Investigating tropical clouds from shallow cumulus to strongly showering with synergistic airborne measurements

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Clouds contribute strongly to uncertainties in numerical weather prediction and global climate models. Highly resolved measurements are lacking especially for tropical maritime clouds. Maritime ground based supersites are rare and satellite observations either lack fine resolution or accuracy. Therefore, the German High Altitude Long range research aircraft (HALO) was equipped with a suite of remote sensing as a flying supersite. During the Next-Generation Aircraft Remote-Sensing for Validation campaigns (NARVAL) over the tropical North Atlantic east of the Caribbean in December 2013 and August 2016, HALO observed trade wind cumuli for about 100 flight hours. We are interested in the liquid water path (LWP) and the integrated water vapor (IWV) to characterize individual clouds and their environment. In the case of shallow trade-wind cumulus clouds, the former should be assessed on a kilometer scale or even smaller to match the cloud sizes. In this presentation, we combine the HALO active and passive Microwave Package (HAMP) with the Water Vapor Lidar Experiment in Space (WALES), which were all operated in nadir pointing mode, in a synergistic retrieval.

LWP is typically retrieved by either solar reflectance or thermal microwave emission measurements. But both methods have their limitations. On the one hand for the interpretation of reflectance measurements, a certain cloud profile has to be assumed and microwave satellites on the other hand are limited by their coarse footprint of about 40 km. Here we use an airborne microwave radiometer to retrieve the LWP of mostly non-precipitating clouds. An airborne microwave radiometer provides the advantage of having a kilometer footprint (depending of flight altitude). To enhance the assessment of thin clouds, a cloud mask derived from a lidar backscatter channel is used to correct the clear sky bias of the radiometer retrieval, which is due to variation in the background signal. When clouds start to precipitate microwave measurements at higher frequency are more and more influenced by scattering. Scattering makes the determination of LWP more difficult. Therefore, for heavy rain producing clouds ($> 1\,\mathrm{kg\,m^{-2}}$), we exploit the attenuation signal of a 35 GHz radar. The accuracy gain of this active and passive microwave radiometry technique is assessed with radiative transfer simulations.

We present a full-scale airborne analysis from light to strongly precipitating tropical clouds. This presentation demonstrates the ability of an airborne microwave radiometer in synergy with a water vapor and backscatter lidar and a cloud radar to characterize trade-wind cumuli on a kilometer scale with high accuracy. This study combines case studies as well as statistical analysis and theoretical simulations.