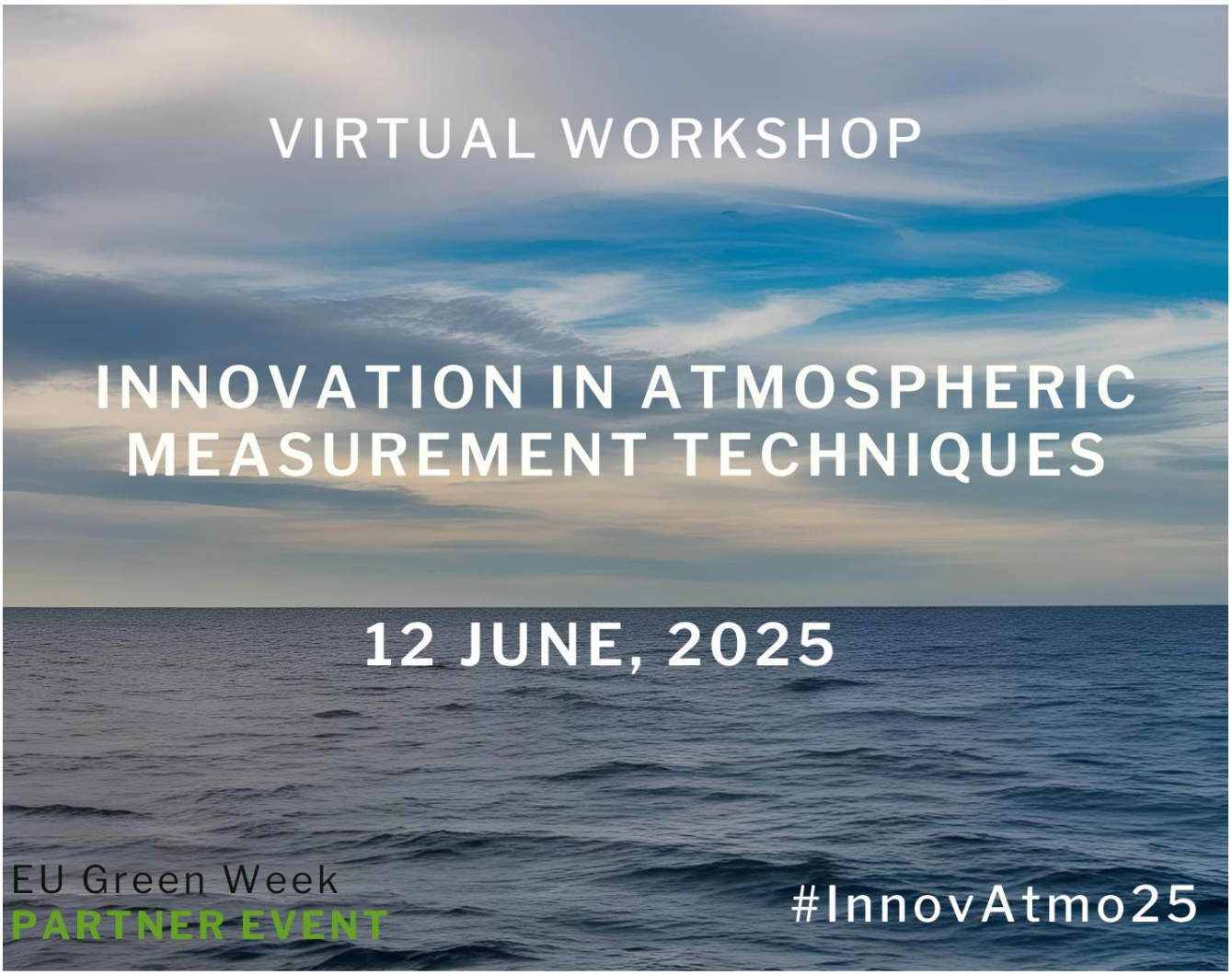

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Welcome to the 5th Annual Innovation in Atmospheric Measurement Techniques Workshop

Dear Colleagues,
Dear Friends,

It is with great pleasure that we welcome you for a fifth consecutive year to the Innovation in Atmospheric Measurement Techniques Workshop.

Firstly, we would like to thank all of you for your participation at the workshop. In this book of abstracts, we are delighted to share with you an exciting program, reporting the main innovations in the field of atmospheric sciences, with the participation of 37 presentations discussing recent relevant advances in the field.

All this has been possible thanks to your contribution.

We do hope that you enjoy your attendance at the Workshop!

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Sauvage Stephane, IMT Nord Europe, France

Zahn Andreas, KIT - Karlsruher Institut für Technologie, Germany

AGENDA

All times are in CEST (Central Europe Standard Time)

08:00 - Opening Session	
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Workshop introduction and opening	**Jean Sciare** The Cyprus Institute
08:15 – VOCs (Chair: Stephane Sauvage)	
Simplified VOC monitoring with a novel VUV PTR Ionization Reactor and Automated Instrument performance checks	**Veronika Pospisilova** TOFWERK, Switzerland
VOCENTINEL - A novel solution for automated real-time monitoring of atmospheric VOCs	**Markus Leiminger** IONICON Analytik GmbH, Austria
Long-term stability & field applicability of a portable paraformaldehyde generator using a temperature-controlled permeation tube system	**Audrey Grandjean** Chromatotec, France
Advancements in the detection and monitoring of VOCs	**Jan Wozniak** PICARRO B.V., Poland
Validation of two on-line instruments for OVOC monitoring, a formaldehyde analyser and an on-line AUTO-GC-FID system: Laboratory validation and field validation at the Puy de Dôme	**Damien Bazin** Chromatotec, France
Multi-Pressure Chemical Ionisation for seamless detection from VOCs to HOMs in a single instrument	**H.J. Jost** Karsa, Finland
Method development for analysis of condensing vapors using thermal desorption mass spectrometry	**Mihai Ciobanu** The Cyprus Institute, Cyprus
09:25 – Greenhouse & Reactive Gases (Chair: Sindu Raj Parampil)	
A dual-platform approach for quantifying methane emissions at site level	**Roubina Papaconstantinou** The Cyprus Institute, Cyprus
A new all-in-one instrument for air quality and greenhouse gas monitoring	**Jonas Bruckhuisen** MIRO Analytical, Switzerland
Ammonia monitoring: meeting new EU Air Quality directive with Picarro pi2103 Analyzer and INI Permacal system	**Magdalena Hofmann** Picarro B.V., Netherland
QUALARIA: an AI system to monitor and predict metropolitan area of São Paulo street-level air quality	**Victória Maria Lopes Peli** MeteoIA Data Science, Brazil
10:05 **Coffee Break**	
10:15 – International Initiatives (Chair: Niku Kivekäs)	
Enabling climate risk research through research infrastructure services	**Päivi Haapanala** Luke, Finland
The DUST doctoral network	**Franco Marenco** The Cyprus Institute, Cyprus
CAELOSCOPE: added-value atmospheric products based on Sentinel-5p/TROPOMI measurements in Terrascope	**Jeroen van Gent** BIRA-IASB, Belgium
10:45 - Aerosol in-situ measurement techniques (Chair: Jean Sciare)	
Monitoring ambient ultrafine particles with modified PN-PTI instruments	**Hüwe Florian** nanoDUST GmbH,

	Germany
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Characterization of the aerosol infrared monitor for autonomous aerosol chemical composition measurements.	**Andrea Baccarini** Aerospec SA, Switzerland
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The measurement of the total number concentration of aerosols without a working fluid	**Patrick Weber** FZ Juelich, ICE-3, Germany
Implementation of real-time source apportionment approaches using the ACSM-Xact-Aethalometer (AXA) set-up with Sofi RT: the Athens case study	**Olga Zografou** NCSR Demokritos, Greece
Microwave induced plasma time-of-flight mass spectrometer (MIPToF): a new tool for real-time quantitative analysis of metals in air	**Alexander Gundlach-Graham** TOFWERK AG, Switzerland
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Can UAV-based and lidar synergistic observations improve mineral dust quantification?	**Alkistis Papetta** The Cyprus Institute, Cyprus
Trinocular all sky imaging network for cloud and solar applications	**Max Aragon** Wematics FlexCo / Mines Paris PSL, France
Dual field-of-view depolarization method using the POLLY-xt Raman lidar of CARO Limassol national facility: parameterization of aerosol-cloud interactions	**Konstantinos Chrysostomou** Eratosthenes CoE, Cyprus
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AEROTAPE: A novel technology for real time quantification and characterization of dust and its sources	**Eleni Kolintziki** The Cyprus Institute, Cyprus
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Fast and fine-scale hourly air quality mapping using hybrid dispersion and KNN approaches	**Lucas Bouche** Atmo Hauts-de-France, France
Dual cavity dual comb interferometry with incoherent light	**Jarni Braal** Univ. College Cork, Ireland
NH_3 sensors and UAVs: a comprehensive assessment of ground-based and aerial nh3 measurements at a poultry farm in northern England	**Clare Pearson** UKCEH, UK

Leveraging advanced sensor networks and machine learning for real-time air quality monitoring: a fusion of innovation and policy impact	**Linchun yu** News, China
Hourly $PM_{2.5}$ and PM_{10} matter concentrations prediction in Pune, India, using Aeronet aerosol optical depth (AOD) and meteorological data	**Ranjitkumar Solanki** National Institute of Technology, Surat, India
Assessing urban land use dynamics and air quality interaction in Ahmedabad using Google Earth engine and earth observation data	**Mahi Patel** Silver Oak University, India
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13:30	**End of Workshop**

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ORAL PRESENTATIONS

Simplified VOC Monitoring with a novel VUV PTR ionization reactor and automated instrument performance checks

Veronika Pospisilova
TOFWERK

Proton Transfer Reaction Mass Spectrometry (PTR-MS) is a powerful technique for real-time monitoring of volatile organic compounds (VOCs), offering broad chemical coverage and high temporal resolution essential for air quality studies. However, its operation and the complexity and size of the resulting datasets pose significant challenges, often requiring extensive time and expertise for data handling.

