

Institute for Atmospheric and Earth System Research





STATION FOR MEASURING EARTH SURFACE – ATMOSPHERE RELATIONS

SMEAR CONCEPT

INSTRUMENT BLOCKS & DESCRIPTIONS

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Topical modules

A. On-line	PM2.5, PM1 mass concentration + inlets
	Aerosol number concentration + inlets
particulate air	CO, NO_{χ}, SO_2, O_3
pollution and	CH ₄ , CO ₂
gas-phase air	Radiation (UV + tot + refl + abs), and basic meteorology (T, p, RH, WS, WD, precipitation)
pollutants	Software, planning, validation and data analysis support package
	PN nanoparticle number size distribution (1-5 nm, PSM) + inlets
B On-line	PN sub-micron number size distribution (DMPS) + inlets
aerosol number size	PN super-micron number size distribution (APS) + inlets
	Air ion size distribution
distribution	Radon and external radiation
	Software, planning, validation and data analysis support package
C. On-line	Aerosol scattering (nephelometer)
atmospheric	Aerosol absorption (aethalometer)
particulate air	Aerosol extinction
pollution /	Visibility
optics and	Ceilometer for boundary layer height
black carbon	Software, planning, validation and data analysis support package
	Aerosol chemical composition (ACSM)
D. On-line	Water soluble components in aerosols (MARGA)
chemistry	Calibration setup
	Software, planning, validation and data analysis support package
	Concentration of aerosol precursors, sulfuric acid and extremely oxidized organic
E. On-line	compounds (CI-APiTOF)
Atmospheric	Concentration of Volatile Organic Compounds
chemistry	Air ion chemical composition (APiTOF)
	Software, planning, validation and data analysis support package (TofTools)
F. On-line	Cloud Condensation Nuclei concentrations (CCN counter)
aerosol-cloud	Aerosol hygroscopicity and mixing state (HTDMA)
interactions	Software, planning, validation and data analysis support package
G. On-line	Micrometeorological fluxes (latent heat, sensible heat, momentum)
atmosphere -	Fluxes (aerosol number, CO ₂ , CH ₄ , COS,O ₃)
surface	Fluxes (VOCs)
exchange	Software, planning, validation and data analysis support package
H. On-line	Cloud radar
aerosol and	Doppler lidar (Halo)
cloud vertical	wind profiler
profiling	Software, planning, validation and data analysis support package
I. On-line ecosystem package	Canopy measurements: automatic dynamic enclosure systems, CO ₂ /CH ₄ /N ₂ O analysers and
	optical measurements
	Stem measurements: sapflow and stem diameter measurements
	Soil measurements: automatic dynamic enclosure systems, CO ₂ /CH ₄ /N ₂ O analysers, moisture and temperature profiles
	Software, planning and data analysis package

Description of instruments

The following instrumentation is required to perform **comprehensive source apportionment of atmospheric air pollution, including trace gases, clusters and atmospheric aerosol components**

