EGU21-6192
https://doi.org/10.5194/egusphere-egu21-6192
EGU General Assembly 2021

The Importance of Radiative Feedbacks in Tropical Cyclogenesis in Idealized Simulations

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Interactions between clouds, radiation, and circulations are fundamental to tropical climate, but until recently, the impact of these interactions on tropical cyclones (TCs) has been relatively unexplored. Simulations of rotating radiative-convective equilibrium confirm that radiative feedbacks are important for spontaneous TC genesis (in which a TC is allowed to form from random noise). While not strictly necessary, radiative feedbacks significantly accelerate TC genesis and especially contribute in the early stages of genesis. These radiative feedbacks arise from interactions between spatially and temporally varying radiative cooling (driven by the dependence of radiative cooling rate on clouds and water vapor) and the developing tropical cyclone (the circulation of which shapes the structure of clouds and water vapor). However, TCs in nature are generally observed to form from pre-existing disturbances, calling into question whether radiative feedbacks play a significant role.

Here, I investigate the importance of radiative feedbacks in TC genesis and the mechanisms underlying their influence in a set of idealized cloud-resolving simulations in which a TC is allowed to develop after initialization from a mesoscale warm, saturated bubble on an f-plane, in an otherwise quiescent and moist neutral environment. TC genesis is delayed by a factor of two or three when radiative feedbacks are removed by prescribing a fixed cooling profile or spatially homogenizing the model-calculated cooling profiles. Further analysis and additional mechanism denial experiments pinpoint the longwave radiative feedback contributed by ice clouds as the strongest influence. These results are consistent with recently published case study simulations in which cloud-radiative effects accelerate TC formation and intensification in realistic scenarios. The important takeaway from the results presented here is that that cloud-longwave radiative feedbacks have a profound impact on TC genesis in a hierarchy of model simulations. Improving the representation of cloud-radiative feedbacks in forecast models therefore has the potential to yield critical advancements in TC prediction.