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Airborne Lidar Observations of Water Vapor Variability in the Northern Atlantic Trades

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During the NARVAL (Next Generation Aircraft Remote Sensing for Validation Studies) field experiments in December 2013 and August 2016 the DLR lidar WALES (Water vapor Lidar Experiment in Space) was operated on board the German research aircraft HALO. The lidar simultaneously provided two-dimensional curtains of atmospheric backscatter and humidity along the flight track with high accuracy and spatial resolution, in order to help improve our knowledge on the coupling between water vapor, clouds, and circulation in the trades. The variability of water vapor, ubiquitous in our measurements, poses challenges to climate models because it acts on the small-scale low-cloud cover. Aloft, the very dry free troposphere in the subsiding branch of the Hadley cell acts as an open window in a greenhouse, efficiently cooling the lower troposphere. Secondary circulations between radiatively heated and cooled regions are supposed to occur, adding complexity to the situation. After recently having identified them to be mainly responsible for the uncertainty in global climate sensitivity, such interactions between shallow convection, circulation and radiation are at the heart of present scientific debate, endorsed by the WCRP (World Climate Research Programme) "Grand Challenge on Clouds, Circulation and Climate Sensitivity". Out of the wealth of about 30 winter and 60 summer flight hours totaling 75000 km of data over the Tropical Atlantic Ocean east of Barbados, several representative lidar segments from different flights are presented, together with Meteosat Second Generation (MSG) images and dropsonde profiles. All observations indicate high heterogeneity of the humidity in the lowest 5 km, as well as high variability of the depth of the cloud layer (1 – 2 km thick) and of the sub-cloud boundary layer ($\sim$1 km thick). Layer depths and partial water vapor columns within the layers may vary by up to a factor of 2, and on a large range of horizontal scales. Occasionally, very dry, up to 100 km wide regions are observed. In winter, 95 % of the water vapor column ($\sim$30 kg/m^2) is below the trade inversion, and the vertical moisture gradient at the trade inversion is mostly stronger than the gradient at the top of the sub-cloud layer. In the summer campaign the ITCZ was closer. There was consequently more moisture in total ($\sim$40 kg/m^2) and particularly also more moisture in the free troposphere above the inversion, of importance for radiation. The typical deviations between lidar and dropsonde water vapor mixing ratio profiles amount to a few percent. This presentation highlights the potential of novel lidar observations to advance science in a complex and climate-sensitive context.