ICOS Cities

Handbook of European urban greenhouse gas observations

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HANDBOOK OF EUROPEAN URBAN GREENHOUSE GAS OBSERVATIONS 2025

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Foreword

Climate change is a global phenomenon that severely impacts urban life. At the same time, cities are key contributors to climate change, as urban activities are major sources of greenhouse gas (GHG) emissions. The European Union (EU) and many of its member states have set respective goals to move towards a low-carbon economy and to cut emissions severely. The European Commission has put climate action as a core of their European Green Deal.

A large share of global and European fossil fuel CO_2 emissions originates from urban areas and other hotspots like point sources. Furthermore, it is expected that a significant part of future emission reductions will occur in urban areas. This is one of the reasons why there are already numerous efforts to experimentally determine fossil fuel CO_2 emissions from urban areas.

This handbook, developed in the context of the ICOS Cities / PAUL H2020 European project, contains a review of existing city observatories in connection with the European research infrastructure landscape. It provides contact points in all 16 member countries in ICOS as well as some other European countries. It aims to leverage the lessons learned from earlier experiences, creating networks on national and regional level and defining state-of-the-art for new initiatives rising in the near future.

Contents

Introduction

Cities and urban areas are critical in global efforts to mitigate climate change as the majority of anthropogenic greenhouse gas (GHG) emissions originate from urban activities. As the European Union and its member states advance ambitious goals to transition toward a low-carbon economy and significantly reduce emissions through initiatives such as the European Green Deal, accurate measurement and monitoring of urban GHG emissions has become essential for evidence-based policy action.

The current reliance on inventory-based methods for evaluating city emissions, typically estimating total city-wide CO_2 emissions on an annual basis, provides valuable baseline information. However, as mitigation efforts intensify, there is a growing need for more detailed, timely, and spatially resolved emissions information, especially at sub-national scales. The level of emissions information required can range from a one-time determination of total city emissions to spatially, temporally, and source sector-resolved emissions information, with the complexity of information enabling increasingly targeted mitigation strategies.

Urban GHG measurement systems address this need through complementary methodologies which can be summarised in the following three tiers. The first tier comprises urban inventory and flux modelling, that provide spatially and temporally explicit emission data products. The second tier consists of direct observational methods which can be based on single or various measurement techniques providing additional information that may not be obtainable from inventory-based methods alone, while offering independent emissions results. The third tier involves data assimilation systems and atmospheric inverse models that combine multiple data streams – including observations, meteorological models, and prior emission information – to produce refined and validated emission maps at high spatial and temporal resolution.

The scientific and technical foundations for these measurement approaches in the urban environment have been established through international initiatives such as the Integrated Global Greenhouse Gas Information System (IG3IS) by the World Meteorological Organization (WMO).

Within Europe, the Integrated Carbon Observation System (ICOS) research infrastructure has emerged as a key platform for standardised, long-term GHG observations. In recent years, ICOS has significantly expanded its focus on urban monitoring, recognizing cities as priority areas for climate actions. This expansion includes the integration of urban measurement sites into the ICOS network alongside traditional natural environment stations, representing a substantial commitment to enhancing urban GHG observation capabilities across the continent. The ICOS Cities / PAUL project builds upon these foundations by creating connections between existing city observatories and the broader European research infrastructure.

By documenting measurement approaches, establishing contact networks across ICOS member countries, and defining state-of-the-art practices, this handbook aims to accelerate the deployment of urban GHG measurement systems. The ultimate goal is to provide cities with the actionable information necessary to evaluate mitigation strategies, track progress toward emission reduction targets, and make informed decisions about climate policy interventions.

The ICOS infrastructure

The Integrated Carbon Observation System (ICOS) is a distributed European research infrastructure (RI) dedicated to high quality measurements of greenhouse gases. With nearly 180 measurement stations across 16 European countries, ICOS provides standardised and open data on GHG concentrations in the atmosphere as well as carbon fluxes between the land surface, the oceans, and the atmosphere. The ICOS community consists of more than 500 scientists in both its current Member countries and beyond. More than 150 renowned universities or institutes are a part of the ICOS community. ICOS data supports research which is crucial for understanding the carbon cycle at global scale as well as developing climate change mitigation efforts.

ICOS aims to conduct standardised, high-precision, and long-term observations to understand the carbon cycle and provide essential information on GHG concentrations and fluxes. ICOS is the European pillar of a global GHG observation system, producing highly standardised data and elaborated products across Europe. It strives to support policy- and decision-making to combat climate change and its impacts on the environment and humans. It also promotes technological developments and demonstrations related to GHG by linking research, education, and innovation. It also aims to integrate its data into major global data systems and networks, meeting international requirements, principles, and agreements.

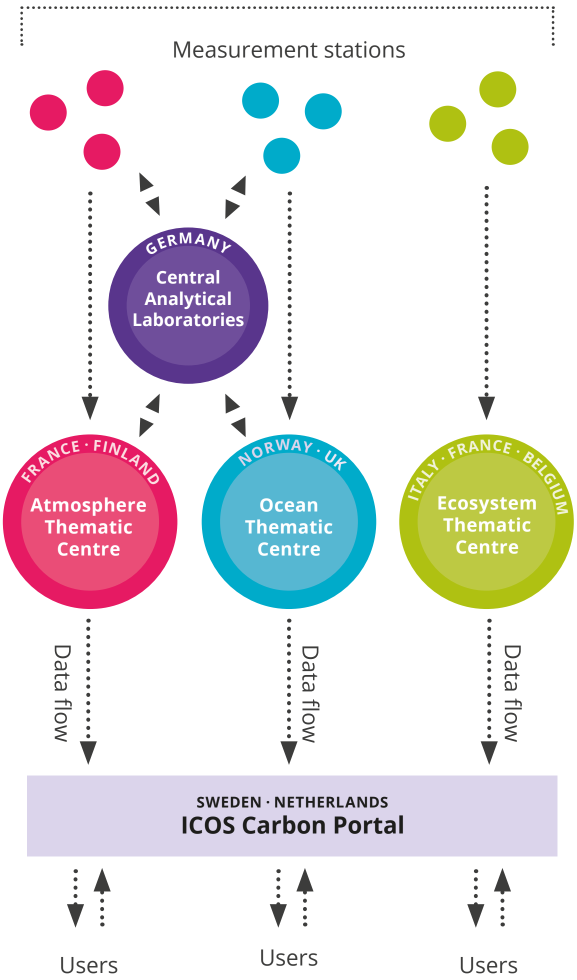

Figure 1: Flowchart of ICOS's organizational structure illustrating the interconnections of the various components of the network. The system is organized into three main domains: atmosphere, ecosystem, and ocean. Each domain includes national measuring station networks, monitoring station assemblies (MSAs), and thematic centers. All components converge in the Carbon Portal, showing an integrated system for collecting, analysing and distributing GHG data.

ICOS organisational structure

ICOS's organizational structure is designed to ensure comprehensive and standardised data collection, processing, and dissemination (Figure 1). The structure comprises two main components:

The station network: currently accounts for about 180 measurement stations across Europe, operating in three domains, Atmosphere, Ecosystem, and Ocean. Some stations are multi-domain, collecting data for two or all thematic domains. The stations are directly supported by national funding and are coordinated by ICOS National Networks in 16 Member countries.

The Thematic Centres (TCs): they are three, the Atmosphere Thematic Centre (ATC), Ecosystem Thematic Centre (ETC) and Ocean Thematic Centre (OTC), each dedicated to a domain with the aim to coordinate observations and support stations. Indeed, they support stations in completing the measurements setup and data collection according to the ICOS standards (labelling process) and provide data services such as processing and quality control, training and technical assistance for site management, developing and testing new measurement sensors, supervising instrument setups and methods, and developing new methods for data processing. As for the data management, the TCs process the raw data acquired by the ICOS stations, typically in near-real-time on a daily basis, with fully standardised methodologies and routines. After processing the standardised data is properly archived in the Carbon Portal, together with the original raw data to ensure reproducibility.

Data structure and management

ICOS data products include raw data (Level 0), near-real-time data (Level 1), quality-controlled data (Level 2) and elaborated products (Level 3) such as flux maps and model outputs. These data are made available through the ICOS Carbon Portal under CC BY licence, ensuring accessibility and usability for researchers, policymakers, and other stakeholders. The whole data flow can be schematised in four consecutive steps:

1. **Data collection:** stations continuously collect raw data according to standardised protocols. These data are automatically sent to the ICOS Carbon Portal on a daily basis and stored in a safe repository. Concurrent metadata are also collected, regularly updated through communication with the Thematic Centres and stored.

2. **Data processing:** Thematic Centres process the raw data, applying standardised routines and quality controls. This is done both daily (near real time) to provide continuous data updates and periodically to release consolidated versions of the products.

3. **Data integration:** The processing results are transferred from the Thematic Centres to the Carbon Portal through automatic machine-to-machine communication ensuring the integrity of data and metadata. The Carbon Portal collects and stores the processed data ensuring their FAIRness.

4. **Data dissemination:** all the data, from raw measurements to processed and quality-controlled products are made openly available through the ICOS Carbon Portal. Descriptions of the ICOS data products and their contents comply with the FAIR principles and can be effectively and easily accessed or shared with other computing centres.

ICOS and urban observations

In recent years, ICOS has significantly intensified its investment in the urban sector for GHG measurements, expanding its network to include urban monitoring sites alongside its traditional natural environment stations. This strategic shift reflects the growing recognition of cities as critical zones for climate action and emissions monitoring.

Currently, 7 urban stations are officially registered within the ICOS network, while 17 additional sites are either in the registration process or have initiated the pathway toward full membership. This expansion represents a substantial commitment to enhancing urban GHG observation capabilities across Europe.

Urban stations are presently incorporated into the network as associated stations, providing micrometeorological eddy covariance (EC) and meteorological data as the multitude of urban GHG measurement approaches discussed in the next chapter are not yet implemented in ICOS. This associated station classification provides a degree of operational flexibility, as it does not mandate strict standardisation of measurement setups or baseline processing of raw data. Site teams are permitted to collect and process data according to customized routines tailored to their specific urban contexts and infrastructural constraints. However, they are required to transmit their data, typically eddy covariance flux measurements and meteorological variables at half-hourly temporal resolution, to the network's central database following a precisely defined standardised format specification. This ensures data interoperability while accommodating site-specific operational approaches. Despite the flexibility in initial data collection and processing, all submitted data undergo centralized, standardised processing at the Ecosystem Thematic Centre. This centralized workflow is essential for producing final datasets that are consistent, comparable, and scientifically robust across all stations in the network. For urban sites specifically, this standardised processing encompasses quality control procedures including filtering based on atmospheric turbulence conditions (such as friction velocity thresholds) and systematic gap-filling algorithms to address missing data periods. These harmonized post-processing steps ensure that inter-site comparisons are methodologically sound and that the resulting datasets meet the rigorous quality standards required for scientific research and policy applications.

Greenhouse gas observation methods

The Basel Klingelbergstrasse (CH-BaK) station in the city center of Basel. It is probably the station with the longest continuous record of urban CO2 flux measurements, starting from 2004 and becoming an ICOS Associated station in 2024.

This section outlines the methodologies applicable for measuring greenhouse gas (GHG) emissions in urban environments. These approaches span from observational methods that detect atmospheric GHGs across limited areas and brief time intervals, to strategies designed to estimate emissions across entire urban atmospheric basins. In addition to variations in spatial and temporal scales, these methodologies differ in terms of implementation and operational management costs. Each approach proves particularly effective in meeting specific scientific and stakeholder requirements regarding emissions, while being less suitable for other applications.

These methodologies range from tools aimed at localized, short-duration analysis to solutions designed for comprehensive, long-term urban emissions assessments. Such tools rely on fundamental data and technologies, including numerous atmospheric observation techniques but also on anthropogenic activity data. Although the various methods can be operated individually, there is significant potential and considerable benefit in applying an integrated suite of methodologies within a single city measurement campaign (co-designed approach).

