VIRTUAL WORKSHOP

INNOVATION IN ATMOSPHERIC MEASUREMENT TECHNIQUES

2 JUNE 2022

BOOK OF ABSTRACTS

HOSTED BY

ACTRiS

ICOS Integrated Carbon Observation System

IAGOS IN-SERVICE AIRCRAFT FOR A GLOBAL OBSERVING SYSTEM

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Republic of Cyprus

Welcome to the Innovation in Atmospheric Measurement Techniques Workshop

Dear Colleagues,
Dear Friends,

It is with great pleasure that we welcome you to our Second Innovation Atmospheric Measurement Techniques Workshop.

First, we would like to thank all of you for your participation at the workshop. In this booklet we are delighted to share with you an exciting program, reporting the main innovations in the field of atmospheric sciences with the participation of 38 talks 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 our Virtual Workshop!

The Hosts & Organizers

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Research Infrastructures Services Reinforcing Air Quality Monitoring Capacities in European Urban & Industrial AreaS (RI-URBANS) - connecting ACTRIS to the urban atmosphere

Tuukka Petäjä

University of Helsinki

Research Infrastructures Services Reinforcing air quality monitoring capacities in European URBAN & Industrial areaS (RI-URBANS) bridges the gap between the expertises and capacities of Air Quality Monitoring Networks and European Research infrastructures, such as ACTRIS. In practice, the project will develop and demonstrate Service Tools (STs) from atmospheric Research Infrastructures (RIs) can be adapted and enhanced to better address the challenges and societal needs concerning air quality (AQ) in European cities and industrial hotspots. RI-URBANS responds to urgent needs to substantially reduce air pollution across EU by providing enhanced AQ observations in support of advanced AQ policy assessment. We develop and enhance synergies between and RIs in the atmospheric domain and combine advanced science knowledge and innovative technologies to develop pilot STs. These will enhance the AQMNs capacity to evaluate, predict and support policies for abating urban air pollution. RI-URBANS deploys tools and information systems in the hands of citizens and communities to support decision-making by AQ managers and regulators. The focus is on ambient nanoparticles and atmospheric particulate matter, their sizes, constituents, source contributions and gaseous precursors. RI-URBANS will evaluate novel AQ parameters, source contributions, and their associated health effects to demonstrate the European added value of implementing such STs. The project builds on existing initiatives for advanced research driven AQ observations at supersites from European cities. Five implemented pilots in 9 cities will demonstrate the ability to integrate complementary STs in AQMNs and data management using FAIR (Findable, Accessible, Interoperable, Re-usable) principles. RI-URBANS will address all aspects of sustainability, including efficient curation, preservation, and provision of access to data, training and capacity building, and how the use of tools will be secured in the future. Finally, upscaling and sustainability will be provided to the offered AQMNs-RIs interoperable services, using advanced instrumentation, modelling, source apportionment, integrated citizens observatories and mobile measurements.

Authors

Petäjä, T., Querol, X. and the RI-URBANS consortium

Pilot Application in Urban Landscapes - Towards integrated city observatories for greenhouse gases (PAUL)

Claudio d'Onofrio
Lund Unversity

The time has come to develop a long-term perspective for city observatories in connection with the European research infrastructure landscape.
PAUL aims to support the European Green Deal by solving specific scientific and technological problems related to the observation and verification of greenhouse gas (GHG) emissions from densely populated urban landscapes. These are fossil fuel emissions hotspots and are therefore at the heart of emission reduction efforts globally.

Authors

Claudio D'Onofrio, Werner Kutsch, Alex Vermeulen, Thomas Lavaux

Pushing scientific boundaries needs continuity and excellent tools

Jost Valentin Lavric

Acoem Australasia (Ecotech Pty Ltd)

"Scientific research builds on past knowledge and experience, coupled with innovation and creative thinking. These are also the values of Acoem Australasia (Ecotech Pty Ltd), with our more than 40 years of working with our scientific customers to provide them with tools they need for pushing the boundaries of their research.

Our hardware and software solutions supply automated high precision gas and particulates measurements and sampling, remote control, integration of your custom measurement setup, and seamlessly integrated tools for data recording, evaluation and validation. Such a portfolio of tools allows the end users to configure a high-quality measurement setup according to their own needs, and to reduce the time between data acquisition and the availability of validated data products – a feature vital not only for good science, but also for decision making related to public health and climate change-related political action.

In addition to our Aurora™ nephelometers that are already widely used in the ACTRIS network and the ICOS network compliant Spectronus™ multispecies GHG analyzer, I will review in my presentation also our other latest products that are of potential interest to this audience."

Author

Lavric, J. V.

Calibrated measurements of the Aerosol absorption coefficient with a multi-wavelength photo-thermal interferometer

Griša Močnik

Haze Instruments d.o.o., University of Nova Gorica

"Direct measurement of aerosol light absorption coefficient is preferrable over indirect methods such as filter photometry or extinction-minus-scattering. Using filter photometers is challenging due to systematic artifacts (Weingartner et al., 2003) and the lack of standardized calibration procedures and materials. A photothermal interferometer probes the change of the refractive index caused by light absorption in (and the subsequent heating of) the sample – the detection is linear and can be traced to first principles. Measurement at two wavelengths allows the determination of its wavelength dependence and the Ångström exponent (AAE).

The photothermal aerosol absorption monitor (PTAAM) uses a folded Mach-Zender interferometer (similar to Moosmüller & Arnott, 1996; Sedlacek, 2006). Two pump lasers at 532 and 1064 nm are modulated at different frequencies and focused in the sample chamber using an axicon (patent granted) for simultaneous measurement. The interferometer signal is detected by two photodiodes and resolved by a dual-channel lock-in amplifier measuring at the two respective frequencies. The green channel is calibrated traceably to primary standards using ~1 μmol/mol NO2. We measured the size distributions of aerosolized nigrosin and used the Mie model to calculate the ratio of the absorption coefficients at the two wavelengths. We transferred the calibration to the infrared channel using this ratio (Drinovec et al., 2022) and validated the Mie model calculation with the comparison of the measured and Mie model derived absorption coefficient at 532 nm.

The instrument was characterized and its uncertainties quantified for the absorption coefficient: 4% (532 nm) and 6% (1064 nm), and the absorption Angstrom exponent (AAE) 9%.

We calibrated filter photometers (CLAP, AE33) in green and near infrared with soot, and determined their cross-sensitivity to scattering for ammonium sulfate particles, resulting in wavelength and size dependent calibration parameters.

A winter ambient campaign has shown similar multiple scattering parameter values for ambient aerosols and laboratory experiments. The spectral dependence of these parameters resulted in AE33 reporting AAE with a bias 0.17-0.3 higher than the PTAAM measurement.

We determined the absorption enhancement using laboratory measurements with uncoated soot and soot coated with secondary organic matter from α-pinene oxidation. The enhancement exhibited a clear wavelength dependence – values at 532 nm ranged from 1.1 (thin coating) to 1.3 (thick coating). A 10% increase of absorption was observed at 1064 nm for thick coating (Kalbermatter et al., 2022).

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Authors

Drinovec, L., Jagodič, U., Pirker, L., Škarabot, M., Kurtjak, M., Vidović, K., Ferrero, L., Visser, B., Röhrbein, J., Weingartner, E., Kalbermatter, D.M., Vasilatou, K., Bühlmann, T., Pascale, C., Müller, T., Wiedensohler, A., Močnik, G.

The four-wavelength photoacoustic aerosol absorption spectrometer PAAS-4Λ for long-term monitoring of the absorption coefficient in the UV-VIS-NIR spectral range

Franz Martin Schnaiter
SchnaiTEC GmbH

The Photoacoustic Aerosol Absorption Spectroscopy (PAAS) is one of the promising methods to specifically measure the absorption coefficient of the atmospheric aerosol without the strong cross-sensitivity to particle light scattering the more established filter-based methods are struggling with. This feature is especially important for remote locations like the Arctic where long-range transported aerosol particles are well mixed, and particle light scattering is dominating the overall extinction coefficient. However, the PAAS technology is generally thought to be less sensitive and less robust than filter-based methods, and PAAS instruments are usually disregarded for unattended monitoring tasks.
In this contribution the novel Photoacoustic Aerosol Absorption Spectrometer PAAS-4λ marketed by schnaiTEC GmbH is introduced. The instrument set-up and its calibration procedure are presented in detail followed by a discussion of the laboratory achieved accuracy, long-term stability, and detection limit. Then, a brief insight into the ongoing monitoring deployment at the Pallas-Sodankylä station "Samamaltunturi" as part of the ATMO-ACCESS activity is given. The main goal of this one-year deployment is to demonstrate the instrument performance under long-term operational conditions at an unattended remote monitoring station to achieve technology readiness level 7. The presentation concludes with an outlook of upcoming instrument validation activities and further development ideas.

Authors

Schnaiter, F. M. and Hyvärinen, A.-P.

