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Clouds and the extratropical circulation response to global warming in a hierarchy of global atmosphere models

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Climate models project that global warming will lead to substantial changes in the position of the extratropical jet streams. Yet, many quantitative aspects of such jet stream changes remain uncertain among models, and recent work has indicated a potentially important role of cloud radiative interactions. Here, I will investigate how cloud-radiative changes impact the extratropical circulation response using a hierarchy of global atmosphere models that range from a dry dynamical core to a coupled atmosphere-slab ocean model in realistic setup. This hierarchy, which I develop based on the ECHAM6 atmosphere model, allows for an identification of robust cloud impacts, as well as for a separation of cloud impacts that work via the atmosphere and the surface energy balance, respectively.

I will first focus on an aquaplanet setup with prescribed sea-surface temperatures (SSTs), which reproduces the model spread found in realistic model setups with interactive SSTs. Simulations with prescribed clouds show that half of the circulation response can be attributed to cloud changes. In particular, the rise of tropical high-level clouds and the upward and poleward movement of midlatitude high-level clouds heat the upper tropical and midlatitude trosphere and thereby lead to poleward jet shifts. The impact of clouds on the jet is qualitatively reproduced in a dry dynamical core, which creates a link to previous dry modeling work on the jet impact of regional temperature changes. I will then show that the aquaplanet results also hold in a realistic setup that includes continents and seasonality. Finally, I will juxtapose these prescribed-SST simulations with interactive-SST simulations, allowing for a comparison of atmosphere and surface cloud-radiative impacts. I will show that atmosphere and surface cloud-radiative impacts are equally important in affecting the jet.

Overall, the results illustrate the need to understand regional cloud changes in order to improve projections of future circulation changes. In particular, they highlight the role of high-level ice clouds and their longwave radiative impact on atmospheric temperatures.