A brief description of the main techniques is reported here. Detailed technical information on the implementation of each can be found in the GAW Report No. 314 (WMO, 2025).

EC telescope tower with instrumentation at roof of TU main building at Campus Charlottenburg in the city centre of Berlin.

Eddy covariance urban fluxes

Eddy covariance (EC) is the only direct approach to continuously measure spatially integrated CO_2 and other GHG fluxes between land surfaces and the atmosphere. EC measurements are performed upon towers above the surface of interest by using co-located high-frequency wind and gas concentration measurements.

The EC technique can be applied over any flat surface, including urban areas, although data processing and interpretation is not that straightforward in cities. The main challenge is that the surface sampled (i.e., the turbulent flux source area) is characterised by the huge heterogeneity of the urban morphology, implying drastic changes of atmospheric and turbulence characteristics as well as of source strength and dynamics. This translates into the need for a rigorous data processing chain and a thorough data quality control.

A second challenge is related to the spatial scale over which the EC technique integrates the estimated fluxes. Indeed, depending on the measurement height, the wind intensity and the roughness of the underlying surface, fluxes are representative of areas extending from hundreds of meters to a few kilometers around the measurement point, so in general at neighborhood scale. For large cities, a single tower EC system is thus often not suitable for monitoring city-scale emissions, requiring the use of multiple EC towers and/or the concurrent deployment of other monitoring techniques which allow extending the local estimates to the whole urban area.

Tall towers greenhouse gas concentration

Continuous *in situ* observations of atmospheric GHG concentrations at tall towers in and around urban areas are a common approach for top-down city emission. Tall towers placed downwind outside the city measure integrated urban emissions and are therefore particularly suitable for determining total city emissions. This advantage comes, however, at the price of smaller concentration enhancements compared to intra-urban observations, integration of biogenic contributions from suburban areas, and little to no information on emission distributions at sub-city scales. To minimise these drawbacks, *in situ* tall towers need to be equipped with high-precision gas analysers allowing them to detect small concentration changes.

Of great interest to policymakers is the partitioning the observed total CO_2 enhancement into fossil and non-fossil sources. To this aim, the most advanced method is radiocarbon ($^{14}CO_2$) measurements of the urban CO_2 gradient. The non-fossil CO_2 share includes different CO_2 sources such as respiration by plants, soils, animals or humans and emissions from the usage of biofuels. Unfortunately, up to now $^{14}CO_2$ still can only be analysed by in grab samples as no continuous $^{14}CO_2$ instrument, with the necessary accuracy, is available. Fossil fuel CO_2 emissions ($ffCO_2$) can be traced by measuring concentration gradients of gas species being co-emitted during fossil fuel combustion like, e.g. CO, or NO_x. Due to different fuel types, combustion processes and efficiencies, different source sectors like e.g. traffic, residential heating or industry have distinct emission ratios between $ffCO_2$ and the co-emitted species, and this can be used to disentangle different urban source-sector contributions.

Roof or street level GHGs concentration

In urban areas, the use of cost-efficient non-dispersive-infrared technology (mid-cost NDIR gas analysers) in a relatively dense network has been deployed in various projects. This has proven to be effective in monitoring GHG dynamics even over long periods and as an appropriate input for mesoscale inversion models. They are typically installed at roof level, eliminating the need for complex infrastructure while still maintaining a certain degree of spatial integration. The disadvantage of a lower measurement precision is compensated by the use of a high number of units (e.g. 10–30), made possible by the relatively low cost of these sensors.

Even more efficient in terms of costs are the so-called low-cost devices (less than 500 € against about 8000 € for the mid-cost devices) for air quality and GHG monitoring. Their technology has remarkably improved in recent years, and considerable efforts were put in defining adequate fields of applications and suitable methodologies for calibration and quality assurance. Of special interest for greenhouse gas emissions are the CO_2 sensors that allow for measuring the atmospheric concentrations at spatial resolutions not reachable by high precision instruments. Given the reduced dimensions and power consumption of these battery-powered devices, they can be installed at the street level, exploiting existing infrastructure such as lampposts, signs, trees, and even mobile devices such as cars or public transport. A significantly denser observation network can be obtained by low-cost sensors and, also in this case, the poor measuring accuracy and precision is compensated by the measurement repetitions (e.g. hundreds of sensors). However, to be sufficiently effective, a low-cost network requires a robust IoT infrastructure, a systematic calibration scheduling and an extensive data processing, especially focused on data QC. The use of a large amount of low-cost sensors can, e.g., provide street-level constraints in Bayesian inversions for atmospheric transport modelling at building-resolved spatial resolution. In addition, these kinds of monitoring networks open an inspiring opportunity to citizen science, and strengthen the feeling of belonging to the place "my city, my air, my climate".

Radio tower (DK-GLX) in Copenhagen equipped with three sonic anemometers at 71 m, 90 m, and 112 m, along with a 10 Hz closed-path gas analysis system. The system adaptively samples at these levels depending on atmospheric stability, enabling long-term tall-tower eddy covariance measurements of CO_2, CH_4, N_2O, CO, and COS.

Total column GHGs concentrations

Total column devices use remote sensing technologies to provide an integrated quantification of the CO_2 between the surface and the top of the atmosphere, supporting the quantification of GHG emissions over large areas such as cities. In comparison to the other *in situ* measurements, they are less sensitive to vertical redistribution of tracer mass, e.g., due to growth of the planetary boundary layer height, and also less influenced by nearby point

View of the atmospheric GHG measurement station in Bologna, Italy.

sources. Furthermore, they are more compatible with the scale of atmospheric models or satellites, as they are not only measuring the concentrations at a certain point next to the surface but within the total atmospheric column. On the other hand, the signals measured are an order of magnitude weaker than those measured on the surface, which represents a significant challenge. By placing these instruments upwind and downwind of an urban emission source deploying differential column measurements (DCM, Chen at al., 2016), the concentration gradients are relatively insensitive to surface fluxes upwind of the city, and therefore provide a good estimation of the integrated urban emissions. In addition to being useful for monitoring urban GHG dynamics, long-term time series of such data can be used to validate urban concentration gradients measured by advanced remote sensing products such as OCO-2/3 and TROPOMI.

Specific and detailed GHGs inventory activities

A city emission inventory is a comprehensive accounting of all emissions produced within a city over a specific period (usually one year or more). It helps cities understand which activities in the city cause GHG emissions, their relative importance and potentially how to reduce them. These inventories can include source sector totals for the entire city, and/or they can be spatially distributed, assigning emissions to specific locations within the city. The strong temporal and spatial variability of urban GHG emissions, e.g., due to rush-hour peaks or temperature-driven heating, can be represented in emission inventories, if properly designed. Spatially and temporally explicit emission inventories are also required for monitoring emission reductions through atmospheric observations and modelling. IPCC guidelines were originally designed for national inventories and are broad enough to accommodate countries with low technological readiness. Very widespread and used, especially by policymakers, are the guidelines and/or protocols directly addressing cities, such as the GHG Protocol for Cities (GHG Protocol, 2025) or the IG3IS Urban Greenhouse Gas Emission Observation and Monitoring Good Research Practice Guidelines (WMO, 2022).

Urban green areas GHG monitoring activities

Urban green areas have a significant impact on the urban atmospheric composition and urban climate. Cities' "greening" is typically used as an urban climate adaptation and mitigation strategy because of the multiple environmental and socioeconomic benefits. The magnitude of green areas'contribution to the urban GHG concentrations depends on some key factors such as the plant status affecting the carbon sink capacity, the extent of the green spaces, the species composition and plant community structure, and management practices (e.g. irrigation, soil fertilization, lawn mowing).

Methods for measuring and monitoring GHG exchanges over urban green spaces include direct methods like micrometeorological techniques (EC), micro-scale measurements (e.g. chambers) or inventory approaches (e.g. carbon pool estimations, soil organic carbon measurements), as well as remote sensing and process modelling. Monitoring urban green space microenvironmental parameters with *in situ* sensors (e.g. soil temperature/water, tree sap flow, park micrometeorology) is also beneficial for process model forcing. The application of such observational and modelling approaches face multiple challenges due to the urban green area patchiness and heterogeneity across the urban landscapes and often a combination of multiple approaches can provide significant benefits. Quantifying, and possibly discriminating from other anthropogenic sources, the contribution of plants to the urban GHG balance is essential for both scientific purposes and for rational urban planning.

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World Meteorological Organization. (2022). IG3IS Urban Greenhouse Gas Emission Observation and Monitoring Good Research Practice Guidelines (GAW Report No. 275). https://library.wmo.int/viewer/58055/?offset=

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The IAGOS RI

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Synergetic GHG monitoring activities

Regular sampling from passenger aircraft

The European Research Infrastructure IAGOS (In-service Aircraft for a Global Observing System) has been established to operate a suite of atmospheric measurement systems installed onboard commercial passenger aircraft, and to provide access to data from regular observations near airports during take-off/climb-out and descent/landing between near surface (a few meters above the runway) and 10–12 km altitude. Besides reactive gases, aerosols, water vapour and cloud measurements, high-precision greenhouse gases, traceable to WMO standards, are targeted. Using CRDS technology identical to that used for ICOS-atmosphere GHG observations, but adopted for deployment onboard aircraft for up to a year without maintenance, the full troposphere can be characterised at specific locations using currently two equipped aircraft from Lufthansa (transferred to Discover Airlines early 2025) and from China Airlines. An example is shown in Figure 2. To ensure data availability in NRT (near-real time), significant progress has been made within the ICOS-Cities project in the automatisation of the data processing, using a python-based database management system to handle all information about individual instruments, their calibration history, and deployment cycles onboard the different aircraft within the IAGOS fleet.

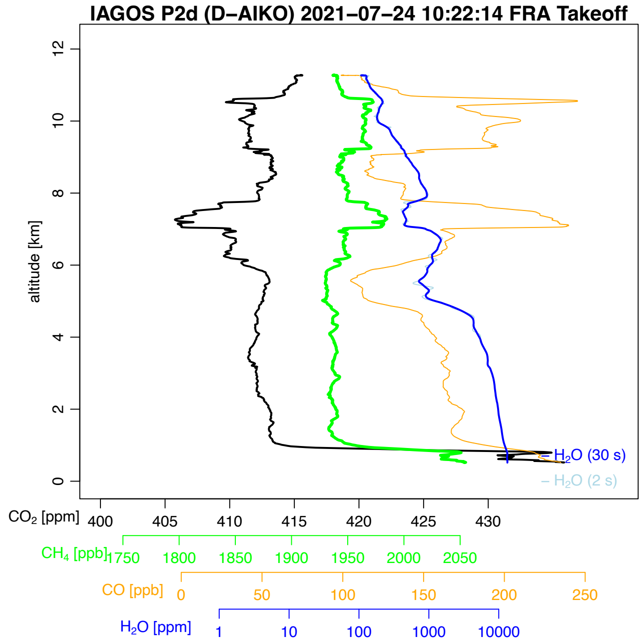

Figure 2: Simultaneous measurements of CO_2, CH_4, CO and water vapour from the IAGOS GHG system made during a climb-out from Frankfurt airport. Note the significant layering in the free troposphere, with layers enriched in CO and CH_4 while depleted in CO_2, most likely related to long-range transport of biomass burning plumes from Canada. CO_2 is expected to show enhancements from biomass burning, however those are small compared to the depletion of CO_2 from strong photosynthetic uptake (Note the emissions from biomass burning are added within the atmospheric boundary layer).

