Synergy of Microwave Radiometer and Differential Absorption Radar: Simulated Retrieval Performance for Water Vapor Profiling in the Cloudy Boundary-Layer

Understanding the interplay between clouds, convection, and circulation processes requires continuous and high-resolution observations of the lower tropospheric water vapor structure particularly in the presence of clouds. As current observational techniques are limited by vertical or temporal resolution or cannot penetrate clouds, the potential of a synergistic combination of ground-based microwave radiometer (MWR) and G-band differential absorption radar (DAR) is investigated for the Trade Wind atmosphere observed at Barbados Cloud Observatory (BCO).

Synthetic observations of typically occurring conditions are generated using the Passive and Active Microwave TRAnsfer forward simulator. The synthetic K-band brightness temperatures and radar dual-wavelength ratios at 167 and 174.8 GHz are combined in an optimal estimation framework to retrieve the absolute humidity profile and Liquid Water Path (LWP). The retrieved profile, retrieval error and information content are analyzed to investigate the synergistic benefits of this novel synergy concept in single- and multiple-layer cloud conditions. The sensitivity of the synergy to assumed measurement uncertainties and detection thresholds is tested.

Based on a single-layer cloud scenario in a year-long variety of different moisture conditions, we find that the synergy enhances the total information content compared to the MWR-only retrieval configuration by 1 Degree of Freedom (DoF), and by 2.7 DoF compared to the DAR-only setup. The profile and information content below and in the cloud layer originate from the radar observations. The synergistic benefit is largest above the cloud layer, where the water vapor information content is increased, and the retrieval error is decreased compared to the single instrument retrieval performance. Case studies of multiple-layered clouds such as observed during the EUREC4A field study show an information content increase and retrieval error decrease particularly between and above the respective cloud layers.

However, current G-band radar detection limits might impair full-cloud profiling in tropical moist conditions, and, thus, reduce the synergistic benefit. Therefore, an outlook will be given for a modeled performance in drier mid-latitude or Arctic environments.

Plain Language Summary:

Vertical water vapor distribution is crucial for the understanding of many atmospheric processes. However, current observing techniques of the water vapor structure in the lowest layers of the atmosphere lack the vertical or temporal resolution needed, particularly in the presence of clouds. In order to overcome this observational gap, we present the potential of a novel concept of combining ground-based microwave radiometer (MWR) and radars operating at two different frequencies, following the Differential Absorption Radar technique (DAR).

When applying the retrieval to simulated measurements of typical moisture and cloud conditions observed at Barbados Cloud Observatory, we find that a synergistic retrieval performs better than each instrument by itself. The uncertainty of the retrieved water vapor profile is reduced around and in the liquid cloud layers, tested for situations characterised by single- or multi-layered clouds. The performance of the concept is also tested for a case study in the Arctic where different cloud and moisture conditions prevail.