We introduce the AirTox Monitor, a next-generation PTR-based instrument featuring a novel vacuum ultraviolet (VUV) ionization source coupled to a time-of-flight mass spectrometer with a mass resolving power of up to 3500. This innovative ion source significantly enhances measurement stability and enables rapid switching between reagent ions (e.g., H_3O^+ and O_2^+), expanding the range of detectable compounds. The mass resolution allows for precise peak assignment and clear distinction between isobaric species. We present a brief characterization of the instrument, including a comparison between postprocessed data and results directly exported via the integrated TRACK software. Furthermore, we introduce the system's automated workflows, such as background subtraction, calibration, and online mass calibration, that traditionally require manual postprocessing. These automated steps ensure high data quality while significantly reducing the time and expertise needed for analysis.

We demonstrate an instrument specifically designed for routine VOC monitoring, enabling high data quality without the need for postprocessing. Its automated operation and robust performance make it well-suited for deployment in monitoring networks, mobile platforms, and highly challenging industrial environments.

Authors
Jorga, S., Yatsyna, V., Lopez-Hilfiker, F. and Pospisilova V.

VOCENTINEL - a novel solution for automated real-time monitoring of atmospheric VOCs

Markus Leiminger
IONICON Analytik GmbH

Volatile Organic Compounds (VOCs), emitted by both biogenic and anthropogenic sources, play a crucial role in atmospheric processes like SOA formation and significantly affect air quality. Despite their importance, routine monitoring of VOCs poses challenges due to limitations in time-resolution, labor intensity, long-term stability, and compound-specific identification capabilities. Proton-transfer-reaction mass-spectrometry (PTR-MS) is widely used for detecting VOCs with high time-resolution and stability. However, as a soft chemical ionization method, it primarily identifies chemical compositions rather than specific compounds. Acquiring additional chemical information through alternative ionization methods remains labor-intensive, making it impractical for long-term VOC monitoring.

Here, we introduce an innovative solution to streamline these time-consuming tasks with the push of a button for key atmospheric VOCs. This new VOC monitor “VOCentinel” leverages Selective-Reagent-Ion (SRI) PTR-MS combined with Automatic Measurement and Evaluation (AME), integrating recent technological advancements in PTR-MS, such as fast switching of reagent ions, extended volatility range (EVR) surface treatment, active humidity control, and automatic pattern matching, alongside IONICON's extensive experience in robust industrial monitoring. Essentially, five ionization modes sequentially ionize specific atmospheric VOCs within one minute, and the resulting mass spectra are immediately analyzed for chemical composition using a pattern matching algorithm. Automatic quality control ensures optimal instrument

performance.

We will present a comprehensive characterization of the VOCentinel, emphasizing its long-term stability, and share initial results from VOC measurements in Innsbruck, Austria. Using isoprene as an example - an important biogenically emitted VOC often subject to chemical interferences in PTR-MS measurements - we demonstrate the system's ability to automatically measure, evaluate, and correctly quantify compounds with isobaric and/or isomeric interferences.

Authors
Leiminger, M., Müller, M., Graus, M., Reinecke, T., Winkler, K., Herburger, A., and Herbig, J.

Long-term stability and field applicability of a portable paraformaldehyde generator using a temperature-controlled permeation tube system

Audrey Grandjean
Chromatotec

Formaldehyde is a significant indoor air pollutant, and precise measurement of its airborne concentration is crucial for effective monitoring and risk assessment. The accuracy of many formaldehyde detection methods relies on the quality of the calibration system used. However, existing calibration techniques often suffer from drawbacks such as limited stability, narrow concentration ranges, and poor suitability for field use due to their bulkiness or high gas consumption. In response to these challenges, we developed and evaluated a compact (<3 kg), portable formaldehyde calibration device that uses a paraformaldehyde permeation tube in a custom-built, temperature-controlled system. The generator operates at low nitrogen flow rates (30–100 mL/min), enabling use with small (<2 kg) portable gas cylinders. It successfully produces formaldehyde concentrations ranging from 8.3 to 464 µg/m³, and up to nearly 50,000 µg/m³ using a high-emission permeation tube—demonstrating remarkable versatility. Permeation is a commonly used technique for standard gas generation. But because permeation tube certification typically relies on mass loss measurements and paraformaldehyde is hydrophilic, accounting for water content is essential for accurate emission rate determination of paraformaldehyde permeation tubes. Very few studies have investigated long-term performance of such tubes. In this work, we present a comprehensive one-year stability study of a low-emission paraformaldehyde permeation tube under a range of controlled temperatures. Emission rates remained within ±5% of the average value across all tested temperatures, confirming excellent long-term stability.

Our results extend current knowledge by quantifying the emission behavior in both low (<15 ng/min) and high (170–1500 ng/min) emission ranges. Notably, we confirmed a simple and robust relationship between temperature and emission rate, following the Antoine equation form (ln ERT = f(1/T)), which holds across two different permeation tubes and membrane types. This predictable temperature-emission correlation allows extrapolation of concentrations beyond the experimentally measured range.

A key innovation of our system lies in its extremely low gas consumption combined with rapid stabilization of generated formaldehyde concentrations—typically within 2 hours. These features, more than the low device weight, define the true portability of the generator. Through real-time monitoring, we demonstrated that dynamic generation at low flow rates can still achieve fast equilibrium, facilitating immediate on-site calibration without the need for external dilution systems or bulky gas cylinders.This device uniquely combines three essential advantages: (i) operation at low gas flow rates, (ii) rapid stabilization of generated concentration, and (iii) high stability over a one-year period. These attributes make it particularly suitable for field applications where compactness, reliability, and ease of use are paramount.

Authors
Grandjean, A., Becker, A., Kustner, C., Wolf, M., Sutter, C., Severac, R., Amiet, J.P., Bazin, D. and Le Calvé, S.

Advancements in the detection and monitoring of volatile organic compounds

Jan Wozniak
PICARRO B.V.

In recent years, there has been increasing interest in monitoring Volatile Organic Compounds (VOCs) in the ambient atmosphere. VOCs in the atmosphere can lead to dangerous levels of ozone, impacting human health and degrading ecosystems. Further, many VOCs are themselves considered highly toxic at parts-per-billion (ppb) and even parts-per-trillion (ppt) levels, potentially causing respiratory problems and contributing to elevated cancer risk in affected populations. More recently, the EPA has proposed more stringent fence line monitoring requirements for six critical air toxics: benzene, ethylene oxide, chloroprene, 1,3-butadiene, vinyl chloride, and ethylene dichloride.

In response to this growing need for high-performance, field-deployable VOC analyzers, Picarro has developed Broad Band Cavity Ring-Down Spectroscopy (BB-CRDS), a laser-based technology that is capable of quantifying a wide variety of VOCs in real time (< 5 seconds) at ppb and ppt levels. This analyzer is capable of simultaneously measuring ten or more compounds, selected from our growing library of nearly 500 characterized species, which includes both VOCs and common inorganics like H2O, CO2, CH4, N2O, and NH3. It is simple to operate, and it can be deployed in harsh environments with little to no consumables. We demonstrate the design and performance of these analyzers, presenting substantial advancements for air quality management and regulatory compliance.

Authors
Woźniak, J., Hofmann, M., Chedgy, R., Skog, K., Lucic, G., Arata, C., Hemenway, T., and Rella, C.

Validation of two on-line instruments for OVOC monitoring, a formaldehyde analyzer and an on-line AUTO-GC-FID system: laboratory validation and field validation at the Puy De Dôme research station

Damien Bazin
Chromatotec

The European Union released a list of recommended molecules to measure to analyze any trend in ozone precursors. This list is part of the new amendment to ANNEX VII section 3 of European Directive (EU) 2024/2881 and includes 47 Volatile Organic Compounds (VOCs). Accurate VOC measurements help improve the understanding of air pollution drivers and enable more effective and targeted mitigation strategies. Automatic gas chromatograph equipped with flame ionization detector (auto-GC-FID) is the reference method for the continuous monitoring of non-oxygenated VOCs—such as alkanes, alkenes, alkynes, terpenes, and aromatics (39 molecules from the list). In contrast, continuous monitoring of oxygenated VOCs (OVOCs), including aldehydes, ketones, and alcohols (8 molecules from the list), remains challenging due to analytical limitations.

These reactive species, originating from both primary emissions and secondary formation via VOC oxidation, are critical to the understanding of photochemical processes. Conventional GC-FID can suffer from insufficient sensitivity and specificity, especially for the monitoring of light OVOCs due to interference with light alkanes and alkynes. Standard methods such as ISO 16000-3, using DNPH cartridges and HPLC-UV, provide high sensitivity for aldehydes and ketones but are labor-intensive and not suited for continuous measurements. To address these limitations, two systems were developed. The first one is an automated GC-FID system for the continuous monitoring of methanol, acetone, and ethanol, employing a three-column configuration with a backflush mechanism for effective compound separation. The second one is an automated formaldehyde analyzer based on the Hantzsch fluorimetric method. Both systems were validated in controlled laboratory conditions, before being deployed at the Puy de Dôme research station (1465 m) from July to September 2024 for field validation in challenging conditions. They provided the first continuous measurements of methanol and acetone at this high-altitude site. The observed concentrations ranged from 0.07 to 9.45 ppb for formaldehyde, 0 to 4.0 ppb for acetone, 0 to 13.11 ppb for methanol, and 0 to 2.94 ppb for ethanol. In addition to the ambient air measurements, the internal calibration devices confirmed the robustness of the analyzers for long-term measurements. It ensured data quality and confirmed both systems' applicability for real-time,

ultra-trace OVOC monitoring in ambient air.

Authors
Bazin, D., Grandjean, A., Mollard, F., Salameh, T., Le Calvé, S., Amiet, J.P. and Borbon, A.