Development of RAPID-E+ for in-situ measurements of bacteria, fungi, pollen, and other bioaerosols

Minghui Zhang
Plair SA

"Background: Real-time monitoring of bioaerosols (e.g., bacteria, fungi, virus aerosols) is attracting more attention since the COVID-19 outbreak. Rapid-E+ was developed in 2020 by Plair to extend the capabilities of Rapid-E (old version) in monitoring large bioaerosols such as pollen to small bioaerosols like bacteria and fungi with diameters down to 0.3 µm.
Purpose: Rapid-E+ measures (1) aerodynamic diameters of bioaerosols, (2) the 2D Mie scattering images to have the full details on particle morphology, (3) timely resolved, polarization and angle dependent Mie patterns, (4) fluorescence spectra resolved over 16 channels, and (5) fluorescence lifetime. These information of each single bioaerosol can then be analysed using artificial intelligence (machine learning).
Methods: We tested Rapid-E+ for testing for classification of bacteria and fungi in confined environment. All detected bioaerosols were analysed based on Rapid-E+'s fluorescence and light scattering information. Firstly, they were analysed with a smart filter block to distinguish non-microbial particles. Secondly ("Classification Algorithm"), the filtered particles were further verified to be microbes, based on the calibration data step.
Microbes were aerosolized in a bioaerosol chamber for Rapid-E+ training, and then for testing under different concentrations. Afterwards, we used several steps to classify and identify microbes. We used Bacillus subtilis to represent bacteria and Penicillium chrysogenum to represent fungal spores. Results: Rapid-E+ enabled identification precision of 99% against background. For further distinguishment of bacteria from fungal spores, the achieved precision was 87% and 89% respectively. The real-time monitoring and classification by Rapid-E+ was also demonstrated by aerosolizing various concentrations of microbes again in the chamber.
Conclusion: Pollen grains and pollen fragments can be detected by Rapid-E+ with similar or even better performance compared to the old version. Proprietary algorithms can be further developed by the user to extend the instrument application on specific microorganisms such as virus aerosol identification. "

Authors

Zhang, M., Fkaier, S., Fernana1, S., Kiseleva, S., and Kiselev, D.

AeroTape: a real-time IoT atmospheric particle analyzer

Adrien Reynaud
Oberon Sciences

Airborne pollen grains are responsible for allergic responses of a growing part of the population, thus it is important to understand their emission and transport. Such processes remain scientific challenges and extensive datasets coupling pollen concentration per taxa and weather data on different geographic locations are valuable so hypotheses can be put forth and conclusions can be drawn. For this purpose, the AeroTape device has been developped.
The AeroTape is an IoT (Internet of Things) aerosol analyzer able to sample atmospheric airborne particles within the range 500 nm - 200 um. It is inspired by Hirst standard EN 16868-19 and is qualified against it. The AeroTape features an impactor designed to precipitate microparticles on a transparent duct tape which is uncoiled at various velocity and modes (continuous or sequential) to avoid picture saturation. This method prevents over-deposition in the optical stage and thus allows the sampling of highly concentrated aerosol environments. This principle allows the objective to automatically perform visible light and fluorescent microscopy to capture real-time pictures of the deposited material. Photographs can be taken at a frequency up to 0.5 Hz and are then sent to a server to be processed by an artificial intelligence (AI) in order to perform real time bio/non bio discrimination over the particle mix, then achieve pollen taxa recognition and counting. The currently implemented AI is the convolutional neural network Inception v3 which has an accuracy of 87% for pollen detection. Furthermore, the output data can be analyzed together with meteorological information thanks to a weather station attached to the case of the AeroTape.
Optical measurement techniques have the potential to provide access to a wide range of particles, which can be coupled with the power of a device network generating real-time data — however some challenges are still to be tackled. For instance, size distribution function requires the instrument to be calibrated using monodisperse aerosols. Ways of development also include the improvement of the AI as well as the implementation of new microscopy techniques so the AeroTape use can be extended to new scientific problems requiring large datasets.

Authors

Reynaud, A., Filippi, D., Sarda Esteve, R., Guinot, B.

A new robust UFP measuring device for long-term low-cost ambient monitoring

Martin Fierz

Naneos particle solutions

Ultrafine particles (UFP) hardly contribute to traditional particle mass measurements (e.g. PM10 and PM2.5). Traditional UFP measurement devices, such as condensation particle counters (CPC) or scanning mobility particle sizers (SMPS) are complex, bulky, and expensive. They also require a significant amount of maintenance. Devices based on diffusion charging are a potential alternative for UFP measurements, with several advantages compared to traditional devices. We have developed a new diffusion-charging-based device intended for 24/7 monitoring of ambient UFP concentrations. It measures the lung-deposited surface area (LDSA). To test the new device, we deployed 10 units in and around Zürich for nearly 2 years. The devices proved to be robust, and an intercomparison after a full year of measurements showed a low inter-device variability. I will present the device, and show some selected results from the last year of the measurement campaign.

Author

Fierz, M.

A new high resolution Cloud Droplet Analyzer for stationary in-cloud Monitoring

Sergej Sel

Palas GmbH

The new Cloud Droplet Analyzer is a high-resolution optical aerosolspectrometer optimized for measuring size distribution and number concentration of cloud aerosols like droplets and ice crystals up to 40 µm. Based on the measurement principle of optical light scattering (90°) on single particles and high resolution components droplets and ice crystals should be distinguished by their scattering. Additional information from temperature and relative humidity can be taken into account for determination of water content and droplet effective diameter.

Authors

Sel, S., Gossmann, A.-K., Weis, F., Weiss M.

Particle Habit imaging and polar scattering (PHIPS) probe for measurement of cloud optical and microphysical properties

Emma Järvinen

Karlsruhe Institute of Technology

Clouds are one of the main contributors to the uncertainties related to climate predictions. Current unresolved research questions are related, among others, to the optical properties of aspherical ice crystals, the existence of small ice, ice formation and multiplication processes as well as mixed-phase cloud phase composition. It is clear that innovative technologies are needed in the field of cloud physics, where a great fraction of the standard in-situ instrumentation used still deploy technologies developed in the 70s.

Here, we give an overview of the Particle Habit Imaging and Polar Scattering (PHIPS) instrument, which is an airborne probe combining stereo-microscopic imaging and angular light scattering measurements on the same particle. The instrument has been operational in airborne studies and in cloud chamber experiments since 2014. In this contribution we will give an overview of the data products and present results on how the instrument has been deployed to answer research questions related to cloud optical properties, cloud phase composition and microphysical processes such as secondary ice and precipitation formation.

Authors

Järvinen, E. and Schnaiter, M.

A Relaxed Eddy Accumulation (REA) LOPAP-System for Flux Measurements of Nitrous Acid (HONO)

Jörg Kleffmann

Physical and Theoretical Chemistry, University of Wuppertal

Background: Nitrous acid (HONO) is an important source of the OH radical, the detergent of the atmosphere. High HONO levels have been observed during daytime in the atmosphere, which were mainly explained by different ground surface source, e.g. the photosensitized conversion of NO2 on organic substrates or the photolysis of nitrate. Despite its origin, HONO sources have been typically quantified using a PSS approach, in which they are mathematically treated as gas phase sources. Caused by strong gradients in the atmosphere, this quantification is highly uncertain and dependent on the turbulent mixing in the atmosphere and the measurement height above the ground surfaces. Here flux measurement is a more suitable way to determine the strength of heterogeneous HONO sources and sinks. Eddy Covariance is the most elegant way to measure fluxes of trace species. However, since fast (>1 Hz) and sensitive (DL<10 ppt) HONO instruments are not available, fluxes were measured in former studies mainly by the flux gradient method or by the Relaxed Eddy Accumulation (REA) approach using instruments with lower time response.

Purpose: A REA system based on the LOPAP (LOng Path Absorption Photometer) technique should be developed and tested in the laboratory and in the field.

Method: By the REA approach up- and downdrafts are separated by two values controlled by the sign of the vertical wind direction measured by an ultrasonic anemometer. The valves are controlled by a homemade software, which also logs all wind and valve switching data and which calculates different parameters, necessary for the flux calculation. The HONO concentrations in the two airmasses are determined by the LOPAP technique, for which the air is pumped through stripping coils in an external sampling unit, in which HONO is sampled by a fast, selective chemical reaction in the liquid phase. After transfer from the external sampling unit by a temperature-controlled reagent line to the main instrument housed in a field rack, a strongly absorbing dye is formed which is detected in long-path liquid core waveguides by Lambert-Beer's law. To correct for interferences, which are always a problem for wet-chemical HONO instruments, three channels are used in the instrument, two for the up- and downdrafts and one to quantify the interferences for both airmasses. The used LOPAP instrument is very sensitive (DL: 1 ppt) and was successfully intercompared with the DOAS technique in several intercomparisons.

Results: In laboratory experiments the REA-LOPAP system was carefully tested and a data evaluation procedure was developed. Since the instrument's channels periodically switch between ambient sampling and zero gas measurement the proper dilution correction was verified using a pure HONO source and a specific valve switching mode of the software. In addition, the interference correction using only one channel for both airmasses was tested by periodically changing the allocation of the two airmasses to the two physical channels. In between the experimental variability the interferences were similar for the up- and downdrafts.

