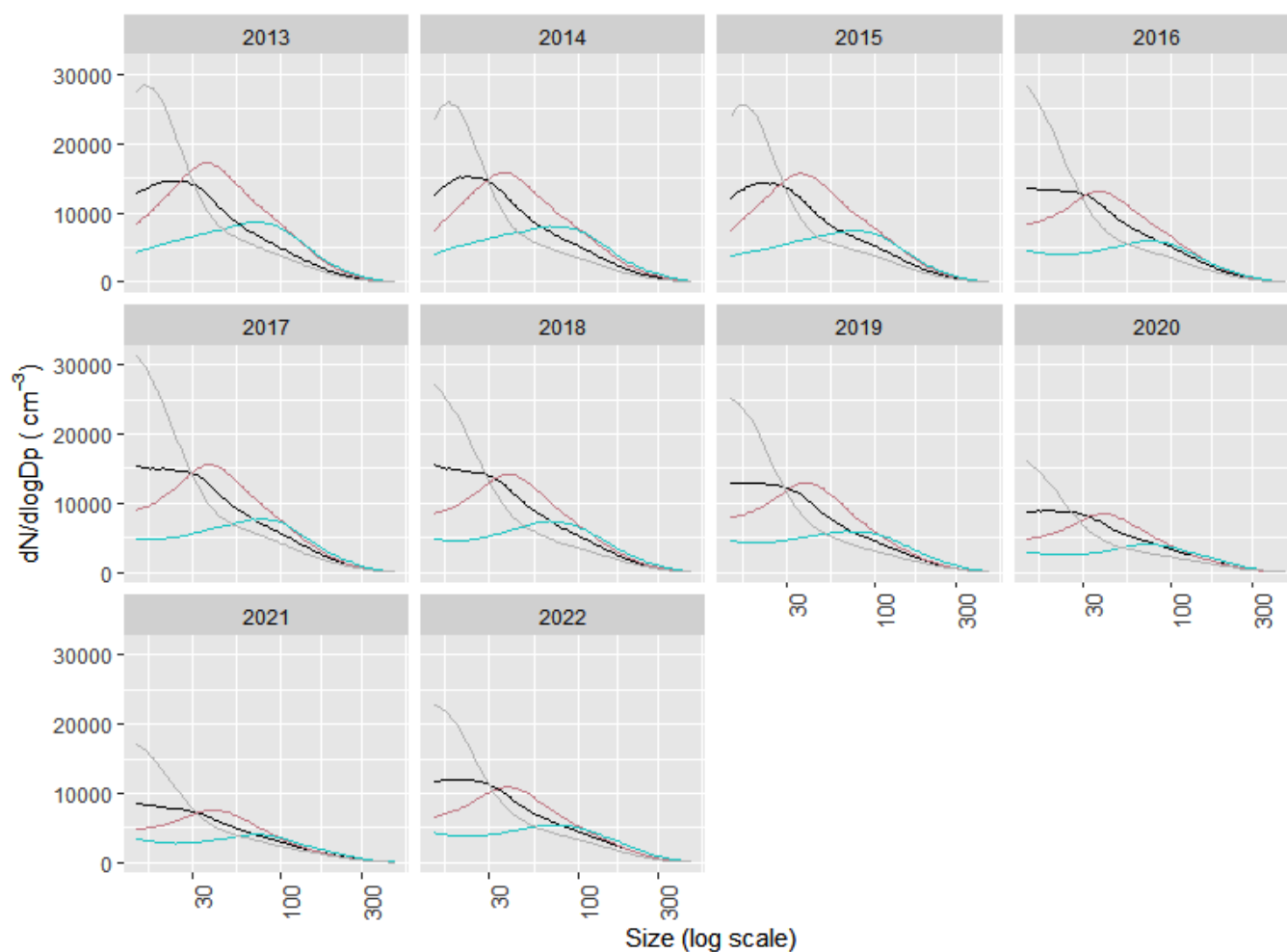


Figure 2. Average particle number size distributions measured in the BCN station during 2013-2022