Synergies between IAGOS and Urban GHG observations

The IAGOS Research Infrastructure and urban GHG observations such as within ICOS-CITIES are inherently complementary in their approaches to monitoring and quantifying urban greenhouse gas emissions. Urban GHG monitoring systems provides dense, high-frequency observations of CO_2, CH_4 and co-emitted tracers within the urban boundary layer using fixed stations, mobile platforms and modelling tools for emission verification. However, the accuracy of urban-scale inversion systems critically depends on well-constrained background concentrations and vertical mixing processes – elements that are often insufficiently represented by surface observations alone. Here, IAGOS fills a crucial observational gap by delivering systematic vertical profiles and cruise-level time series of greenhouse gases from commercial aircraft ascending and descending over major European urban hubs.

By combining IAGOS free-tropospheric background characterisation with ICOS-Cities surface-based urban measurements, a more robust separation of local emissions from regional and long-range transport signals becomes possible. IAGOS data can serve as direct boundary-condition input (or at least to evaluate model-based boundary conditions) for ICOS-Cities inversion

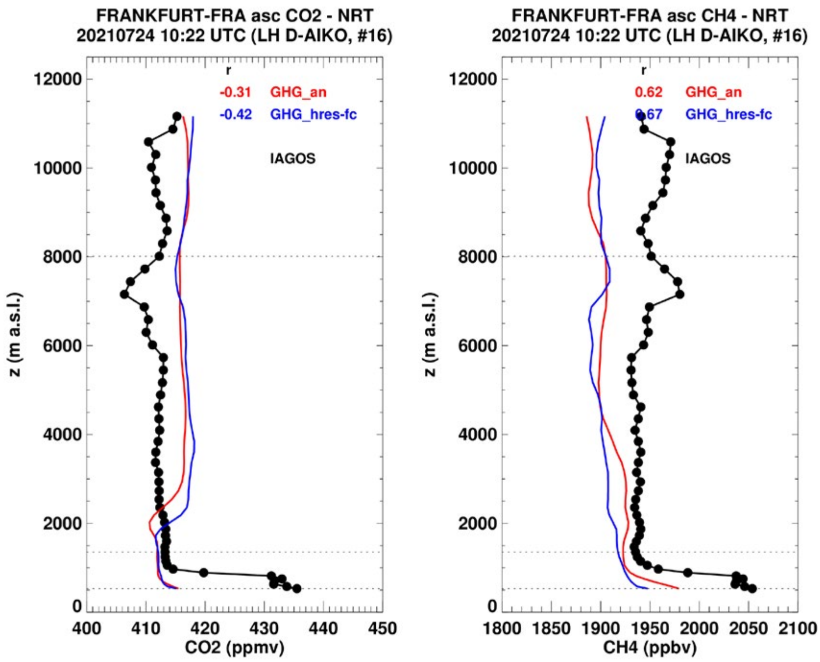

Figure 3: Copernicus Atmosphere Monitoring Service (CAMS) carbon dioxide (CO_2) and methane (CH_4) forecast compared with IAGOS observations.

frameworks and as an independent benchmark for validating urban-scale atmospheric transport models and mixing-layer parameterisations.

An example for an evaluation of potential boundary condition fields is the ongoing CAMS validation using IAGOS GHG observations. A specific example is shown in Figure 3, showing the same vertical profile as in Figure 2. It is obvious that in spite of the high vertical and horizontal resolution of the CAMS product, the strong layering cannot be reproduced, leading to errors when using CAMS fields as boundary conditions.

Data availability

Vertical profile information involving different aircraft of the IAGOS fleet is available from various cities across Europe, including Frankfurt, Paris, Munich, Amsterdam, Brussels. Currently, GHG data are collected from two A330 aircraft (see above), and an extension of the fleet to Air France and Hawaiian Airlines is expected within the next few years, resulting in additional coverage with vertical profiles over European cities.

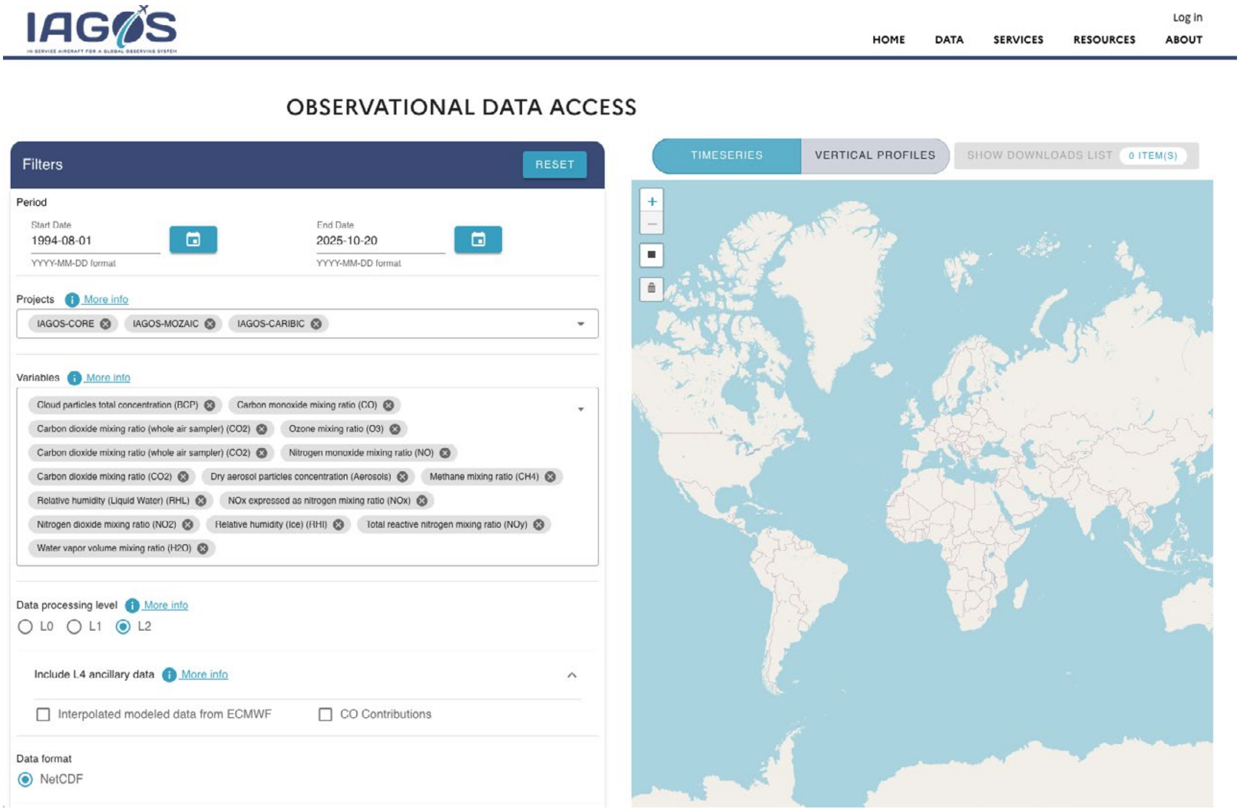

Figure 4: Screenshot of the IAGOS observational data selection web page (https://iagos.aeris-data.fr/download/)

Data can be accessed through the IAGOS data portal under www.iagos.org (via the link to the "IAGOS data portal"), see figure 4. Registration is necessary, an account can easily be created e.g. via a personal ORCID (among other authentication methods). This also includes a visualization tool to assess observational data availability through https://iagos.aeris-data.fr/data-availability. Machine-to-machine access to IAGOS data is provided through the REST API, see https://services.iagos-data.fr/prod/swagger-ui/index.html.

Synergies exist with RI-URBANS, where details can be found under the deliverable report D5.3 "Service Catalogue on ACTRICE and IAGOS services for urban sites", section 3 "IAGOS Services", available under https://riurbans.eu/wp-content/uploads/2025/07/RI-URBANS_D37_D5_3.pdf. There the focus is on reactive gases, including NO_x and CO, which are highly relevant also for GHG monitoring given the fact that they are co-emitted with CO_2 during combustion processes.

Furthermore a service for the visualization using the "source-receptor link" model called SOFT-IO of footprints and air mass origin sampled by IAGOS (characterised by carbon monoxide observations) is available through the data portal (under https://services.iagos-data.fr/atmo-access/footprint). It is based on pre-generated Level 4 products calculated from the FLEXPART model coupled to different emissions inventories for biomass burning and anthropogenic sources.

Ongoing urban activities in European countries

Austria

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Ongoing urban GHG monitoring activities

Eddy covariance urban observations

Vienna: Arsenal Tower, urban tall tower station (Lat. 48.18183, Lon. 16.39085, height 144 m), active, measuring CO_2 fluxes since December 2017 and CH_4 fluxes since May 2022. Fluxes measurements to be continued until at least Dec 2027. Currently operating as part of the CVCF project (contact: Andreas Stohl), previously running under the Vienna Urban Carbon Laboratory project. The site is registered in the FLUXNET network with the code AT-VnA and flux measurements are operated by Bradley Matthews and Helmut Schume (BOKU).

Innsbruck: The site is an urban flux tower (Lat. 47.26409 Lon. 11.38582; height: 42.8 m), operational since 2017. The site is also registered as a national facility within ACTRIS and provides additional observations of trace gas fluxes. In addition the site offers a turbulence tower into the street canyon with optional measurements from street level to 42.8 m above street level (up to 5 levels), and meteorological remote sensing observations (e.g. Wind Lidars). CO_2 fluxes have been measured since 2017 with a Campbell closed path system. Methane fluxes are available since 2021 (LosGatos CRDS) and are planned to be continued with an AERIS MIRA Ultra (CH_4/C_2H_6). NO_x and O_3 fluxes have been measured since 2017 and 2021 respectively (Ecophysics analysers). NMVOC fluxes were measured during several campaigns since 2017 (PTR-TOF). In 2025 modifications are being made to comply with ACTRIS *in situ* trace gas observations with additional compounds anticipated to be measured (e.g. CO fluxes). The site is registered in the FLUXNET network with the code AT-Inn.

Tall towers/total column GHG concentration measurements

At the same tower in Vienna, a Picarro system is operated since May 2022 measuring CO_2 and CH_4 mole fractions and 13C in CO_2. The inlet is sampling air at the same height (144 m). Measurements to be continued until at least June 2026. These measurements are operated by Kathiravan Meeran (BOKU), Simon Leitner (BOKU) and Andrea Watzinger (BOKU, Co PI of VUCL and CVCF).

Roof or street level concentration measurements

The University of Vienna (Bernadett Weinzierl) plans to install a Picarro G2401 instrument measuring CO, CO_2, CH_4, and H_2O at their Aerosol Observatory located at the rooftop-level of the Physics building at Boltzmanngasse 5, Vienna (35 m above ground). The Aerosol Observatory is on track to become a National Facility for aerosol *in situ* observations within the pan-European Aerosol, Clouds, and Trace Gas Research Infrastructure ACTRIS. It focuses on extensive research on aerosol-cloud-climate interactions and aims to provide high-quality data and information on short-lived atmospheric constituents representing urban background conditions.

Furthermore, in the last year repeated mobile campaigns have been conducted sampling street level CO_2 mole fractions, using the CO_2 concentrations at street level and those measured at Arsenal in a gradient approach to estimate spatially resolved CO_2 fluxes. The mobile measurements are operated by Enrichetta Fasano (BOKU) and Helmut Schume (BOKU).

Specific and detailed GHG inventory activities

The Environment Agency Austria compiles both the national and subnational emission inventories providing annual, sector emission GHG and air pollutant estimates for Vienna. In addition, the City of Vienna itself maintains an emission cadaster, providing spatially resolved emissions of air pollutants and CO_2 for specific reference years principally for the purpose of air quality monitoring and modelling.

Urban green areas GHG monitoring activities

As part of CVCF, a tall tower station above a peri-urban forest north-west of the Vienna city centre (Exelberg tower, Wiener Wald; Lat. 48.24902, Lon. 16,24449) was set up in July 2025 to measure background CO_2 concentrations and isotopes, as well as forest NEE fluxes. The site is registered in the FLUXNET network with the code AT-Exb.

