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The representation of low-level clouds during the West African monsoon in weather and climate models

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The West African monsoon is one of the most important large-scale circulation features in the tropics and the associated seasonal rainfalls are crucial to rain-fed agriculture and water resources for hundreds of millions of people. However, numerical weather and climate models still struggle to realistically represent salient features of the monsoon across a wide range of scales. Recently it has been shown that substantial errors in radiation and clouds exist in the southern parts of West Africa (8°W–8°E, 5–10°N) during summer. This area is characterised by strong low-level jets associated with the formation of extensive ultra-low stratus clouds. Often persisting long after sunrise, these clouds have a substantial impact on the radiation budget at the surface and thus the diurnal evolution of the planetary boundary layer (PBL). Here we present some first results from a detailed analysis of the representation of these clouds and the associated PBL features across a range of weather and climate models. Recent climate model simulations for the period 1991–2010 run in the framework of the Year of Tropical Convection (YOTC) offer a great opportunity for this analysis. The models are those used for the latest Assessment Report of the Intergovernmental Panel on Climate Change, but for YOTC the model output has a much better temporal resolution, allowing to resolve the diurnal cycle, and includes diabatic terms, allowing to much better assess physical reasons for errors in low-level temperature, moisture and thus cloudiness. These more statistical climate model analyses are complemented by experiments using ICON (Icosahedral non-hydrostatic general circulation model), the new numerical weather prediction model of the German Weather Service and the Max Planck Institute for Meteorology. ICON allows testing sensitivities to model resolution and numerical schemes. These model simulations are validated against (re-)analysis data, satellite observations (e.g. CM SAF cloud and radiation data) and ground-based eye observations of clouds and radiation measurements from weather stations.
Our results show that many of the climate models have great difficulties representing the diurnal cycle of winds and clouds, leading to associated errors in radiation. Typical errors include a substantial underestimation of the lowest clouds accompanied by an overestimation of clouds at the top of the monsoon layer, indicating systematic problems in vertical exchange processes, which are also reflected in large errors in jet speed. Consequently, many models show a too flat diurnal cycle in cloudiness.
This contribution is part of the EU-funded DACCIWA (Dynamics-Aerosol-Chemistry-Cloud Interactions in West Africa) project that aims to investigate the impact of the drastic increase in anthropogenic emissions in West Africa on the local weather and climate, for example through cloud-aerosol interactions. The analysis of the capability of state-of-the-art numerical models to represent low-level cloudiness presented here is an important requisite for the planned assessments of the influence of anthropogenic aerosol.