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First airborne water vapor lidar measurements in the tropical upper troposphere and mid-latitudes lower stratosphere: accuracy evaluation and intercomparisons with other instruments

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Abstract. In the tropics, deep convection is the major source of uncertainty in water vapor transport to the upper troposphere and into the stratosphere. Although accurate measurements in this region would be of first order importance to better understand the processes that govern stratospheric water vapor concentrations and trends in the context of a changing climate, they are sparse because of instrumental shortcomings and observational challenges. Therefore, the Falcon research aircraft of the Deutsches Zentrum für Luft- und Raumfahrt (DLR) flew a zenith-viewing water vapor differential absorption lidar (DIAL) during the Tropical Convection, Cirrus and Nitrogen Oxides Experiment (TROCCINOX) in 2004 and 2005 in Brazil. The measurements were performed alternatively on three water vapor absorption lines of different strength around 940 nm. These are the first aircraft DIAL measurements in the tropical upper troposphere and in the mid-latitudes lower stratosphere. Sensitivity analyses reveal an accuracy of 5% between altitudes of 8 and 16 km. This is confirmed by intercomparisons with the Fast In-situ Stratospheric Hygrometer (FISH) and the Fluorescent Advanced Stratospheric Hygrometer (FLASH) onboard the Russian M-55 Geophysica research aircraft during five coordinated flights. The average relative differences between FISH and DIAL amount to −3%±8% and between FLASH and DIAL to −8%±14%, negative meaning DIAL is more humid. The average distance between the probed air masses was 129 km. The DIAL is found to have no altitude- or latitude-dependent bias. A comparison with the balloon ascent of a laser absorption spectrometer gives an average difference of 0% ±19% at a distance of 75 km. Six tropical DIAL under-flights of the Michelson Interferometer for Passive Atmospheric Sounding (MIPAS) on board ENVISAT reveal a mean difference of −8%±49% at an average distance of 315 km. While the comparison with MIPAS is somewhat less significant due to poorer comparison conditions, the agreement with the in-situ hygrometers provides evidence of the excellent quality of FISH, FLASH and DIAL. Most DIAL profiles exhibit a smooth exponential decrease of water vapor mixing ratio in the tropical upper troposphere to lower stratosphere transition. The hygropause with a minimum mixing ratio of 2.5

µmol/mol is found between 15 and 17 km. A high-resolution (2 km horizontal, 0.2 km vertical) DIAL cross section through the anvil outflow of tropical convection shows that the ambient humidity is increased by a factor of three across 100 km.

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