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The atmospheric pathway of the cloud-radiative impact on the circulation response to global warming: important and uncertain

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Previous work showed that the poleward expansion of the atmospheric circulation in response to global warming is strongly modulated by clouds and their radiative interactions, and highlighted the role of surface radiative heating by clouds. Here, a hierarchy and an ensemble of global climate models in present-day setup are used to study the circulation impact of changes in atmospheric radiative heating by clouds in the absence of sea-surface temperature (SST) changes, which is referred to as the atmospheric pathway of the cloud-radiative impact. For the MPI-ESM global climate model, it is found that about half of the total cloud-radiative impact, and in fact the total circulation response, can be attributed to the atmospheric pathway. The atmospheric cloud-radiative forcing is substantial in the lower and upper troposphere. However, because SST is prescribed the circulation response is dominated by the upper-tropospheric cloud-radiative forcing, which results from the upward shift of high-level clouds. The poleward circulation expansion via the atmospheric pathway and the upper-tropospheric cloud-radiative forcing are qualitatively robust across three global models, yet their magnitudes vary by a factor of three. A substantial part of these magnitude differences are shown to be related to the present-day simulation of high-level clouds and their cloud-radiative interactions. A comparison with observations highlights the model deficits in representing the radiative interactions of high-level clouds, and indicates that reducing these deficits can contribute to improved predictions of regional climate change.