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Initial evaluation of airborne water vapour measurements by the IAGOS-GHG CRDS system

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Accurate and reliable airborne measurements of water vapour are still a challenge. Presently, no airborne humidity sensor exists that covers the entire range of water vapour content between the surface and the upper troposphere/lower stratosphere (UT/LS) region with sufficient accuracy and time resolution. Nevertheless , these data are a pre-requisite to study the underlying processes in the chemistry and physics of the atmosphere. The DENCHAR project (Development and Evaluation of Novel Compact Hygrometer for Airborne Research) addresses this deficit by developing and characterizing novel or improved compact airborne hygrometers for different airborne applications within EUFAR (European Facility for Airborne Research).
As part of the DENCHAR inter-comparison campaign in Hohn (Germany), 23 May – 1 June 2011, a commercial gas analyzer (G2401-m, Picarro Inc.,US), based on cavity ring-down spectroscopy (CRDS), was installed on a Learjet to measure water vapour, CO_2, CH4 and CO. The CRDS components are identical to those chosen for integration aboard commercial airliner within IAGOS (In-service Aircraft for a Global Observing System). Thus the campaign allowed for the initial assessment validation of the long-term IAGOS H_2O measurements by CRDS against reference instruments with a long performance record (FISH, the Fast In-situ Stratospheric Hygrometer, and CR2 frostpoint hygrometer, both research centre Juelich).
The inlet system, a one meter long 1/8" FEP-tube connected to a Rosemount TAT housing (model 102BX, deiced) installed on a window plate of the aircraft, was designed to eliminate sampling of larger aerosols, ice particles, and water droplets, and provides about 90% of ram-pressure. In combination with a lowered sample flow of 0.1 slpm (corresponding to a 4 second response time), this ensured a fully controlled sample pressure in the cavity of 140 torr throughout an aircraft altitude operating range up to 12.5 km without the need of an upstream sampling pump. This setup ensures full compatibility with the future deployment of the analyser within IAGOS.
For the initial water calibration of the instrument, a calibration of a similar instrument performed at MPI-BGC Jena against a dew point mirror (Dewmet, Michell instruments Ltd., UK) in the range from 0.7 to 3.0% was transferred to all subsequently manufactured CRDS instruments by Picarro. During the campaign the analyzer was compared against a reference frost point hygrometer, which is also used for calibration of the reference instrument FISH. The dew point mirror calibration was within 0.7 % of the FISH calibrator, but showed an offset of 14.45 ppm, which is consistent with the H_2O content of dry tank air and diffusion effects through the inlet line (FEP). Furthermore, a new independent calibration method, based on the dilution effect of water vapour on CO_2, was tested. It showed a 9 % low bias compared to the dew point mirror calibration.
Comparison of the in-flight data against the reference systems showed that the analyzer is reliable and has a good long-term stability. Flight data from the DENCHAR campaign suggest a conservative precision estimate for measurements made at 0.4 Hz of 4 ppm for $H_2O < 100$ ppm, and 4 % (relative) for $H_2O > 100$ ppm. Accuracy at mixing ratios below 50 ppm was difficult to assess, as the reference instruments suffered from lack of stability.
We present the results of the campaign flights and comparison with the reference instruments. The different calibration methods will be discussed.