Finally, the instrument was tested at the field site Melpitz (Germany), which is operated by the TROPOS institute in Leipzig and is used as a regional station by the Global Atmosphere Watch (GAW) program. The station is located on grass land and is exposed only to moderate pollution. HONO fluxes in the range of -4x10^13 molecules m^-2 s^-1 (deposition) to +1.0x10^14 molecules m^-2 s^-1 (emission) were obtained. A typical diurnal variation of the HONO fluxes was observed with low, partly negative fluxes during night-time and higher positive fluxes around noon. After an intensive rain period the positive HONO emissions during daytime were continuously increasing, which was explained by the drying of the upper most ground surfaces. Similar to other campaigns, the highest correlation of the HONO flux was observed with the product of the NO2 photolysis frequency and the NO2 concentration, which implies a HONO formation by photosensitized conversion of NO2 on organic surfaces, like e.g. humic acids. Other postulated HONO

formation mechanisms are also discussed, but are tentatively ranked being of minor importance for the present field campaign.
Conclusion: In the present study a Relaxed Eddy Accumulation (REA) system for the quantification of vertical fluxes of nitrous acid (HONO) was successfully developed and tested in the laboratory and in the field. The system is based on a three-channel-LOPAP instrument coupled to a REA gas inlet, for which an ultrasonic anemometer controls two fast magnetic valves to separate up- and downdrafts. In a field campaign over grassland typical diurnal flux profiles were observed with low, partly negative fluxes during night-time and higher positive fluxes around noon. From the correlation of the HONO flux with J(NO2)·[NO2]) HONO formation by photosensitized conversion of NO2 on organic surfaces, like e.g. humic acids is proposed.

Authors
Von der Heyden, L., Wißdorf, W., Kurtenbach, R., and Kleffmann, J.

The ICAD NO2 / NOX instrument: calibration free in-situ measurements of trace gases for atmospheric and emission studies

Denis Pöhler

Airyx GmbH, Eppelheim, Germany

The Airyx ICAD NO2/NOx monitor measures ambient concentrations of NO2, NOx and NO. NO2 is measured directly via broad band spectroscopy relying on characteristic molecular absorption features between 435 – 465nm. With the spectroscopic approach, overlying absorptions of H2O, Glyoxal and Ozone are derived. This minimizes cross-interferences and avoids the need of a water dryer. By using literature absorption cross-sections, the system is NO2 calibration gas free.
To achieve high accuracy and low detection limits in the ppb or ppt range, the absorption is enhanced with an optical resonator creating optical absorption paths up to several km in a cell of 25cm length. In contrast to similar setups (BB-CEAS, CE-DOAS, CAPS, CRDS), ICAD applies a different spectroscopic analysis algorithm with one main advantage: the derived concentration is independent of the absolute measured intensity. Absolute intensities vary often due to changing instrument temperature, vibration and aging and thus lead to systematically deviating concentrations and thus larger errors. ICAD avoids this influence and thus systems can be built simpler, they are less sensitive to perturbations and achieve higher accuracy. Detection limits of 0.5 ppb at a time resolution of 2s or 100ppt at 60s are achieved. With high grade configurations, accuracies of 100ppt at 2s time resolution and down to 6ppt at 1800s can be achieved. NOx is measured with an additional NO to NO2 converter based on ozone titration. NO is calculated from the difference of NOx to NO2.
The ICAD instrument is available in different housings: waterproof IP64 plastic housing for field applications and harsh environments and a 19'-rack version for monitoring and laboratory applications. Also, customized solutions are possible e.g. a weight-reduced UAV-version was built.

Typical applications are for example:
- High precision NO2 / NOx measurements
- Air quality monitoring
- Mobile applications to derive NO2 / NOx maps
- Real driving vehicle emissions using the plume chasing method
- Workspace monitoring

Authors

Lampel, J., Pöhler, D., Horbanski, M., Schmitt, S., and Platt, U.

A new instrument for in-situ HONO measurements by iterative cavity enhanced DOAS

Johannes Lampel

Airyx GmbH, Eppelheim, Germany

"We present a new spectroscopic instrument to measure directly ambient in-situ HONO (nitrous acid) concentrations using the ICAD technique. HONO concentrations can be measured with an error of 200 ppt at 10s and 20 ppt at 1000s time resolution. The advantage of the ICAD spectroscopic technique is that it does not require gas calibration and allows for simple long term operation with high accuracy while not relying on the absolute stability of the light source intensity.

Atmospheric HONO concentrations are of interest since they significantly influence OH radical concentration and thus the tropospheric oxidation capacity. Also, HONO can give rise to the formation of highly mutagenic species in the human lung. HONO sources are still largely unknown in detail and discrepancies are observed between measured and modelled HONO concentrations. We present in-door and out-door in-situ observations of HONO and long-term stability tests.

The instrument provides simultaneous measurements of NO2 with a measurement error of 400 ppt at 10s time resolution and 40 ppt at 1000s time resolution (based on modified Allan deviation). With an overall power consumption of typically 40W, its robustness to vibrations and a 19" Rack housing size of 13,5 x 49 x 66 cm^3, it is also suitable for mobile applications as is the commercially available NO2/NOX version of the instrument."

Authors

Lampel, J., Pöhler, D., Schmitt, S., Horbanski, M., and Platt, U.

New solution for simultaneous monitoring of greenhouse gases and air pollutants with extremly high precision

Morten Hundt
MIRO Analytical AG

Continuous monitoring of air pollutants and greenhouse gases is crucial for ambient air quality improvement and mitigation of climate change. A wide range of sources, both natural and man-made, emit harmful substances into the air. While some pollutants are short-lived and pose only a localized threat, others can persist in the atmosphere for years, causing widespread damage. Precise assessment of the ambient air quality is essential in order to identify sources and track various pollutants. This information can then be used to take action to mitigate their impact, whether it be through regulation of polluting sources or developing strategies to remove pollutants from the atmosphere. Greenhouse gases are of particular concern due to their role in climate change. By continuously monitoring these gases, we can gain a better understanding of their impact on the environment and reduce their emissions.
At MIRO Analytical AG we are developing and producing new innovative series of MGA1-MGA10 analysers that can simultaneously measure up to 10 greenhouse gases and air pollutants. Our analysers are based on direct mid-IR laser absorption spectroscopy and combine several Quantum Cascade Lasers (QCL) as light sources. Our QCL analysers demonstrate extremely high precision and very good stability of the measurements. Main advantages of our MGA analysers:

1. Measures up to 10 gases simultaneously: CH4, CO, CO2, SO2, NH3, N2O, NO, NO2, H2O, O3 and optionally OCS, HONO.
2. Can be tuned to different combinations of gases depending on application requirements.
3. Direct measurements of all components, no convertors or sample pre-treatment.
4. High measurement rate (1Hz and 10Hz), ideal solution for eddy-covariance flux measurements.
5. Compact and suitable for field deployment with temperature stabilized enclosure.
6. Suitable for mobile and airborne monitoring (aircrafts, ships, cars).
7. Suitable for soil monitoring and chamber measurements.

In this contribution we will demonstrated how MGA analysers can be used for your research and measurement campaigns in various research areas.

Authors

Morten Hundt, Maria Timofeeva, Oleg Aseev

Ammonia dry deposition measurements using two new instruments

Arjan Hensen

TNO

Good ambient air ammonia concentration measurements a challenge, good ammonia flux measurements are even more demanding.
The sticky nature of the ammonia molecule is a serious problem for any instrument with an inlet line. In this presentation we will show some first results of an intercomparison campaign that was carried out in the Dutch Ruisdael RITA campaign in the summer of 2021. An open path UV-based miniDOAS 2.2D system (RIVM, Netherlands) and the QCL infrared-based HT-8700E (Healthy Photon Ltd., China) were used simultaneously for dry deposition measurements of ammonia over a peat soil pasture at Cabauw (NL). We will show the concept of the two measurement systems and the advantage of these when compared to closed path measurement systems, especially for applications that require fast time response data. We'll discuss the potential use of this type of ammonia measurement systems and the ways to further improve them (and the closed path systems as well) for the coming years.

Authors

Hensen,A., Zhang,J, Swart, D.P.J., Van der Graaf, S.C, Rutledge-Jonker,S., Berkhout,J.P.J., Wintjen P., van der Hoff, G.R., Haaima, M., Frumau, K.F.A., Van den Bulk, W.C.M., Van Dinther, D., Schulte, R., Van Goethem., T.M.W.J.