Relevant links

CVCF project: https://www.wwtf.at/funding/programmes/esr/ESR24-021/

Urban Carbon Laboratory project: https://www.wwtf.at/funding/programmes/esr/ESR20-030/

Vienna tower page on European fluxes database: https://www.europe-fluxdata.eu/home/site-details?id=AT-VnA

https://www.wwtf.at/funding/programmes/esr/ESR20-030/

Innsbruck tower page on European fluxes database: https://www.europe-fluxdata.eu/home/site-details?id=AT-Inn

National Level Experts

Bradley Matthews Environment Agency Austria/BOKU University (urban flux measurements and downscaling of national emissions)

Andrea Watzinger BOKU University (urban CO_2 and stable isotope measurements)

Andreas Stohl University of Vienna (urban to global scale inversions)

Thomas Karl University of Innsbruck (urban atmospheric observations – fluxes and concentrations)

Helen Ward University of Innsbruck (urban micrometeorology / GHG fluxes)

Bernadett Weinzierl University of Vienna (urban atmospheric observations – aerosols)

Helmut Schume BOKU University (urban and forest flux measurements)

Belgium

Urban Focal Point:
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Ongoing urban GHG monitoring activities

Tall towers/total column GHG concentration measurements

Royal Belgian Institute for Space Aeronomy (BIRA-IASB) in collaboration with University of Antwerp and University of Liege are setting-up the BE-MVS system. BIRA-IASB is in charge of setting up remote sensing total column and *in situ* GHG concentration measurements for the purpose of improving the National GHG Inventory Reporting with top-down information. The measurements will be at regional/national scale.

The total column measurements of GHG will be performed using a Fourier transform infrared spectrometer of the Bruker Invenio type. The measurements will be part of COCCON following all the necessary steps as outlined by the network. The measurements site is in the campus of the Royal Belgian Institute for Space Aeronomy in the southern part of Brussels (Lat. 50.797, Lon. 4.358). The measurements will start on a campaign basis in 2025 and on a permanent basis in 2026.

The *in situ* GHG concentration measurements will be performed at a tower in the Meerdaal forest in the town of Oud-Heverlee (Lat. 50.815, Lon. 4.692) about 20 km East of Brussels center using a Picarro G2401 analyser from two intake heights of 58 m and 81 m. The measurements are expected to begin by the end of 2025. It will be a candidate site for class 2 ICOS atmospheric site in 2026.

These systems will give us more expertise that may be useful for future urban emission measurements or for calibration purposes (by providing reference measurements), e.g., of mid- to low-cost sensors.

Others

Campaign-based (short-term) measurements of XCO2 and XCH4 using COCCON compliant low-resolution FTIR spectrometers. During the campaign several compact FTIR instruments are deployed upwind and downwind of a city to measure concentration gradients over the area.

Presently one campaign was carried out using 4 spectrometers around the city and port of Antwerp in April and May of 2024. A second similar campaign is planned for next year.

National Level Experts

Mahesh Kumar Sha Royal Belgian Institute for Space Aeronomy
(FTIR; TCCON; COCCON; ICOS)

Sieglinde Callewaert Royal Belgian Institute for Space Aeronomy (WRF-GHG modelling, inverse modelling)

Filip Desmet Royal Belgian Institute for Space Aeronomy (FTIR; ACTRIS; ICOS)

Czechia

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Global Change Research Institute of the Czech Academy of Sciences (CzechGlobe)
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Ongoing urban GHG monitoring activities

CzechGlobe measures ad hoc (campaigns) energy fluxes in urban areas (e.g. comparison of the colors of the roofs and its impact on cooling/heating the cities, green areas impacts on climate).

National Level Experts

Marian Pavelka Global Change Research Institute of the Czech Academy of Sciences (experimental setup)

Daniel Kopkáně Global Change Research Institute of the Czech Academy of Sciences (modelling)

Denmark

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Ongoing urban GHG monitoring activities

Eddy covariance urban observations

Copenhagen: Tall tower (Gladsaxe, Isbanevej 4, radio tower maintained by CIBICOM A/S, Lat 55.73504, Lon 12.49169) with three sonic anemometers at 71 m, 90 m, and 112 m levels and a 10 Hz, closed-path gas analysis system with adaptive choice of sampling at these levels depending on atmospheric stability. Gases sampled are CO_2, CH_4, N_2O, CO, and COS. Sequential concentration profile system at 5 levels for gases mentioned above, except COS. The station was set up in January 2025 and is operated by the Technical University of Denmark (contact: Konstantinos Kissas).

Specific and detailed GHG inventory activities

Mapping of residential, traffic-related and industrial GHG sources and vegetation in a 4 km radius around the eddy covariance tower.

Urban green areas GHG monitoring activities

Remote sensing of green area around the eddy covariance tower. Spatial modelling of CO_2 exchange of urban green areas.

Others

Collaboration with Gladsaxe municipality, working on a concept to disseminate the results and the project's potential to motivate citizens and enterprises to engage in the green transition of Denmark.

Relevant links

Danish Centre For Environment And Energy (DCE): https://dce.au.dk/en/

National Level Experts

Andreas Ibrom Technical University of Denmark (project leader of the national urban GHG exchange project and ICOS focal point for Denmark)

Konstantinos Kissas Technical University of Denmark (urban GHG eddy covariance)

Susanne Wiesner Technical University of Denmark (satellite and CO_2 exchange modelling of urban green areas)

Charlotte Scheutz Technical University of Denmark (ground-based GHG source emission quantification with tracer dispersion approaches)

Finland

Urban Focal Point:
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Ongoing urban GHG monitoring activities

Eddy covariance urban observations

Helsinki: Kumpula tower (Lat. 60.20289, Lon. 24.9611, height: 31m). The semi-urban station is ICOS Associated Ecosystem Station FI-Kmp. Monitored gases CO_2 and H_2O since December 2005. Co-location with ACTRIS air quality station and operated by University of Helsinki (contact: Leena Järvi).

Helsinki: Torni tower (Lat. 60.16780, Lon. 24.93869, height: 60m). This station represents the highly built surface of the city centre of Helsinki. Monitored gases CO_2 and H_2O since October 2010. Additional measurements include aerosol particle fluxes and supporting meteorological measurements. The site is operated by the University of Helsinki and registered in FLUXNET with the code FI-HTr (contact: Leena Järvi).

Tall towers/total column GHG concentration measurements

Kuopio: Puijo Tower (ICOS semiurban atmospheric station PUI, Lat. 62.90889, Lon. 27.65861, elevation 305 m above sea level and 224 m above surrounding lake level), high precision CO_2, CH_4 and CO mixing ratios and meteorological parameters measured at 84 m and 47 m above ground by a Picarro G2401 on top of Puijo hill close to city of Kuopio. Instrument operated and calibrated according to ICOS standards. Station houses also ACTRIS aerosol *in situ* and cloud *in situ* stations with addition of air quality measurements (O_3, NO_x, SO_2, particulate PM_{10}) and it is operated by University of Eastern Finland (contact: Arttu Ylisirniö).

Roof or street level concentration measurements

In the city of Helsinki, on the Kumpula eddy covariance tower, high precision CO_2, CH_4 & CO mixing ratios measured at 30 m above ground by a Picarro G2401. Calibrated using WMO CCL standards (CO_2: X2019, CH_4: X2004A, CO: X2014A scales). The station is operated by the Finnish Meteorological Institute (contact: Hermanni Aaltonen).

Urban green areas GHG monitoring activities

In Helsinki and the Kumpula botanical garden. Continuous, automatic shoot and soil chamber measurements of CO_2 and H_2O fluxes since 2020. In total, three shoot chambers on Tilia Cordata trees and two soil chambers on the soil surface underneath the trees. Additional supporting measurements cover sap flux measurements from the same three trees, soil temperature and moisture measurements, root growth and air temperature and humidity measurements. In 2025 the soil chambers were complemented by CH_4 and N_2O flux measurements. In addition, various campaign measurements in the EC source area in different vegetation types and management experiments with manual chambers and supporting instruments. The monitoring is coordinated by University of Helsinki (contact: Leena Järvi).

Relevant links

Kumpula tower webpage in the ICOS Carbon Portal: https://meta.icos-cp.eu/resources/stations/ES_FI-Kmp

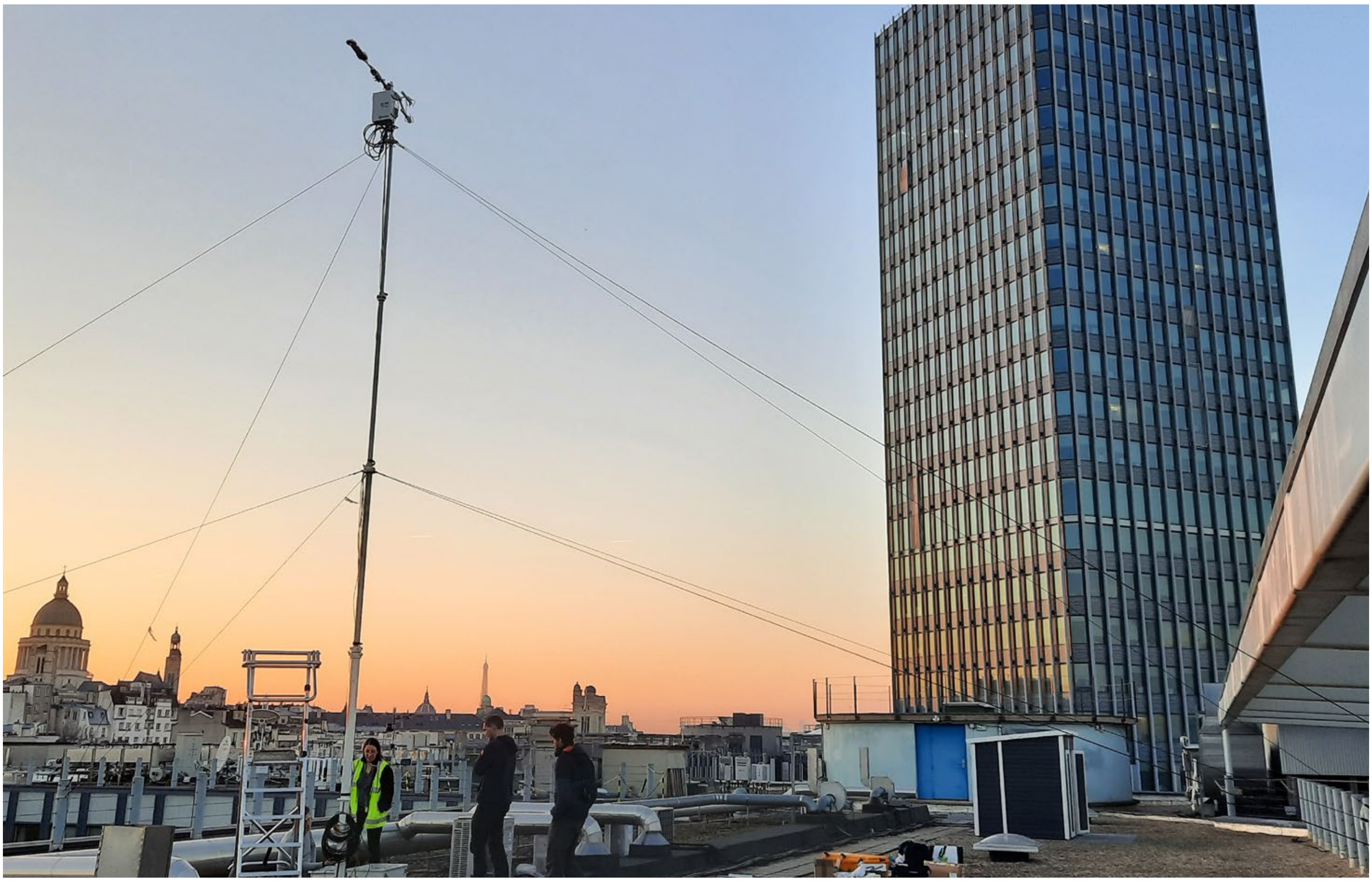
National Level Experts

Leena Järvi University of Helsinki (eddy covariance, biogenic GHG exchange)

Hermanni Aaltonen Finnish Meteorological Institute (atmospheric concentrations, chamber measurements)

Liisa Kulmala Finnish Meteorological Institute (ecosystem modelling, chamber measurements, biogenic GHG exchange)

Arttu Ylisirniö University of Eastern Finland (concentration measurements)



France

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Ongoing urban GHG monitoring activities

Eddy covariance urban observations

Paris: Three eddy covariance sites are present in the city (Table 1):

Romainville: The FR-Rmv site (Lat.: 48.88552, Lon.: 2.42219) is located in the municipality of “Les Lilas” on the NE periphery of Paris, in a densely urbanised area. The EC setup is composed of an IRGASON (Campbell, US) installed on the west side of a platform at 102.5 m height on the telecommunication tower “Tour Hertzienne TDF Romainville”. The corresponding flux footprint is very wide and heterogeneous, spanning several km and including part of the Paris city centre and part of the periphery with some vegetated patches. From June 2023 to June 2024 the tower hosted a 7-species gas analyser (MGA7, MIRO Analytical).

