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Atmospheric cloud-radiative forcing as important as surface cloud-radiative forcing for atmospheric circulation response to global warming

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Clouds change their radiative properties in response to global warming, creating a cloud-radiative forcing that impacts the atmospheric circulation. It remains unclear, however, if the cloud-radiative impact is robust across models, depends on the nature of the warming, and is caused by cloud-radiative forcing inside the atmosphere or at the surface. To address these questions, we study the cloud-radiative impact on the annual-mean zonal-mean circulation in the two CMIP5 atmosphere models MPI-ESM and IPSL-CM5A run in aquaplanet and present-day setups with prescribed and interactive sea surface temperatures. We use the cloud locking method to separate the impact of SST changes and radiative changes of clouds and water vapor. Cloud-radiative changes are important in both models and all setups, and are more important in the present-day than the aquaplanet setups. Specifically, clouds dominate the expansion of the Hadley circulation and the poleward shift of the extratropical jet, as well as the strengthening of the Southern Hemisphere jet. The cloud-radiative forcing inside the atmosphere is as important as the forcing at the surface highlighted by previous studies. This shows that both the atmospheric and the surface cloud-radiative forcing need to be considered and can contribute to model differences in the overall circulation response to global warming.