

Combining ground-based differential absorption radar and microwave radiometer observations for improved water vapor profiling in the cloudy atmosphere

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Accurately and automatically measuring water vapor in the lower troposphere still remains challenging despite satellites and radiosonde networks which are limited by low spatial and temporal resolution. Remote sensing observations from ground-based measurement sites, such as the Jülich ObservatorY for Cloud Evolution (JOYCE-CF) and the Barbados Cloud Observatory (BCO), provide continuous measurements with high temporal resolution and can help closing this observational gap. Combining the information of active and passive instruments, for example radar and microwave radiometer, can improve the information content of water vapor profile retrievals.

The presented synergistic optimal estimation algorithm retrieves Liquid Water Path (LWP) and the vertical absolute humidity profile. We analyse the performance of the algorithm for a trade wind specific liquid single-layered cloud scenario using synthetic observations. More specifically, we simulate the brightness temperature in 7 water vapor sensitive microwave radiometer channels and the Dual Wavelength Ratio (DWR) of the radar reflectivities at 35.5GHz and 94GHz using the microwave radiative transfer model PAMTRA based on atmospheric profiles measured by radiosondes. We compare the results of using these low radar frequencies already available at BCO and JOYCE-CF to the retrieval performance using a hypothetical combination of higher frequencies in the G-band with stronger water vapor absorption.

Case study results show that including the active observations increases the information content for the retrieved profile by 0.5 degrees of freedom for signal (DoF) from 3.1 to 3.6 compared to an application using passive observations only. However, liquid water attenuation contributions to the DWR signal cause insensitivity of the retrieved profile to the atmospheric water vapor profile in and above the cloud layer. The usage of two higher radar frequencies (167 and 174GHz) leads to higher DWR signals, and, in combination with the MWR, to increasing DoF (4.9) and a more realistic retrieved profile within the cloud layer.

In addition to improving the water vapor profiling capability of the MWR, W- and Ka-band DWR observations can also be used to quantify the partial Integrated Water Vapor (IWV) below cloud base. Based on case studies, we find differences with less than 10% compared to radiosonde measurements. These synthetic results are evaluated using observations from BCO and simultaneous radiosonde ascents.