Jussieu-Qualair: The FR-Jus site (Lat.: 48.84632, Lon.: 2.35639), running since February 2023, is located in the centre of Paris, in a densely built-up area. Nearby, on the SE side, is the "Jardin des Plantes", while around 200 m apart, on the N-NE-E sectors, flows the river Seine. The EC mast is installed on the rooftop of the Marie Curie campus of the Sorbonne University and uses an IRGASON (Campbell, US) at 31 m a.g.l and includes also a 4-component radiometer.

Vincennes: The FR-Vin site (Lat.: 48.83469, Lon.: 2.46638), running since March 2024, is located within the CIRAD campus (Jardin d'agronomie tropicale de Paris – René Dumont Campus), within the urban deciduous forest of Vincennes. The EC setup is composed of an IRGASON (Campbell, US) installed on the rooftop of the taller building on the CIRAD campus, on a 10 m height mast leading to a height of 23 m a.g.l. The building is surrounded by trees with an average height of 18 m. EC measurements were supplemented by 4-components radiation measurements in addition to main meteorological data and a Phenocam.

Tall towers/total column GHG concentration measurements

Paris: The Parisian network of tall towers and total column measurements is operated by LSCE (contacts: Michel Ramonet and Morgan Lopez). CO_2, CH_4 and CO measurements from tall towers are performed using CRDS analysers. Total column measurements at QUALAIR are part of TCCON, whereas total column measurements at Saclay and Gonesse are done with EM27/SUN instrument, encapsulated in an automatic casing developed and patented at LSCE. A total of 9 towers are operated and the characteristics are summarized in Table 2. Urban stations have also been installed in Marseille and Reims, operated respectively by PyTHEAS (contact: Irène Xueref-Remy) and GSMA (contact: Lilian Joly).

Table 1: Characteristics of the urban eddy covariance towers in France

City	Site	Coordinates	GHG	Height	Period	Institution in charge	Reference Contact	Co-location
Paris	Romainville Site code: FR-Rmv	Lat 48.8854, Lon: 2.4225	CO_2	102 m	Start: 03/2023	INRAE	Benjamin Loubet	ROV tall tower
Paris	Jussieu/Qualair Site code: FR-Jus	Lat: 48.8461 Lon: 2.3548	CO_2	31 m	Start: 02/2023	INRAE	Benjamin Loubet	JUS total column
Paris	Vincennes Site code: FR-Vin	Lat: 48.8346 Lon: 2.46638	CO_2	23 m	Start: 03/2024	INRAE	Benjamin Loubet	

Table 2: Characteristics of the tall towers and total column measurements in the Paris area

City	Site	Coordinates and elevation	Elevation	Sampling height	GHG	Period	Notes
Paris	Andilly (AND)	Lat: 49.0126 Lon: 2.3018	175	60	CO_2, CH_4, CO	Since 2015	
Paris	Cite des Sciences (CDS)	Lat: 48.8956 Lon: 2.3880	45	34	CO_2, CH_4, CO	Since 2015	
Paris	Coubron (COU)	Lat: 48.9242 Lon: 2.5680	126	30	CO_2, CH_4, CO	Since 2014	
Paris	Gonesse (GNS)	Lat: 49.0052 Lon: 2.4205	81	36	CO_2, CH_4, CO	Since 2017	Column for XCO2, XCH4, XCO
Paris	Jussieu/Qualair (JUS)	Lat: 48.8464 Lon: 2.3561	38	30	CO_2, CH_4, CO	Since 2016	Column for XCO2, XCH4, XCO
Paris	OVSQ (OVS)	Lat: 48.7779 Lon: 2.0486	150	20	CO_2, CH_4, CO	Since 2014	
Paris	Saclay (SAC)	Lat: 48.7227 Lon: 2.1420	160	15, 60, 100	CO_2, CH_4, CO N_2O, NO_x, BC	Since 2015	Column for XCO2, XCH4, XCO
Paris	Romainville (ROV)	Lat 48.8854, Lon: 2.4225	128	103	CO_2, CH_4, CO N_2O, NO_x, BC	Since 2023	
Paris	Meudon (MEU)	Lat 48.8025, Lon: 2.2044	173	45, 65, 95	CO_2, CH_4, CO N_2O, NO_x, BC	Since 2023	
Reims	Moulin de la Housse (MDH)	Lat: 49.2434, Lon: 4.0616	124	24, 48	CO_2, CH_4, CO, N_2O	Since 2023	Column for XCO2, XCH4, XCO
Marseille	Marseille Longchamp (CAV)	Lat: 43.3059, Lon:5.3950	65	5	CO_2, CH_4	Since 2016	NO_x, PMs
Marseille	Station Marine Endoume (SME)	Lat: 43.2806, Lon:5.3499	10	2.5	CO_2, CH_4, CO	2016–2018	

Roof or street level concentration measurements

Paris: seven roof level sites equipped with mid cost CO_2 sensors (NDIR): 25 Senseair K96, 9 Senseair HPP and 3 Vaisala GMP343 (few sites have 2 or 3 CO_2 mid cost sensors). The network is operated by LSCE (Senseair K96 and Vaisala GMP343, contact: Olivier Laurent) and SUEZ Origin (Sensair HPP, contact: Hervé Utard). CO sensors have been collocated with CO_2 sensors on 3 sites.

Specific and detailed GHG inventory activities

Paris inventory is performed by AIRPARIF, in charge of the air pollution network, updated every couple of years. Another inventory is performed by SUEZ Origin aiming to provide a more frequent update. Marseille inventory is performed by ATMOSUD, in charge of the air pollution network.

Relevant links

Paris Vincennes eddy tower webpage in the ICOS Cities Portal:
https://citymeta.icos-cp.eu/resources/stations/ES_FR-Vin

Paris Jussieu eddy tower webpage in the ICOS Cities Portal:
https://citymeta.icos-cp.eu/resources/stations/ES_FR-Jus

Atmospheric composition time series result from Andilly (60.0 m):
https://citymeta.icos-cp.eu/objects/66zVAgYBqemPxRVYVlZiFa3D

Atmospheric composition time series result from Jussieu (40.0 m):
https://citymeta.icos-cp.eu/objects/aDU0HCVcCdY7veTVbdxTy3vb

Atmospheric composition time series result from Gonesse (36.0 m):
https://citymeta.icos-cp.eu/objects/I7zGuG2ZZVgO7GNfUmLVI1Q8

Atmospheric composition time series result from Coubron (30.0 m):
https://citymeta.icos-cp.eu/objects/vy7s6TeXPnkTqzVprU8sfevO

Atmospheric composition time series result from OVSQ (20.0 m):
https://citymeta.icos-cp.eu/objects/H11rx8zQY6jhFif-i7FAJ5I1

Atmospheric composition time series result from Cite des sciences (34.0 m):
https://citymeta.icos-cp.eu/objects/ZYBsOb7O5cG96riKxym4qkYg

Atmospheric composition time series result from Saclay (100.0 m):
https://citymeta.icos-cp.eu/objects/kRrdOs1QaLvL4TLz8idzyRdj

Atmospheric composition time series result from Meudon (90.0 m):
https://citymeta.icos-cp.eu/objects/rG27jnHMZkpSIBTmv8gVgX7B

Atmospheric composition time series result from Romainville (103.0 m):
https://citymeta.icos-cp.eu/objects/5t0-mcDHMHCKtelM2NhmX9l4

National Level Experts

Pascal Karavec Ecole centrale de Nantes (urban heat fluxes)

Thomas Lauvaux LSCE (atmospheric modelling)

Olivier Laurent LSCE (atmospheric measurements)

Benjamin Loubet INRAE (eddy flux measurements)

Germany

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Ongoing urban GHG monitoring activities

Eddy covariance urban observations

Five eddy covariance towers are operational in Germany, two in Berlin, one in Munich and one in Munster. The Berlin DE-BeR site is also an ICOS Associated station while the one tower in Munich is part of the ICOS Cities network. Details are reported in Table 3.

Table 3: Characteristics of the eddy covariance towers in Germany

City	Site	Coordi-nates	GHG	Height	Period	Institution in charge	Reference Contact	Co-location
Berlin	TU Campus Charlottenburg Site code: DE-BeC	Lat: 52.51228 Lon: 13.32785	CO_2	56 m	Start: 2014	TU Berlin	Fred Meier	Ceilometer Microwave radiometer Wind-Lidar Phenocam Particles (TU Braun-schweig)
Berlin	Rothenburg-strasse Site code: DE-BeR	Lat: 52.45723 Lon: 13.31588	CO_2	39.75	Start: 2018	TU Berlin	Fred Meier	Wind-Lidar Phenocam
Munich	Oberpost-direktion Site code: DE-Opd	Lat: 48.14742 Lon: 11.54979	CO_2	85 m	Start: 2022	KIT	Christopher Holst	Doppler Wind LiDAR, 2 Mid-cost sensors (TUM)
Münster	University campus, Heisen-bergstraße Site code: DE-Hbs	Lat: 51.96923 Lon: 7.59588	CO_2	34 m	Start: 2025	University of Münster	Mana Gha-run	Ceilometer Phenocam

Tall towers/total column GHG concentration measurements

There are eight GHG concentration measurement sites operational in Germany, five in Munich and one in Bremen, Heidelberg and Karlsruhe. All the sites are equipped with a FTIR spectrometer for total column for CO_2 and CH_4 except for the Heidelberg site that is co-located with the ICOS-CRL Pilot *in situ* station with a flask sampler monitoring a larger range of gas species (CO_2, CH_4, CO, NO_x, N_2O, δ13CO_2, $^{14}CO_2$, ^{222}Rn, H_2, SF_6). Details are reported in Table 4.

Table 4: Characteristics of the total column sites in Germany

City	Site	Coordinates	Period	Institution in charge	Reference Contact	Notes
Munich	TUM (Center)	Lat: 48.151 Lon: 11.569	Since 2015-09	TU Munich	Jia Chen	MUCCnet
Munich	Feldkirchen (East)	Lat: 48.148 Lon: 11.730	Since 2019-09	TU Munich	Jia Chen	MUCCnet
Munich	Wessling (West)	Wessling: Lat: 48.0867 Lon: 11.2797	Since 2019-09	TU Munich	Jia Chen	MUCCnet
Munich	Gräfelfing	Gräfelfing: Lat: 48.121 Lon: 11.425	Since 2019-09	TU Munich	Jia Chen	MUCCnet
Munich	Oberschleisheim (North)	Lat: 48.258 Lon: 11.548	Since 2019-09	TU Munich	Jia Chen	MUCCnet
Munich	Taufkirchen (South)	Lat: 48.047 Lon: 11.608	Since 2019-09	TU Munich	Jia Chen	MUCCnet
Bremen		Lat: 53.1037 Lon: 8.849517	Since 2007-01	Uni Bremen	Thorsten Warneke	TCCON Network
Karlsruhe		Lat: 49.1002 Lon: 8.4385	Since 2009-09	KIT	Frank Hase	TCCON Network
Heidelberg	HEI	Lat 49.417, Lon: 8.6747	Since 1996	Uni Heidelberg	Samuel Hammer André Butz	Two mobile laboratories available.