Enabling comprehensive gas-phase analysis with solid-state reagent ionization and multi-pressure mass spectrometry

H.J. Jost
Karsa

Atmospheric science is increasingly dependent on high-resolution, chemically selective instrumentation capable of capturing the full spectrum of gas-phase compounds—from nonpolar VOCs to highly functionalized oxygenates and amines. However, existing chemical ionization mass spectrometry (CIMS) systems are often constrained by narrow chemical coverage, maintenance-heavy reagent sources, and single-mode ionization limitations. In this presentation, we introduce two recent innovations designed to address these gaps: solid-state uronium ionization and multi-pressure chemical ionization mass spectrometry (MPCIMS).

The first innovation centers on a solid-state reagent ion source that generates uronium ions (protonated urea) by X-ray desorption from solid urea under ambient pressure. This new ionization method enables ppq-level detection of a wide array of moderately polar and basic compounds, including amines, ammonia, DMSO, and pyridine, which play key roles in secondary particle formation and health-relevant oxidation pathways. The uronium ion shows strong clustering behavior, low humidity sensitivity, and exceptional operational stability, running for months without resupply or retuning. This makes it particularly well suited for long-term or remote atmospheric deployments.

The second innovation is the MPCIMS architecture, which unifies high- and low-pressure ionization regimes in a single instrument. Using a custom multi-reagent inlet (MION2) at ambient pressure in combination with a low-pressure ion source (e.g., fluoranthene-based cations) inside a Thermo Orbitrap Exploris 120, the system allows researchers to simultaneously quantify weakly polar precursors (e.g., monoterpenes, aromatics) and highly functionalized oxidation products (e.g., HOMs, organonitrates, acids). By integrating reagents like uronium, Br^-, and protonated amines, users can build a reagent-switching toolkit that spans chemical classes traditionally measured by separate instruments.

Critically, coupling this platform to Orbitrap high-resolution mass spectrometry (up to 240,000 resolution) enables robust identification of unknown compounds, isobar resolution, and improved formula assignment, facilitating data-rich insights into VOC oxidation cascades, atmospheric nucleation mechanisms, and exposure-relevant trace gases.

Together, the solid-state ion source and the MPCIMS design establish a versatile, low-maintenance analytical platform that bridges chemical specificity with field applicability. We will present recent laboratory and field results, including compound-specific detection limits, ionization pathways, and comparisons with conventional systems. These technologies offer a compelling solution for research infrastructures aiming to simplify operations while enhancing chemical insight—particularly as atmospheric research shifts toward integrated, long-term observation networks.

Authors
Jost, H. J., Partovi, F., Finkenzeller, H., and Shcherbinin, A.

Method development for analysis of condensing vapors using thermal desorption mass spectrometry

Mihai Ciobanu
The Cyprus Institute

Understanding the dynamics of condensable vapors in the atmosphere is critical for unraveling important atmospheric processes, such as new particle formation (NPF), particle growth to cloud condensation nuclei (CCN), and long-range transport of volatile compounds. Yet, analytical limitations have historically constrained our ability to measure these compounds at atmospherically relevant concentrations, often in the ppqv range. In addition, the medium to high mass-to-charge ratio (m/z) compounds have proven difficult to deconvolute in conventional mass spectroscopy, due to multiple peaks overlapping.

In our work, a novel high-resolution measurement platform combining Thermal Desorption, Multi-scheme Chemical Ionization, and Orbitrap Mass Spectrometry (TD-MION-Orbitrap) is being tailored for the measurement of condensing vapors. The system's sensitivity is crucial for detection at low concentrations, whereas its unparalleled resolution of 180,000 ensures robust peak separation—especially at high m/z—making analysis clear and straightforward. This platform can support multiple reagent ion chemistries, which enhances its selectivity and adaptability across diverse chemical classes, and it allows the measurement of filter samples, which enables vapor profiling at high spatial resolutions.

Atmospheric samples collected on filters from diverse field sites (e.g., Cyprus and Finland) were subjected to thermal desorption to release low-volatility trace vapors. These vapors are introduced into a chemical ionization interface where they are selectively and efficiently ionized. The generated adduct ions are analyzed using Orbitrap high-resolution mass spectrometry, enabling precise determination of exact masses, elemental compositions, and, where applicable, molecular signatures for a wide range of oxidized vapors. However, calibration challenges pose a roadblock for quantification of individual species, as filter adsorption influences each compound uniquely. To address this, a modular calibration protocol will be developed, which will enhance both qualitative confidence and provide robust quantitative possibilities.

Initial results reveal a rich array of oxygenated species, including highly oxidized organic compounds (HOMs) and sulfates, with clear differences between the agriculturally influenced rural Cyprus and boreal environments of central Finland. The instrument successfully detects over 500 distinct compounds within the 50–600 m/z range, and its high mass resolving power allows for clean isolation of overlapping peaks, particularly in the 300–600 m/z region, where traditional CIMS approaches suffer from isobaric interference. We further demonstrate the platform's capacity to detect ultra-trace levels of pesticide residues from ambient air filters, showcasing its utility in broader environmental and regulatory contexts.

The TD-MION-Orbitrap platform represents a significant advancement in trace-level vapor analysis, combining high chemical specificity with broad application potential. It bridges gaps between atmospheric chemistry, analytical science, and applied atmospheric monitoring. By measuring complex mixtures of atmospheric vapors, its adaptability opens doors to emerging applications in chemical forensics, air quality assessment, and health risk screening.

Authors
Ciobanu, M. & Jokinen T.

A dual-platform approach for quantifying methane emissions at site level

Roubina Papaconstantinou
The Cyprus Institute

Rising atmospheric levels of carbon dioxide (CO_2) and methane (CH_4) due to human activities present a significant challenge to climate change mitigation efforts. Methane, which has a global warming potential 28 times greater than CO_2 over a 100-year timespan, is the second most influential greenhouse gas and demands immediate action. Successfully reducing CH_4 emissions requires targeting specific sources such as industrial natural gas operations, landfills, and agricultural sites. Therefore, the

creation of dependable, site-specific tools for detecting and quantifying emissions is essential for implementing focused mitigation strategies.

Recent progress in atmospheric CH_4 measurement techniques has facilitated the use of mobile in situ technologies mounted on aircraft, ground vehicles, and increasingly, unmanned aerial vehicles (UAVs). UAVs offer the ability to sample methane plumes at both point and facility scales, especially in areas where conventional methods are less effective (Liu et al., 2024). In this context, we present a dual-platform approach that integrates simultaneous CH_4 measurements from mobile (vehicle-mounted) and aerial (UAV-based) systems. This combined strategy yields complementary datasets, enhancing understanding of methane plume behaviour and spatial variation.

The UAV platform utilizes an ABB LGR GLA131 methane sensor alongside 3D wind data, mounted on a high-endurance octocopter equipped with advanced autopilot functions. This setup enables precise source detection and emission quantification. The ground-based system incorporates the MIRA Ultra Mobile LDS, offering detailed, high-resolution maps of surface-level CH_4 emissions. Together, these tools broaden the scope and improve the precision of methane monitoring initiatives.

Our study includes measurements from sites previously examined using only ground-based methods (Liu et al., 2023). That earlier research found that top-down methane emission estimates from waste and livestock sources in Cyprus surpassed the bottom-up national inventory figures by 160% and 40%, respectively. By combining drone and vehicle-based monitoring, we achieve three-dimensional characterization of methane plumes, leading to better sampling and more accurate quantification. This methodology enhances understanding of plume formation, spread, and variability, making it especially effective in addressing emissions from complex, multi-source environments like agricultural areas, industrial sites, and landfills, where environmental and topographic factors significantly affect methane dispersion.

Authors
Papaconstantinou R., Paris, J-D., Quehe, P-E., Kezoudi, M., Biskos, G. and Sciare, J.

A new all-in-one instrument for air quality and greenhouse gas monitoring

Jonas Bruckhuisen
MIRO Analytical

Air pollution and greenhouse gas emissions are deeply interconnected challenges, stemming from a wide range of sources including transportation, buildings, waste management, agriculture, and natural events like wildfires. Simultaneously tracking air pollutants and GHGs with high sensitivity and selectivity is crucial for pinpointing their sources and sinks, and for revealing how they interact.

Traditionally, monitoring complex gas mixtures has been challenging, often limited to detecting only a few gases or requiring multiple instruments with different technologies, which makes the process both cumbersome and expensive. To overcome this obstacle, MIRO Analytical has developed an innovative multicompound gas analyzer (MGA). This device can simultaneously and precisely measure up to 10 gases, including key greenhouse gases (such as CO2, N2O, H2O, and CH4), major air pollutants (like CO, NO, NO2, O3, SO2, and NH3), and other atmospheric trace gases (such as OCS, HONO, and CH2O) all within a single instrument. With a time-resolution of up to 10Hz, it is well-suited for detecting the relationships between co-emitted pollutants and GHGs as well as eddy-covariance flux studies.

In this presentation, we will highlight the latest advancements and enhancements to our technology, including the introduction of a new isotopic N2O analyzer. We will also showcase key application examples that particularly benefit from our all-in-one atmospheric gas analyzer. Special emphasis will be placed on how it streamlines mobile and eddy-covariance measurement campaigns, enabling broader gas coverage and unlocking a wide array of new research and monitoring opportunities.

Key words: multicompound gas analyzer, eddy covariance, mobile monitoring, GHG monitoring, air quality monitoring

Authors
A Bruckhuisen, J., Espic, C., Aseev, O., and Hundt, M.

Ammonia monitoring: meeting new EU Air Quality directive with Picarro pi2103 Analyzer and LNI Permacal system

Magdalena Hofmann
PICARRO B.V

Ammonia (NH_3) is a hazardous air pollutant with significant impacts on human health and ecosystems. The primary sources of NH_3 emissions into the atmosphere are associated with agricultural activities and processes, including fertilizer use, organic matter decomposition, and livestock waste. The new EU air quality directive 2024/2881 emphasizes the need for more comprehensive urban and rural NH_3 measurements to assess and manage air quality. However, accurate ammonia monitoring is challenging due to its high reactivity, surface adsorption, and the scarcity of stable calibration gases.