Monitoring the Spatial aerosol distribution of volcanic ashes and Sahara dust on La Palma Island

Ann-Kathrin Goßmann

Palas GmbH

Airborne dust affects both human health and the environment. In the human lung, dust deposition can cause respiratory diseases. And dust deposition of snow and glaciers for example intensifies melting and probably also influences other atmospheric conditions that are related to climate change. This wide range of effects leads to a major interest in aerosol measurements for large group of researchers. One factor of interest is the transport of dust in the atmosphere. To study this, 9 AQ Guard Smart Aerosol Spectrometers have been installed on la Palma Island during the volcano eruption in Autumn/Winter 2021. The devices were installed around the volcano with focus on the most affected areas but also on the far side of the mountain chain dividing the island in east and west part. Aerosol size and number concentration as well as particulate matter values were measured from mid of November until mid-February thus covering a period with Vulcanic activities (until 13.12.2021) and without. Additionally, we also captured two days of airborne Sahara Sand dust washing over the Canary Islands. The local differences in particulate matter occurring during the volcano eruption were studied on the data basis obtained from the 9 devices. The highest values were recorded in Los Llanos, the town closest to the volcano. The particulate matter readings of the other locations were found to vary depending on wind conditions. Especially the difference between the east and west site of la Palma was found to be very pronounced which is in accordance with the island being divided by a mountain chain. The particle size distribution obtained during the volcano eruption and the Sahara sand dust event at the same location were compared. While sand dust influences the whole captured particle size range, volcanic dust is found to be much coarser resulting in a bimodal distribution.

Authors

Goßmann, A. , Weis, F., Weiß, M., Sauleda Brossa, A., Vilches Sarasate, J. and Gallo Acosta, V.M.

Cutting-edge technologies for research in aerosols and gases in urban air quality (TIGAS-CM PROJECT)

Begoña Artiñano

CIEMAT

Background: Air quality is one of the main environmental problems affecting population health worldwide. To cope with this issue, integrated studies on atmospheric constituents and dynamics are required to get a complete overview of the main processes and variables involved. These should be supported by high quality data and parameters, which in many cases are almost exclusively obtained in research stations and installations like ACTRIS, the EU infrastructure, in which the most advanced techniques, both remote sensing and in situ, are used for atmospheric research.

Purpose and Methods: The dynamics of the urban plume of the Madrid city and its related physico-chemical processes is studied by means of the Madrid-CIEMAT Actris station instrumentation. Surface measurements (SMPS, Q-ACSM, H-TDMA, aethalometer, nephelometer, off-line characterization) on aerosol properties and gases (DOAS, O3 & NOx analyzers) and vertical profiles provided by aerosol remote sensing instruments (LIDAR, ceilometer) allow analyzing the evolution of the urban pollutants from a local perspective.

To complement this view, a co-located MAXDOAS 2D instrument based on the ground-based Multi AXis Differential Optical Absorption Spectroscopy technique, provides a two dimensional view (in height and Viewing Azimuth Angle) of irradiance extinction and NO2. Thus, new mesoscale information provided by this instrument contributes to the study of the pollution transport dynamics in Madrid.

Results and conclusion: A comprehensive database of simultaneous surface and vertical profile measurements has been obtained in the framework of the TIGAS-CM project. After the analysis of a two-year time series several conclusions have been obtained and a number of hypotheses have been proposed requiring further investigations, like those affecting the vertical structure of the polluted airmasses and the observed upper layers. The particular atmospheric and air quality conditions taking place in Madrid during January 2021, as a consequence of the extreme weather event, so-called Filomena storm, which almost completely paralyzed the city for a week as a result of the intense snowfall, allowed the study of a very specific scenario, providing useful information on the pollution dynamics.

This work has been partially financed by the Madrid Regional Government Y2018/EMT-5177 and the ERDF and ESF European funds.

Authors

Artíñano B., Saiz-Lopez A., Pujadas M., Cuevas C. A., Nuñez L., Serna J.A., Barragan R., Benavent N., Palacios M., Molero F., Fernandez-Pampillón J., Gómez-Moreno FJ., Alonso E., Coz E., Díaz E., Salvador P. and Fernandez J.

Long-term & high-time resolution monitoring of desert dust PM concentration using an aerosol absorption photometer

Michael Pikridas

Climate & Atmosphere Research Centre (CARE-C), The Cyprus Institute

Real-time quantification of black and brown carbon in ambient aerosol has been achieved via absorption photometers taking advantage of the optical (absorbing) properties of these components. Mineral dust is a third constituent found in ambient aerosol, which absorbs in the visible and ultra violet part of the spectrum. Direct quantification of mineral dust concentration using optical aerosol absorption methods is theoretically possible but challenged by the simultaneous presence of the other two absorbing components that feature a higher absorbing cross-section by 2 orders of magnitudes.

A new method that overcomes this challenge is presented here for real-time and high-resolution quantification of mineral dust using absorption photometers (Aethalometer AE33, Aerosol doo). Based on Drinovec et al. (2020), this method primarily relies on the fact that dust particles lie in super micron sizes contrary to black and brown carbon particles that are mostly found in the submicron range. As such, the aerosol absorption signal of the coarse aerosol mode is enhanced by employing a high-flow virtual impactor that can enrich by 10-20 times this fraction (relatively to the submicron mode). A second absorption photometer is used to monitor the absorption coefficient of the submicron aerosol, and the difference of the two instruments is used to calculate the absorption of concentrated dust particles.

We report here, for the first time, two (2) years (2018 and 2019) of continuous observations of PM dust using this methodology at the ACTRIS National Facility of Agia Marina Xyliatou which is part of the Cyprus Atmospheric Observatory (CAO) network. Simultaneous observations of aerosol chemical composition were performed with daily filter sampling, both at PM2.5 and PM10 sizes. A good agreement (R2=0.63) was found between the enhanced absorption coefficient of supermicron aerosols (e-babs) and calcium concentration, a proxy of desert dust. The agreement improved slightly (R2=0.70) when higher resolution (hourly) measurements of PMcoarse (PM10-PM2.5) mass were considered.

To showcase the method's ability to capture short-term events, a 3- month intensive campaign took place from March till May 2019 at the urban background station of CAO. Additional to the aforementioned instrumentation, it included online measurement of selected cations (Na+, Mg2+, Ca2+) in PM10 with 10-min time resolution using a Particle-into-liquid-sampler coupled with an Ion Chromatograph (PILS-IC). Diel profiles of PM10 dust, derived from e-babs, suggest the presence of two dust sources, traffic-related dust resuspension showing a maximum at rush hours and intrusion of long-range transported desert dust. The potential and limitations of this new method to monitor long-term PM from desert dust are further discussed here.

Authors

Pikridas Michael, Matic Ivančič, Sarda-Estève Roland, Oikonomou Konstantina, Bimenyimana Elie, Unga Florin, Rigler Martin, and Sciare Jean

Quantifying CH4 emissions from in-situ measurements and comparison with national emission inventory results

Yunsong Liu
Le Laboratoire des Sciences du Climat et de l'Environnement (LSCE)

The Eastern Mediterranean and the Middle East (EMME) region is an emerging regional hotspot of greenhouse gas (GHG) emissions. However, due to the absence of systematic atmospheric GHG measurements in EMME, it remains challenging to characterize, validate and quantify the spatial distributions and the intensity of emissions in this region. Therefore, we performed year-long mobile methane (CH4) measurements from October 2020 to September 2021 (24 survey days) at representative hotspots in Cyprus, an island in EMME region with methane emission sources emanating primarily from waste and agricultural activities. The surveyed areas include an active landfill (Koshi), a closed landfill (Kotsiatis), and a concentrated cattle farm area (Aradippou), accounting for about 28% of national CH4 emissions. The emission rates were estimated using the Gaussian plume model. The total methane emission from both landfills (25.9±6.4 Gg yr-1 at the 95% confidence level) and enteric fermentation of cattle (10.4±4.4 Gg yr-1 at the 95% confidence level) were about 160% and 40% greater than the respective bottom-up inventory estimation. The difference may result from i) the obsolete inventory data possibly based on empirical/regional/default input values based on limited and outdated research; ii) incorrect attribution of emissions from the closed landfill, which is deep unmanaged and did not meet the standards for landfills of European Union directives. Therefore, our analysis showed that the approach or default values used in the FOD model (IPCC, 2006) are not appropriate for estimating landfill CH4 emissions in Cyprus and the method used for landfill CH4 emission estimation in the inventory at a national level could be improved by integrating information from measurements. Notably, an average 21% uncertainty is coupled to the in-situ measurements, which is attributed to the atmospheric variability. This study selected representative methane emission hotspots and provided complete, independent, and temporally and spatially consistent measurement data to validate the bottom-up inventory at a national scale.

