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In-Situ Turbulence Measurements With Unmanned Research Aircraft in the Atmospheric Boundary Layer

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Remotely Piloted Aircraft (RPA), also known as Unmanned Aerial Vehicles (UAV) or by the more general term Unmanned Aerial Systems (UAS) have become an increasingly popular tool for research in various fields. While in many geo- and environmental sciences the remote sensing capabilities (i.e. to capture high resolution, multi-spectral imagery) is of high value, atmospheric sciences can profit from the possibility to carry out in-situ measurements in the Atmospheric Boundary Layer (ABL) with a much higher flexibility than ever before. However, just like in manned airborne meteorology, UAS also need special considerations regarding sensor equipment and measurement strategies to be able to provide valuable data of mean values and turbulent structures of thermodynamic quantities. While large UAS are able to carry almost the same sensors as manned research aircraft (e.g. DO-128 or METAIR DIMO), smaller UAS with a total weight of less than 20∼kg, and especially the smallest UAS with less than 5∼kg, demand miniaturized sensors. The charm of small sized UAS is their flexible operation, low cost and low legal barriers. In Germany, UAS below 5∼kg can receive a general permit to be operated up to 100∼m altitude in almost any non-populated area. Therefore, at the University of Tübingen, small UAS are developed and equipped with customized sensor technology to probe the ABL.
The UAV MASC (Multipurpose Airborne Sensor Carrier) was developed in cooperation with the University of Stuttgart, University of Applied Sciences Ostwestfalen-Lippe and 'ROKE-Modelle'. Its purpose is the investigation of thermodynamic processes in the atmospheric boundary layer (ABL), including observations of temperature, humidity and wind profiles, as well as the measurement of turbulent heat, moisture and momentum fluxes.
The aircraft is electrically powered, has a maximum wingspan of 3.40∼m and a total weight of 5-8∼kg, depending on battery- and payload. In normal operation, the aircraft is automatically controlled by the ROCS (Research On-board Computer System) autopilot to be able to fly predefined paths at constant altitude and airspeed. The standard meteorological payload consists of temperature sensors, a humidity sensor, a flow probe, an inertial measurement unit and a GNSS. Special care was taken to achieve reliable and high resolution data for the thermodynamic quantities. A short introduction to the sensor technologies will be given. While temperature sensors and flow probe were optimized to resolve turbulent structures up to 20∼Hz, a different approach was chosen for humidity measurement. A dynamic model of a small and light-weight capacitive humidity sensor was identified and by in-flight parameter identification, measured data can be corrected for the sensor dynamics to be able to resolve turbulent structures up to at least 3∼Hz.
Since 2010 the system has been tested and improved intensively. In September 2012 first comparative tests could successfully be performed at the Lindenberg observatory of Germany's National Meteorological Service (DWD). In 2013, several campaigns were done with the system, including fundamental boundary layer research, wind energy meteorology and assistive measurements to aerosol investigations.