Introduction & Overview

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In the outskirts of Leipzig, on the campus of the former Academy of Sciences, in close neighborhood of the Environmental Research Center, other research establishments and businesses you find the Institute for Tropospheric Research. It was founded in 1991 for the investigation of physical and chemical processes in the polluted troposphere (roughly the first 10 km of our atmosphere).

Fig. 1: *IfT main building.*

Meanwhile a well-defined and globally unique research profile emerged with a focus on aerosols, i.e. small airborne particles and clouds. Despite their minute absolute amount aerosols and clouds are essential parts of the atmosphere because they control the budgets of energy, water and trace substances of the Earth System. The research interest in these highly disperse systems is stimulated foremost by their potential change through human activities. These system changes feed back into the anthroposphere not only through regional and global climate change but also directly through health effects of inhaled haze and fog particles.

Despite strong connections between humans, aerosols, and clouds important physico-chemical processes of aerosol and cloud formation and the relationships with climate and health are poorly understood. This limitation is mainly due to analytical difficulties with the very small samples and with the complex behavior of tropospheric multiphase systems, in which individual processes seldom can be distinguished. In climate research this limitation is reflected in much larger uncertainties in predicted anthropogenic aerosol and cloud effects in comparison to numbers published by the Intergovernmental Panel on Climate Change for additional greenhouse gases.

Rapid advances in our understanding of tropospheric multiphase processes and an application of this process understanding to the prediction of the consequences of human impacts can only be expected from concerted approaches from several directions. Consequently, the Institute for Tropospheric Research conducts field studies in several polluted regions parallel to the development of analytical methods for aerosol and cloud research.

Fig. 2: Particle sampling systems during the INTERCOMP 2000 campaign at the research station Melpitz.

These tools are not only applied in field experiments but also in extensive laboratory investigations, which form a second major activity. A third and equally important approach consists of the formulation and application of numerical models that reach from process models to regional simulations of the formation, transformation and effects of tropospheric multiphase systems.

Field experiments

The atmosphere is an aerosol, i.e. a carrier gas mixture with suspended solid and liquid particles. Field experiments elucidate the atmospheric life cycle and related processes of aerosol and cloud particles. This task is vastly more difficult than comparable trace gas studies, in which only one number has to be known for each substance at each point in time and space. Particles sizes over more than six orders of magnitude occur in atmospheric aerosols and clouds, all of which play an important role in certain processes. All condensable substances of the Earth System can be found in the aerosol and a large number of them contributes to climate and biospheric effects. As a consequence of this multidimensional system essential aerosol and cloud properties are not well-established on a global scale yet.
The uncertainty and thus the studies of the Institute for Tropospheric Research start with particle sources. The combustion of fossil and contemporary fuels is one of the most prominent aerosol sources. However, these sources are still poorly characterised in terms of climate-relevant aerosol parameters. In collaboration with car manufacturers the institute establishes size dependent particle emission data of cars at test stands, in particular in the nanometer size range that was not covered by conventional emission studies. According to long-term measurements of the institute in a street canyon the car related emissions of particles and their precursor gases are subject to strong physical and chemical transformations even before they reach the sidewalk. These transformations will be investigated by a new mobile aerosol laboratory on a trailer behind a moving car in traffic.
Emission studies at cars are complemented by measurements at stationary combustion sources. Here the research focuses on particle properties that determine the absorption of solar radiation. Dedicated methods have been developed for the analysis of soot components, a major absorber of sun light. With aerosol measurements at welding stands finally the Institute for Tropospheric research characterises toxic industrial particle emissions. Health related aerosol studies will be expanded in the future in collaboration with the Environmental Research Center with coupled indoor and outdoor aerosol experiments and concurrent clinical investigations in the urban region of Leipzig.
Even the largest highly polluted regions in the

plumes of North America, Europe, the Indian subcontinent and Eastern Asia are insufficiently characterised in terms of aerosol burdens and ensuing climate effects. Thus, the institute focused the most recent field campaigns on the European and Indian plumes. These experiments were conducted within a large framework of international collaboration.

As baseline reference an austral area near Tasmania has been studied. By means of an intercontinental commercial aircraft, the results of the regional experiments are connected through regular CARIBIC flights between Germany, the Indian Ocean and Southern Africa (cf. Fig. 3).

Process studies are conducted at suitable locations such as mountain observatories, tethered balloons and over cooling towers of large power plants.

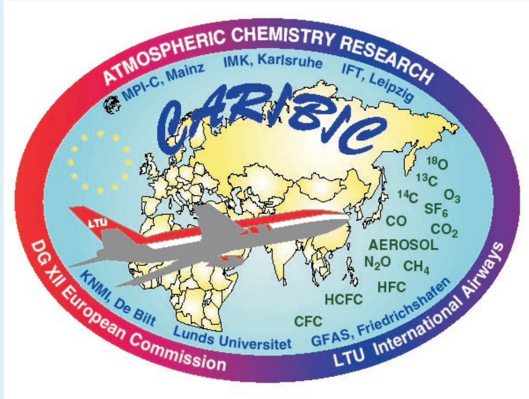

Fig. 3: The logo of the international project CARIBIC (Civil Aircraft for Regular Investigation of the atmosphere Based on an Instrument Container).

Fig. 4: Tethered balloon measurements near the coast of the North Sea.

These experiments are dedicated to particle nucleation, particle processing through clouds and the influence of anthropogenic aerosols on the optical properties of clouds.

