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Tropical cloud-radiative changes contribute to robust DJF jet exit strengthening over Europe under global warming

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During boreal winter (December to February, DJF), the North Atlantic jet stream and storm track are expected to extend eastward over Europe in response to climate change. This will affect future weather and climate over Europe, for example by steering storms which are associated with strong winds and heavy precipitation towards Europe. The jet stream and storm track responses over Europe are robust across coupled climate models of phases 3, 5, and 6 of the Coupled Model Intercomparison Project (CMIP; Harvey et al., 2020, JGR-A, https://doi.org/10.1029/2020JD032701). We show that the jet stream response is further robust across CMIP5 models of varying complexity ranging from coupled climate models to atmosphere-only General Circulation Models (GCMs) with prescribed sea-surface temperatures (SSTs) and sea-ice cover. In contrast to the jet stream response over Europe, the jet stream response over the North Atlantic is not robust in the coupled climate models and the atmosphere-only GCMs.

In addition to the CMIP5 simulations, we investigate Amip-like simulations with the atmospheric components of ICON-NWP, and the CMIP5 models MPI-ESM-LR and IPSL-CM5A-LR that apply the cloud-locking method to break the cloud-radiation-circulation coupling and to diagnose the contribution of cloud-radiative changes on the jet stream response to climate change. In the simulations, SSTs are prescribed to isolate the impact of cloud-radiative changes via the atmospheric pathway, i.e., via changes in atmospheric cloud-radiative heating, and global warming is mimicked by a uniform 4K SST increase (cf. Albern et al., 2019, JAMES, https://doi.org/10.1029/2018MS001592 and Voigt et al., 2019, J. Climate, https://doi.org/10.1175/JCLI-D-18-0810.1). In all three models, cloud-radiative changes contribute significantly and robustly to the eastward extension of the North Atlantic jet stream towards Europe. At the same time, cloud-radiative changes contribute to the model uncertainty over the North Atlantic. In addition to the jet stream response, we investigate the impact of cloud-radiative changes on the storm track response in ICON-NWP and discuss similarities and differences between the jet stream and storm track responses over the North Atlantic-European region.

In ICON-NWP, the impact of cloud-radiative changes on the jet stream response is dominated by tropical cloud-radiative changes while midlatitude and polar cloud-radiative changes have a minor impact. A further division of the tropics into four smaller tropical regions that cover the western

tropical Pacific, the eastern tropical Pacific, the tropical Atlantic, and the Indian Ocean shows that cloud-radiative changes over the western tropical Pacific, eastern tropical Pacific, and Indian Ocean all contribute about equally to the eastward extension of the North Atlantic jet stream towards Europe because these regions exhibit substantial upper-tropospheric cloud-radiative heating in response to climate change. At the same time, cloud-radiative changes over the tropical Atlantic hardly contribute to the jet response over Europe because changes in atmospheric cloud-radiative heating under climate change are small in this region. As for the impact of global cloud-radiative changes, we also discuss the impact of the regional cloud-radiative changes on the storm track response over the North Atlantic-European region to climate change.