Comprehensive precursor characterization

- Chemical Ionization Atmospheric Pressure interface Time-of-Flight Mass Spectrometer. **CI-APi-ToF MS** The key instrument to determine the chemical components in the atmospheric clusters is the CI-APi-ToF. Utilizing the soft chemical ionization schemes in front of Atmospheric Pressure interface Time of Flight Mass spectrometer (APi-ToF¹), we are able to determine the chemical composition of atmospheric clusters² in a quantified manner. With the nitrate ion chemistry at ambient pressure we are able ionize and quantify concentrations of e.g. sulfuric acid containing clusters. With this CI-source we are able to detect extremely low volatility organic compounds (ELVOC, e.g. $C_{10}H_{14}O_9$, ³) that cluster with the reagent ions enabling us to quantify the ambient concentrations. Overall, the CI-APi-ToF has been adapted to different reagent ions, which enables selective detection of precursor vapors, such as sulfuric acid, amines, ELVOCs or semi-volatile vapors⁴. The high resolving power (R>3000) and accuracy (20 ppm) mean that we can identify the compounds by defining the exact mass and performing Kendrick analysis as well as looking into isotopic patterns and correlograms between the masses and applying the proton affinity considerations ¹. The Cl-APi-ToF data is utilized in source apportionment studies for the condensable vapors⁵ enabling us to probe the relative contributions of different atmospheric oxidation pathways.
- PTR-TOF Proton-Transfer Reaction Mass Spectrometer. Aerosol formation from a suite of precursors requires a detailed understanding on the concentrations of the precursors, their oxidation during their lifetime and their capacity to condense and nucleate to form Secondary Organic Aerosol (SOA). The CI-APi-ToF provides us data on ELVOCs and PTR-ToF will complete the picture with data on more abundant organics.
- **MARGA** The instrument for Measuring AeRosols and Gases. The MARGA ambient air monitoring system (Applikon Analytical BV, Netherlands) will be used for measuring the gas phase concentrations of NH₃, HNO₃, HCl, HONO, and SO₂, as well as the particulate matter concentrations of the main ionic compounds NO_3^- , Cl⁻, SO_4^{-2} , NH_4^+ , Na^+ , K^+ , Ca^{2+} and Mg^{2+} . The instrument draws in ambient air (1 m³/h) through a Teflon coated PM_{2.5} inlet. The gases are then quantitatively absorbed in a wetted rotating denuder and the aerosols, which pass through the denuder, are trapped in a steam-jet aerosol collector using condensational growth with supersaturated steam. The liquid streams from the wet rotating denuder and the steam-jet aerosol collector are mixed with an internal standard (LiBr) before controlled injection into an anion and a cation ion chromatograph. After the chromatographic separation, all the components are detected by conductivity measurements. Using this semi-continuous on-line ion chromatograph we are able to measure inorganic gases and the chemical composition of aerosols in ambient air with one hour time resolution.

Thermo Fisher Scientific model 49i (O₃) Ozone concentration is monitored with Thermo Fisher Scientific (Waltham, MA, USA) model 49i. The ozone detection is based on O_3 absorption of the ultraviolet (UV) light (λ =254 nm). By comparing with the UV light intensity passing through a reference gas, the attenuation of UV light by the sampled air is measured. The instrument has a detection limit of 1 ppb and a relative accuracy of \pm 3 %.

Thermo Fisher Scientific model 42i TL (NO _x)	Nitrogen oxide (NO_x) concentrations are measured as the sum of the concentration of both nitrogen monoxide (NO) and nitrogen dioxide (NO_2) with a chemiluminescence analyzer (42i TL, Thermo Fisher Scientific, Waltham, MA, USA). The instrument is based on measuring the luminescence signal from the reaction between sampled NO and added O_3 . Thus, a pre-conversion of NO_2 -to-NO is needed when the nitrogen dioxides concentration (or the total NO_x concentration) are desired. The instruments directly give the measured concentrations in ppb with a detection limit of 0.1ppb and an accuracy of the total NOx concentration of +/- 10.
Thermo Fisher Scientific model 43i-TLE (SO ₂)	A Thermo Fisher Scientific (Waltham, MA, USA) model 43i-TLE trace gas monitor will be used to measure SO ₂ concentration. This instrument analyzes the volume mixing ratio of SO ₂ in air by stimulating fluorescence by UV light. The detected intensity of fluorescence light is proportional to the volume mixing ratio of SO ₂ molecules in the sample gas. The accuracy of the instrument is +/- 5 ppb.
Picarro G2401 (CO_2 , CH_4 , CO and H_2O)	CO_2 , CH_4 , CO and H_2O concentrations are simultaneously monitored with G2311-f (Picarro Inc., USA; FGGA, Los Gatos Research, USA), which is based on cavity ringdown spectroscopy (CRDS). CRDS is a technique where a gas sample is introduced into a high-finesse optical cavity and the optical absorbance of the sample is determined, thus providing concentration measurements of a particular gas species of interest.

1 Junninen, H., Ehn, M., Petäjä, T., Luosujärvi, L., Kotiaho, T., Kostiainen, R., Rohner, U., Gonin, M., Fuhrer, K., Kulmala, M., and Worsnop, D. R.: A high-resolution mass spectrometer to measure atmospheric ion composition, Atmos. Meas. Tech., 3, 1039-1053, 2010.