Authors

Yunsong Liu[(1) (2)], Jean-Daniel Paris[(1) (2)], Mihalis Vrekoussis[(2) (3)], Pierre-Yves Quéhé[(2)], Maximilien Desservettaz[(2)], Jonilda Kushta[(2)], Florence Dubart[(2)], Demetris Demetriou[(2)], Philippe Bousquet[(1)], Jean Sciare[(2)]

(1). Laboratoire des Sciences du Climat et de l'Environnement, 91191 Gif sur Yvette, France
(2). The Cyprus Institute, Climate and Atmosphere Research Center (CARE-C), Nicosia, Cyprus
(3). University of Bremen, Institute of Environmental Physics and Remote Sensing (IUP) & Center of Marine Environmental Sciences (MARUM), D-28359 Bremen, Germany

Vertical profile of greenhouse gases (CO2, CH4, CO, N2O, H2O) from surface up to 35 km with Aircore: long term monitoring program at Trainou, France

Julien Moyé

LSCE

The AirCore technique consists of using a long custom-made tubing under a stratospheric balloon which enables the passive sampling of atmospheric air from up to 35 km altitude down to the surface (Karion et al. 2010, Membrive et al. 2017). After AirCore recovery, the air sample is pushed into gas analyzers enabling precise measurement with low volume of air. The measurement program has started at the Trainou ICOS tall tower in France, in October 2016, and since November 2020, two analyzers (Picarro G2401 (CO2, CH4, CO, H2O) and Picarro G5301 (N2O, CO, H2O)) are coupled to measure N2O in addition to CO2, CH4, H2O and CO, which makes Trainou the unique site in Europe with monthly profiles of those 5 species. More than 90 vertical profiles have been performed since 2016, and 30 of them since the coupling of the two analyzers. This presentation will focus on the mounting of these two instruments in parallel and will also present some results of vertical profiles and comparisons. We will present an evaluation of the measurement uncertainties by comparing the pairs of AirCores launched simultaneously. One AirCore is measured through the two instruments and one is measured through the G24 only. The comparison of CO2, CH4 and CO gives good agreement between the two mountings: between 1 and 15 km high, for the coupled instruments, the mean difference is 0.1 ±0.1 ppm, 1.2 ±1 ppb and 1.1 ±1 ppb for CO2, CH4 and CO respectively.

A comparison of the observed vertical profiles with the CAMS analysis will be also presented, as an illustration of the interest of such measurements to validate atmospheric transport models.

Authors

Moyé, J., Laemmel, T., Ramonet, M., Lopez, M., Laurent, O., Philippon, C., Latchabady, S.

Characterizing regional methane emissions from the oil and gas sector using non-methane hydrocarbons

Emeric Germain-Piaulenne

Climate & Atmosphere Research Centre (CARE-C), The Cyprus Institute

Methane is a potent greenhouse gas but its sources remain poorly quantified in the Eastern Mediterranean and Middle East (EMME) region. Light alkanes, such as ethane (C2H6), are co-emitted by fossil fuel (oil and gas) activities and are promising tracers for quantifying the methane emissions from this sector. Cyprus is an ideal location for studying the composition of air masses of varied origin and for characterizing different emission source signatures at a regional scale. A Picarro analyzer and two field-based Gas Chromatography Flame Ionization Detectors (GC-FID) were deployed and an extensive dataset is generated. Our aim is to use these observations for identifying regional and local anthropogenic methane sources, for assessing tropospheric concentrations, while evaluating the significance of long-range transported versus local sources. Continuous methane observations were performed between February 2020 and December 2021 at a suburban background site of the capital city of Nicosia in Cyprus. NMHC (C2-C12) measurements were also performed on the same site between February and December 2021, and include both anthropogenic (alkanes, alkenes, aromatics) and biogenic (isoprene, monoterpenes) compounds that help in the separation of sources originating from different sectors. Our initial results suggest strong local methane and NMHC sources. We also provide evidence for long-range transport, using the observations obtained during a 3-month field campaign using a Mobile Laboratory (MoLa) deployed at the south-eastern edge of the island between December 2021 and February 2022. The aim was to study the contribution of methane emissions from Middle Eastern oil and gas operations while minimizing the influence of local (island-based) emissions. Our measurements will ultimately provide a better understanding of pollution sources at local and regional scale in the Eastern Mediterranean region.

Authors

Germain-Piaulenne, E., Sciare, J., Gros, V., Paris, J-D., Quehe P-Y., Desservettaz, M., Baisnee, D., Liu, Y., Bourtsoukidis, E.

Retrieving Vertically Resolved Cloud Condensation Nuclei Concentrations from Spaceborne Lidar measurements

Piyushkumar Patel
Jet Propulsion Laboratory

Aerosol and cloud-mediated change in climate forcing is the most uncertain one among all forcing agencies in the climate system, representing the largest challenge in climate predictions. Quantifying this at a global scale needs space-borne retrieval of cloud condensation nuclei (CCN) number concentration. Our inability to do so introduces the highest uncertainty regarding aerosol-cloud interactions and their climate forcing. This can be addressed by the emerging capability of estimating CCN concentrations using space-borne lidar measurements. The present study offers a novel approach to estimating vertically resolved CCN concentration at different supersaturations from multi-wavelength measurements from space-born lidar instruments. The algorithm uses backscatter and extinction coefficients from Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) along with the inverse-Mie technique to determine the aerosol size parameters for predefined aerosol types. Followingly, the critical radius of CCN activation at various supersaturation determines using the maximum of κ-Köhler theory. Finally, the CCN concentrations are calculated by integrating the aerosol size distribution over a range of critical radii at various supersaturation. Furthermore, the present retrieval approach will provide the 3D high-resolution benchmark datasets of CCN concentrations on a global scale which will be decisive for an improved quantitative estimate of climate forcing due to anthropogenic impacts.

Authors

Patel, P. N., Jiang, J. H.

The NO2 camera: A spectral imager for mapping urban pollution

Emmanuel Dekemper
Royal Belgian Institute for Space Aeronomy (BIRA-IASB)

Nitrogen oxides (NO and NO2) are formed in combustion processes taking place in, e. g. car engines, heaters, or thermal power plants. They are among the key species in air quality budgets, yielding respiratory diseases, and participating to the formation of smog. As such, national, EU, and WHO regulations impose maximum levels of NOx concentration in order to limit the exposure of human beings.As seen from space (by the TROPOMI instrument for instance), tropospheric NO2 is widely spread over industrialized regions, without being able to distinguish local sources (except a few isolated large power plants). On the other hand, citizen-powered projects (like the CurieuzeNeuzen campaign in Belgium) have emphasized how inhomogeneous can be the distribution of NO2 among the streets of a city. There is currently a wide gap between what is ideally needed (urban-wide street-level NO2 exposure maps), and what is currently offered by remote sensing instruments. We have developed an instrument which can measure the abundance of NO2 in air masses with an unprecedented spatial resolution. The instrumental concept is totally different than regular scanning spectrometers. Here, the instrument is a spectral imager using a tunable bandpass filter with sufficient spectral resolution for exploiting the absorption cross-section structures of the NO2 molecule. A typical observation with this NO2 camera consists of taking spectral images of the scene at a number of wavelengths in a sequential manner. The spectrum recorded by each pixel is processed by a DOAS algorithm, and the NO2 column density seen by the pixel is derived. Tests have been carried out in different contexts, illustrating the capabilities of the NO2 camera. An intercomparison with a reference instrument (MAX-DOAS) has confirmed the accuracy of the instrument. The next step is to make another round of hardware improvement, and to identify concrete application cases.

Authors

Dekemper, E., Vanhamel, J., Merlaud, A., Van Roozendael, M.

The SKYSPEC instrument: Atmospheric monitoring with passive DOAS remote sensing

Jan-Lukas Tirpitz
Airyx GmbH, Eppelheim, Germany

Multi-Axis or direct Sun Differential Optical Absorption Spectroscopy (MAX-DOAS) is a passive remote sensing technique for atmospheric monitoring. High resolution ultra-violet and visible radiation spectra of scattered skylight recorded in distinct viewing directions are analysed to infer information on the abundances of various trace gases (e.g. NO2, SO2, O3, HCHO, HONO, H2O, IO, BrO, Glyoxal) and aerosols integrated along the effective light path though the atmosphere. Sets of spectra recorded at different viewing geometries provide information on the spatial distribution of the detectable species and advanced inversion algorithms even allow to infer vertical concentration profiles. In the recent decades, MAX-DOAS experienced great advances within the scientific community. However, measurements are mostly performed with prototypes. Airyx developed the SkySpec instrument series, comprising commercial hard- and software for MAX-DOAS and direct Sun observations. As a spin-off from the Environmental Physics department of the University of Heidelberg, it can resort to a long-year experience with scientific grade DOAS instrumentation and related requirements. The SkySpec combines state-of-the-art instrument specifications with easy and flexible operation as well as low maintenance requirements. Light is gathered by the instrument's narrow field-of-view telescope unit, available with up to two motorised axes to realise arbitrary viewing directions and Sun tracking over the entire sky hemisphere. Viewing angles are automatically calibrated using inertial measurement units inside the telescope and the Sun's position as reference. Gathered light is coupled into a fibre and guided into temperature stabilised low-straylight spectrometers. Internal sensors and light sources are used to monitor the overall stability and performance of the spectrometer in order to obtain high-quality spectroscopic data. New standardized data analysis software provide directly vertical atmospheric columns of trace gases and surface concentrations SkySpec instruments can be operated by scientist and technicians without DOAS expertise, making it well suitable for application in atmospheric monitoring networks.

Authors

Tirpitz, J.-L., Poehler, D., Lampel, J., Schmitt, S., Horbanski, M. and Platt, U.