2.2. BIRMINGHAM

2.2.1. Site description

With a population of 1.14 million in 2019 (ONS, 2017), the UK city of Birmingham is the location (latitude of 52° 27' 19.872" N and longitude of 1° 55' 44.213" W, Figure 3) of Birmingham Air Quality Site (BAQS; urban background). BAQS is one of three the Natural Environment Research Council (NERC) funded supersites in the UK, the other two being at Manchester Piccadilly and London Honor Oak Park sports ground. The Birmingham facility is located within a self-contained cabin within a small green space within the grounds of the University of Birmingham (UoB) which itself is surrounded by green space residential and campus facilities. There is a trainline 84 m NW of the site and the nearest roads are: Farquhar Road (177 m); Edgbaston Park Road (132 m); and Pritchatts Road (262 m). The next largest facility is the Queen Elizabeth Hospital (1.1 km) and the edge of the city centre (taken as the A4540 ring-road) is 2.1 km to the NE. According to the West Midlands Road traffic statistics, 4.21 billion vehicle miles were travelled on roads in Birmingham in 2019, 3.44 billion of which were cars and taxis. Edgbaston Park Road takes roughly 4,800 vehicle per day and Vincents Drive takes traffic from Pritchatts Road and Farquhar Road to the Hospital takes roughly 6,814 vehicle per day (DfT Road Traffic Statistics for counting sites 945338 and 947763:

<https://roadtraffic.dft.gov.uk/local-authorities/141>). The BAQS site experiences an average air temperature of 11 °C; and atmospheric pressure of 995 hPa.

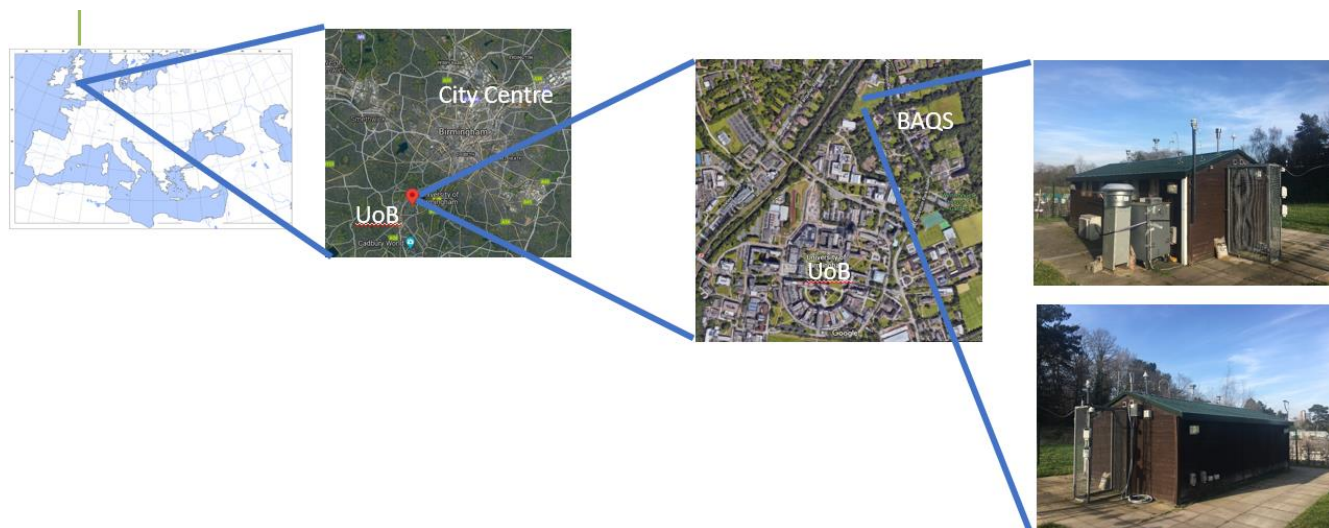


Figure 3. The Birmingham Air Quality Site (BAQS; urban background) in Birmingham, UK. Upper panel: Overview of the geographical positioning of the site. Lower left panel: proximity of the sampling sites to the city centre (defined by the ring road shown in green). Lower right panel: location of BAQS within the University of Birmingham (UoB) grounds.