Roof or street level concentration measurements

Munich: Two networks of sensors are operational in the city, both developed in the context of the ICOS Cities project (contact point: Jia Chen): the mid-cost sensor (high performances) network ACROPOLIS (Autonomous and Calibrated Roof-top Observatory for MetroPOLItan Sensing) composed by 20 measurement points and the low-cost (lower performances) network SCOUT (Street-level Carbon Observatory for Urban Territory) with 100 sensors.

Heidelberg and Mannheim: A mid-cost (high performances) sensors network (UNICORN – University Network for CO_2 in the Rhine-Neckar metropolitan area) is under development, with 18 fixed BEACO2N sensors for CO_2 (GMP343),CO, PM2.5 and O_3 measurements. Contact point: Sanam Vardag and André Butz.

Urban green areas GHG monitoring activities

Two extensive green roofs are monitored in Germany for CO_2 exchanges through the eddy-covariance method at 1.15 m above roof level, both under the responsibility of TU Braunschweig (contact: Stephan Weber). Details are reported in Table 5. Further, in Munich there are 5 measurement sites in urban parks to regularly sample biogenic fluxes from grassland and trees (contact: Jia Chen, Stavros Stagakis).

Table 5: Characteristics of the urban green monitoring sites in Germany

City	Site	Urban Green Type	Co-ordinates	GHG	Period
Berlin	Airport Berlin-Brandenburg, BER	Extensive Green roof	Lat: 52.37 Lon: 13.51	CO_2	2014-07 ongoing
Obernburg Main	Industrial Center Obernburg, ICO	Extensive Green roof	Lat: 49.830 Lon: 9.154	CO_2	2022-03 ongoing
Munich	Maßmannpark	Urban parks and sidewalk	Lat:48.1524, Lon: 11.5592	CO_2	2024-04 ongoing
Munich	Alter Botanischer Garten	Urban parks and sidewalk	Lat:48.1416, Lon: 11.5642	CO_2	2024-04 ongoing
Munich	Arnulfpark	Urban parks and sidewalk	Lat:48.1437, Lon:11.5408	CO_2	2024-04 ongoing
Munich	Marsstraße	Urban parks and sidewalk	Lat:48.1466, Lon:11.5459	CO_2	2024-04 ongoing
Munich	Nymphenburger Str.	Urban parks and sidewalk	Lat:48.1489, Lon:11.5519	CO_2	2024-04 ongoing

Relevant links

Munich Oberpostdirektion tower webpage in the ICOS Cities Portal:
https://citymeta.icos-cp.eu/resources/stations/ES_DE-Opd

Munich total column measurements in ICOS Cities Portal (MUCCnet):
https://citymeta.icos-cp.eu/collections/_gw1SA37USG80FZxMPgReMDo;

Munich low-cost measurements in ICOS Cities Portal (ACROPOLIS):
https://citymeta.icos-cp.eu/collections/3u2A8TqpgBhI8m81F-xrfSI7;

Munich mid-cost measurements in ICOS Cities Portal (SCOUT):
https://citymeta.icos-cp.eu/collections/gciax7x_xF8Q6r-PK2OjRjeE;

Berlin Rothenburgstrasse tower webpage in the ICOS Carbon Portal:
https://meta.icos-cp.eu/resources/stations/ES_DE-BeR

Berlin Charlottenburg tower page on European fluxes database:
https://www.europe-fluxdata.eu/home/site-details?id=DE-BeC

Münster University Campus tower dashboard:
https://www.uni-muenster.de/BAI/en/weather/site_description.shtml

Munich Leaf area index biogenic *in situ* observations (L2):
https://citymeta.icos-cp.eu/objects/yw1YlrnusFsJpXXMQSP2-XbF

Munich Leaf Photosynthesis biogenic *in situ* observations (L2):
https://citymeta.icos-cp.eu/objects/EqduNQUFq80VUwORVBgRK8ns

Munich Photosynthetically Active Radiation biogenic *in situ* observations (L2):
https://citymeta.icos-cp.eu/objects/UXE1ARCQNix2qqOt3ibf99Mi

Munich Sapflow biogenic *in situ* observations (L2):
https://citymeta.icos-cp.eu/objects/MLXAbr3SAPbI1WeeyQ5d6qAw

Munich Soil respiration biogenic *in situ* observations (L2):
https://citymeta.icos-cp.eu/objects/q2INggZ07LBFuvXY644Hctwn

Munich Soil sensors biogenic *in situ* observations (L2):
https://citymeta.icos-cp.eu/objects/xTVSHrmBXLvD2vWBicVB6m28

National Level Experts

Andreas Christen Albert-Ludwigs-Universität Freiburg (eddy covariance, bottom-up modeling of urban GHG sources and sinks)

Sanam Vardag Universität Heidelberg (budgeting urban GHG emissions, simulating atmospheric transport, designing observing system simulation experiments – OSSE)

Jia Chen TU München (total column GHG concentration measurements, inversion modelling)

Hartmut Bösch Universität Bremen (satellite GHG observation)

Christopher Holst Karlsruhe Institute of Technology (wind-lidar, eddy covariance)

Samuel Hammer Universität Heidelberg ($^{14}CO_2$ and *in situ* observations and proxy-to-ffCO_2 determination)

Greece

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Ongoing urban GHG monitoring activities

Eddy covariance urban observations

Heraklion: Two eddy covariance sites are active in the city of Heraklion, both labelled as ICOS Associated stations with the codes GR-HeK (Lat. 35.33613, Lon. 25.1328, 27m above surface) for Kornarou and GR-HeM (Lat. 35.32343, Lon. 25.13017, 24.6m above surface) for the Mastabas and under the responsibility of the RSLab of the Foundation for Research and Technology (FORTH). The two stations are equipped with an IRGASON (Campbell) system on a mast mounted on roof top and their footprints cover different urban areas. In addition to the CO_2 fluxes, the same group operates Unmanned Aerial Systems with hyperspectral, optical and thermal cameras, a Sun Photometer contributing to AERONET network and a network of meteorological Stations in the city of Heraklion.

Relevant links

Heraklion Kornarou tower webpage in the ICOS Carbon Portal:
https://meta.icos-cp.eu/resources/stations/ES_GR-HeK

Heraklion Mastabas tower webpage in the ICOS Carbon Portal:
https://meta.icos-cp.eu/resources/stations/ES_GR-HeM

Equipment of the stations (RSLab):
https://rslab.gr/equipment.html

Real time measurements of the stations:
https://rslab.gr/products.html

National Level Experts

Nektarios Chrysoulakis Foundation for Research and Technology Hellas

Konstantinos Politakios Foundation for Research and Technology Hellas (eddy covariance observations)

Nektarios Spyridakis Foundation for Research and Technology Hellas (eddy covariance observations)

Emmanouil Panagiotakis Foundation for Research and Technology Hellas (GHG modelling)

Hungary

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Ongoing urban GHG monitoring activities

Roof or street level concentration measurements

Debrecen: There is an urban background (relatively far from direct pollution) monitoring site equipped with a Picarro G2310 CO_2/CH_4 analyser in the garden of HUN-REN ATOMKI. The institute is in charge of its operation (contact person: Mihály Molnár). The measurements are co-located with radiocarbon (14C) and stable carbon isotopes (13C/12C) in CO_2 and CH_4 samplings, in addition to aerosol monitoring (PM2.5, PM10, EC/OC, C-isotopes). Tall tower urban eddy covariance measurements of CO_2-flux is planned.

Relevant links

Debrecen data access system:
https://zoldorszem.debrecen.hu/en/measurements/11

National Level Experts

Mihály Molnár HUN-REN ATOMKI (GHG mole fraction analyses, radiocarbon and stable isotope measurements, operation of the urban monitoring station)

Sándor Bán HUN-REN ATOMKI (GHG mole fraction analyses, radiocarbon and stable isotope measurements, operation of the urban monitoring station)

Balázs Áron Baráth HUN-REN ATOMKI (GHG mole fraction analyses, radiocarbon and stable isotope measurements, biomonitoring using 14C in plants, operation of the urban monitoring station)

László Haszpra HUN-REN ATOMKI(GHG mole fraction analyses)

István Major HUN-REN ATOMKI (radiocarbon and stable isotope measurements)

Tamás Varga HUN-REN ATOMKI (radiocarbon and stable isotope measurements, biomonitoring using 14C in plants)

Italy

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Ongoing urban GHG monitoring activities

Eddy covariance urban observations

The Italian network of urban flux towers is composed of six sites, all currently operational except the Naples tower that can be restored easily if needed. Two of the towers are labelled as ICOS Associated stations (IT-OXm and IT-Sas). The towers use a variety of gas analysers and sonic anemometers and collect meteorological data in parallel to the fluxes. Details are provided in Table 6.

Table 6: Characteristics of the urban eddy covariance sites in Italy

City	Site	Coordinates	GHG	Height	Period	Institution in charge	Reference Contact	Co-location
Modena	Modena city center	Lat: 44.64794 Lon: 10.92978	CO_2	45 m	Start: 2025	University of Modena and Reggio Emilia	Alessandro Bigi	
Naples	San Marcellino Site code: IT-SMc	Lat: 40.84765 Lon: 14.25815	CO_2 CH_4	32 m	Start: 2014 End: 2018	CNR-ISAFOM	Vincenzo Magliulo	Dust and O_3 fluxes, N_2O concentrations (campaigns)
Sassari	Sassari city center Site code: IT-Sas	Lat: 40.71696 Lon: 8.57596	CO_2	24 m	Start: 2024	University of Sassari	Costantino Sirca	
Florence	Osservatorio Ximeniano Site code: IT-OXm	Lat: 43.77446 Lon: 11.25511	CO_2 NO_x	33 m	Start: 2005	CNR IBE	Beniamino Gioli	
Prato	Prato city center Site code: IT-Prt	Lat: 43.88056 Lon: 11.09639	CO_2	38 m	Start: 2021	CNR IBE	Beniamino Gioli	
Pesaro	Osservatorio Valerio Site code: IT-OVr	Lat: 42.91221 Lon: 12.90477	CO_2	25 m	Start: 2014	CNR IBE	Alessandro Zaldei	

Tall towers/total column GHG concentration measurements

A total column site has been operational since April 2024 just outside the city of Bologna (Lat. 44.52361, Lon. 11.33833, measurement height 20 m), equipped with a EM27/SUN Fourier Transform Interferometer (XCO2, XCH4, XCO). An IFS HR125 Bruker FTIR is also available and will be activated in 2026 at a nearby ground-level location in the CNR campus (same coordinates). The site is operated by CNR-ISAC. At the same site O_3, NO_x and eqBC are monitored.

Roof or street level concentration measurements

Bologna: a roof top observation site, co-located with the total column station, has been operational with a CRDS sensor since April 2024, sampling at 20m from the ground (contact: Paolo Cristofanelli).

Prato: an environmental monitoring network is active since 2021in the city of Prato, currently composed of 38 fixed urban stations integrating in a single, compact and low-cost device, CO_2 concentration, other air quality monitoring sensors (CO, NO_2, O_3, PM10 and PM2.5) as well as main environmental parameters. The network is managed by the CNR-IBE (contact: Tommaso Giordano).