- 2 Jokinen, T., Sipilä, M., Junninen, H., Ehn, M., Lönn, G., Hakala, J., Petäjä, T., Mauldin III, R. L., Kulmala, M., and Worsnop, D.
 R.: Atmospheric sulphuric acid and neutral cluster measurements using CI-APi-TOF, Atmos. Chem. Phys., 12, 4117-4125, 2012.
- 3 Ehn, M., Thornton, J.A., Kleist. E., Sipilä, M., Junninen, H., Pullinen, I., Springer, M, Rubach, F., Tillmann, R., Lee, B., Lopez-Hilfiker, F., Andres, S., Acir, I-H., Rissanen, M., Jokinen.T., Schobesberger, S., Kangasluoma, J., Kontkanen, J., Nieminen, T., Kurtén, T., Nielsen, LB., Jørgensen. S., Kjaergaard. H.G., Canagaratna, M., Dal Maso, M., Berndt, T., Petäjä, T., Wahner, A., Kerminen, V-M., Kulmala, M., Worsnop, D.R., Wildt, J. and Mentel, T.F.: A large source of low-volatility secondary organic aerosol, Nature, 506, 476–479, 2014.
- 4 e.g. Lee, B.H., Lopez-Hilfiker, F.D., Mohr, C., Kurtén, T., Worsnop, D.R., and Thornton, J.A.: An lodide-Adduct High-Resolution Time-of-Flight Chemical-Ionization Mass Spectrometer: Application to Atmospheric Inorganic and Organic Compounds, Environmental Science & Technology 48 (11), 6309-6317, 2014.
- 5 Yan, C., Nie, W., Äijälä, M., Rissanen, M. P., Canagaratna, M. R., Massoli, P., Junninen, H., Jokinen, T., Sarnela, N., Häme, S. A. K., Schobesberger, S., Canonaco, F., Yao, L., Prévôt, A. S. H., Petäjä, T., Kulmala, M., Sipilä, M., Worsnop, D. R., and Ehn, M.: Source characterization of highly oxidized multifunctional compounds in a boreal forest environment using positive matrix factorization, Atmos. Chem. Phys., 16, 12715-12731, 2016.

Aerosol physical characterization

The aerosol physical characterization is required for a comprehensive understanding of the aerosol variability and acts as an independent quality control for the source apportionment analysis as follows:

- 1) The DMPS is system is the backbone of various parameters inferred from the particle size distribution, which are needed in further analysis. These parameters include: particle formation and growth rates, condensable vapor concentration source rates, vapor condensation sink, analysis of aerosol formation events, formation event type classification. The NAIS enables determination of cluster formation rates for ions, neutral clusters and their growth rates as a function of particle size¹.
- 2) The PSM allows us to determine both actual atmospheric nucleation rate of particles as well as their initial growth rate as a function of particle size. These data products tell us indirectly the abundance of nucleating and condensing vapors that will be compared with the direct observations with the mass spectrometers.
- 3) The NAIS provides us the gap-filling observations between the PSM and DMPS size ranges and additionally describes the charging state of the aerosol particles.
- 4) The APS provides us additional data on super-micron contribution to the aerosol population. This is crucial in differentiating the dust pollution episodes with other high aerosol loading incidences.
- **DMPS** Differential Mobility Particle Sizer. The DMPS system² is the standard aerosol particle size distribution monitoring instrument. The DMPS provides a total size range from 10 to 800 nm, which will be complemented by other size distribution instruments, such as PSM and NAIS in the ultra-fine range and APS for the super-micron aerosols.

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- particle formation and growth rates
- condensable vapor concentration source rates
- vapor condensation sink
- analysis of aerosol formation events, formation event type classification

The DMPS system provides us a direct comparison against the measured condensable vapor concentrations (from precursor measurements) and the effective aerosol size increase that is linked to the abundance of the vapors. Furthermore, we will utilize the DMPS size distributions as a reference against the chemical composition measurements as the mass spectrometric methods are most sensitive for accumulation mode aerosols.

