Investigating the Small-Scale Vertical and Horizontal Variability of the Atmospheric Boundary Layer Aerosol using Unmanned Aerial Vehicles

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Introduction

Beside numerous ground based measurements only few aerosol data from higher altitudes taken by airborne instrumentation are available. These data showed a number of interesting phenomena, such as new particle formation often induced by turbulence. However, such data are rare and more continuous aerosol and turbulence measurements in higher altitudes are needed to close this gap.

One approach to realize airborne measurements with low logistical effort compared to aircraft measurements is the application of unmanned aerial vehicles (UAV) for atmospheric studies. The new UAV Carolo P360 "ALADINA" (see Figure 1) equipped with aerosol instrumentation provides a unique and flexible tool for characterizing the vertical and horizontal variability of the boundary layer aerosol. The Carolo P360 with a wingspan of 3.6 m is designed to carry up to 2.5 kg of payload in the front compartment. With electrical propulsion, it has an endurance of about 40 minutes. The cruising speed is 25 m/s.

Figure 1. Picture of the UAV ALADINA.

Instrumentation

For aerosol measurements, ALADINA will be equipped with a set of light-weight instruments. To reach the weight limit of 2.5 kg for the payload, commercially available instruments were chosen and modified in terms of space and weight. Two Condensation Particle Counters, CPCs, (TSI, model 3007, TSI Inc., St. Paul, USA) with different lower cut-offs will be used to measure the total particle number concentration between ~6 nm and 1 μm (N_6) and ~12 nm and 1 μm (N_{12}), respectively. The difference between N_6 and N_{12} will be used as indicator for new particle formation. To reduce weight, housing, internal batteries, and display of the CPCs were removed.

Larger aerosol particles will be measured using an Optical Particle Counter, OPC (Met One, model GT-526, Met One Instruments Inc., Washington, USA). This OPC counts particles in 6 size channels from 0.3 to 5.0 μm. Again, housing, battery, and display were removed.

The aerosol instruments will be characterized and improved in the laboratory with respect to the lower detection diameter and the response time of the CPCs.

Moreover, an additional meteorological payload for measuring the turbulent 3D wind vector, temperature and humidity is constructed by Tübingen University. These sensors and an aerosol inlet will be mounted in front of the UAV.

Electrical power for all three instruments will be provided by a common battery. A measurement and data acquisition system is developed at Tübingen University with the possibility of real-time data transfer by a telemetry downlink. This new UAV system will be flight tested for proper instrument operation while airborne.

Experiment

A first field experiment is planned in September 2013 in Melpitz, the research site of TROPOS. Here, the UAV aerosol and meteorological measurements will be completed by ground-based and helicopter-borne measurements. In addition, Lidar measurements will provide continuous measurements of the vertical structure. The UAV has the potential to close the gap of atmospheric aerosol measurements between long-term ground-based observations and expensive helicopter-borne measurements. Complementary to these measurements, UAV observations allow for investigating the small-scale and short-term aerosol variability in vertical and horizontal direction at low cost and with minimal logistical requirements. Two additional UAV of type MASC of Tübingen University equipped with turbulence instrumentation add the opportunity to study the interaction of the aerosol concentration with turbulent transport and exchange processes of the surface and the atmosphere. The combination of different flight patterns of the three UAV allows new insights in atmospheric boundary layer processes.

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