This study presents performance data for the next-generation PI2103 Cavity Ring-Down Spectroscopy (CRDS) analyzer. The PI2103 analyzer is the successor of the G2103 analyzer and the ideal solution for air quality monitoring at ambient concentrations as well as close to ammonia sources. Key features of the PI2103 are: (i) excellent response time, (ii) low drift, (iii) field deployment, (iv) negligible interference (interference-free) [1], and (v) long term unattended operation.

We explore two approaches for validating the analyzer's performance: (i) linearity verification using CO_2 as a surrogate gas, and (ii) combined linearity and accuracy assessment using the portable PermaCal permeation system from LNI Swissgas which allows to generate NH_3 in situ. The latter approach aligns with the EU directive's calibration requirements by employing NH_3 gas, offering a reliable and practical solution for regulatory compliance.

Reference
Kamp, J. N., Chowdhury, A., Adamsen, A. P. S. & Feilberg, A. Negligible influence of livestock contaminants and sampling system on ammonia measurements with cavity ring-down spectroscopy. Atmos. Meas. Tech. Discuss. 1–20 (2019).

Authors
Hofmann, M. E. G., Selvaratnam, T., Woźniak, J., Dembicki, A., Swinkels, P., and Hemenway, T.

QUALARIA: an AI System to monitor and predict metropolitan area of São Paulo street-level air quality

Victória Maria Lopes Peli
MeteolA Data Science

Chemical-Meteorological Models (CMMs) are widely used to estimate and predict atmospheric chemical composition in the Metropolitan Area of São Paulo (MASP), Brazil. However, they have a high computational cost and the most used spatial-resolution is up to 5 km. Artificial Intelligence (AI) Models have a smaller computational cost, and their results for meteorological variables can reach the spatial-scale of meters. Therefore, it is possible to evaluate the applications of AI models to estimate and predict atmospheric chemical composition, yet adding CMM information, in order to reach finer spatial resolutions. The German-Brazilian Project "QUALARIA: Artificial Intelligence based system for sub-urban scale air quality prediction" aims to create an operational AI-based system to monitor and predict air quality in the MASP, with high spatial resolution (https://meteoia.com/qualaria/). Advanced global and regional chemical-meteorological models, such as CAMS global composition forecast, and WRF-Chem simulations are applied to derive the climatological state of air

composition.

Measurements of PM10, PM2.5 NO2, and O3 concentrations from the São Paulo State Environmental Agency (CETESB) Air Quality Network are used to capture the pollutant concentration in some spots to validate the models. The spatial and temporal disaggregated local vehicular emission inventory and the building height from the Global Human Settlement Layer dataset are also used as input. Preliminary results produced air pollution concentration maps at 100 m and showed an increase in Pearson correlation and a reduction in the mean absolute error compared to CAMS forecast. Other high spatial resolution datasets and measurement from other states air quality networks are being explored to increase the input datasets. In the following steps of the project, low-cost sensors are going to be deployed to increase the spatial coverage of MASP and its surroundings, complementing the CETESB stations. Then, from their predicted downscaled pollutant concentration fields, the system will provide an online dashboard to display relevant air quality indicators, and to inform the impacts of air pollution on human health. To improve the dashboard design, stakeholders from the public and private sectors are being engaged and consulted for the development of its user interface and features.

Authors
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Enabling climate risk research through research infrastructure services

Päivi Haapanala
Luke

Understanding and responding to climate change related risks requires access to advanced tools, data, and facilities. The Integrated Research Infrastructure Services for Climate Change risks (IRISCC) project supports this need by providing a comprehensive catalogue of services from European research infrastructures (RIs). These services span key domains relevant for climate risk research, including atmospheric research, and are designed to foster cross-sectoral, interdisciplinary collaborations. Provision of these services is facilitated through Virtual Access (VA) and dedicated calls for Transnational Access (TA).

This presentation will introduce the IRISCC Catalogue of Services and explain how researchers can access world-class RI facilities, data, and tools for their projects. It aims to raise awareness among atmospheric science stakeholders about IRISCC's support mechanisms, including how the open access calls operate for TA and how to utilise the always-open VA route. The presentation will showcase how these pathways can be leveraged for cutting-edge research and innovation.

IRISCC offers two main pathways of access to the involved RIs:

- TA (Transnational Access): enabling physical, remote, or hybrid use of research infrastructures, following an open call and peer-review process.
- VA (Virtual Access): offering continuous, open, and free access to selected digital services and data through an online management tool, without the need for an application.

IRISCC provides a unique opportunity for the atmospheric research community to collaborate, access cutting-edge RIs, and advance innovation in measurement techniques. Whether you're a researcher, industry innovator, or policy advisor, IRISCC supports your journey from idea to impact. This presentation will guide participants on how to engage with IRISCC and take advantage of its services—now and in the future.

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The DUST doctoral network

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Mineral dust is a major atmospheric aerosol, and it impacts visibility, radiation, climate and also health, transportation and energy production. It is not fully understood at the fundamental level (microphysical properties, dust emissions, source regions) and atmospheric models fail to fully reproduce its impacts. Dust observations using ground-based instrumentation, remote sensing and aircraft are abundant, but not evenly distributed; in particular they are missing near the major sources. The methodologies to study dust are still under development, with each giving a different picture of a phenomenon with multiple facets. For example, super-coarse and giant dust particles have gone undetected for a long time due to limitations in the measurement and modelling tools in use for decades, and this misdetection alters understanding and predictions. Finally, dust has impacts on the transportation and energy sectors, the nature and cost of which is not fully understood and quantified. Several methodologies exist to study mineral dust, each giving its own differing picture of a complex phenomenon. To address these challenges, the first doctoral network on a European scale on the topic of dust has started activity, bringing together multidisciplinary expertise on dust in the atmosphere. Dust-DN is a strategic international, interdisciplinary and intersectoral alliance of high-profile partners, able to leverage on unique state-of-the-art facilities and innovative spaceborne missions. Seventeen doctoral candidates will provide critical mass on dust science, and a careful blend between individual research projects and integrated training and networking will be provided. The network comprises applied research projects, with direct contributions and impacts embedded with the societal and industrial sector. It involves 8 leading partners and 15 associated partners, representing 9 countries and the World Meteorological Organisation.

Dust-DN officially started in November 2024 and is funded by the European Union and the national agencies of the United Kingdom (UKRI) and Switzerland (SERI).

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CAELOSCOPE: added-value atmospheric products based on Sentinel-5p/TROPOMI measurements in Terrascope

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BIRA-IASB

The Sentinel-5P/TROPOMI instrument is the first Copernicus sounder that is fully dedicated to measuring atmospheric composition. Since its launch in October 2017, it has provided excellent results that have led to numerous scientific papers on topics related to ozone, air quality, environmental hazards, and climate.

With support from ESA and the Belgian Science Policy office (BELSPO), Belgium has established the Terrascope platform, hosted by VITO. This Belgian Copernicus Collaborative Ground Segment is a platform that enables easy access to and visualisation of Copernicus data for all societal sectors, the development and implementation of tailored or derived products based on Copernicus measurements, and the development of innovative tools. In recent years BIRA-IASB has worked with VITO on the implementation in Terrascope of the first TROPOMI total column products, as well as a near-surface concentration product for nitrogen dioxide (NO2), derived using machine-learning methods.

The BELSPO-funded CAELOSCOPE project (2024-2027) wants to take a step closer towards the Terrascope user community by

providing a range of new products related to concentrations of ozone (near-surface) and NO2 (from surface until 5 km height). These allow for direct comparison with in situ measurements and provide a more direct indicator of environmental health and air quality and, therewith, are thought to facilitate uptake by user communities ranging from scientists measuring air quality from ground to policy makers, the agricultural sector, and public health bodies.

In addition, for the existing TROPOMI vertical column data products already present in Terrascope, CAELOSCOPE will calculate multi-year trends, both on the local scale as well as deviations from the global mean value. As with all TROPOMI products in Terrascope, this data will be freely available for analysis through the Terrascope user environment and as data-aggregated maps in the Terrascope Viewer.

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Monitoring ambient ultrafine particles with modified PN-PTI instruments

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Ultrafine particles (UFPs) are regarded as an emerging air pollutant of major concern (Schraufnagel, 2020). The World Health Organization (WHO) recommends a daily average limit value of 10.000 cm-3 not to be exceeded (WHO, 2021). Furthermore, the new European Air Quality Directive (EU) 2024/2881 demands member states monitor UFPs at pollution hotspots (European Commission, 2024). Yet, the assessment of absolute UFP pollution levels as well as the evaluation of their health impact remains a challenge. The ACTRIS networks has made great advances in comparing the background level of UFP pollution on an international scale by standardizing the comparability between measurement sites. Yet, establishing a deeper understanding of local exposure to UFP pollution, especially closer to the hotspots remains a big challenge. This is partially due to the complexity, traceability and costs of the equipment used for UFP ambient monitoring since most monitoring sites rely on a Scanning Mobility Particle Sizer (SMPS) together with a Condensation Particle Counter (CPC).

Within the EU HORIZON funded MI-TRAP project, nanoDUST has developed the AirPN10 particle counter as a solution for a cost-effective and more dense monitoring of high-pollution traffic sites with the help of diffusion-charging-based particle number counters based on particle counters used for periodic technical inspection (PN-PTI). PN-PTI instruments have been developed to measure the solid particle number concentration in vehicle exhausts at idling engines. These instruments are traceably calibrated to national standards, they are easy to operate by workshop personnel. Most instruments sell well below 10’000 €, and more than 30'000 instruments have been supplied to the German market alone. This makes PN-PTI instruments the most affordable and most abundantly available particle number counting technology.