- **PSM** Scanning Particle Size Magnifier. Atmospheric nucleation below 2 nm in size¹ will be observed with the Particle Size Magnifier (Airmodus A11), which is a dual stage Condensation Particle Counter³. In the PSM the aerosol is turbulently mixed with air saturated with di-ethylene glycol, therefore creating a supersaturation high enough to activate even 1 nm ions, the nominal cut-off size being about 1.5 nm. The 50% activation diameter can be varied between 1.1 (\pm 0.2) and 2.1(\pm 0.2) nm in mobility diameter by changing the mixing ratio of the saturator and sample flows. The PSM allows us to determine both actual atmospheric nucleation rate of particles as well as their initial growth rate as a function of particle size. These data products tell us indirectly the abundance of nucleating and condensing vapors that will be compared with the direct observations with the mass spectrometers. The PSM will include a sampling inlet that enables us to differentiate automatically between the contribution of neutral and ion pathways to the aerosol formation⁴.
- **NAIS** Neutral Cluster and Air Ion Spectrometer measures mobility distribution of naturally charged and neutral nanoparticles in high time resolution. The size range is 2-42 nm and 0.8-42 nm for the neutral clusters and ions. The NAIS is a robust, field-worthy instrument, which can be operated for extended periods even unattended⁵. The instrument enables determination of cluster formation rates for ions, neutral clusters and their growth rates as a function of particle size¹.

- APS Aerodynamic Particle Sizer 3321 (APS spectrometer, TSI Inc., St. Paul, MN) provides highresolution, real-time aerodynamic measurements of particles from 0.5 to 20 microns. The APS also measures light-scattering intensity in the equivalent optical size range of 0.37 to 20 microns. By providing paired data for each particle, the APS spectrometer allows studying the makeup of an aerosol.
- 1 Kulmala, M., Petäjä, T., Nieminen, T., Sipilä, M., Manninen, H.E., Lehtipalo, K., Dal-Maso, M., Aalto, P.P., Junninen, H., Paasonen, P., Riipinen, I., Lehtinen, K.E.J., Laaksonen, A. and Kulmala, M.: **Measurement of the nucleation of atmospheric aerosol particles**, Nature Protocols 7, 1651-1667, 2012.
- 2 Aalto, P., Hämeri, K., Becker, E., Weber, R., Salm, J., Mäkelä, J.M., Hoell, C., O'dowd, C.D., Hansson, H-C., Väkevä, M., Koponen, I.K., Buzorius, G. and Kulmala, M.,: **Physical characterization of aerosol particles during nucleation events**, Tellus B: Chemical and Physical Meteorology, 53:4, 344-358, 2001.

3 Vanhanen, J., Mikkilä, J., Lehtipalo, K., M. Sipilä, M., Manninen, H.E., Siivola, E., Petäjä, T., and M. Kulmala, M.: **Particle Size Magnifier for Nano-CN Detection**, Aerosol Science and Technology 45, 533-542, 2011.

4 Kangasluoma, J., Attoui, M., Korhonen, F., Ahonen, L., Siivola, E., and Petäjä, T. : Characterization of a Herrmann-type high-resolution differential mobility analyzer, Aerosol Science and Technology, 50:3, 222-229, 2016.
5 Manninen et al. 2010 EUCAARI ion spectrometer measurements at 12 European sites – analysis of new particle formation events Atmos. Chem. Phys., 10, 7907–7927, 2010 doi:10.5194/acp-10-7907-2010.

Aerosol chemical characterization

The ACSM data will utilized to determine aerosol sources in the Beijing area. The instrument enables separation of sulfate, nitrate and different organic aerosol sources, such as hydrogen-like organic aerosol, low-volatile and semivolatile organic aerosols. These will be connected to e.g. traffic, biogenic sources and aerosols from industrial processes. In the source apportionment, the ACSM data will be combined with the trace gas data (e.g. CI-APi-ToF, gas analyzers) and other aerosol instruments (e.g. size distribution, soot concentration, soluble ion concentrations) in an on-line, automatized process for the analysis for the source contributions in the Beijing area.

