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WaSul-Hygro: A diode laser based photoacoustic instrument for airborne measurement of water vapor and total water concentration

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Improving our knowledge on the spatial and temporal distribution of water vapor and total water in the atmosphere is expected to improve the reliability of both meteorological forecast models as well as climate models. For this purpose highly reliable airborne hygrometer instrumentation with sub-ppm accuracy, excellent selectivity and wide measurement range is needed, with capability of long term, fully automatic operation, without the need of frequent recalibration. We have developed and tested a DFB diode laser based photoacoustic water vapor concentration measuring instrument (WaSul-Hygro) for airborne operation meeting these requirements. One of our WaSul-Hygro system is operated on-board a commercial aircraft within the CARIBIC project since May 2005, while another one is tested in lower altitude measurements on-board of a twin engine airplane (within an Eufar project).

The main parts of the WaSul-Hygro system are (1) the laser, (2) the measuring PA cell (or cells), (3) the electronics and (4) the gas handling unit.

1: WaSul-Hygro is based on a commercially available, room temperature operated telecommunication type diode laser. Using these types of lasers offers several advantages such as an expected operational lifetime exceeding ten years.

2: Our photoacoustic cells offer high sensitivity, small size, fast response time (below 10 seconds), operation under continuous gas flow and large immunity to outside disturbances. Furthermore with one laser light source up to four photoacoustic cells can be illuminated through, so that different gas streams can be measured simultaneously. In the CARIBIC project in one cell water vapor and in the other cell total water is measured, while the third cell is used as a reference cell with fixed water vapor concentration for precise wavelength locking of the laser.

3: The electronics is a compact and integrated unit which provides laser driving, signal processing, concentration calculation and long term storage of the calculated concentration or alternatively continuous data transfer to a master computer.

4: Gas handling is a critical part of the system: the direction of the inlet with reference to the flight direction determines whether water vapor or total water is sampled; the sampling line has to be short and preferably heated. Acoustic silencers (filters) are inserted into the sampling line to avoid excessive acoustic flow noise to interfere with the measurement.

In order to extend the measurement range of the WaSul-Hygro system, a measurement procedure is introduced with which the laser wavelength can be automatically switched between strong and weak water vapor absorption line depending whether the aircraft flies at high or low altitudes, respectively.

Various measurement campaigns justified the applicability of our system for airborne operation in wide concentration and pressure range. A series of measurement results will be presented.

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