We provide details on the modified PN-PTI instruments, traceable calibration data as well as first real-world application data assessing the performance of the AirPN10 for ambient air quality monitoring. The instrument measures the concentration (PN) and geometric mean diameter (GMD) of both the solid (s) and total particle number (t) to better identify the emission source of the UFPs at hotspots.
AirPN10 units have been calibrated at METAS with polydisperse miniCAST soot. The two-stage DC sensor provides an estimate of the GMDmob with excellent agreement to that measured by a scanning mobility particle spectrometer (SMPS; TSI 3752, 3082 and 3085). The sPN and tPN concentrations were compared to a traceable reference condensation particle counter (CPC; TSI 3752). For GMDmob = (15 – 120) nm, the measured counting efficiency of the devices was well within the acceptance bands of ± 25% or 1500 cm-3.

In a next step, the AirPN10 will be used within the MI-TRAP project to monitor solid particle number pollution related to transport emissions in traffic hotspots of 10 European cities.

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AE36s improving aerosol source understanding with the AE36s aethalometer model

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Aethalometers are filter photometers that provide real-time, high-time-resolution measurements of equivalent black carbon (eBC). Traditionally, seven-wavelength Aethalometers (370, 470, 520, 590, 660, 880, 950 nm) have been used to apportion BC to liquid fuel-related sources, typically from traffic, and solid fuel-related sources, such as biomass and coal burning. The newly developed Aethalometer model AE36s includes two additional wavelengths, 340 nm and 400 nm, enhancing the characterization of the optical properties of light-absorbing aerosols.

To achieve this, the Angstrom absorption exponents were determined for two spectral ranges (2D AAE): the long wavelength range (590-950 nm) and the short wavelength range (400-590 nm). Our findings indicate that the absorption coefficient at 340 nm often deviates from the theoretical exponential law in the short wavelength range, providing additional information for the apportionment of different aerosol types.

The 2D AAE approach was applied to a year-long measurement campaign conducted at the ATMOS site in Athens. The relationship between 2D AAE characteristics and known aerosol types enabled us to identify distinct AAE fingerprints for fresh traffic-related aerosol, aged aerosols, nighttime biomass burning aerosols, aerosol dominated by large particles, wildfire aerosol, open biomass burning aerosol and mineral dust (Fig.1). This manual classification was refined by automatic clustering.

We analyzed the diurnal profiles and seasonal distribution of aerosol clusters. This method enhances source apportionment in urban environments and contributes to improved detection of special events like Saharan dust intrusions.

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Characterization of the aerosol infrared monitor for autonomous aerosol chemical composition measurements

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Infrared (IR) spectroscopy is a powerful technique for comprehensive chemical characterization of particulate matter (PM), capable of quantifying both organic functional groups and inorganic species simultaneously. Filter-based IR methods are currently used in major monitoring networks (IMPROVE, ASCENT, SPARTAN) to quantify aerosol mass, carbon fractions (OC, EC, TC), and key inorganic components including ammonium, nitrate, sulfate, and crustal elements. However, these filter-

based methods are slow, labor-intensive, and prone to sampling artifacts and filter substrate interference.
The Aerosol InfraRed Monitor (AIRMon; Aerospec SA) addresses these limitations through autonomous, time-resolved PM characterization using Fourier-Transform Infrared (FTIR) spectroscopy. The instrument combines automated aerosol collection with real-time measurement capabilities, delivering quantitative analysis of both organic and inorganic components with 30-minute to multi-hour time resolution. By using IR-transparent substrates instead of Teflon filters, AIRMon eliminates spectral interference and expands access to previously restricted spectral regions.
We present comprehensive AIRMon characterization based on calibration studies with individual compounds, biomass burning emission measurements, and ambient data from the National Observatory of Athens ACTRIS site.
AIRMon measurements are compared against established methods, including aerosol mass spectrometry and PM monitors. This work will explore how real-time functional group analysis enhances aerosol chemical composition measurements, advancing capabilities for air quality monitoring, source identification, and health impact assessments.

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Towards a portable device for real-time monitoring of oxidative activity in aerosols

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The World Health Organization (WHO) has recognized airborne particulate as a major worldwide health challenge. Extensive research in the fields of epidemiology and toxicology has demonstrated a significant correlation between exposure to particulate matter (PM) and a wide range of health issues. The discussion about PM's role as a harmful agent is ongoing, with evidence indicating that oxidative stress in the lungs, caused by reactive oxygen species (ROS), plays a significant role in these negative impacts. ROS are highly reactive molecules that can be inhaled with PM or produced within the body. This internal generation, along with the depletion of antioxidants, defines the oxidative potential (OP) of PM [1], which is now a new pollution metric under the European air quality directive [2].
The most employed techniques to assess the OP of PM are the cell-free assay methods. The process typically involves exposing chemical markers, like ascorbic acid, to PM samples and monitoring the rate at which they are consumed. This consumption rate is indicative of the reactive oxygen species (ROS) generated by the PM, providing a reliable measure of its OP [3]. A key reference method within this category is the chemical activity assay utilizing ascorbic acid (AA), in which AA depletion is measured spectrophotometrically [4]. The simplicity and precision of this method make it highly effective for environmental monitoring and research. However, traditional applications of this assay have been limited by the need for benchtop laboratory equipment, which complicates its integration into portable systems and consequently restricts the spatial resolution of the data obtained. More portable real-time monitoring solutions are now being developed to overcome these limitations and improve the applicability of the assay in a variety of environments.

In this context, an electrochemical sensor based on poly(azure A)-platinum nanoparticles deposited on pre-activated screen-printed carbon electrodes [5] was developed to monitor AA-OP. In this method, the AA, after oxidation by PM, is directly measured by flow injection analysis with chronoamperometric detection.
To optimize electroanalytical performance, various factors such as composition and sonication of the buffer solution, temperature, flow rate, and detection potential for chronoamperometric readout were thoroughly evaluated. Moreover, the sensor was tested for oxidative activity using model oxidants. All these studies were performed in parallel to the classic AA assay obtaining excellent results.

Finally, preliminary studies have been made to achieve semi-automation of the detection system. To achieve this, we

simulated the measurement of the oxidative activity of Cu^{2+} (used as model oxidant) and monitored the electric current generated by the oxidation of AA at a potential of 0 V over time. An increase in electric current indicates the onset of reaction kinetics. The slope of the current-time (i-t) curve was found to be dependent on the rate of AA consumption, making it a valuable analytical signal for quantitative analysis. Various parameters were examined, including those related to the reaction module (e.g., flow rate of the automatic injector and automatic cleaning of the reaction vessel) and the electrochemical cell. The results are highly promising for integrating the electrochemical cell with an online aerosol collection system, enabling the creation of a fully autonomous instrument for real-time measurement of PM oxidative activity.

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The measurement of the total number concentration of aerosols without a working fluid

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Aerosols containing ultrafine particles smaller than about 100 nm in diameter cannot be easily measured. Condensation particle counters (CPC) are extremely important for such measurements, as their particle counting process is essentially independent of particle size. A conventional CPC works by vaporising a working fluid through heating, and subsequent cooling to cause condensation onto the particles. This leads to a significant increase in particle size, enabling detection in an optical measuring cell. Therefore, the working fluid is an essential component of every CPC. Ideally, it should require only low consumption and be neither toxic nor harmful to the environment or people.

We will present results of our experiments using 1) a non-hazardous working fluid with an incredibly low consumption rate (Weber et al., 2023), as well as 2) our recently introduced sublimation particle counter (SPC, Weber et al., 2024). The

advantage of the SPC technique is that it can measure the total number concentration of airborne particles without the need of a working fluid. We will describe the measurement principle and operating conditions and show results for key performance characteristics of an SPC.

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Implementation of real-time source apportionment approaches using the ACSM-Xact-Aethalometer (AXA) set-up with Sofi RT: the Athens case study

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Source apportionment (SA) of ambient PM is essential for effective air quality management. Traditional SA approaches often rely on offline data collection, limiting timely responses to pollution events. SA applied on data from online techniques, especially with high temporal resolution is advantageous over offline techniques, enabling the study of the diurnal variability of emission sources and also the study of specific events. Recent technological advancements now enable real-time SA, allowing continuous, detailed analysis of pollution sources. This study presents the first application of the ACSM-Xact-Aethalometer (AXA) setup integrated with SoFi RT software for real-time source apportionment (RT-SA) of PM in Athens, Greece. The AXA setup integrates chemical, elemental, and black carbon data streams, covering a broad spectrum of PM components and capturing a comprehensive representation of PM sources in an urban environment. Each instrument's data from the AXA set up is processed independently, with the model applying instrument-specific constraints and generating separate source factors, effectively performing two parallel source apportionments in a single ME-2 run. Equivalent sources identified across the two instruments are then combined post-analysis to provide a unified interpretation of source contributions. The results demonstrate that traffic-related emissions are the largest contributors to PM, with significant contributions from secondary species such as sulfate, nitrate, ammonium, and secondary organic aerosols, which together accounted for approximately 57% of the PM mass. Primary sources such as biomass burning and cooking contributed around 10% each, with natural sources like dust and sea salt comprising the remainder. The SoFi RT software is employed for continuous SA, offering automated analysis of PM sources in near real-time (minutes after the measurements). Our findings demonstrate that this setup effectively identifies major pollution sources. This work underscores the AXA system's potential for advancing urban air quality monitoring and informs targeted interventions to reduce PM pollution.

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Microwave induced plasma time-of-flight mass spectrometer (MIPToF): a new tool for real-time quantitative analysis of metals in air

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Determination of the elemental composition of airborne nanoparticles and micro-particles is essential to understand the source(s) of these particles and also to predict potential health effects. The most common approach to measure the metal

content of air is to collect samples on filters and then analyze digests by ICP-MS; however, this strategy offers poor time resolution (e.g. days) and only provides bulk element composition information. To understand the spatiotemporal characteristics of the emission of metal-containing aerosols, which is key to assessing exposure, real-time analysis strategies are essential. Here, we report the development of a microwave-induced plasma time-of-flight mass spectrometer (mipTOF) that can be used for the direct analysis of metal-containing airborne particles.

