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A COOKIE for climate change?

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Cloud-radiative interactions are an important factor for the response of the large-scale circulation to global warming. Two approaches have been put forward to study the radiative impact of clouds in global climate models. The COOKIE method makes clouds transparent to radiation. The cloud-locking method prescribes the radiative properties of clouds to either the present-day or global-warming conditions. The cloud-locking method successfully quantifies the contribution of cloud-radiative changes to the model-projected circulation response. However, the method requires fairly substantial model modification and a large set of prescribed-cloud simulations. In contrast, the COOKIE method is easy to implement and requires only two simulations with transparent clouds. This raises the question if the COOKIE method can be used to study the impact of cloud-radiative changes on the circulation response to global warming.

Here, we compare the COOKIE method to the cloud-locking method in the three global climate models MPI-ESM, IPSL-CM5A and ICON, and in simulations with aquaplanet and present-day boundary conditions. We find that while cloud-locking diagnoses a robust poleward circulation expansion due to cloud-radiative changes, COOKIE fails to capture this impact. In particular, COOKIE does not capture the cloud-radiative impact on the response of the Hadley cell width and strength, and on the poleward extent of the subtropical dry zones. The discrepancies are somewhat smaller in the extratropics. COOKIE qualitatively captures the cloud-induced poleward shift of the jet stream, but it tends to underestimate the cloud impact. We argue that the lack of success of the COOKIE method results from large differences between the clouds-on and clouds-off control climates, and the fact that COOKIE includes radiative changes of water vapor.

Our results show that COOKIE, while being a valuable tool to understand the impact of clouds on the present-day circulation, it less suited to study the impact of cloud-radiative changes on the circulation response.