2.2.2. Instrumentation & data

Since the start of its operation in 2019, BAQS has typical yearly mean measured values for both gases and aerosols: O_3 48 $\mu\text{g}/\text{m}^3$; NO 3 $\mu\text{g}/\text{m}^3$; NO_2 18 $\mu\text{g}/\text{m}^3$; BC 777 ng/m^3 ; $PM_{2.5}$ 9.4 $\mu\text{g}/\text{m}^3$; PM_{10} 13 $\mu\text{g}/\text{m}^3$, and, in the framework of RI-URBANS, for PNC and PNSD measurements the site has recently gone through an upgrade to ACTRIS standards.

Before the upgrade, the SMPS comprised of a TSI 3082 classifier, operated with a TSI 3081 DMA and a TSI 3750 CPC. This was operated in conjunction with a stand-alone TSI 3750 CEN-CPC. An average particle number size distribution measured using the SMPS is shown in Figure 4. Both the SMPS and CEN-CPC were connected to a Sampling System for Atmospheric Aerosol Model – TSI-3772200. This is described under the Technical Specification CEN*/TS 16976 which aimed at harmonizing the continuous measurement of particle number concentration in ambient air. It described a standardized method not only for CPC for which we also added the SMPS via a T-piece.

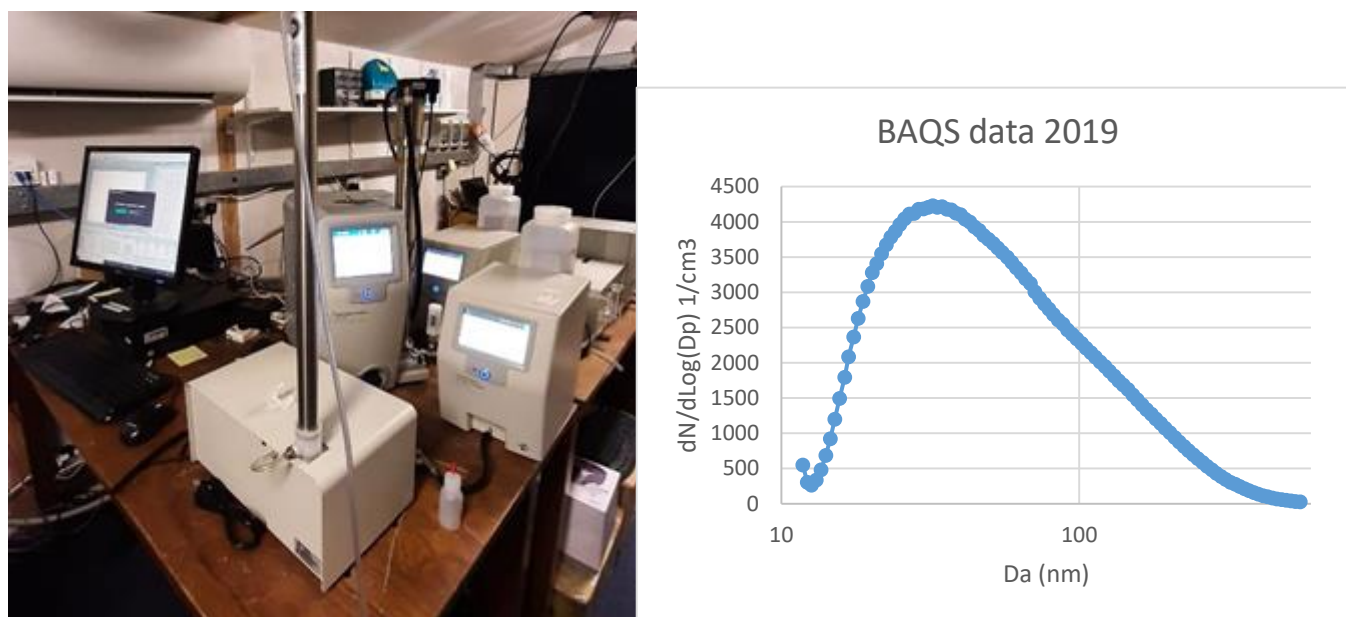


Figure 4. Left panel: original SMPS system installed at BAQS. Right panel: average number size distribution of the data collected from the 8th of July 2019 using the original MPSS. The lower and upper size bins are 11.8 and 552 nm, respectively.

Figure 5 shows the SMPS after its upgrade to ACTRIS standards. The TSI-3082 classifier has been upgraded to Dual Polarity; the DMA has been upgraded to the 3083 which specializes on covering the size range from 10 to 800 nm in one single scan; and the sampling system has been upgraded to the TSI-3750200, designed follows all requirements specified in the European standards CEN/TS 16976 and 17434. Aerosol enters through a PM10 head, passes through an optional PM2.5 cyclone, and is then dried to <40% relative humidity. An isokinetic flow splitter¹ distributes particles to one or multiple attached instruments (CPC and/or SMPS). The software, although yet to be successfully stably operated has been upgraded to AIMS11 for monitoring.

¹ In the photograph in Figure 5 is missing the 4-way splitter and is currently using a T-piece until stock is available.

