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Fast, multi-phase H_2O measurements on board of HALO: Results from the novel HAI instrument during the first field campaigns.

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Water vapor is a key species for many questions in atmospheric research [1] [2] but is also a gas species which is complex to handle. A particular challenge is the simultaneous quantification of gas and condensed phase water. This is especially true for measurements on airborne platforms but also for laboratory experiments [3]. On research aircraft, total water measurement (i.e. the sum of gas-phase and ice-phase) is realized by sampling air with an inlet faced into flight direction (“forward” sampling) and subsequent evaporation of the ice crystals in the heated sampling lines. Gas-phase detection is typically realized using inlets facing against flight direction (“backward” sampling) or “Rosemount” inlets where an air stream is sampled perpendicular to the high speed airflow through the inlet. For both methods it is believed that no ice crystals reach the downstream hygrometer, but the question remains - especially for Rosemount inlets - if some small ice particles or water droplets may have entered the sampling lines. In addition to the question of proper sampling of the water phases, currently no hygrometer exists that measures all phases with the same measurement principle in one instrument. In the rare occasions that multi-phase measurements are realized, gas-and condensed-phase observations rely on different methods and calibration strategies so that precision and accuracy levels are difficult to compare.

The novel HAI (Hygrometer for Atmospheric Investigation) realizes a simultaneous multi-phase hygrometer in a unique concept [4]. Water detection with HAI is based on Tunable Diode Laser Absorption Spectroscopy (TDLAS) with a special evaluation method allowing absolute water vapor measurements without any sensor calibration [5]. The HAI instrument contains two independent dual-channel spectrometers, one at 1.4 μm and one at 2.6 μm which allows to cover a very wide water concentration range from 1 to 30 000 ppmv. Both HAI spectrometers couple one light path in a so called "closed-path" cell [6] for total water measurement via a forward facing inlet. The other part of the laser light is coupled to an "open-path" cell [7] placed outside of the aircraft fuselage to measure gas phase water without any possible artifacts from ice or liquid particles. The frequency of the measurements can be up to 240 Hz (4.2 msec) for all four channels. Altogether, the novel HAI instrument allows fast, accurate and precise dual-phase water measurements. The individual evaluation of the multi-channel raw-data is done afterwards, without any channel interdependencies, in a calibration-free mode. The water signals are combined with an extensive set of more than 100 housekeeping data to enable a holistic data quality management and a rigorous signal scrutiny to maximize the confidence level of the final H_2O values. HAI therefore represents a new unique research tool for atmospheric hygrometry to address numerous open topics in atmospheric research. First scientific HAI campaigns have been successfully realized in 2012 onboard the German research plane HALO (High Altitude and Long Range Research Aircraft) during the TACTS and ESMVal missions. The first two HALO campaigns in clouds (MLCIRRUS and ACRIDICON) will be realized in 2014. In our contribution we present and discuss the performance of HAI and show detailed evaluations of typical inflight data. The results of the first two HAI campaigns on HALO resulted in more than 100 operation hours of continuous data and show nice agreement between the closed-path and open-path under clear sky conditions, despite the different sampling conditions of the sensor channels and airspeed of up to 900 km/h in the open path section. All mission data are and will be uploaded to the HALO database and are available for further scientific exploitation. Furthermore, the HAI principle can be adapted to other (airborne) platforms and be used for phase resolved science of the atmospheric water cycle. In parallel HAI’s cal-free data evaluation principle will be validated with metrological scrutiny to further investigate the possibility of flying field-qualified metrological transfer standards to resolve the persistent discrepancies in atmospheric hygrometry.

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