The GRASP-SAS High resolution Air Quality product

Richard Kleidman
AirPhoton Inc

The proper characterization of airborne particulate pollution is extremely difficult owing to its high spatial and temporal variability. In-situ measurements by ground and airborne instrument provide high accuracy but are very limited in spatial extent. Satellites provide high spatial coverage but do a poor job of representing human exposure at ground level. AirPhoton Inc. and GRASP-SAS will use a combination of satellite and ground observations and the GRASP (Generalized Retrieval of Atmosphere and Surface Properties) analytical platform to provide a high-quality air quality product that represents human exposure at the ground. Airphoton's new generation of polar-nephelometers with GRASP retrieval can provide real-time optical and microphysical properties of the aerosols. The GAPMAP (GRASP-AirPhoton Multi-Angle Polarimeter) series of imaging calibrated multi—angle polarimeters on cubesats will be launched over the next several years. The first in-orbit-demonstrator will be launched in January 2023 as part of the ADLER-2 mission managed by SPIRE. A constellation of these instruments will monitor selected targets on earth approximately 5 times per day allowing us to capture the diurnal cycle of the air particulates. The ground and satellite observations will be combined with a modeling effort to simulate chemical transformation and transport on large scales, coupled with high resolution local modeling. The proposed presentation will introduce the comprehensive system for particulate pollution characterization: ground and satellite instruments, algorithms, inversion software, and models. With this new system, GRASP/AirPhoton intends to provide revolutionary new information for the science, industry and policy communities.

Authors

Fuertes, D., Dubovik, O., Martins, J., Remer, L.

Karsa multi ion chemical ionization inlet (MION2) for ultrasensitive trace vapor detection

Juha Kangasluoma
Karsa Ltd

Background: Full characterization of the atmospheric reactive vapor phase requires a suite of instrumentation, and the current chemical ionization mass spectrometers typically accommodate the use of only one reagent ion at a time. The measurement of these trace gases has been recently included into the ACTRIS research infrastructure. Here we discuss the most recent advances in the second generation of the Karsa multi ion chemical ionization inlet (MION2) (Rissanen et al. 2019), and its applications to the measurement of atmospheric and pesticide vapors. Purpose: The purpose of the presented efforts is to increase the sensitivity and selectivity of the MION2 toward a range of different chemical species, and to allow full chemically selective characterization of the vapor phase using only one mass spectrometer. Methods: The design of the MION2 makes it possible to semi-simultaneously use up to three different reagent ions to ionize the vapor phase. We present improvements in the ion optics to decrease the detection limits. Use of an electrospray source to produce new reagent ions for the MION2 is demonstrated. Results: The new ion optics increase the reagent ion concentrations by an order of magnitude compared to the previous MION generation, and this decreases the detection limits by an order of magnitude, as shown with sulfuric acid calibration and detection limit of 8e4 cm-3 (~1 ppqv). For the detection of pesticides, we utilize Br-, H3O+, acetonylacetone, Na+ and NH3+ as the reagent ions to detect more than 500 different pesticides. Conclusions: MION2 is an extremely sensitive inlet for the detection various trace vapors with semi-simultaneous use of two or more different reagent ions.

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Authors

Kangasluoma, J., Mikkilä, J., Shen, J., He, X., Partovi, F., Juuti, P., Mikkilä, J., Iakovleva, E., Jost, H.J., Shcherbinin, A.

Performance of a New Higher-Resolution Aerosol Chemical Speciation Monitor for Long-Term Measurements of Non-Refractory Aerosol

Benjamin Nault
Aerodyne Research Inc

Long-term measurements of the composition and mass concentration of particulate matter (PM) are essential for source apportionment, epidemiological studies, and air quality trends. The Aerosol Chemical Speciation Monitor (ACSM) has been widely used for in-situ, high time resolution measurements. However, current ACSMs have near unit mass resolution (UMR). UMR impacts detection limits and separation and identification of ions, limiting source apportionment. Further, uncertainty in organic aerosol (OA) relative ionization efficiency (RIE) in both ACSM and aerosol mass spectrometer (AMS) measurements can impact quantification. Here, we present a new instrument, the Time-of-Flight ACSM with eXtended resolution (TOF-ACSM-X) with updated analysis software (Tofware) to allow for high-resolution peak fitting. The TOF-ACSM-X has a mass resolution of ~2000 m/Δm, which is approximately an order of magnitude increase compared to the other current versions of ACSMs. This enhanced resolution improves ammonium detection limits by approximately 2-orders of magnitude, from ~0.10 µg m-3 to ~0.004 µg m-3 (TOF-ACSM versus TOF-ACSM-X, respectively), for 15-minute integration times. Further, this resolution allows for improved separation and identification of organic ions, leading to the ability to measure organic aerosol O:C and H:C ratios, improved performance in source apportionment, and the ability to separate organic and inorganic aerosol nitrate. Finally, the performance of the TOF-ACSM-X is compared to TOF-ACSM and high-resolution time-of-light Aerosol Mass Spectrometer for ambient and lab generated aerosol.

Authors

Benjamin A. Nault, Manjula Canagaratna, Philip Croteau, Edward Fortner, Andrew Lambe, Harald Stark, Donna Sueper, Leah Williams, Douglas Worsnop, John Jayne

Versatile chemical ionization time of flight mass spectrometer for detecting organic and inorganic trace gases

Matthieu Riva
Tofwerk

Volatile organic compounds (VOCs) have a major impact on aerosol particle formation in the atmosphere. The rapid development of new interfaces coupled to time-of-flight mass spectrometers—brings new knowledge to better understand the process chain from VOC emissions to oxidized compounds and condensation onto aerosol particles. However, to quantify each step of these chemical and physical processes, it is crucial to measure across the entire oxidation product spectrum, which includes low to highly oxygenated molecules (HOMs) and VOCs. Traditionally, gas-phase measurements have been realized using many mass spectrometers deployed in parallel, each employing a different ionization method to cover a broad range of volatilities from VOCs to HOMs as well as gaseous inorganic species. However, this is problematic in many ways. Calibrating all the instruments in a comprehensive and reproducible way remains challenging. In addition, operating several instruments is laborious, and the availability of space and electricity can be limited in remote locations. Therefore, instruments that can measure a wider range of compounds would be of great interest. Here we introduce the newly developed Vocus Adduct Ionization Mechanism (AIM) ion-molecule reactor (IMR) coupled to a new generation of a fast polarity switching time of flight mass spectrometer (FS-TOF). The Vocus AIM FS-TOF enables atmospheric pressure sampling, and medium pressure ionization while offering simultaneous detection of positive and negative ions (100 ms). Within the present study, we explore the capabilities of Vocus AIM FS-TOF using a wide variety of chemical ionization schemes, including chloride (Cl–), bromide (Br–), iodide (I–), nitrate (NO3–), benzene cations (C6H6+), ethanol dimers ((C2H5O)2H+), and ammonium (NH4+) reagent ions. Additionally, the Vocus Aim FS-TOF uses a system of dopants to ensure the sensitivity of adduct ionization chemistries is independent of ambient humidity, which is a significant improvement over conventional instrumentation and ionization approaches. The capabilities of the new generation of Vocus instruments were evaluated by measuring simultaneously the wide variety of oxidation products generated from the ozonolysis of alpha-pinene under various experimental conditions. Experiments were performed in an aerosol flow tube reactor under dry conditions, at room temperature, and atmospheric pressure. The chemical characterization performed for each reagent ion will be presented and compared to several other types of chemical ionization mass spectrometers. In summary, the Vocus AIM reactor coupled with a new generation of fast polarity switching time-of-flight mass spectrometers can cover the full range of VOCs, HOMs, and inorganic species using a unique interface under atmospherically relevant conditions and is a powerful tool for air monitoring and research applications.

Authors

M.Riva, V. Pospisilova, C. Frege, M.Z. Kamrath, U. Rohner, F. Lopez-Hilfiker

Thermo desorption – multi-scheme chemical ionization inlet - Mass Spectrometer for Atmospheric aerosol precursor and security research

Tuija Jokinen

Climate & Atmosphere Research Centre (CARE-C), The Cyprus Institute

Background and methods:

Gas phase compounds of low volatility such as sulfuric acid and iodic acid are capable of condensing and forming new aerosol particles in nanometre diameter ranges (Kulmala et al., Science, 2013 and Sipilä et al., Nature, 2016). These particles can grow larger in diameter by condensation of e.g. highly oxygenated organic molecules (HOM) (Ehn et al., Nature, 2014) and affect climate by reflecting solar radiation or by acting as cloud condensation nuclei (IPCC, 6th report, 2021). The measurements of these aforementioned compounds can be conducted using new high-resolution mass spectrometric devices with selective chemical ionization techniques (Jokinen et al., 2012). However, even with new technologies, aerosol precursor measurements from ambient air are relatively rare due to the high instrumental cost and complexity to run the mass spectrometer for long, uninterrupted time periods. Thus, the aim of this study is to explore alternative, portable and cost-efficient methods on aerosol precursor compound detection using filter sampling coupled with a newly developed multi-scheme chemical ionization inlet (MION) – mass spectrometer (Rissanen et al., AMT, 2019). Similar method has been explored in laboratory experiments for the detection of explosives such as nitro-glycerine.

