International Workshop on Airborne Particle Inlets
Within the Framework of EUFAR
Leipzig, 12-13 April 2002

Short Report
Given by Manfred Wendisch and Hugh Coe: 12 June 2002

On 12 and 13 April 2002 the first workshop on 'Airborne Particle Inlets' of the two EUFAR working groups 'Aerosol Microphysics' and 'Aerosol Chemistry' was held. The workshop was hosted by the Institute for Tropospheric Research (IfT) Leipzig and was jointly organized by the two EUFAR working group coordinators Manfred Wendisch and Hugh Coe. 27 scientists from seven countries (Germany, United Kingdom, France, Portugal, Israel, USA, and Mexico) working in the field of airborne aerosol measurements attended the workshop. Additionally one expert from Sweden submitted a presentation to the workshop coordinators. The European participants represented the majority of the aerosol inlets operated on European research aircraft.

The workshop was split into five sessions (Introduction, Inlet Designs, Experimental Inlet Characterization, Inlet Characterization Using Models, Applications). 15 presentations were given including a discussion of each talk. The talks generated much interest and considerable debate. The sessions were followed by a round table discussion of all participants.

The topic for the workshop is a very specific and urgent problem, which weighs heavily on the mind of the two working groups: Airborne particle inlets. Inlets connect the scientific instruments with the atmosphere. Therefore, both the aerosol microphysics and the aerosol chemistry community have the same serious problem, that on the one hand inlets are needed to get the particles inside the aircraft, and on the other hand these inlets distort the measurements. The inlet-related problems are caused by:

- Removing very small (particle diameter d_p < 30 nm, due to diffusion to the inlet walls) and large particles (d_p > 1 µm, due to inertial effects and turbulent deposition), and by
- Changing the particle chemical composition and ambient size due to hydrating of water and other volatile materials from the particles within the mostly heated inlet system.

Further disturbances of the aerosol measurements are caused by:

- Misalignment of the inlet with the free air stream flow,
- Losses on tubing walls in transport from the inlet to the instruments,
- Disturbance of air due to the aircraft such that shadow zones form where no particles can be measured,
- Anisokinetic sampling that modifies the concentration of some sizes, and
- Atmospheric turbulence in front and inside of the inlets, causing further depositional losses.

These aerosol inlet problems were extensively discussed during a workshop at NCAR in 1992. After ten years it was time to again bring these problems on the agenda and to summarize the progress achieved within the last ten years, as well as to give a prospect for future needs. This was the major motivation of the workshop in Leipzig.

The workshop participants agreed to provide all presentations for inclusion in the EUFAR website; to provide a set of recommendations (summarised below); and to write a detailed report on the status of aircraft aerosol inlets in Europe, outlining current gaps and future areas of investigation. The presentations are already included in the EUFAR website, the detailed report will be available by the end of August.

It was clear from the workshop that a dedicated programme of particle inlet system validation must be carried out on all aircraft in a consistent and comparable way. The workshop generally recommends:

1. The development of a standard portable reference system to intercalibrate different aircraft inlets against a unique system.
2. As minimum, standard aerosol instrumentation a Condensation Particle Counter (CPC) with its own simple inlet that is never affected by other developments should serve as a long term reference in each aircraft.

The workshop also made several more specific recommendations to (a) the aerosol scientific community represented by the respective EUFAR working groups, (b) aircraft operators, and (c) funding agencies.

(a) Recommendations for the aerosol scientific community:
The discussion at the workshop has shown, that active control of the boundary layer can reduce turbulence within the inlets, which significantly minimizes the large particle losses (d_p>1µm) in the inlets. It is suggested that this technique be used for sampling of super-micron aerosol particles. However both permanent monitoring of the inlet performance (e.g. pressure, temperature, exit velocity) along the sampling line and numerical calculations of the inlet behavior are needed to predict and control the passing efficiency (enhancement factors) of the inlet systems. There has been dramatic progress in the field of numerical calculations of the flow field in and around the inlets since the 1992 NCAR inlet workshop, but it was made very clear at the EUFAR workshop that these need to be extended by the calculation of particle trajectories, as well. Characterizing the flow field within and around the particle inlets is definitely not enough. Also it was pointed out at the workshop that the numerical flow field calculations need experimental verification, e.g., using five-hole probes. In parallel, easy parameterizations should be derived and existing formulas need to be evaluated with detailed numerical calculations. Furthermore, there is an urgent need for a comprehensive community inventory of available validation, standardization, and calibration tools for airborne aerosol inlets.

(b) Message to aircraft operators:
Absolute calibration of aerosol sampling systems, including inlets, tubing and instruments is extremely difficult. An alternative is proposed with the development of a reference standard to be used successively on the European instrumented aircraft for intercalibration. The system could be based on an equipped external pod. Operators are required to examine if such a pod installation is feasible on their aircraft and EUFAR is required to seek funding for the development and instrumentation of such a reference pod. In addition to the intercalibration objective, an instrumented external pod will be very useful in most of the field experiments. For these developments the aircraft operators need to agree on standard installation and hard-points. The group also recommends that every aircraft of the fleet be equipped with a standard minimum-requirement inlet for simple and "standard" aerosol instruments like the CPC. Such a system should be installed and separated from more sophisticated inlets used for specialised measurements.

(c) Message to funding agencies:
A comprehensive airborne inlet validation experiment jointly planned and performed by both modelers and experimentalists needs to be funded in two steps: 1) A series of experiments utilizing wind tunnel measurements and 2) Airborne validation experiments under a range of atmospheric conditions. In parallel with these two sets of experiments there should be a workshop in which various inlet models are intercompared and tested against the wind tunnel and aircraft measurements.

Specific scientific questions require measurements that utilize specific inlet designs; therefore no general inlet can be suggested which suits all scientific needs. However, the most important result of the workshop was that the discussion among the scientists on particle-inlet-related problems has been revived with a general interest and motivation to address the practical issues of the aircraft operators and the scientific community.

The participants agreed that it would be beneficial to publish the detailed workshop report in a journal with broad, scientific readership, e.g., through a peer-reviewed article in Bull. Am. Meteor. Soc.