TRR181 subproject L4 (Multiscale Ocean-Atmosphere Coupling): Investigating the triggering of tropical deep convection by mesoscale SST features in global coupled km-scale simulations

The mechanisms by which deep convection is triggered over tropical warm oceans are still poorly understood. This is because direct atmospheric observations over tropical oceans are sparse and, until quite recently, general circulation models have mostly had to parameterize deep convection. Based on theory, a frequently proposed mechanism is the triggering of tropical deep convection by mesoscale sea surface temperature (SST) patches of scales of 20–200 km. Such patches can locally alter surface fluxes and drive shallow mesoscale convergence, both of which can potentially trigger new convective cells. While highly idealized modeling studies demonstrate that mesoscale SST patches can indeed trigger deep convection, and simple satellite-based observations confirm this finding, a comprehensive assessment of the relevance of mesoscale SST patches in triggering deep convection is still lacking. Furthermore, there still is some uncertainty in the detailed mechanisms of this mesoscale air-sea coupling at play. In the present project, we thus use global km-scale simulations with the coupled ICON model, in which deep convection in the atmosphere and mesoscale ocean eddies are explicitly resolved, to investigate the relevance of mesoscale air-sea coupling in triggering tropical deep convection in a statistical sense. This means that, compared to previous studies, our modeling approach is no longer limited by necessary idealizations and parameterizations. Therefore, we will be able to provide a global assessment of the relevance of mesoscale SST patches in triggering of tropical deep convection for the first time.

Furthermore, our project aims at clarifying the role of mesoscale air-sea interactions for the realistic representation of the tropical precipitation climatology in km-scale models, which still suffers from pronounced biases as shown in a recent study by Segura et al. (2022). While the detailed causes for these biases are still unclear, one hypothesis is that even at km-scale resolutions a substantial fraction of air-sea interactions is not sufficiently resolved. To test this hypothesis, we will vary the resolution of the ocean and the atmosphere component of the coupled ICON model together as well as independently from each other, and analyze the impact of those variations in resolution on the simulated tropical precipitation climatology. This work will ultimately help to reduce biases in the representation of tropical precipitation in km-scale models.

A huge advantage of coupled atmosphere-ocean simulations is their ability to simulate potential feedback loops between atmospheric deep convection and the upper ocean layers. In our project, one feedback process of particular interest is the ability of surface rain layers, which can form as a consequence of convective precipitation, to trigger new convective cells, which was proposed in a recent study by Shackelford et al. (2022). However, the relevance of this feedback in triggering tropical deep convection compared to other feedbacks is still unclear and can only assessed by realistic coupled global km-scale simulations such as those performed in the present project. The fact that these simulations apply various different resolutions will further allow us to give statements about the relevance of representing feedbacks, particularly the rain layer feedback, for present resolution-driven model biases.

The present project is part of the phase 3 of the collaborative research center TRR 181 on „Energy transfers in atmosphere and ocean“ under the subproject L4 on „Energy-consistent ocean-atmosphere coupling“ (see www.trr-energytransfers.de).

References

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