Multi-layer cloud conditions in trade wind shallow cumulus -- confronting models with airborne observations

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The treatment of shallow clouds over the vast, sub-tropical, oceans remains a large source of uncertainty in climate models. Improving climate model parametrizations mainly relies on high resolution models which are in parts under-determined as well. Partly, this is due to the scarceness of detailed observations of clouds over the oceans. Luckily, the research aircraft HALO offers us the opportunity to fill this gap.

In this presentation, remote sensing observations over the Atlantic Ocean upstream from Barbados are used to characterize the trade wind clouds and to benchmark two cloud resolving ICON model simulations at kilo- and hectometer scales. The observations reveal two prominent modes of cumulus cloud top heights separating the clouds into two layers. For the model benchmark, forward operators convert the model data into the observational space for comparable cloud detection. This presentation paves a pathway for objective cloudiness comparisons during upcoming campaigns like EUREC^{4}A in 2020.

The clouds were observed by the airborne nadir pointing WALES lidar, HAMP cloud radar, and HAMP microwave radiometer[1] during daytime in the tropical dry season. The lower mode of cloud tops relates to boundary layer convection around the lifted condensation level at about 700 m above sea level (asl). The second mode is driven by shallow moist convection but also contains shallow outflow anvils and is closely related to the trade inversion at about 2300 m asl. The lower mode consists of mostly thin water clouds that are best seen by the backscatter lidar and frequently missed by the radar. However, the upper mode clouds contain more and larger droplets that scatter sufficient microwave radiation to be detected by the radar in addition to the lidar. Overall, the upper mode was observed more frequently.

The ICON model data is compared to the measurements using radar and lidar forward operators. The ICON simulations were run on large nested domains (> 1500 x 900 km) and were realistically forced with ECMWF analysis data. The comparison reveals how important it is to carefully consider the instruments sensitivities, e.g. by using forward operators. The kilometer scale model in principle reproduces a lower cloud mode of lidar visible clouds and an upper mode of radar and lidar visible clouds. However, the observed separation and relative occurrence of both modes is simulated differently than observed. The hectometer scale model reproduces the bimodal distribution of cloudiness seen in the observations, but mostly during nighttime. During daytime, the hectometer scale model mostly simulates clouds that reach up to the trade inversion.

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References

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