The mipTOF is a field-deployable trace-element mass spectrometer. It uses a nitrogen-sustained high-power plasma (MICAP, Radom Instruments) to vaporize, atomize, and ionize aerosols with sizes from the ultrafine to PM10. Ambient air is sampled into the plasma via a concentric pneumatic nebulizer at a flow rate of ~100 mL/min. Atomic ions generated in the plasma are extracted into the mass spectrometer, where they are sorted according to mass-to-charge ratio (m/Q) and recorded. With the mipTOF, concentration LODs range from 10 ng/m³ (potassium) to 0.05 ng/m³ ((lead) in a 10-second measurement. The high-sensitivity, high-speed metal-aerosol measurements possible with mipTOF enable new research into the spatiotemporal characteristics of metals in air. We will report on the use of the mipTOF in mobile measurements to quantify metal-containing aerosols in rural, urban, and industrial settings.

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LAST: A Cutting-Edge System for Multi-Spectral Lidar Signals Simulation

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An innovative lidar echo simulator has been recently designed and developed by ALA - Advanced Lidar Applications s.r.l. company, in order to simulate the behavior of several LIDAR atmospheric echoes, by replicating the large dynamic range of LIDAR signals at different wavelengths and making it possible to test a single device both in the laboratory and on field. The LAST (LidAr Synthetic echo Transmitter) represents a breakpoint in the test and calibration of LIDARs systems: it allows testing the linearity of the acquisition unit for several signal and background intensity conditions, the sensors response at different wavelengths, the response of all optical and electronic elements of a LIDAR system, the presence of optical/electronic crosstalk between channels (polarization channels and elastic/Raman channels) and the optical chain alignment of the receiver.

LAST was designed to simulate elastic polarized signals at 355 nm and 532 nm (+/- 5 nm, on request +/- 0.5 nm, outer band < E-7, polarization > 800:1), unpolarized high power signals at 355 nm, 532 nm and 1064 nm (+/- 50 nm); unpolarized signals at 386 nm, 407 nm and 607 nm (Raman channels, +/- 50 nm). It has the capability to rotate 0-360° the emitted polarization by software, for both 355 nm and 532 nm polarized channels. Moreover, a skylight background emission (UV + green) can be added to each emitted curve.

The LAST system is composed of three main units.

- The transmitter unit, a dome containing the emitting sources and the collimating optics along with all the electronics for driving the correct power to the emitting sources, controlling their temperature, and returning to the logic unit the feedback. The dome can be rotated and tilted to achieve a perfect alignment between the polarization plane of the emitting unit and the receiver of the tested LIDAR system;
- The console, a standalone (battery-powered) aluminum box connected by a multipole cable to the transmitter unit; its electronics manages and controls the synthetic LIDAR echoes emission of the transmitter unit;
- The software for the control unit, to be installed on an external PC to set up LAST system. It uses a USB port and manages the storage of several synthetic LIDAR profiles from different atmospheric conditions; once the main parameters are set up and the chosen synthetic profiles are transmitted to LAST logical unit, the software control unit can be disconnected from the LAST logical unit.

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Can UAV-based and lidar synergistic observations improve mineral dust quantification?

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Understanding the quantity and distribution of aerosols is essential for climate modelling, air quality assessment, and aviation safety. Remote sensing techniques, such as lidar and sun photometers, provide valuable optical measurements that must be converted into mass concentrations for most practical applications. A key factor in this conversion is the volume-to-extinction ratio (ζ), which is the link between optical properties, such as the extinction coefficient, and physical properties, like aerosol volume, and therefore its mass.

This combines observations of the particle size distribution (PSD) by optical particle counter (OPC) mounted on unmanned aerial vehicles (UAVs) with ground-based lidar extinction to investigate ζ for mineral dust. Data were collected during the 2021 Cyprus Fall Campaign and the ASKOS Campaign (2022) in Cape Verde (Marinou et al. 2023). Several dust events originating from the Middle East, Central Sahara, and West Sahara were captured by this combination of instruments, providing a diverse dataset for analysis.

The PSD observations reveal the presence of giant dust particles, which appear to be underestimated by sun photometer retrievals during the ASKOS campaign. Particles larger than 20 μm were observed and an imbalance between the importance of the fine and coarse mode appeared between the two methods. This difference impacts the ζ ratio which is approximately proportional to the effective radius. The analysis of the different events revealed a substantial variability in ζ values.

Furthermore, the observed ζ values are compared with estimates from the MOPSMAP scattering model (Gasteiger et al. 2010) and with values assumed within the WRF-Chem-GOCART meteorological model (Ukhov et al. 2021), as well as with reported values from the literature (Ansmann et al. 2012). The MOPSMAP simulations come close to the direct observations but show some differences that suggest the need for refinements in the particle shape assumptions. Additionally, observed ζ values deviate by up to 25% from those reported in the literature estimates and up to 60% from the estimations derived for this date from AERONETs.
The synergistic approach, which combines airborne in-situ observations with remote sensing, provides valuable insights into this important ratio, essential for remote sensing and atmospheric modeling.

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Trinocular all sky imaging network for cloud and solar applications

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Cloud dynamics significantly impact solar irradiance forecasting and atmospheric studies. To advance research in the domain, we present a dataset collected from a network of three sky cameras deployed on the Saclay plateau, France, within 1.5 km of the SIRTA Atmospheric Research Observatory. The purpose of this dataset is to enable the development and validation of multi-view cloud detection and nowcasting algorithms. Each camera captures 12.3 MP high dynamic range sky images at 30-second intervals, supplemented by synchronized irradiance measurements and environmental parameters including temperature, humidity, and pressure. The dataset is complemented by data products from the SIRTA CloudNet station, offering a valuable multi-modal resource for the atmospheric and solar energy research community.

Authors
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Dual field-of-view depolarization method using the POLLY-xt Raman lidar of CARO Limassol national facility: parameterization of aerosol-cloud interactions

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Despite being one of the most studied fields in atmospheric research, aerosol-cloud interactions (ACI) still remain one of the most uncertain parameters in how aerosols, clouds and their interrelation affect Earth's energy balance, as well as how aerosols influence the formation, lifetime and evolution of clouds. The novel Dual-Field-of-View (DFOV) polarization lidar approach comes as a competent solution to the aforementioned challenges, since it operates only with lidar data alone and it has the ability to deliver requisite information on liquid-water, or even, mixed phase clouds' microphysical properties. Properties like the Cloud Droplet Number Concentration (Nd), their effective radius (Re), the cloud extinction coefficient (α), and the Liquid Water Content (LWC). Additionally, by using products like the quasi backscatter coefficient and by implementing Doppler Lidar's data, the cloud condensation nuclei (CCN) concentration and the vertical wind below the cloud base can be retrieved, and therefore, the influence of certain type of aerosols and their concentration in relation also to the behaviour of the wind, can yield to an unprecedent view of aerosol-cloud interactions. For this study, measurements taken by the Cyprus Atmospheric Remote-Sensing Observatory (CARO) National Facility of the Eratosthenes Centre of Excellence and more specifically by the PollyXT Raman Lidar and the Halo Photonics (Snoopy) Doppler Lidar are going to be utilized for the examination of liquid-water or mixed-phase cloud cases in Limassol. Using the DFOV Depolarization method on these cases for the first time in the Eastern Mediterranean, Middle East and Northern Africa (EMMENA) region, cloud properties and aerosol's influence on them can be adequately retrieved, also adding to ACI studies.

Authors
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Synergistic measurements from satellite and in-situ sampling for air quality applications

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GRASP Earth

GRASP Earth is advancing synergistic aerosol monitoring by integrating in-situ sampling with satellite-based remote sensing to improve air quality assessments. Both approaches use multi-angle, multi-wavelength, and polarization measurements, processed through the GRASP inversion algorithm. The objective is to bridge satellite observations with real-world exposure by aligning remote measurements with aerosol properties measured directly at the "nose level."

In-Situ Instrumentation
GRASP developed the IMAP 100, a polar nephelometer that mirrors space-based MAP sensors by capturing multi-angle, multi-wavelength, and polarized light scattering. IMAP uses the GRASP algorithm, ensuring comparability between in-situ and satellite data. It includes aerodynamic size selection to measure PM1, PM2.5, PM4, and PM10, simulating how particles are deposited in the human respiratory system. This design supports evaluation of how optical properties retrieved from satellites relate to health-relevant particulates. Though not providing vertical profiles, IMAP allows users to determine when satellite and ground-based measurements align or diverge in aerosol microphysics such as size, refractive index, and sphericity. A lower-cost version, Mini-IMAP, enables broader deployment in ground-based networks.

Satellite Instrumentation and Data Products
In 2023, GRASP Earth launched GAPMAP0, a CubeSat demonstrating low-cost, privately funded multi-angle polarimetry. Its data is undergoing Level 2 processing. GAPMAP0 complements upcoming MAP instruments like HARP2 and SPEXone (PACE), with ESA's 3MI and NASA's MAIA expected soon. GRASP is also developing a satellite-derived PM2.5 product under ESA's BASS project. BASS combines data from multiple satellite sources using a flexible algorithm to deliver consistent, user-friendly PM2.5 estimates.

By combining satellite and in-situ measurements with shared methodology, GRASP enhances the relevance of remote sensing data for understanding air quality and human health impacts.

Authors
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VPICOs

Hydrogen leak detection at ppm-level in real time at an industrial site

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New energy carriers are required to mitigate climate change and replace fossil fuels. Hydrogen is a promising solution due to its high energy density. Consequently, several hydrogen strategies have been published since 2017. As the lightest molecule, hydrogen is highly volatile, and emissions from industrial processes are expected. While hydrogen itself is not a greenhouse gas, it affects other greenhouse gases, particularly methane and Ozone through different chemical reactions. Therefore, it is considered an indirect greenhouse gas with a Global Warming Potential (GWP) of 12.8.