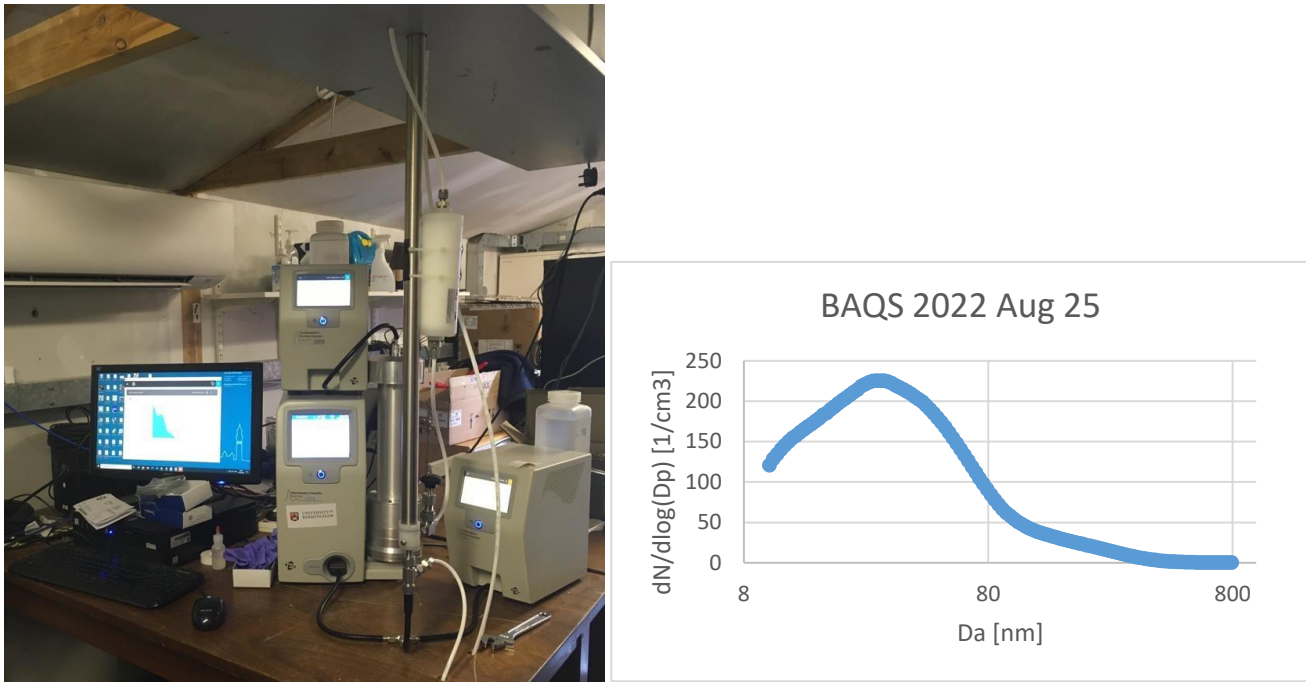


Figure 5. Left panel: upgraded SMPS and CEN system to ACTRIS standards, now scanning from 10 to 800 nm. Right panel: sample of data collected from the new MPSS setup.

2.3 HELSINKI

2.3.1. Site description

Helsinki is the capital of Finland, located (60° 10' 15" N; 24° 56' 15" E) on the coast of the Baltic Sea. The population is 660,000 inhabitants, with ca. 1.6 million people living in the metropolitan area surrounding Helsinki. In Helsinki, we are conducting PNSD measurements within RI-URBANS at two nearby sites. Both are located ca. 4 km from the Helsinki city centre (see Figure 6). The Mäkelänkatu site is an urban traffic site operated by the Helsinki Regional Air Quality Authority (HSY), while Station for Measuring Ecosystem-Atmosphere Relations (SMEAR) -III is an urban background site operated jointly by the University of Helsinki and Finnish Meteorological Institute (FMI).

