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Why do global climate models struggle to represent low-level clouds in the West African summer monsoon?

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Climate models struggle to realistically represent the West African monsoon (WAM), which hinders reliable future projections and the development of adequate adaption measures. Low-level clouds over southern West Africa (5–10°N, 8°W–8°E) during July–September are an integral part of the WAM through their effect on the surface energy balance and precipitation, but their representation in climate models has so far received little attention. These clouds usually form during the night near the level of the nocturnal low-level jet (∼950 hPa), thicken and spread until the mid-morning (∼09 UTC), and then break up and rise in the course of the day, typically to about 850 hPa. The low thermal contrast to the surface and the frequent presence of obscuring higher-level clouds make detection of the low-level clouds from space rather challenging.

Here we use 30 years of output from 18 models participating in the Coupled Model Intercomparison Project Phase 5 (CMIP5) as well as 20 years of output from 8 models participating in the Year of Tropical Convection (YoTC) experiments to identify cloud biases and their causes. A great advantage of the YoTC dataset is the 6-hourly output frequency, which allows an analysis of the diurnal cycle, and the availability of temperature and moisture tendencies from parameterized processes such as convection, radiation and boundary-layer turbulence.

A comparison to earlier analyses based on CMIP3 output reveals rather limited improvements with regard to the represenation of low-level cloud and winds. Compared to ERA-Interim re-analyses, which shows satisfactory agreement with surface observations, many of the CMIP5 and YoTC models still have large biases in low-level cloudiness of both signs and a tendency to too high elevation and too weak diurnal cycles. At the same time, these models tend to have too strong low-level jets, the impact of which is unclear due to concomitant effects on temperature and moisture advection as well as turbulent mixing. Part of the differences between the models and ERA-Interim appear to be related to the different subgrid cloud schemes used. While nighttime tendencies in temperature and humidity are broadly realistic in most models, daytime tendencies show large variation in the vertical transport of heat and moisture. Many models simulate too low near-surface relative humidities, leading to insufficient low cloud cover, abundant solar radiation, and thus a too large diurnal cycle in temperature and relative humidity.

Currently, targeted model sensitivity experiments are conducted to test possible feedback mechanisms between low clouds, radiation, boundary-layer dynamics, precipitation and the WAM circulation in the framework of the EU-funded DACCIWA (Dynamics-Aerosol-Chemistry-Cloud Interactions in West Africa) project (http://www.dacciwa.eu).