Specific and detailed GHG inventory activities

The regional inventory of atmospheric emission sources (IRSE) represents one of the tools used by the Tuscany region to monitor air quality and greenhouse gases emissions. In particular, the emission inventory is for defining the related Protection and Remediation Plans (Regional Air Quality Plan (PRQA). The Regional Inventory of Emission Sources in Ambient Air IRSE reports for the years 1995 and the updates for the years 2000, 2003, 2007, 2010, 2017 and 2019. The most recent inventory, conducted in full for the year 2019, focuses on so-called “key sources” – those contributing most significantly to emissions. These include traffic, domestic heating, fires, solvent use, natural sources, and forestry, all of which were thoroughly assessed. Further information on the data can be requested from ARPAT by filling out the web form “IRSE data request”. Contact person: Lorenzo Brilli (CNR-IBE).

Urban green areas GHG monitoring activities

An eddy covariance station is operational in the Capodimonte park that can be considered a urban park of the Naples city. The station, registered in FLUXNET with the code IT-PCm, is also a candidate ICOS Associated station and it is managed by CNR-IRET (contact: Terenzio Zenone).

Relevant links

Sassari tower webpage in the ICOS Carbon Portal:
https://meta.icos-cp.eu/resources/stations/ES_IT-Sas

Florence tower webpage in the ICOS Carbon Portal:
https://meta.icos-cp.eu/resources/stations/ES_IT-OXm

Naples tower page on European fluxes database:
https://www.europe-fluxdata.eu/home/site-details?id=IT-SMc

Pesaro tower page on European fluxes database:
https://www.europe-fluxdata.eu/home/site-details?id=IT-OVr

National Level Experts

Vincenzo Magliulo CNR ISAFOM (urban GHG eddy covariance)

Paolo Cristofanelli CNR- ISAC (urban GHG and air quality atmospheric measurements)

Elisa Castelli CNR – ISAC (total column GHG measurements: ground-based and satellites)

Beniamino Gioli CNR-IBE (urban GHG eddy covariance)

Alessandro Zaldei CNR IBE (low-cost dense sensor networks)

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Dario Papale Università degli Studi della Tuscia (eddy covariance, network management)

Gabriele Guidolotti CNR IRET (urban green area, eddy covariance)

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Norway

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Ongoing urban GHG monitoring activities

NILU conducted the URban Greenhouse gas Emissions assessment through inverse modeling (URGE) project, a pilot study in the Oslo area focussed on emission fluxes of anthropogenic CO_2. It included comprehensive uncertainty estimates based on inverse transport modelling techniques, produced city-level emission inventories and assessed the optimized use of measurements (network design). NILU was part of the CHE (Carbon Human Emissions) project aiming at separating human impact from the natural carbon cycle that included the assessment of satellite data based flux estimations. Connected activities include the assessment of emissions from the oil and gas industry, particularly methane, based on Lagrangian (forward and backward) atmospheric transport and inverse modelling.

Relevant links

CHE project deliverable on sampling strategy :
https://www.che-project.eu/node/243

National Level Experts

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Ongoing urban GHG monitoring activities

Roof or street level concentration measurements

A GHG monitoring network in the Metropolitan Area of Barcelona (AMB) in under implementation, consisting of PICARRO G-2301 gas analysers to measure the concentrations of CO_2, CH_4, and H_2O. The network is designed to include the various land uses of the AMB to capture the heterogeneity of the city. Currently, four stations are up and running: Collserola forest (Observatori Fabra, since 2022), the urban coastline (Instituto de Ciencias del Mar- CSIC), an urban park amidst highly built area (UPC-IDAEA, since 2021), and close to densely-used highway (ICTA-UAB, since 2020). All the sites submit data to the ICOS Carbon portal.

Specific and detailed GHG inventory activities

The Earth Sciences Department of the Barcelona Supercomputing Center (BSC) maintains and develops the High-Elective Resolution Modelling Emission System (HERMES; Guevara et al., 2020 doi: 10.5194/gmd-13-873-2020), which provides bottom-up emission estimates of air pollutants and GHG for Spain to support modelling efforts. The BSC and the State Meteorological Agency of Spain (AEMET) are currently co-coordinating with the RESPIRE-CLIMATE national project, which has the goal of developing a national monitoring system for GHG emissions, specifically for CO_2 and CH_4, combining information from very detailed bottom-up emissions with observations derived from ground-based instruments. The RESPIRE-CLIMATE project has recently been endorsed by the WMO Integrated Global Greenhouse Gas Information System (IG3IS), which will increase the visibility and international recognition of the project.

COCCON-Spain

The national network COCCON-Spain aims to address the existing gap in atmospheric greenhouse gas observations in Spain by implementing a network of stations for GHG measurements at a national scale. This initiative, co-ordinated by AEMET, will initially consist of twelve stations for measuring key GHG. The measurement locations are selected based on their placement in major urban/industrial greenhouse gas emission zones as well as background environments, under different surface reflectance conditions for possible satellite measurement validation. COCCON-Spain also includes monitoring greenhouse gas emission flows (not just atmospheric concentrations) in key areas, such as the metropolitan areas of Madrid and Barcelona. Additional instrumentation is planned to be installed in these cities, outlining the metropolitan areas for estimating their corresponding emissions. COCCON-Spain will have hybrid stations combined with the national node of the ICOS Research Infrastructure.

Relevant links

Roof and street Barcelona data access on the ICOS Cities portal:
https://citydata.icos-cp.eu/portal/#%7B%22filterKeywords%22%3A%5B%22Barcelona%22%5D%7D

Catalunya GHG inventories:
https://canviclimatic.gencat.cat/en/canvi/inventaris/index.html

GHG Monitoring network of Barcelona:
https://urbag.eu/ghg/

RESPIRE-CLIMATE national project:
https://respire.bsc.es

COCCON-Spain:
https://izana.aemet.es/coccon-spain-toward-an-integrated-greenhouse-gas-observation-system-in-spain/

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Paula Castesana Barcelona Supercomputing Center (emissions modelling and inventory)

Vanesa Monteiro Autonomy University of Barcelona (atmospheric observations of greenhouse gases, GHG monitoring networks).

Edgar Lorenzo Sáez Universitat Politècnica de València (urban mobility emissions)

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Ongoing urban GHG monitoring activities

Eddy covariance urban observations

The Natrium Atmospheric and Climate Measurement site in Gothenburg (Lat. 57.68622, Lon. 11.96077) is under finalization and starting end of 2025 will measure CO_2, H_2O, CH_4 and N_2O fluxes using a MIRO MGA-10 gas analyser. The site is co-located with air pollution measurements station for NO, NO_2, SO_2, O_3 and NH_3.

Relevant links

Nartium meteo data:
https://www.gu.se/en/earth-sciences/weather-station

National Level Experts

Fredrik Lindberg University of Gothenburg (urban climatology, GIS, urban green area, processes influencing the local climate in urban areas)

Natascha Kljun Lund University (flux footprint modelling, source attribution, convolution with emission inventory, eddy covariance)

Cheng Wu University of Gothenburg (flux measurements, atmospheric processing)

Epameinondas Tsiligiannis University of Gothenburg (sampling system for GHG flux measurements)

Switzerland

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Ongoing urban GHG monitoring activities

Eddy covariance urban observations

There are three operational eddy covariance sites in Switzerland, two in Basel and one in Zurich, all registered in FLUXNET. The CH-BaK station is labelled as Associated in ICOS while the CH-Har has been constructed in the context of the ICOS Cities project and in the period August 2022 – March 2023 measured also fluxes of CH_4 and N_2O. Details are in Table 7.

Table 7: Characteristics of the urban eddy covariance sites in Switzerland

City	Site	Coordinates	GHG	Height	Period	Institution in charge	Reference Contact
Basel	Aeschenplatz Site code: CH-BaA	Lat: 47.55123 Lon: 7.5956	CO_2	41 m	Start: 2009	University of Basel	Stavros Stagakis
Basel	Klingelbergstrasse Site code: CH-BaK	Lat: 47.56173 Lon: 7.58049	CO_2	39 m	Start: 2004	University of Basel	Stavros Stagakis
Zurich	Hardau Site code: CH-Har	Lat: 47.38139, Lon: 8.51008	CO_2	112 m	Start: 2022	University of Basel	Stavros Stagakis

Roof or street level concentration measurements

As a component of the ICOS Cities project, a “mid-cost” NDIR (nondispersive infrared) CO_2 sensor network was deployed across the city of Zurich (Switzerland), known as ZiCOS-M. The network was operational between July 2022 and July 2024 and consisted of 26 monitoring sites, 21 of which were located in or around the city of Zurich, with 5 sites outside the urban area. This network is currently being redesigned and reduced to about 12 sites. Furthermore, about120 street level low-cost (Senseair LP8) CO_2 sensors have been operational in the period 2022–2025. More details and updates on the GHG measurement strategy in Switzerland are provided in the Swiss GCOS implementation plan, which is available online. Contact: Lukas Emmenegger.

Specific and detailed GHG inventory activities

An emission inventory MapLuft of the city of Zurich covering 9 air pollutants and the 3 greenhouse gases CO_2, CH_4, N_2O is freely available on a 100 m raster. A much more detailed GIS version of the inventory with point, line and area sources is also available but not publicly accessible due to privacy issues. For regions outside the city boundaries, an inventory for the whole Switzerland is available at 100 m resolution. Contact: Gian-Marco Alt.

Urban green areas GHG monitoring activities

Two cities have CO_2 exchange monitoring activity in urban green areas, all under the responsibility of University of Basel (contact: Stavros Stagakis). The measurements are not any more operational. Zurich measurements were conducted in the context of the ICOS Cities project. Details are reported in Table 8.

Table 8: Characteristics of the urban green monitoring sites in Switzerland

City	Green Area Type	Co-ordinates	Method	GHG	Frequency	Period
Basel	Urban forest	Lat: 47.5745 Lon: 7.6193	Eddy covariance	CO_2	Continuous	2021
Basel	Urban parks (2) and forest (1)	Lat: 47.5656 Lon: 7.5707	Soil chambers (dark)	CO_2	Monthly	2020–2021
Zurich	Urban parks (4)	Lat: 47.3794 Lon: 8.5131	Soil chambers (dark)	CO_2	Biweekly	2022–2024

Others

There are projects going on about soil C sequestration in urban soils and gardens, tree transpiration and growth, remote sensing of urban biosphere, and urban climate across different cities in Switzerland, carried out by various persons and institutions. University of Basel, ETH Zurich and Empa collaborate with University of Zurich to study urban biosphere carbon, energy and water fluxes in Basel and Zurich in a project called UrbaNature.

Relevant links

Basel Klingelbergstrasse tower webpage in the ICOS Carbon Portal:
https://meta.icos-cp.eu/resources/stations/ES_CH-BaK

Zurich Hardau tower webpage in the ICOS Cities Portal:
https://citymeta.icos-cp.eu/resources/stations/ES_CH-Har

Basel Aeschenplatz tower page on European fluxes database:
https://www.europe-fluxdata.eu/home/site-details?id=CH-BaA

Swiss GCOS implementation plan:
https://www.meteoswiss.admin.ch/about-us/research-and-cooperation/programmes-gaw-ch-and-gcos-ch/gaw-ch-and-gcos-ch-reports.html

Swiss-wide network of street sensors:
https://www.decentlab.com/swissco2live

Emission inventory of the city of Zurich:
https://www.stadt-zuerich.ch/geodaten/download/Emissionskataster_Luftschadstoffe_und_Treibhausgase

COST Action CA23148 European Network for the Integrative Approach of Urban Forestry (INTUF):
https://www.cost.eu/actions/CA23148/

UrbaNature project:
https://duw.unibas.ch/en/research-groups/atmospheric-sciences/our-research/urbanature/

Waldlabor project: https://www.waldlabor.ch/

National Level Experts

Lukas Emmenegger EMPA (measurements and modeling of air quality and greenhouse gases)

Dominik Brunner EMPA (measurements and modeling of air quality and greenhouse gases)

Nina Buchmann ETHZ (eddy covariance, tree ecophysiology)

Stavros Stagakis University of Basel (eddy covariance)

Christian Feigenwinter University of Basel (eddy covariance, urban climate)

Corinne Hörger UGZ (air quality measurements)

Gian-Marco Alt Amt für Abfall, Wasser, Energie und Luft, Zürich (Inventory)

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Ongoing urban GHG monitoring activities

Eddy covariance urban observations

Amsterdam: a flux tower (Lat. 52.36655, Lon. 4.89291) 40m above street level that records surface fluxes, i.e. the shortwave and longwave radiation, as well as energy balance components sensible heat flux, latent heat flux, friction velocity. In addition, turbulent fluxes of CO_2 (and methane for 2018–2020) are recorded since June 2018. The site is registered in FLUXNET with the code NL-Amd. Contact: Gert-Jan Steeneveld.