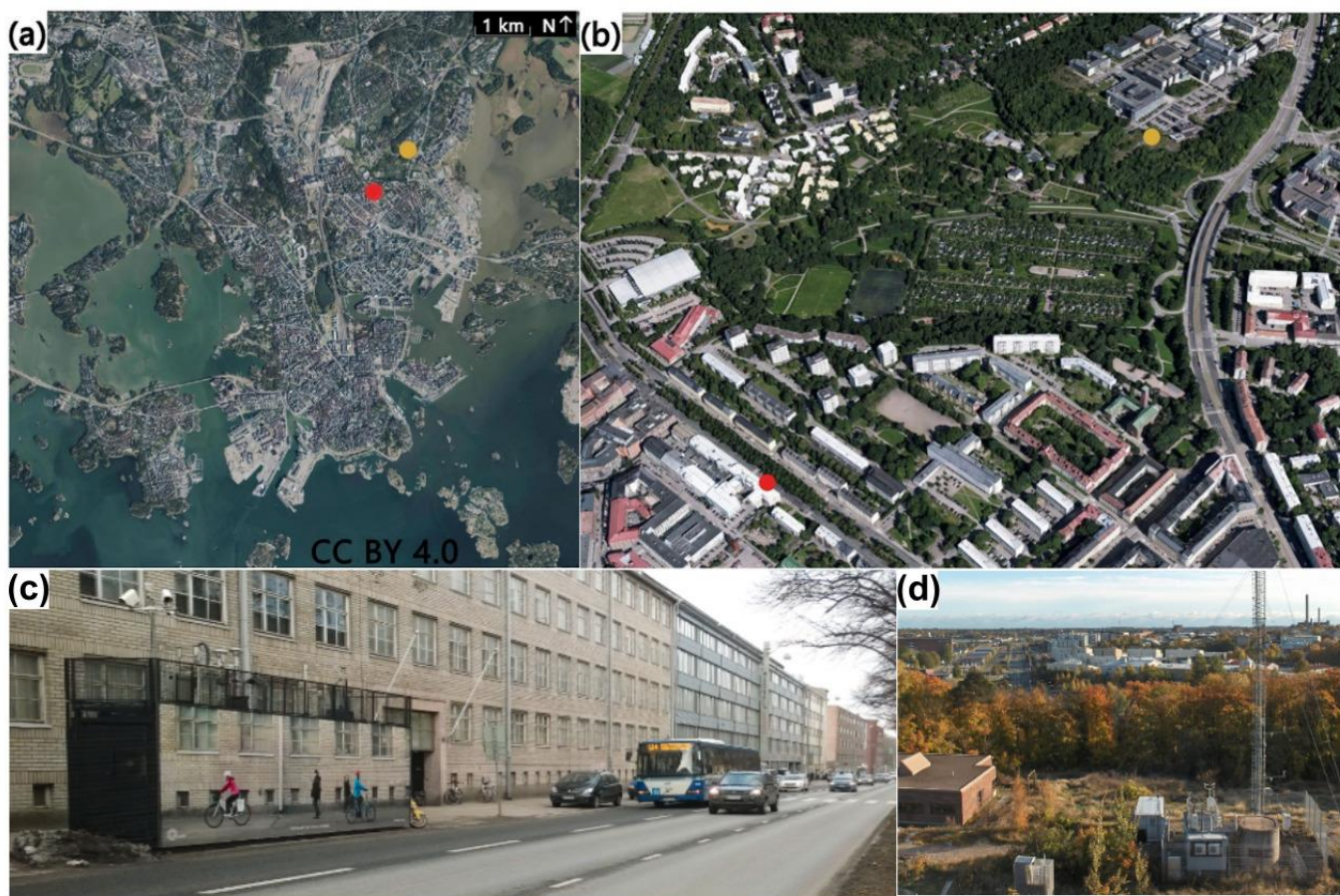


Figure 6. Measurement sites in Helsinki, Finland. Red dot is Mäkelänkatu road-side site, yellow dot is the SMEAR-III site located at the Kumpula Campus area of the University of Helsinki. Panel (c) a view of the Mäkelänkatu site and panel (d) a view towards south-east of the SMEAR-III site.

2.3.2 Instrumentation & data

The SMEAR-III site was established in 2004 to provide long-term measurements of the chemical and physical properties of aerosol particles, trace gas concentrations, and meteorological parameters in an urban background environment. The instruments are located in a container and a 31 m tall tower that is next to the container (Figure 6d). SMEAR-III is an ACTRIS site and, therefore, follows the ACTRIS recommendations for sampling. The Mäkelänkatu site was established in 2015 and the set of measured variables is comparable to the SMEAR-III site. The instruments are in a container that is next to a busy road (Figure 6c).

The PNSD at the SMEAR-III station is measured by a Twin-DMPS (Differential Mobility Particle Sizer) system. The twin system consists of a Hauke-type DMA with a TSI Model 3756 CPC and a second Hauke-type DMA with a TSI Model 3772 CPC. The combined diameter range is 3-820 nm. The DMPS system at SMEAR-III first became operational in August 2004. Mäkelänkatu site also has a DMPS system but it uses a single Vienna type DMA with an Airmodus CPC model A20. The measured diameter range is 6-800 nm. The data availability starts from 2015. Figure 7 shows an example of particle NSD measurements at the two sites over several days during February 2022.

For the SMEAR-III site a NRT data delivery system has been configured, however for the Mäkelänkatu site some more work still needs to be done as the measurement system is slightly different.

