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Development and Evaluation of Novel and Compact Hygrometer for Airborne Research (DENCHAR): In-Flight Performance During AIRTOSS-I/II Research Aircaft Campaigns

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Water vapour is one of the most important parameters in weather prediction and climate research. Accurate and reliable airborne measurements of water vapour are a pre-requisite to study the underlying processes in the chemistry and physics of the atmosphere. Presently, no airborne water vapour sensor exists that covers the entire range of water vapour content of more than four order of magnitudes between the surface and the UT/LS region with sufficient accuracy and time resolution, not to speak of the technical requirements for quasi-routine operation.

In a joint research activity of the European Facility for Airborne Research (EUFAR) programme, funded by the EC in FP7, we have addressed this deficit by the Development and Evaluation of Novel and Compact Hygrometer for Airborne Research (DENCHAR), including the sampling characteristics of different gas/ice inlets. The new instruments using innovative detecting technics based on tuneable diode laser technology combined with absorption spectroscopy (TDLAS) or photoacoustic spectroscopy (PAS): (i) SEALDH based on novel self-calibrating absorption spectroscopy; (ii) WASUL, based on photoacoustic spectroscopy; (iii) commercial WVSS-II, also a TDLAS hygrometer, but using 2f-detection technics.

DENCHAR has followed an unique strategy by facilitating new instrumental developments together with conducting extensive testing, both in the laboratory and during in-flight operation. Here, we will present the evaluation of the in-flight performance of the three new hygrometer instruments, which is based on the results obtained during two dedicated research aircraft campaigns (May and September 2013) as part of the AIRTOSS (AIRcraft Towed Sensor Shuttle) experiments. Aboard the Learjet 35A research aircraft the DENCHAR instruments were operated side by side with the well established Fast In-Situ Hygrometer (FISH), which is based on Lyman (alpha) resonance fluorescence detection technics and calibrated to the reference frost point hygrometer MBW DP30 at the ground based FISH calibration bench.. The hygrometers were flown together with cloud detecting instruments, such that we also will report on the performance of the different inlet systems used during both campaigns under different cloud and non-cloud conditions.

All data of the hygrometers (incl. FISH) were stored “blind” before any comparison was made. From the intercomparisons the instruments showed very good and consistent performance over a wide range of humidity levels covering more than three orders of magnitudes between 10 ppmv and 20,000 ppmv water vapour mixing ratios. Flight by flight the DENCHAR-instruments showed a very consistent behaviour as well as among each other and against the FISH-reference instrument. Within their uncertainty range (5-10%) all instruments agreed very well and were traceable within about 10% uncertainty to the accurate DP30 (MBW) frost point hygrometer.