Enschede: an Eddy Covariance flux tower (Lat. 52.21762, Lon. 6.89088) is operational since July 2015, 10 meters on top of a 46 meter high tower-flat, with flux observations at 5 and at 10 meters above the rooftop. The EC set-up records surface fluxes (shortwave and longwave incoming and outgoing radiation, sensible heat flux, latent heat flux, friction velocity) in addition to the turbulent fluxes of CO_2. Contact: Wim Timmermans.

Roof or street level concentration measurements

Amsterdam: The Amsterdam Atmospheric Monitoring Supersite (co-funded by the AMS-Institute) consists of a network of 24 weather stations measuring temperature, humidity, wind speed in street canyons for the assessment of the urban heat island. Further the AAMS measures precipitation and black globe temperature in 5 of the 24 sites, and indoor temperature, humidity, sound, and CO_2 concentrations in 100 households. Contact: Gert Jan Steeneveld.

Rotterdam: The Ruisdael observatory maintains three city background stations around Rotterdam, all equipped with a Picarro gas analyser for CO_2, CH_4 and CO. Two stations are under the responsibility of TNO (Contact: Hugo Denier van der Gon) and one (Slufter) under RUG (Contact: Bert Scheeren). All stations are co-located with air quality monitoring. Details are provided in Table 9.

Table 9: Characteristics of the Rotterdam network

City	Station name	Coordinates	Sampling height (m)	Period
Rotterdam	Westmaas	Lat. 51.78667, Lon. 4.45054	10	Since 2017
Rotterdam	Zweth	Lat. 51.96439, Lon. 4.39465	10	Since 2017
Rotterdam	Slufter station	Lat. 51.93351, Lon. 3.99984	10	Since 07/2022

Enschede: The Enschede Earth Observation Site (EEOS, co-funded by Enschede municipality and housing association Domijn) consists of a network of 10 weather stations measuring air temperature, humidity, air pressure and incoming solar radiation in street canyons for the assessment of the urban heat island, operational since March 2024. Contact: Wim Timmermans.

Others

Enschede: In addition to the EC system integral sensible and latent heat fluxes over the city center are obtained through a combined Microwave and

XLAS scintillometer system, with Transmitter (Lat. 52.21837, Lon, 6.92546, 29 m above ground) and Receiver (Lat. 52.23756, Lon. 6.86067, 52 m above ground) positioned 4950 m apart from each other. Further the EEOS measures indoor temperature, humidity, sound, and CO_2 concentrations in 13 households since June 2024 with another 20 households scheduled for June 2025. Contact: Wim Timmermans.

Relevant links

Amsterdam tower page on European fluxes database:
https://www.europe-fluxdata.eu/home/site-details?id=NL-Ams

Amsterdam observatory:
https://ruisdael-observatory.nl/amsterdam-atmospheric-monitoring-supersite/

Rotterdam observatory:
https://ruisdael-observatory.nl/rotterdam/

Enschede observatory:
https://www.itc.nl/about-itc/scientific-departments/water-resources/en-schede/#purpose-of-observation

National Level Experts

Herman Russchenberg Delft University of Technology (atmospheric remote sensing)

H.A.C. (Hugo) Denier van der Gon TNO Utrecht (emissions of greenhouse gases and air pollutants)

Gert-Jan Steeneveld Wageningen University & Research (urban meteorology)

Sander Houweling Vrije Universiteit Amsterdam (modelling of greenhouse gases)

Arjan Hensen TNO EMSA Petten (mobile measurements of greenhouse gases and air pollutants)

Wim Timmermans University of Twente Enschede (eddy covariance, remote sensing of hydro-meteorological processes)

Bert Scheeren University of Groningen (measurements of greenhouse gases)

United Kingdom

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Ongoing urban GHG monitoring activities

Eddy covariance urban observations

There are three urban eddy covariance towers in the United Kingdom, one active and two which are currently inactive where the reactivation can be evaluated. The towers use a variety of gas analysers and sonic anemometers and collect meteorological data in parallel to the fluxes. Details are provided in Table 10.

Table 10: Characteristics of the urban eddy covariance sites in United Kingdom

City	Site	Coordi-nates	GHG	Height	Period	Institu-tion in charge	Reference Contact	Co-location
London	BT Tower Site code: UK-LBT	Lat: 51.52142 Lon: -0.13884	CO_2 CH_4 N_2O	190	Start: 2011	UKCEH, Univ. of York, Univ. of Reading	Eiko Nemitz	CO, NO, NO_2, O_3, C2H6 (fluxes) VOCs, BC, aerosol chemical components (campaign fluxes), GHG isotopes (concentra-tions)
London	King's Col-lege London (KCL)	Lat: 51.511667 Lon: -0.11667	CO_2	49	2008–2013	Univ. of Reading	Sue Grim-mond	
Edin-burgh	Nelson Mon-ument	Lat: 55.95472 Lon: -3.1825	CO_2 CH_4 N_2O	35	2000–2005 (campaigns)	UKCEH	Eiko Nemitz	VOCs, aero-sol chemical components, particle num-ber

Tall towers/total column GHG concentration measurements

There are two networks operated in the United Kingdom, all based on the use of EM27/SUN solar absorption spectrometers to constrain urban CO_2 emissions.

UK national network (GEMINI-UK): it consists of four already operational stations in Birmingham (Lat. 52.45, Lon. -1.93, 150 m asl) operated by University of Birmingham, London (Lat. 51.52, Lon. -0.13, 68 m asl) operated by University College London, Cardiff (Lat. 51.49, Lon. -3.18, 31 m asl) operated by Cardiff University and Newcastle (Lat. 54.98, Lon. -1.62, 55 m asl) operated by Northumbria University. They are all monitoring total dry air column concentration of CO_2, CH_4 and CO. Three additional stations are planned in Aberdeen (Lat. 57.17, Lon. -2.10, 33 m asl) operated by University of Aberdeen, Glasgow (Lat. 55.87, Lon. -4.29, 42 m asl) operated by University of Glasgow and Belfast (Lat. 54.58, Lon. -5.94, 73 m asl) operated by Queen's University Belfast. Contacts: Neil Humpage and Paul Palmer.

Edinburgh: it is composed of five monitoring stations in the city of Edinburgh, all monitoring CO_2, CH_4 and CO under the responsibility of the University of Edinburgh (contacts: Will Morrison and Paul Palmer). Details of the stations are provided in Table 11.

Table 11: Characteristics of the measurement stations in the Edinburgh network of total column measurements

City	Site code	Height agl (m)	Coordinates	Period
Edinburgh	NARO	0.5	Lat: 55.91316 Lon: -3.32543	Since 2025-04
Edinburgh	JCMB	21	Lat: 55.92161 Lon: -3.1744	Since 2024-10
Edinburgh	CHRY	28	Lat: 55.94413 Lon: -3.19077	Since 2025-05
Edinburgh	LDST	37	Lat: 55.98273 Lon: -3.17563	Since 2025-06
Edinburgh	QMUM	5	Lat: 55.9305 Lon: -3.0724	Since 2025-06

Roof or street level concentration measurements

Urban NERC Air Quality Supersites: three urban supersites with measurements of CO_2, CH_4 and CO by ABB-LGR GLA331 MCEA1 together with a wide range of other air pollutants, including NO_x, SO_2, NH_3, VOCs, aerosol size distribution, aerosol chemical composition by ACSM and XACT. The three sites are located in London (LAQS, Lat. 51.449, Lon. -0.0374) operated by Imperial College London, Birmingham (BAQS, Lat. 52.4555, Lon. -1.9290) operated by Birmingham University and Manchester (MAQS Lat. 53.4566 Lon. -2.2142) operated by Manchester University. Contact: Grant Forster.

Egham: monitoring station on the Queen's Building, Royal Holloway Campus (Lat. 51.4267, Lon. -0.5611E, 15 m above ground level), measuring CH_4 (since October 1995) and CO_2 (since Sept 1999) on WMO scales using a Picarro G2301 gas analyser. Contact: Rebecca Fisher and Dave Lowry.

Bristol: monitoring station in the Chemistry Building of Bristol University (Lat. 51.45634, Lon. -2.60098), monitoring CO_2, CH_4, N_2O, SF_6 and H_2. Contact: Kieran Stanley.

Specific and detailed GHG inventory activities

In addition to the UK National Atmospheric Emissions Inventory, which covers the entire UK and the UK's 4 nations (England, Scotland, Wales, Northern Ireland) separately, The Greater London Authority (GLA) compiles and publishes the London Energy and Greenhouse Gas Inventory (LEGGI), which breaks down emissions by London Boroughs.

Relevant links

London BT tower page on European fluxes database:
https://www.europe-fluxdata.eu/home/site-details?id=UK-LBT

London Energy and Greenhouse Gas Inventory (LEGGI):
https://data.london.gov.uk/dataset/leggi/

National Level Experts

Eiko Nemitz UK Centre for Ecology & Hydrology (eddy covariance flux measurements)

Paul Palmer University of Edinburgh and National Centre for Earth Observations (remote sensing and inverse modelling)

Peter Brown Ricardo (GHG lead of the UK National Atmospheric Emissions Inventory)

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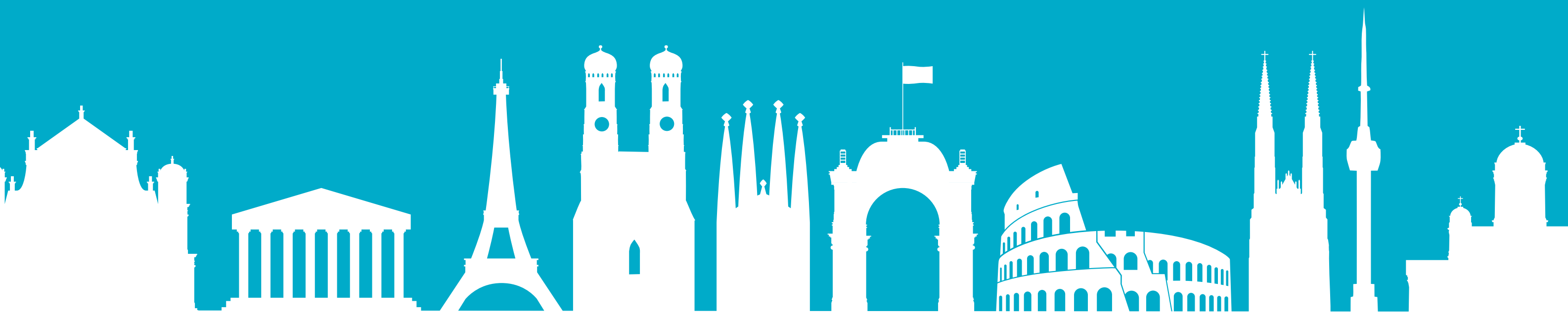

ICOS | Cities

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