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Photo-acoustic laser spectroscopy of water vapour and cloud content onboard passenger aircraft

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Water in form of water vapour and clouds is one of the most important trace species in the upper troposphere and lower stratosphere (UTLS), as it is responsible for ∼75% (or ∼25 K) of the natural greenhouse effect (Schmidt et al., JGR, 2010) and carries huge amounts of latent heat. Better climate models and realistic future predictions are therefore depending on how well the global hydrological cycle is understood and described in the models. Accurate measurements of water vapour and cloud water/ice in the UTLS are one essential step towards this goal.

Here, we describe the technical set-up of a 2-channel photo-acoustic laser spectrometer (PAS) that was designed for fully unattended use aboard the CARIBIC passenger aircraft. The instrument makes use of an accurate frost-point hygrometer for in-flight calibration of two fast-responding PA channels to measure water vapour and cloud water, respectively. The efforts that were necessary to achieve high-precision (low acoustic noise) photo-acoustic signals within a noisy environment are described. Detailed system analyses were carried out prior and during the operational phase of this instrument. The precision of the instrument is ∼0.8 ppmv at 3 sec integration time, and can be improved to 85 ppbv when averaging the data for 300 s. The accuracy is determined by the frost-point hygrometer, and is found to be better than ∼0.5 ppmv.

With its capability to accurately measure both water vapour and cloud water, this instrument provides unique insight in the hydrological cycle. It is operated since 2005 for four intercontinental flights per month aboard the CARIBIC passenger aircraft. Some scientific results gained during its airborne operation are presented. These include (i) a flight through ice clouds which demonstrates the performance of the device, (ii) the seasonal variation of water vapour from the UT up to 5 km above above the (mid-latitude) tropopause, or (iii) the distribution of the supersaturation inside and outside of clouds.