Modeling

For the description of complex atmospheric processes, model systems of varying dimensions and complexity are developed, tested and applied to micro to mesoscale problems. The ultimate goal is to simulate the many interactions between aerosol particles, gases and clouds in a coupled three-dimensional meteorology-chemistry-transport model. With this model system as a toolbox scientific as well as legal tasks are addressed.

The Fifth Framework Program of the European Union states as long-term goal that no critical loads may be exceeded in the acidification and eutrophication of soils and water and for surface ozon. For the reduction of these critical loads guidelines are requested for national limits in sulfur dioxide, nitrogen oxides, ammonia and volatile organics. Already today European guidelines define limits in particulate mass concentrations below 10 µm (PM10). It is expected that these guidelines will be extended shortly to smaller particles (PM2.5). To meet these guidelines significant regionally different efforts will have to be undertaken in order to reduce emissions.

Models are indispensable tools in the search for efficient and cost-effective means of meeting present and future limits of gaseous and particulate air pollution. As done in the past, the Institute for Tropospheric Research will give advice to the Saxonian government on preventative air pollution measures.

The knowledge of the present emissions is a prerequisite for the development and evaluation of strategies for emission strategies directed and an improvement of air quality. As a basis for the simulation of present and future scenarios the institute developed a dynamic emission inventory for Saxony. This inventory enables us to supply emission data for natural and anthropogenic air pollutants (SO_2, NO_x, CO, NH_3, non-methane hydrocarbons, dust, heavy metals, polychlorinated dibenzo-dioxines/-furanes. For extended investigations emissions of the greenhouse gases CO_2, CH_4 and N_2O can be supplied for numerical simulations of the transport and transformation of air pollutants over Saxony. The use of a geographical information system (GIS ArcInfo) allows a spatial resolution of emission data and a connection with political and or geographical structures including a digital road map and land use data.

Fig. 5: Measurement with the multi-wavelength aerosol LIDAR during a field campaign.

Laboratory experiments

In atmospheric research there is a continuous development of physico-chemical models for the description of the most relevant process. These models are based on process parameters, which need to be determined in physical and chemical laboratory experiments.

In the physics section of the institute laboratory experiments cover the development of a large number of methods to characterize atmospheric particles and drops, in particular their size distribution and thermodynamic properties. Complex measuring and sampling systems are being designed for the characterization of cloud drops and interstitial particles.

Spectroscopic techniques such as the Differential Optical Absorption Spectroscopy have been developed for the analysis of trace gases and aerosol particles. There is an ongoing development of the multi-wavelength aerosol LIDAR (Light Detection and Ranging) technique that includes the measurement of atmospheric state parameters such as temperature and wind. Graphitic carbon is specified and quantified with a dedicated Raman spectrometer combined with multi-wavelength absorption measurements on aerosol samples.

Process-oriented laboratory studies are being carried out jointly by the physics and chemistry sections in two main areas. The first of these activities concerns a laminar flow tube reactor in which particle formation from (SO_2) and organic precursors (e.g., terpenes) is being investigated. In the second activity the transition from a moist aerosol to a cloud will be simulated in a laminar flow channel.

In the chemistry section there are several process-oriented laboratory studies. Gas phase reactions of the radicals OH and NO_3 are being investigated in flow reactors. These reactions are important for ozone and particle formation caused by biogenic and anthropogenic emissions of volatile hydrocarbons. The chemical identity of atmospheric particles will be characterized in reaction chambers. In a single drop experiment phase transfer parameters of trace gases and radicals are being determined for different chemical species and surfaces. Mechanisms of non-radical oxidations in the liquid phase are being studied with the stopped-flow technique and optical detectors. Experiments with radical reactions in the liquid phase form a core activity of the laboratory experiments because of their importance for processes in haze particles, fogs and clouds. For the understanding of the oxidation of organic trace gases in the tropospheric multi-phase system a large number of reactions with the OH and NO_3 radicals are being studied as well as reactions of halogenated oxidants. The latter species are of interest for the emission of reactive halogen compounds from sea salt particles.

Fig. 6: *The IfT laminar flow tube reactor.*

Several laboratory experiments are dedicated to the chemical characterization of atmospheric organic aerosol components. Besides the conventional combustion techniques, mass spectroscopic and chromatographic techniques coupled directly to analysis by mass spectrometry or capillary electrophoresis with different sampling and segregation techniques are being developed. The close cooperation of the physics and chemistry section has lead to the development of a patented sampling method for narrow well-defined particle size ranges that is coupled directly to the mass spectroscopic analyses.

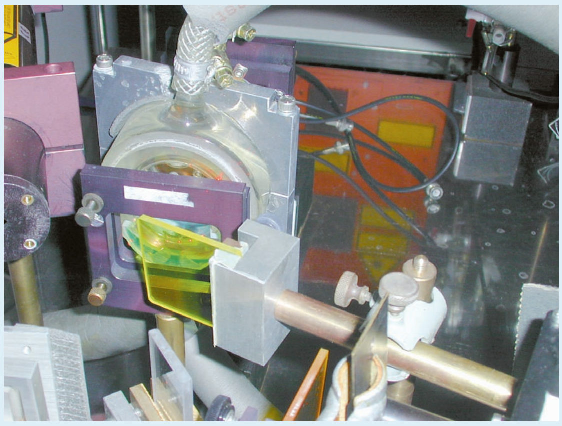

Fig. 7: *A laser photolysis-long path laser absorption experiment for the study of nitrate radical kinetics in aqueous solution.*