Purpose and results:

The first filters are already collected during the winter from the SMEAR I station in the Finnish Lapland, where the filters were detected to contain sulfuric acid in minute quantities, but no iodic acid or HOM signals were detected due to lack of solar radiation (photochemical production) or iodine and HOM source during the time of measurements. We chose to do more experiments at the CAO station in Cyprus because it served as an ideal location to measure aerosol precursors in the close proximity of the Mediterranean Sea as a source of iodine compounds and frequent new particle formation events at the site due to active photochemistry (Baalbaki et al., ACP, 2020). This project was designed to serve as a proof-of-concept study of the filter sampling that it is suitable for iodic acid and possibly HOM collection on top of sulfuric acid sampling and that it is deployable in different environments (Finnish sub-Arctic and Mediterranean). We also aim to analyse the filters for traces explosive materials that could be found at the site because of the military shooting practise range close to the field site. All together we collected 14 samples from Cyprus with time resolution ranging from approximately 3 to 20 hours. The samples are being analysed in Finland at the time writing this abstract. Conclusions: Successful execution of this project will help us develop a portable, low cost method to detect aerosol forming compounds and possibly also traces of explosives. This new method has potential to gain larger spatial coverage of aerosol precursor observations from locations that are currently geographically under-presented in atmospheric models due to lack of funds to purchase state-of-the-art mass spectrometers. We also see a possibility to develop the method to utilize it in security research.

Authors

Jokinen, T., Mikkilä, J. T., Sipilä, M., Partovi, F., Naseri, N., Mikkilä, J. A., Schherbinin, A. and Sciare, J.

The new multi-instrument payload onboard the IAGOS-CARIBIC Airbus A350

Andreas Zahn

Karlsruhe Institute of technology (KIT)

As one of the two technical approaches and as flying reference system, a laboratory equipped with up to 20 strongly modified commercial instrument and custom-made devices is installed in the cargo bay of a modified passenger aircraft. For the deployment on board an A350 by Lufthansa, a new 9-rack laboratory (with 19 instruments provided by 13 groups) is built up which is able to measure >100 trace gases, aerosol and cloud parameters. The presentation will shortly describe the multi-function air inlet system and the laboratory infrastructure consisting of safety system, master computer (i.a., for the downlink of real real-time data), central power unit and central pump system. Focus will be on the description of the new payload that comprises 5 instruments for aerosol concentration and composition, fast trace gas instruments (of up to 10 Hz) and exceptional instruments for e.g. NO3, N2O5, SO2, HCN, acids or the isotopic composition of water vapour and cloud particles.

Authors

A. Zahn, H. Harald, T. Gehrlein, F. Obersteiner, E. Förster, A. Streili, P. Braesicke, M. Hermann, M. Pöhlker, H. Ziereis, A. Roiger, J. Schneider, U. Kuhn, Y. Cheng, X. Pan, C. Köppel, S. Yue, J. Williams, U. Bundke, C. Mahnke, A. Petzold, F. Stroh, S. Albers, H. Smit, C. Gerbig, T. Schuck, A. Ruth, B. Dube, S. Brown, H. Bozem, P. Hoor, M. Miltner, E. Kerstel, S. Hofmann, H. Franke

Profiling mineral dust with UAV-based in-situ instrumentation and ground-based in-situ and remote sensing instrumentation (Cyprus Fall campaign 2021)

Maria Kezoudi

Climate & Atmosphere Research Centre (CARE-C), The Cyprus Institute

The Unmanned Systems Research Laboratory (USRL) of the Cyprus Institute is a new mobile exploratory platform of the EU Research Infrastructure Aerosol, Clouds and Trace Gases Research InfraStructure (ACTRIS). This allows USRL to offer Unmanned Aerial Vehicle (UAV)-sensor solutions that can be deployed everywhere in Europe and beyond, for intensive field campaigns through a transnational access scheme in compliance with the drone regulation set by the European Union Aviation Safety Agency (EASA) for the purpose of research, innovation, and training.

UAV-sensor systems allow for cost-effective height-resolved in-situ atmospheric observations within the lower troposphere. Taking advantage of the private runway and dedicated airspace of the USRL in Orounda (Nicosia, Cyprus), an intensive campaign focusing on mineral dust observations was conducted between 18 October and 18 November 2021. This, involved UAV flights (36 in total), ground-based in-situ and active and passive remote-sensing observations during two distinct dust outbreaks over Cyprus. The first dust event occurred between 25 October and 1 November, and HYSPLIT back-trajectories revealed that the observed air masses were mainly originated from NE Sahara (Libya, Egypt). The second dust event was observed from 13 to 18 November 2021. HYSPLIT back-trajectories revealed that the observed air masses at the beginning of the second event were originated from the Middle East (Saudi Arabia, Syria), but the air mass origin switched to NW Saharan dust midways through the event. The Aerosol Optical Depth at 500-nm as measured by our sun-photometers was found to be above 0.2 all the time, and in some days reached up to 0.5. The observed aerosol layers were found to be extending from ground up to 5 km Above Sea Level (ASL).

This study presents results of the vertical aerosol structure/height-resolved information of each dust event from its arrival to its departure as observed by instruments on-board the UAVs including: a pair of Universal Cloud and Aerosol Sounding System (UCASS) Optical Particle Counters (OPCs), Printed Optical Particle Spectrometer (POPS) OPC, a pair of Compact Optical Backscatter AerosoL Detector (COBALD) and filter samplers. The combined range of the used OPCs provide particle mass concentrations and particle size distributions (PSDs) in the size range between 0.1 and 40.0 in diameter. During the campaign, PSDs from UCASS indicate the presence of large particles (up to 25 μm diameter). Sampling analysis using Scanning Electron Microscope (SEM) of the filters collected on-board UAVs shows the presence of numerous minerals, including hematite, kaolinite, silicates etc. Data obtained from COBALD on-board UAV indicate particle orientation within the observed dust layers. Similar to the AERONET AOD values were also retrieved from the total-column UAV-based OPC measurements.

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Authors

Kezoudi M., Papetta A., Marenco F., Keleshis C., K. Kandler, Girdwood J., Stopford C., Wienhold F. G., Gao R. S. and Sciare J.

Design of innovative modular multi-species balloon-borne sampling platform in the Parisian sky

Yaël Bourgeois

Laboratoire des Sciences du Climat et de l'Environnement

Launched in 2021, the « Pilot Application in Urban Landscapes – Towards integrated city observatories for greenhouse gases » aims at providing capacities for anthropogenic emission monitoring in various urban environment (from small to large European cities). This H2020 European project will help community work towards the emission reduction goals set by the European Green Deal.
The Laboratoire des Sciences du Climat et de l'Environnement (LSCE) is leading the observatory activities in Paris by deploying different types of sensors. In additions to these sensor networks, LSCE will also contribute to this pilot observatory in Paris through airborne sampling using the GENERALI tethered balloon located in the André-Citroën park. Weather conditions allowing, the balloon performs vertical flights up to 150m every 15minutes, with possibilities to go as high as 300m upon occasions. This unique feature provides an exciting opportunity to design and develop a robust, autonomous, innovative and modular airborne sampling platform for greenhouse gas (GHG), reactive gas and particles measurements. From battery autonomy and technology selection to multi-instrument of various form factor housing, including a portable calibrated compressed-air canister for daily instrument deviation monitoring and autonomous data-logging and communication, every aspect of this platform are designed for a user-friendly, versatile and durable experience.
The mission statement includes powering various instruments including but not limited to a cavity enhanced absorption spectroscopy CO2/H2O analyser (LI-COR LI-7815), a tune-able laser diode absorption spectroscopy CH4/CO2/H2O analyser (ABB MGGA GLA131) and a black-carbon (BC) aethalometer (Aethlabs MA350). Onboard flight telemetry will be recorded through a portable Vaisala WXT520/530-like weather station, a magnetic compass, a 6-degree of freedom inertial measurement unit and a GPS station. Special care is given to the platform's power autonomy, alternating between diurnal airborne 14.4V, 15A battery power for a continuous 15-hours of flight operations and nocturnal 24V, 25A ground cabled main power with regards to airborne safety regulations whilst also minimizing the total weight of the platform. The platform is scheduled to come in operation in September 2022.
In this presentation, the overall strategy of the project is presented with the general power requirements, innovative battery strategy explored, versatile light-weight aluminium casing design and autonomous monitoring and data-logging solution provided for easy, lasting and robust exploitation of the platform.

Authors

Bourgeois, Y., Laurent, O., Giacomoni, J., Lienhardt, L., Bouillon, L., Culeux, O., Doc, J., Gobbi, M., Niquet, C., Paris, A., Gros, V., and Ramonet, M.

