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Inter-model differences in tropical free-tropospheric humidity and their impact on the clear-sky radiation budget in global storm-resolving simulations

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Although the humidity distribution in the tropical free troposphere plays a key role in controlling the Earth's energy budget, it is poorly simulated in Global Circulation Models (GCMs). A major uncertainty in these models arises from parameterizations of unresolved processes, above all the convective parameterization. An important step in global atmospheric modelling has been made with global storm-resolving models (GSRMs). By forgoing the convective parameterization GSRMs nourish the hope that they better represent processes relevant for humidity, but it is unclear to what extent the uncertainty in free-tropospheric humidity is reduced. The main goal of our study is to quantify this uncertainty as well as the resulting uncertainty in the clear-sky radiation budget based on the spread in an ensemble of GSRMs called DYAMOND. We find that the inter-model spread in relative humidity (RH) in DYAMOND has reduced by at least a factor of two throughout most of the free troposphere compared to the GCMs that participated in the CMIP5 AMIP experiment. However, the remaining RH differences in DYAMOND still cause a considerable inter-model spread of 1.2 Wm^{-2} in tropical mean clear-sky outgoing longwave radiation (OLR). For the most part this spread is caused by the RH differences in the lower and mid free troposphere, whereas RH differences in the upper troposphere (above 10 km) have a minor impact on OLR. We only find a direct connection between anomalies in RH and anomalies in the resolved humidity transport in the upper troposphere, suggesting that differences in the parameterizations of unresolved processes like microphysics and turbulence play a major role in the altitude regions with the strongest impact on OLR. Comparing model fields in moisture space, i.e. sorted from the driest to the moistest atmospheric column, reveals that two tropical regimes contribute most to the spread in tropical mean OLR: the driest subsidence regimes and moist regimes at the transition from deep convective to subsidence regions.