- Acrosol Chemical Speciation Monitor. In ACSM^{1, 2} the particles enter to an aerodynamic lens through a critical orifice of 100 mm diameter at a rate of 0.1 L min⁻¹ under vacuum. This focused particle beam impacts and vaporizes on a hot oven (~600 °C), becomes ionized with 70 eV electrons, and the resulting ions are detected using quadrupole mass spectrometry. From the resulting ion (organic ions, SO₂⁻, NO₃⁻, NH₄⁺, and Cl⁻) spectrum the composition of the aerosol particles can be calculated.
- 1 Ng, N. L., Herndon, S. C., Trimborn, A., Canagaratna, M. R., Croteau, P. L., Onasch, T. B., Sueper, D., Worsnop, D. R., Zhang, Q., Sun, Y. L., and Jayne, J. T.: An Aerosol Chemical Speciation Monitor (ACSM) for Routine Monitoring of the Composition and Mass Concentrations of Ambient Aerosol, Aerosol Science and Technology, 45:7, 780-794, 2011. DOI: 10.1080/02786826.2011.560211
- 2 Äijälä, M., Heikkinen, L., Fröhlich, R., Canonaco, F., Prevot, A.S.H., Junninen, H., Petäjä, T., Kulmala, M., Worsnop, D., Ehn, M.: Resolving anthropogenic aerosol pollution types deconvolution and exploratory classification of pollution events. Atmospheric Chemistry and Physics. 2017 17(4):3165-3197. 2017 .DOI: 10.5194/acp-17-3165-2017.

Aerosol optical characterization

The aerosol optical properties provide an independent measure on the relative contribution of black carbon and scattering aerosols (sulfate and organic aerosols), which will be evaluated against the source apportionment with the chemical measurements. The optical measurements provide us a way for a full closure and consistency of aerosol observations. The optical properties can be calculated from the physical and chemical measurements. Therefore, their measurements provide an additional quality control measure.

- **Nephelometer** Aurora 3000 (EcoTech Aurora 3000, Australia. Integrating nephelometers directly measure the light scattered by aerosols and gases in an enclosed sample volume. The sampling chamber and light source are confined to a small volume so that the instrument makes a "point" or localised measurement of scattering, continuously and in real-time. The total measurements are then combined with a backscatter measurement that will only sample between 90° and 170° to give a more in-depth analysis of particle scattering. This information can be combined with data measured by other aerosol instruments and then inserted into mathematical models to derive the following additional parameters: aerosol asymmetry parameter, ångström exponent and single scattering albedo. These parameters are relevant for differentiating the black carbon and the scattering aerosol from each other.
- MAAPThermo Model 5012 Multi Angle Absorption Photometer is used to measure ambient black
carbon (BC) concentrations and aerosol light absorption properties^{1,2}. MAAP is the regarded
as the most reliable filter-based instrument for measurement of BC. In MAAP the BC
concentration is measured at a single wavelength 670nm. The typical filter-loading-related
artifacts are taken into account in the design and the internal programming of the
instruments. For example, the effect caused by light scattering from particles on the filter is
taken into account. Lower detection limit is less than 50ng/m3 in BC and 0.33 Mm in
absorption with 10 min averaging time. Sample flow is typically 1 m3/h and particles larger
than 10um are separated from the sample.

The Aethalometer measures the transmission of light through a filter tape containing the sample and through an unloaded reference spot at seven different wavelengths (370, 470, 520, 590, 660, 880, 950 nm). It deduces the BC concentration from the rate of change of the attenuation of light in the particle-laden filter. In the Aethalometer model AE33, two measurements are obtained simultaneously from two sample spots with different rates of accumulation of the sample³. The two results are then combined to minimize nonlinearities and to provide a compensated particle light absorption and BC mass concentration. In addition, the algorithm delivers a compensation parameter k that yields information on the state of aging of the BC particles. The spectral dependence of absorption allows a real-time source apportionment, i.e, an estimate of the contributions by fossil fuel burning and wood burning to the observed BC concentrations⁴. The manufacturer reports as the 30 ng/m3 at a 1 min averaging time with a 5 LPM flow rate.

The AE33 and the MAAP complement each other in that the MAAP yields a more accurate absorption coefficient at one wavelength and thus BC concentration whereas the Aethalometer yields also the wavelength dependence of absorption and thus information on the sources and processes of the absorbing aerosol.

The aerosol optical properties provide an independent measure on the relative contribution of black carbon and scattering aerosols (sulfate and organic aerosols), which will be evaluated against the source apportionment with the chemical measurements. The optical measurements provide us a way for a full closure and consistency of aerosol observations. The optical properties can be calculated from the physical and chemical measurements. Therefore, their measurements provide an additional quality control measure. In addition, measurements of aerosol optical properties are essential for calculating visibility effects and the direct radiative forcing by aerosols. 1 Petzold, A., M. Fiebig, H. Flentje, A. Keil, U. Leiterer, P. Schroder, A. Stifter, M. Wendisch, and P. Wendling: Vertical variability of aerosol properties observed at a continental site during LACE 98, J. Geophys. Res., 107, 2002.

