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The Importance and Technology for Measuring Atmospheric Humidity in Airborne Applications

Zoltán Bozóki (1,2), Dávid Tátrai (2), Gábor Gulyás (1), Attila Varga (1), and Gábor Szabó (2)
(1) Hilase Ltd. Hungary, (2) University of Szeged, Hungary

The concentrations of atmospheric water vapour (i.e. humidity) and total water (i.e. water vapour plus liquid water and ice particles) are crucially important parameters for weather forecast and climate research, while these substances also play dominant roles in aircraft icing and contrail formation. Their concentration varies over more than three orders of magnitudes in the troposphere and stratosphere with high temporal and spatial variation especially when being measured by an instrument operated on-board of a research or commercial aircraft. Therefore an instrument for their measurement has to have short response time, long-term maintenance free operation, small size, low weight, as well as accurate and reliable operation even under extreme conditions. We have developed a diode laser based dual channel instrument (Hilase-Hygro) which operates on a special type of optical absorption methods (i.e. the photoacoustic principle) and which can measure the concentration of water vapour and total water simultaneously while meeting the strictest requirements listed above. One of our instruments is in operation as a part of an automatic laboratory deployed intermittently into the cargo bay of a passenger aircraft within the framework of the CARIBIC project since 2002. Other instrument takes part in various measurement campaigns within the framework of the EUFAR (European Facility for Airborne Research) project.
Recently the instrument has been improved in several topics: The wavelength of the applied laser now can be locked with 10-8 relative accuracy, what results a maximum of 0.1% error in the measured optical absorption, i.e. in the measured humidity levels. The calibration method was also improved, what also increased the performance of the whole instrument. This new calibration method gives the possibility for real time mixing ratio calculation both for water vapour and total water content.
Altogether now the instrument is capable for measuring humidity with 1second temporal resolution from the subppmV level up to $\sim$70000 ppmV (highest noncondensing humidity level at 40°C instrument temperature) in the 100-1000 mbar pressure range. The pressure range seems to be expandable down to $\sim$50mbar without significant sensitivity loss.
The performance of the instrument will be demonstrated through independent laboratory comparison tests and flight measurements performed within the CARIBIC and EUFAR frameworks.
Authors believe that the presented instrument will find much more applications in climate research and hopefully in air traffic management for optimal route planning.