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

1 Motivation

The treatment of shallow clouds over the vast, sub-tropical oceans remains a large source of uncertainty in climate models. Therefore, cloud-resolving kilometer-scale resolution models are applied in climate studies as a means of improving the cloud representation. But...

- ...how do those models represent marine shallow cumuli compared to observations?
- What is the best way to assess the clouds?
- And how does the liquid water path help to interpret differences between observed and simulated cloud structures?

The research aircraft HALO offers us the opportunity to answer this question with respect to two cloud-resolving models.

2 Airborne observations and atmospheric models

Nadir pointing instruments on-board the high altitude and long range research aircraft (HALO):
- Aerosol backscatter lidar: Backscatter ratio (BSR) detects cloud top height of small droplets.
- Cloud and precipitation radar: Radar reflectivity is scattered back by large droplets and precipitation from cloud top to base.
- Microwave radiometer: Retrieval of integrated liquid water path.

ICON-ahedral Nonhydrostatic storm resolving model (SRM):
- Forced with ECMWF data
- 1.25 km grid, 75 levels
- One-moment microphysics
- Resolves deep convection

ICON large eddy model (LEM):
- Nested in SRM
- 300 m grid, 150 levels
- Two-moment microphysics
- Resolves cloud circulation

3 Benefit of forward simulations

The observable signals are forward simulated from drop size distributions of cloud and rain water given by the models. The lidar signal is sensitive to the number of droplets and therefore depends only on the high number of small cloud droplets. The radar signal is more sensitive to large droplets and thus detects rain or thick clouds.

4 Overview: Cloud boundaries - the influence of different sensors

- Observation of cloud tops in two layers. Lower layer is mostly visible to lidar only.
- Both models reproduce lower layer, but only LEM clearly develops upper layer.

5 Details: Liquid water path enriches cloud analysis

6 Conclusions and outlook

- Lidar and radar forward simulations allow to impose instrumental thresholds to model data.
- Connection with retrieved LWP helps to understand differences between models and observations.
- Comparison reveals lack in clear layer separation in SRM.
- Both models are unable to represent larger but non-raining droplets (drizzle).
- Methods are ready to be applied on even more coordinated model and observation activities during the upcoming EUREC'A campaign Jan/Feb 2020.

Acknowledgments

The work has been supported by the German Research Foundation (DFG) within the DFG Priority Program (SPP 1294) “Atmospheric and Earth System Research with the Research Aircraft HALO” under grants CR 111/10-12 and CR 111/12-1.

We would like to thank Daniel Käse and Matthias Brück for running the ICON simulations and the German Climate Computing Centre (DKRZ) for storing and supplying the data.

Data references

- Käse et al. (2017), Nature Geosci., DOI: 10.1038/ngeo2990.