Recent Advances at Brechtel MFG. in UAS-deployable aerosol instruments

Fred Brechtel

Brechtel Manufacturing Incorporated

Background:
Understanding physical processes like radiative forcing, cloud droplet nucleation, precipitation, and new particle formation requires the ability to perform vertical profile measurements of aerosol properties in the atmosphere. Unmanned Aerial Systems (UAS) are ideal profiling platforms, and here we describe small, light, and low power instruments to facilitate a variety of aerosol property measurements on-board UAS's.

Purpose:
The primary purpose of the work is to develop smaller and lighter aerosol instrumentation for easy deployment on-board UAS platforms and for other applications where size, weight, and power are constraints.

Methods:
Scientists and engineers at Brechtel have been working on a suite of UAS-deployable aerosol instruments including a fast-response particle counter, an aerosol light absorption photometer, optical and electrical mobility size distribution measurement systems, and an 8-channel, remotely controllable filter sampler. Isokinetic sampling inlets have also been developed for UASs. A combination of miniaturization, highly engineered resins for 3D printing, and novel designs has been used to shrink the devices to the size of one or two coffee cups. Typical dimensions of the various modules are between 5 and 15 cm with weights between 0.2 and 4 kg. Many of the devices have been tested at freezing temperatures and low pressures to simulate flight conditions.

Results:
The instruments have been deployed on a variety of UASs and traditional research aircraft in the US, India, EU, as well as over the Arctic and other locations. Tests at low temperatures and pressures indicate stable operation under simulated flight conditions. Intercomparisons with traditional, benchtop-size instruments indicate good agreement, typically within +/-15%.

Conclusions:
Existing bench-top aerosol instruments may be redesigned to much smaller size and weight through novel design and fabrication approaches. However, this process requires multi-disciplinary expertise, a significant investment in resources, and diligent testing to succeed.

Authors

Brechtel, F. J., Corless, A., Lopez-Yglesias, X., and Robbins, Z.

Development and assessment of "mid cost" sensors for urban monitoring network

Olivier Laurent

LSCE/CEA

In the framework of the ICOS Cities – PAUL, a H2020 European project aiming to assess different techniques and methodologies to better estimate the CO2 emission in urban area, the LSCE is developing and deploying a network of 30 “mid cost” CO2 NDIR sensors within Paris and its near suburb. In addition to few stations equipped with high precision spectrometers, such dense “mid cost” CO2 sensor network allows a better monitoring of the complex spatial distribution of CO2 gradient at a local scale. In order to represent larger footprint and avoid the direct measurement of very local CO2 sources (e.g. traffic) difficult to handle by inversion model, these sensors are deployed at the roof level (between 25m and 180m agl). With this network configuration, the typical site to site CO2 gradient observed in Paris is limited to few ppm and up to 10-20 ppm depending mainly to the meteorological conditions (wind speed, mixing layer height). In order to be able to monitor this atmospheric signal, the “mid cost” CO2 sensors accuracy target has been set at 1 ppm.

This presentation presents the results of the “mid cost” CO2 sensor metrological performance test conducted at the ICOS ATC Metrology Lab (at LSCE), the related calibration and quality control strategy to meet the performance objective and the integration done to provide a stand-alone sensor box (so called AtmoBox) suitable for operational network.

Authors

Laurent, O., Lienhardt, L., Chariot, M., and Utard, H.

Challenges associated with using FIGARO TGS 2611-E00 semiconductor-based sensors to derive methane mole fraction

Adil Shah

Laboratoire des Sciences du Climat et de l'Environnement

Methane is a potent greenhouse gas, yet precisely measuring in-situ methane mole fraction ([CH4]) at a high sampling frequency requires expensive instrumentation. Semiconductor-based metal oxide sensors, such as the Figaro TGS 2611-E00, may serve as a promising alternative due to their low cost (approximately 20 €), ease of manufacture and availability. The semiconductor resistance of these sensors changes in response to reducing gas exposure, thus allowing gas composition to be deduced. Although Figaro sensors are sensitive to methane, they are marketed to target large [CH4] enhancements of the order of 103 ppm. As they are cross-sensitive to other reducing gases, the TGS-6211-E00 incorporates a carbon monoxide filter. It was found that when bringing these sensors into the parts-per-million-level [CH4] detection range, accounting for environmental conditions becomes increasingly important. Figaro sensors are particularly sensitive to temperature and water mole fraction at low [CH4], which we characterised in a large environmental chamber, allowing us to access a vast range of environmental conditions. We found that water response is not instant and Figaro resistance takes many hours to adjust to abrupt changes in water mole fraction. We also tested Figaro resistance response to different reference gases. Figaro resistance in natural air was found to be lower than resistance in synthetic air containing 2 ppm [CH4], although the reason for this this not clear. The nuances of the electronics within the logging system also become important, as Figaro sensitivity is greatly enhanced in this low [CH4] regime. The Figaro TGS 2611-E00 sensor remains a challenge to characterise and further testing is required to fully exploit its merits in the context of high-frequency [CH4] sampling.

Authors

Shah, A., Laurent, O., Lienhardt, L. and Ciais, P.

VAISALA AQT530 sensors as a tool in comprehensive Air Quality Monitoring

Hilkka Timonen

FMI

New cost-effective air quality sensors can provide novel insights into the spatio-temporal variability of aerosol particles and trace gases. Here we characterized the optical particle detector used in AQT530 (Vaisala Ltd.) air quality sensor in the laboratory and conducted a campaign with a network of AQT530 sensors in Helsinki, Finland in 2020–2021. We show a long-term performance evaluation of five sensors for particulate (PM10, PM2.5) and gaseous (NO2, NO, CO, O3) components during a half-year co-location study at an urban traffic site. Results from a short-term (few weeks) co-location tests were performed for 25 sensors to provide sensor-specific correction equations for the fine-tuning of selected pollutants in the sensor network. We illustrate the value of network of 25 sensor units to address the spatial variability of trace gases and aerosol mass concentrations in an urban environment. The results are important in optimization of road dust and construction dust emission control and can help to control traffic exhaust and localized wood combustion emissions in the residential areas.

Authors

Petäjä, T., Ovaska, A., Fung, P.L., Poutanen, P., Yli-Ojanperä, J., Suikkola, J., Laakso, M., Mäkelä, T., Niemi, J.V., Keskinen, J., Järvinen, A., Kuula, J., Kurppa, M., Hussein, T., Tarkoma, S., Kulmala, M., Karppinen, A., Manninen, H.E. and Timonen, H.

Field Performance Evaluation of Low-cost Air Quality Sensors

Roubina Papaconstantinou

Climate & Atmosphere Research Centre (CARE-C), The Cyprus Institute

Modern electrochemical gas sensors hold great potential for improving practices in Air Quality Monitoring (AQM) as their low cost, ease of operation and compact design can enable dense observational networks. Despite that, however, numerous studies have shown that the performance of these sensors depends on a number of factors (e.g., environmental conditions, sensor quality, maintenance and calibration etc.), thereby adding significant uncertainties in the reported measurements and large discrepancies from reference-grade instruments. In this work we investigate the performance of electrochemical sensors, provided by two manufacturers (namely Alphasense and Winsen), for measuring the concentrations of CO, NO2, O3 and SO2. To achieve that we carried out yearlong collocated measurements with reference-grade instruments at a traffic AQM station in Nicosia, Cyprus where temperatures range from almost 0 °C in the winter and up to 50 °C in the summer. The CO sensors exhibited the best performance having minimal relative error compared to reference instruments (ca. 5%), whereas the SO2 sensors reported concentration values that were at least one order of magnitude higher than the respective reference measurements. Variabilities in the environmental conditions (i.e., temperature and relative humidity) appear to affect significantly the performance of the sensors. For example, at temperatures below 10 °C the correlation between the LCS measurements and those by the reference instruments exhibited R2 values in the range of 0.59-0.80 while at high temperatures, above 30 °C, R2 was in the range of 0.03-0.12. Similar correlations were observed with RH, with very low R2 values observed for low (i.e. RH < 30%; R2 = 0.005-0.31) compared to high values (i.e. RH > 75%; R2 = 0.41-0.7). Also, the Alphasense NO2 sensor showed high cross-sensitivity with O3 while the O3 sensor with NO2.
In parallel, Alphasense B-series sensors were tested in the framework of VAISALA Boost project where a high-resolution air quality network of low-cost sensors was created in the city of Nicosia, Cyprus. Six VAISALA compact sensor platforms located near ground level assessed the air pollution at six different parts of Nicosia. Data are as input to a high-resolution model for air quality modelling and forecasting. The platforms were capable of measuring the concentrations of NO2, NO, CO, O3 and PM. Two platforms were collocated with reference instruments adding to their performance evaluation. The six different locations provided useful information on traffic pollution gradient along the city.
Our results show that to make the performance of low cost sensors independent of meteorological conditions and improve their comparability with reference instruments, further work is needed both towards improving the hardware as well as their calibration.

Authors

Papaconstantinou, R., Demosthenous, M., Bezantakos, S., Hadjigeorgiou, N., Costi, M., Savvides, C., Biskos, G.