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The Role of Low-Level Clouds over Southern West Africa in the Regional Monsoon: a NWP model study with ICON

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The complex multi-scale West African monsoon (WAM) system is currently not adequately represented in climate and weather models. One potential reason are the extensive ultra-low stratus clouds that form during nighttime in southern West Africa (8°W–8°E, 5–10°N) in connection with the nocturnal low-level jet. Since these clouds often persist until midday, they have a strong impact on the local radiation budget, hence influence the boundary layer development. A recent study based on climate models participating in CMIP5 and Years of Tropical Convection (YoTC) indicates that the majority of models is uncapable to reproduce the lifecycle of these low clouds. The objective of the present study is to investigate the impact of the radiative effects of these clouds on the larger WAM system and its diurnal cycle. The presented work is part of DACCIWA (Dynamics-Aerosol-Chemistry-Cloud Interactions in West Africa), which aims to investigate the impact of the drastic increase in anthropogenic emissions in West Africa on the local weather and climate.
The low-level clouds' influence on the development of the regional scale dynamics in southern West Africa is assessed via sensitivity simulations with the numerical weather prediction model ICON of the German Weather Service. For these simulations, the optical thickness of the lowest cloud decks in the model is modified prior to calling ICON's radiation scheme. This way, the radiative effects of the clouds on the further development of the model's atmosphere can be analysed in a fully nonlinear fashion. The experiments cover the monsoon season July–September 2006, with standard as well as convection-permitting simulations. The simulations are initialized with European Centre for Medium-Range Weather Forecasts (ECMWF) ERA-Interim re-analysis and include 5-day runs started (i) daily for a background climatology and (ii) every 4 days for the sensitivity experiments in standard and convection-permitting configurations. We used ICON's nesting capability to obtain grid-spacings of 14 km (standard run) and 6.5 km (convection-permitting) over the region of interest.
Results show a strong response of the model, particularly for the cloud water content, cover and precipitation. An altered diurnal cycle of cloud development occurs in the region of interest. Reduction of cloud optical thickness (COT) leads to an intensified nocturnal low-level jet and more nocturnal cloudiness, which tends to break up later at day-time. In the afternoon, the increased radiation in experiments with reduced COT leads to higher surface temperatures and earlier as well as more convection, which in turn leads to more rainfall over southern West Africa. Consistently, optically thickened clouds produce less rain. The surface pressure over southern West Africa decreases for more transparent clouds, leading to an increased north-south gradient near the coast, supporting the stronger jet. The observed effects on the meteorological variables propagate northwards with the monsoon flow in the course of the night and can influence the precipitation pattern farther north. Details of the response depend on the representation of convection in the model. Convection-permitting simulations show overall decreased precipitation and an even stronger influence on regions outside of the domain modified in the sensitivity experiments.