The climate impact of hydrogen depends on its method of production and leakage across the value chain. However, industrial monitoring instruments are typically optimized for safety rather than environmental detection. While hydrogen's flammability limit is around 4 %, its atmospheric background concentration is approximately 0.5 ppm. Therefore, emissions at ppm or ppb levels often go undetected. A recent study in the Netherlands by Westra et al. (2024) used a combination of AirCore and flask sampling with an in-laboratory gas chromatography setup, which allowed the detection of industrial hydrogen emissions on ppb levels.

Currently, few instruments offer accurate, real-time hydrogen measurements on mobile platforms. This study introduces the Agilent 990 Mobile Micro GC System, which uses a thermal conductivity detector to detect hydrogen at levels as low as 1 ppm, with a time resolution of 140s. The system was tested at a hydrogen storage facility in Mannheim, Germany, where elevated hydrogen concentrations were detected near tubing, dispensers, and within the compressor room. No significant

concentrations were observed further from the source.

While the instrument enables emission source localisation, precise quantification via atmospheric models remains limited. Therefore, combining real-time detection with sampling techniques such as AirCore or flask collection may provide a more comprehensive strategy for monitoring and quantifying hydrogen emissions.

Authors
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New UAV observations to assess the dust particle morphology and orientation

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Understanding if aerosols warm or cool the planet—and how this effect varies spatially and temporally—is essential for mitigating and predicting climate change scenarios. Aerosols influence the Earth's radiation budget both directly, through scattering and absorption of solar and terrestrial radiation and indirectly, by serving as cloud condensation nuclei that impact cloud formation. Atmospheric mineral dust plays a major role in the climate system, contributing one of the largest global mass fluxes of primary aerosols. The impact of dust on the radiation budget depends on its morphological and microphysical properties—like size, shape, refractive index, and orientation. Some studies suggest that dust particles may exhibit preferred orientation within the atmospheric column. Both particle morphology and orientation are expected to significantly influence aerosol modeling, atmospheric processes, and climate projections.

This study seeks to improve the understanding of dust particle size, shape, and orientation. This may fill the gaps in our overall understanding of the dust lifecycle and global observational capability. A twofold approach is employed to characterize both the morphology and orientation of dust particles. The dual-FOV two-wavelengths backscatter sonde COBALD (λ = 455 and λ = 940 nm) is deployed aboard a UAV, enabling backscatter measurements from two differently oriented instruments (horizontal and vertical) within vertical profiles of the boundary layer and free troposphere. Particle orientation may be inferred through analyzing orientation-dependent differences in the dust cross-section from the COBALD backscatter signals. Complementing this, specially modified Giant Particle Collectors (GPAC), also mounted on a UAV, have been adapted to carry TEM grids, allowing particles to be sampled and analyzed using transmission electron microscopy (TEM). These grids permit the electron beam to pass through sampled particles, yielding high-resolution, three-dimensional images that reveal particle morphology like shape and internal structure. UAVs are operated under dust-laden atmospheric conditions across multiple flight campaigns to ensure robust datasets for both measurement techniques. These unique, novel approaches may yield significant contributions to the current understanding of dust microphysical properties and related atmospheric processes alike.

Authors
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AEROTAPE: A novel technology for real time quantification and characterization of dust and its sources

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EU Member states are allowed to subtract the PM10 contribution from natural sources (such as desert dust or sea salts) from the observations, when verifying compliance with air quality standards. However, they must do so with pertinent data, which can be sometimes challenging. The recent EU Air Quality Directive enforces a drastic reduction of PM10 annual limit values (from 40 to 20μg/m3) and daily limit values (from 35 times above 50μg/m3 to 18 times above 45μg/m3) by 2030. These constraints will increase the need to apportion carefully natural and anthropogenic PM sources in the coarse fraction with a

particular attention to traffic sites. In fact, the latter exhibit high PM concentrations and are exposed to various local (road traffic resuspension) and regional (long-range transported) dust sources.

We present here a novel analyzer instrument that focuses on super micron particles, named AEROTAPE, which is developed at Oberon Sciences, France. AEROTAPE samples atmospheric particles within the range of 0.8 – 10 µm diameter. The Aerotape's impactor collects particles onto a transparent adhesive tape, after which an on-board microscope takes an image and sends it to a data server for hourly processing. The sample is illuminated at different angles and at different wavelengths to deduce particle size and nature using the on-board camera. The tape is uncoiled at variable velocity to prevent picture saturation. This technique enables the sampling of extremely concentrated aerosol conditions by preventing over-deposition in the optical stage. Sampling is performed over a three-minute period at a flow rate of 15 L/min. An artificial intelligence (AI) module automatically processes the pictures of the collected particles, taken at a frequency of up to 0.5 Hz. This allows real-time differentiation of particle types, as well as the derivation of particle size and shape distribution. The added value of AEROTAPE compared with a traditional Optical Particle Counter (OPC) is the use of a camera instead of a laser/detector system, which allows visual information on the geometric shape of the particles as well as their color using an RGB array. Moreover, the image processing algorithm allows to measure the area of individual particles and at the end a geometric size. By providing detailed information on particle shape and color, the Aerotape will allow for improved differentiation between particle types such as dust, pollen, and combustion ash thus enabling a more accurate assessment of natural contributions to PM levels.

Results presented here highlight the metrological (accuracy and precision) performance of the AEROTAPE in measuring PM in the coarse fraction and counting super micron aerosols in different size fractions. Strong correlation between the simultaneous observation with two AEROTAPEs confirmed the very good precision of the instrument while its accuracy was assessed against reference devices such as TEOM – 1405 as well as other commercial OPCs (FIDAS, GRIMM, PoPs).

We plan to further optimize the Aerotape technique through a series of field campaigns, allowing us to collect particles from diverse locations influenced by different sources. This will provide a robust dataset for training and refining particle classification methods. One aim is to characterize PM dust from transportation emissions in different regions and climates, via intensive field campaigns conducted at traffic sites in Paris (France) and Limassol (Cyprus). Moreover, desert dust will be characterized during intensive field campaigns in the UAE and Cyprus, combined with remote sensing and in-situ monitoring technologies (drones, balloons, and ground-based). This will help create a database of PM dust sources in cities and address the quantification of local vs regional dust.

Authors
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Global dust estimation from novel space missions

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Understanding and quantifying the role of atmospheric dust in the climate system remains a significant challenge in the atmospheric sciences, largely due to uncertainties in its global distribution. In particular, dust observations using ground-based instrumentation, remote sensing and aircraft are abundant, but not evenly distributed as they are missing near the major dust sources. The recently launched EarthCARE satellite provides observations of the spatial and temporal structure of aerosols, clouds and radiative fluxes. Moreover, the PACE mission provides polarimetric observations which are useful for dust detection and quantification.
Within the Dust Doctoral Network (Dust-DN) framework, we aim to exploit these novel observations to infer information on the four-dimensional (4D) global distribution of dust in the atmosphere. The project will estimate atmospheric dust components—specifically, fine-mode and coarse-mode fractions—by applying techniques such as the Polarization-Lidar

Photometer Networking (POLIPHON) to ground-based and spaceborne observations. Also, the analysis will incorporate microphysical properties (e.g., particle size distribution, composition, and shape) from airborne in-situ campaigns, and optical properties (e.g., extinction and backscatter coefficients), to estimate the concentrations of cloud condensation nuclei (CCN) and ice nucleating particles (INP). We aim to re-evaluate the Lidar climatology of Vertical Aerosol Structure (LIVAS) and improve it thanks to EarthCARE and PACE. The goal is to contribute to a better understanding and quantification of the global dust distribution and create a dataset suitable for dust climatology, atmospheric model validation, radiative impact assessments, and evaluation of dust-related air quality concerns particularly those involving inhalable particles.

Authors
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Fast and fine-scale hourly air quality mapping using hybrid dispersion and KNN approaches

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High-resolution spatial forecasting of hourly air quality remains a computational challenge, particularly when aiming to accurately capture industrial plumes and the temporal variability of traffic emissions. This study presents an efficient method for generating hourly pollutant concentration maps at a fine spatial scale (25 m) across large urban regions, suitable for operational applications.

Our approach decomposes pollutant concentrations into three distinct components: traffic emissions, industrial emissions, and background concentrations. Background pollution is estimated using established fine-scale dispersion modeling with the ADMS-Urban system, which incorporates meteorological and regional data. However, traditional ADMS-Urban simulations are computationally intensive, especially at high spatial and temporal resolutions.

To overcome this, we employ a k-nearest neighbors (KNN) machine learning strategy that predicts traffic and industrial contributions by leveraging a precomputed database of hourly ADMS-Urban simulations under various meteorological and emission scenarios. Real-time data inputs include monitoring station observations, meteorological variables such as temperature and wind speed, and emission inventories. The KNN algorithm quickly identifies the closest matching scenarios to generate pollutant concentration estimates at unmonitored locations. This hybrid method significantly improves the temporal and spatial representation of traffic and industrial emissions while reducing computational time by a factor of 100 compared to running full dispersion simulations in real time. This reduction enabled operational forecasting using a single server instead of multiple servers, yielding substantial energy savings and making the approach scalable for large regions.

Despite these advances, certain limitations remain. Expanding the historical dataset of ADMS-Urban simulations would increase the diversity of conditions available for KNN matching, potentially improving prediction accuracy. We also recognize the need to integrate additional real-time data sources. Future work will focus on incorporating measurements from emerging low-cost microsensors, which offer enhanced spatial coverage but present challenges in data quality and accuracy. Optimizing data assimilation methods will be essential to seamlessly integrate these heterogeneous data streams.

Furthermore, to refine traffic emission estimates, we are exploring the integration of automatic vehicle counting station data. Combining real-time traffic flow with air quality observations can improve the spatial resolution and reliability of emission source representation, enabling more precise mapping of urban pollution dynamics.

