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Validation of GPM IMERG rainfall estimates for different rainfall types in southern West Africa

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Rainfall over southern West Africa (SWA) is controlled by the West African monsoon (WAM) and exhibits pronounced variability on interannual to interdecadal timescales. Due to a gradual degradation of ground-based rainfall measurements in recent decades over SWA, rainfall retrievals from space with high spatio-temporal resolutions have become more and more important, which, however, still suffer from errors and regional biases. Thus, in a novel and extensive approach, the performance of a state-of-the-art rainfall product from the Global Precipitation Measurement (GPM), namely the half-hourly based Integrated Multi-Satellite Retrievals for GPM (IMERG, Version 5), is evaluated here on multiple time scales using a two-year dataset (2016-2017) from a network of one-minute based rain gauges (RGs) located in the moist forest region of Ghana as well as the spaceborne cloud product CLAAS-2 (Cloud property dataset using SEVIRI edition 2). The RG network was established in 2015 for the field campaign of the DACCIWA ("Dynamics-aerosol-chemistry-clouds interaction in West Africa") project in June and July 2016 over SWA. The high resolution of the RGs enables the identification of several types of rainfall systems. They range from short and low-intensity rainfall to long-lasting and intense events, the latter of which typically are connected to mesoscale convective systems (MCSs).

On a monthly scale, IMERG agrees very well with the RGs and is able to capture the distinct characteristics of the seasonal cycles of the two years. This is unsurprising given the monthly gauge calibration of the satellite product. However, the skill of IMERG decreases for shorter periods. The evaluation of the sub-daily timescale reveals three distinct aspects: (1) IMERG is prone to false alarms, which overall account for almost one quarter of its total rainfall; (2) IMERG almost exclusively overestimates the frequently occurring weak and short rainfall events, while the intensity of relatively rare MCSs are strongly underestimated, leading to an error compensation between different rainfall types; and (3), the skill decreases during the local little dry season in July and August, which is known to exhibit enhanced cloudiness over SWA due to a deep moist tropospheric column. Upon further analysis using CLAAS-2 cloud information, aspects (1) and (2) can be traced back to a flawed treatment of ice clouds. IMERG detects rainfall too early particularly for thin ice clouds and links higher rainfall rates to higher cloud optical thickness, which is a poor predictor over SWA. The decreased skill during the little dry season, in turn, is related to an increased occurrence of low-intensity and short warm rain events, i.e. rainfall from purely liquid mid- and low-level clouds, which are widely missed by IMERG.

Despite the aforementioned deficiencies on small time scales, the overall significance of IMERG for data-sparse regions such as SWA has to be emphasised. At the same time, this work stresses the importance of regional-based validations that can help improve the understanding of IMERG's behaviour and, ultimately, the underlying atmospheric processes.