2 Petzold, A. and Schönlinner, M.: Multi-angle absorption photometry - A new method for the measurement of aerosol light absorption and atmospheric black carbon, J. Aerosol Sci., 35, 421–441, 2004.

3 Drinovec, L., Močnik, G., Zotter, P., Prévôt, A. S. H., Ruckstuhl, C., Coz, E., Rupakheti, M., Sciare, J., Müller, T., Wiedensohler, A., and Hansen, A. D. A.: **The "dual-spot" Aethalometer: an improved measurement of aerosol black carbon with real-time loading compensation**, Atmos. Meas. Tech., 8, 1965-1979, 2015.

4 Drinovec, L., Gregorič, A., Zotter, P., Wolf, R., Bruns, E. A., Prévôt, A. S. H., Petit, J.-E., Favez, O., Sciare, J., Arnold, I. J., Chakrabarty, R. K., Moosmüller, H., Filep, A., and Močnik, G.: **The filter-loading effect by ambient aerosols in filter absorption photometers depends on the coating of the sampled particles**, Atmos. Meas. Tech., 2017.

Aerosol and trace gas fluxes determining the local and regional emission strengths

The extensive set of flux measurements are crucial in providing data on the connection between anthropogenic activities at the surface and the aerosol and gas concentrations aloft. The flux measurements provide a direct measurement of the emission strengths that provide the modeling activities crucial data on the interchange between the surface and the atmosphere. The flux data also provide insights into the planetary boundary layer dynamics, and mass and energy transfer between the surface and atmosphere that are relevant for pollution transport and dilution.

Flux tower	Next to, or close by, the measurement site a tower is needed. The height of the tower depends on the surrounding obstacles and terrain. From the tower the VOC flux sample will be drawn to the instrument. Also, particle counters are placed to the tower to measure particle fluxes. The fast 3D wind profile measurement will be placed to the tower next to the instrument inlet lines, allowing the use of eddy covariance method in determining the fluxes.
3D anemometer	A fast response 3D ultrasonic anemometer (Metek uSonic-3 Scientific, METEK Meteorologische Messtechnik GmbH, Elmshorn, Germany) will be used to measure 3D wind at the location where flux instruments take their sample. The wind speed measured at 10 Hz will be combined to each variable of interest by using the eddy covariance method, yielding the flux.
LI-COR LI-7200 and LI-7700 Gas Analyzer	CO_2 , H_2O and CH_4 fluxes are measured with the fast LI-COR LI-7200 and LI-7700 sensors (LI-COR Biosciences UK Ltd, St. John's Innovation Centre, Cambridge, United Kingdom) with 10 Hz frequency, which are based on infrared absorption. The concentration data is combined to the wind data from the 3D anemometer, giving the CO_2 , H_2O and CH_4 flux.
PTR-TOF	VOC fluxes will be measured with the eddy covariance method. The turbulent sample flow is drawn from the tower down to ground level PTR-TOF, which measures the VOC concentrations at 10 Hz frequency. The VOC concentration is then combined with the 3D anemometer located next to the sample inlet in the tower, giving the VOC fluxes for all species the PTR method is able to detect.
TSI 3772 Condensation particle counter	The aerosol particle fluxes are measured with eddy covariance method so that the particle counter (TSI Inc., St. Paul, MN) is placed to the measurement height to the tower, and the particle counter samples the turbulent sample flow. The particle concentration measured at 10 Hz frequency will be combined to the 3D anemometer located next to the sample line inlet.

Supporting ancillary observations

The local meteorological measurements provide us the local conditions in the atmosphere that affect atmospheric chemistry and physics, boundary layer development. The local conditions and the vertical atmospheric structure of the lower atmosphere is important for the analysis of pollution emission, dispersion and dilution. The cost-effective Vaisala air quality sensors provide us small scale variability of certain aerosol and trace gas parameters in the vicinity of the super-site.

- Visibility
- Cloud base height (Vaisala CL51 Ceilometer, Vaisala, Finland)



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