In summary, this work offers a novel, computationally efficient framework that balances the physical rigor of dispersion modeling with the speed of machine learning. It delivers timely, high-resolution hourly air quality maps that better capture complex emission sources. This approach is particularly relevant to operational air quality forecasting and supports informed decision-making for urban air pollution management.

Authors
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Dual cavity dual comb interferometry with incoherent light

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In recent years, applications using two phase coherent frequency combs have attracted great interest in the field of molecular spectroscopy and trace gas sensing. In Dual Comb Spectroscopy (DCS) two frequency combs produce a time dependent interferogram on a detector after passing through a gas sample. This interferogram can be Fourier transformed to extract high resolution optical spectra using a single photodetector.

Using DCS in conjunction with optical cavities for enhanced absorption sensitivity, however, has proven challenging due to the difficulties in matching frequency combs to the mode structure of high finesse cavities, which requires stable active electronic locking schemes. In contrast Dual Cavity Dual Comb Interferometry (DC-COIN) is a novel method using a high intensity broadband incoherent light source to generate interferograms analogous to DCS by combining the light transmitted by two optical cavities with slightly different free spectral ranges. It allows a spectrum to be obtained with a single detector, with high resolution and high sensitivity.

In this presentation we show that using incoherent NIR light (1540-1560 nm) from a spectrally filtered and amplified superluminescent light emitting diode enables the detection of CO2, C2H2, and H2O with a resolution of ~306 MHz with DC-COIN. Proof-of-principle measurements will be presented and pros and cons of the DC-COIN approach for next generation gas sensing will be discussed.

Authors
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NH_3 sensors and UAVs: a comprehensive assessment of ground-based and aerial NH_3 measurements at a poultry farm in northern England

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NH_3 is the major alkaline gas in the atmosphere and the third most abundant N-containing species, after N_2 and N_2O. It is an important target pollutant due to its role in N deposition processes impacting over ecosystems, and it is also a precursor of fine particulate matter (PM), known to cause several impacts on human health (Cape et al., 2009, Tang et al., 2021). Being able to detect and quantify NH_3 is essential for determining the best mitigation policies to reduce these impacts, yet this is challenging given the high spatial and temporal variabilities of this pollutant. Miniaturized sensors would ideally provide the high time resolution and spatial flexibility required to tackle these issues, however current market available sensors have high LODs, slow response times, sensitivity, cross – interferences and very scarce options for outdoor monitoring, compared to the offer for indoor applications targeting over ppm level concentrations.

Based on the results of a prior sensor intercomparison (Espina-Martin et al., 2025), several TB600B-10-NH_3 (ECsense, Germany) sensors were deployed at a poultry farm in Northern England in December 2024 at different compartments of the farm. Three NH_3 sensors were placed outside the chicken sheds alongside a Picarro NH_3 G2103 analyzer to assess their

performance at real environment – conditions. Sensor boxes containing 2-parallel NH_3 sensors were installed within the chicken flock enclosure to measure the indoor concentrations during two weeks at three different sheds with different activities occurring during the measurement period. Finally, a NH_3 sensor was equipped to an unmanned aerial vehicle (UAV) to perform trial flights for around 30-40 minutes to assess the feasibility of using NH_3UAV technology to carry out spatial surveys with high-time resolution.
NH_3 sensors were able to detect NH_3 near-source during high concentration periods, but unable to track accurately the temporal changes in NH_3 concentrations compared to the Picarro, especially during ambient concentration periods. The high inter-sensor variability suggested that they need to be used in arrays of ≥3 sensors. Indoor sensors were able to measure realistic concentrations of NH_3 and follow daily temporal patterns as well as certain farm activity events such as flock depopulation or shed cleaning, however inter-sensor variability was observed as well, further evidencing the need to deploy the sensors in arrays. The aerial trials suggest that the NH_3 sensors are able to pick up higher concentrations whenever the UAV passes over sources, however the technical limitations such as the low response times and the high LODs limit the usefulness of the measurements and longer flights would be necessary to improve the confidence on the measurements.

These results highlight the potential of miniaturized sensors as tools for democratization of pollution visualization, however several technical challenges need to be solved in order to use these measurements as useful information to feed on clean air policies.

Authors
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Leveraging advanced sensor networks and machine learning for real-time air quality monitoring: a fusion of innovation and policy impact

Linchun Yu

News

Air quality monitoring remains critical for addressing health risks and climate challenges, particularly for EU- and non-EU-regulated pollutants. Traditional methods often face limitations in real-time data provision, spatial resolution, and scalability. This study presents an innovative approach combining low-cost sensor networks with machine learning (ML) algorithms to enhance the accuracy and accessibility of air quality data.

We deployed a mesh network of 50 low-cost sensors across an urban area to measure PM2.5, O3, NO2, and CO2, integrating these with high-resolution meteorological data. An ML model was trained to calibrate sensor outputs against reference-grade measurements, achieving R^2 >0.9 for all pollutants. The system's predictive capabilities were further validated using satellite-derived aerosol optical depth (AOD) from the Copernicus program, enabling seamless fusion of ground-level and remote sensing data.

Preliminary results demonstrate real-time pollutant mapping at 1 km spatial resolution, identifying previously undetected urban hotspots. Policy-relevant insights include correlations between traffic emissions and exceedances of EU NO2 limits, informing municipal transportation strategies. Additionally, the platform's open-access dashboard and API are designed to support atmospheric data products for researchers and policymakers, promoting transparency and collaboration.

This work aligns with international R&I initiatives like the European Green Deal and Copernicus, emphasizing scalable, cost-effective solutions for air quality management. By bridging sensor technology, atmospheric modeling, and data science, our approach advances innovation in measurement techniques while fostering equitable access to actionable environmental intelligence. Future efforts aim to expand the framework to greenhouse gas monitoring and meteorological modeling, further contributing to global sustainability goals.

Keywords: Air Quality, Sensor Networks, Machine Learning, Copernicus, Policy Impact, Open Data

Authors
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Hourly $PM_{2.5}$ and PM_{10} matter concentrations prediction in Pune, India, using Aeronet aerosol optical depth (AOD) and meteorological data

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Air pollution can impact on the climate and pose health risk on populous cities. Pune is one of the most populous and second-largest Indian cities of Maharashtra, and it is surrounded by the western margin of the Deccan plateau, with an altitude of 560 m above sea level. It is situated at about 18° 32" N and 73° 51" E longitude. This study used AERONRT AOD level 2.0 data and observed hourly averaged PM (Both PM10 and PM2.5). Meteorological data is taken from Central Pollution Control Board (CPCB) site at Pune to estimate particulate matter (PM).

Statistical results reveal that the significant pollutant in Pune City is PM10 during the pre-monsoon season; the average concentrations of PM2.5 and PM10 are 85 μg/m³ and 110 μg/m³, respectively. The relation between AOD and PM2.5/PM10 using Model I Linear Regression Model II Multiple Linear Regression with meteorological data.

Conclusion: The study's main aim is to the PM2.5 and PM10 estimation using regression methods. A relationship has been found between PM2.5 and AERONET AOD with and without meteorological parameters, Temperature (T), Relative Humidity (RH), and wind speed (WS). Then, the multilinear regression method is used between PM and meteorological variables. And AERONET AOD and T had positive coefficients. In contrast, RH and WS had negative coefficients when compared with PM2.5, while AERONET AOD had positive coefficients, whereas T, RH, and WS had negative coefficients when compared with PM10.

Authors
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Assessing urban land use dynamics and air quality interaction in Ahmedabad using Google Earth engine and earth observation data

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Rapid urbanization in Ahmedabad, one of India's fastest-growing cities, has significantly altered its land use and land cover (LULC) patterns, directly influencing air quality and microclimate. This study investigates the spatio-temporal impact of LULC changes on atmospheric pollution in Ahmedabad over the years, using Earth observation data processed via Google Earth Engine (GEE). Major land use and land cover (LULC) classes, including water bodies, vegetation, built-up areas, and barren land, were extracted from Landsat 8 imagery and classified using Google Earth Engine's cloud-based processing platform. The results indicate a steady increase in built-up areas, primarily at the expense of agricultural and barren land. From 2018 to 2024, urban sprawl intensified in central and western zones, while green cover slightly declined. Concurrently, Sentinel-5P satellite data were used to assess air pollutants such as nitrogen dioxide (NO_2), carbon monoxide (CO), sulfur dioxide (SO_2), methane (CH_4), and formaldehyde (HCHO). Spatial analysis reveals that zones with rapid urban growth exhibit elevated concentrations of NO_2 and CO, especially during pre-monsoon months, reflecting increased vehicular and industrial emissions. This integrated approach demonstrates the potential of combining GEE and satellite-based atmospheric measurements for dynamic monitoring of urban air quality. The findings can support urban planners and environmental authorities in

implementing targeted mitigation strategies for sustainable city development.

Authors
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Traffic induced atmospheric pollution and associated health impact – a pilot study with street fruits vendors

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Africa is experiencing unprecedented growth and is home to fast growing cities. In these cities, the informal economy plays a major role where street vendors are found on roadsides, selling various types of goods. Street vendors spend the entire day near roads and are exposed to pollution from motor vehicles. In the city of Thiès, Senegal, a study was conducted to assess the impacts of traffic related pollution on street fruits vendors. A survey was carried out and an OPC was used to monitor particles concentrations. Within a stretch of 10 km, more than 50 fruits vendors were recorded, and the survey was carried with 35 of them. 86% of the vendors were aged 30-50, and 65% of the vendors were female. More than 40% of vendors declared having frequently or often symptoms such as cold, cough, headaches, eyes irritation and sore throat related to respiratory illnesses. PM2.5 concentrations exceeded by two up to fivefold the threshold value of 15 µg.m-3. The study concluded to the need to develop policies to protect workers and those living on near roads.

Authors
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