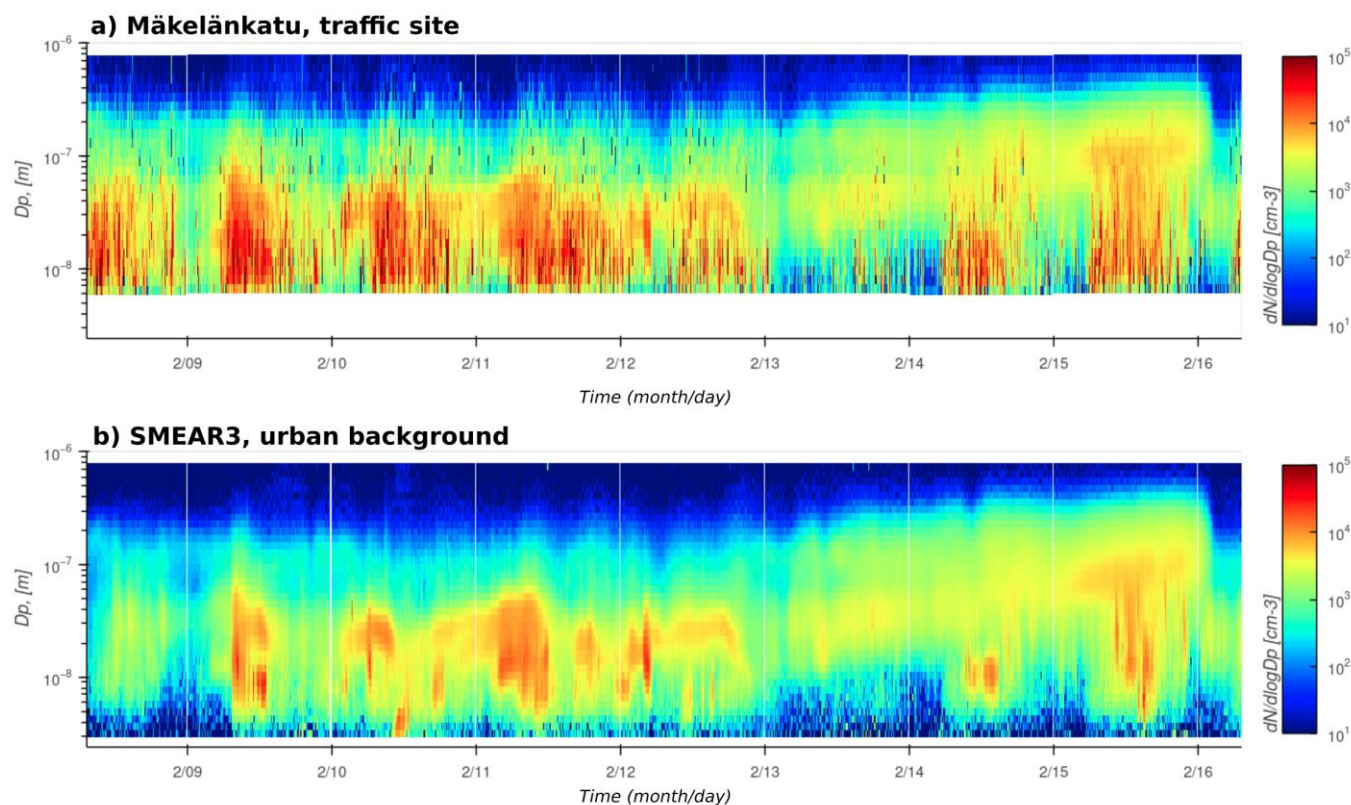


Figure 7. Aerosol particle number size distribution measured at the (a) Mäkelänkatu traffic and (b) SMEAR-III urban background sites in Helsinki, Finland during 9-16 February 2022.

3. CONCLUSIONS AND NEXT STEPS

All in all, as planned, the near real time measurements of aerosol particle number size distribution have started and are ongoing at all the pilot sites from RI-URBANS' Pilot #2 cities. ACTRIS central facility on aerosol in-situ measurements (world calibration center) has been consulted to make the measurements ACTRIS compatible. Most of the measurements systems were recently upgraded to comply with the ACTRIS standards and guidelines, or they are waiting for final modifications. The near-real time data provision status is site dependent, with Barcelona already exporting data in a continuous manner and have already tested the chain. Discussions with ACTRIS Data Center are on-going to enable near real time submission from all sites.