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Convection-resolving climate simulation of the tropical-to-subtropical Atlantic

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Even though the complexity and resolution of global climate models has increased over the last decades, the inter-model spread in equilibrium climate sensitivity has not narrowed. The representation of tropical and subtropical marine clouds remains a major source of uncertainty in climate models. Going to higher model resolution to explicitly resolve a larger fraction of the underlying convective circulations is the most direct way towards reducing the uncertainty associated with these clouds. Convection-resolving models (CRMs) are therefore an attractive complementary tool to study tropical cloud feedbacks. Even though decade-long global CRM simulations are not yet computationally feasible, CRMs can be used in climate applications for selected limited-area domains and periods.

Here we run 3-year-long CRM simulations with the COSMO model over the tropical-to-subtropical Atlantic. We run a control simulation to evaluate the model's capability of representing the clouds and the radiative balance. We also run a climate change scenario simulation using the pseudo-global warming (PGW) approach to study cloud-radiative feedbacks at convection-resolving resolution.

We find a good agreement between the simulated and observed annual cycle in the top-of-the-atmosphere radiative fluxes, despite a mean bias that should be possible to reduce through model calibration. There are pronounced improvements in the CRM simulation compared to the CMIP6 models over the ITCZ and the trade-wind cumulus region, while the representation of stratocumulus clouds remains challenging also in the CRM simulation. The simulated cloud-radiative feedback is at the upper end of what the CMIP6 models predict due to a pronounced positive longwave feedback at the ITCZ caused by an increase in high clouds. The shortwave cloud-radiative feedback is moderately positive and lies well within the range of the CMIP6 models with a reduction in the low-level cloud fraction over the subtropics and a partly compensating increase in the cloud fraction at the ITCZ.