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Airborne meteorological measurement unit for small UAVs

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In lower-atmosphere research the atmospheric boundary layer (ABL) is of high interest because the exchange of energy between earth surface and the atmosphere begins here. Many of the processes and interactions in this layer are known, but not fully understood, which makes it necessary to gain a better understanding by observing the characteristic variables of the system.

Observing in the atmosphere can be done by means of airborne measurements. For this purpose a UAV platform (MASC - Multi-purpose Automatic Sensor Carrier) was developed at the University of Tübingen that is able to carry meteorological payloads. MASC is equipped with an autopilot to be able to fly pre-defined routes autonomously.

As the basic meteorological payload a measuring unit is designed and developed which is capable of measuring temperature, humidity, pressure and aircraft attitude with high resolution and precision. The unit is designed to fit on MASC, but is easily exchangeable and does not interact with the navigation and power units of the aircraft. In this set-up the measuring system can be used to measure vertical profiles of the ABL, as well as turbulent flux in heat, humidity and momentum.

In detail, the system consists of meteorological sensors including a five-hole probe connected to high precision pressure transducers, a fast response thermocouple and a fast response humidity sensor. Additionally, to calculate position and attitude of the aircraft, an inertial measurement unit (IMU) and a GPS receiver are installed in the unit.

The thermocouple is designed to be able to measure temperatures in a range of -20 °C to 200 °C. First tests are demonstrated that proof high sensitivity and fast response times that allow to resolve turbulent fluctuations as fast as 20 Hz and more.

To measure humidity, two sensors with specified static response times of about 2 s were compared and shown to be able to resolve turbulent fluctuations up to 10 Hz. Both of the sensors are based on capacitive measuring principles.

All sensors are directly connected to a central board computer developed in cooperation with the University of Applied Sciences Ostwestfalen-Lippe (AMOC - Aerial Meteorological On-Board Computer). This embedded computer is equipped with two microcontrollers, a 24-bit analog-digital-converter, an SD-card and common interfaces (Analog, SPI, CAN, Uart) for all sensors as well as additional optional periphery. An 868 MHz wireless module is connected to the board computer and makes it possible to send live data to a ground station computer. On the ground station all sensor data can be visualized and observed during the flight, making it possible to see if sensors are functional and adapting the flight plan according to the current meteorological situation.

All data is logged onto the sd-card at a rate of 100Hz. In post-processing, the raw sensor data will be used to calculate turbulent flux, wind vector and precise attitude of the UAV.

First tests and results will be presented, including vertical profiles of the ABL and power spectrums of humidity and temperature.