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The negative shortwave cloud feedback at high latitudes: mechanisms and observational constraints

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Climate models agree on a negative shortwave cloud feedback at high latitudes, driven by increases in cloud optical depth and liquid water path (LWP), but the mechanisms remain uncertain. We assess the importance of microphysical processes for the negative optical depth feedback by perturbing temperature in the microphysics schemes of two aquaplanet models, both of which have separate prognostic equations for liquid water and ice. We find that most of the LWP increase with warming is caused by a suppression of ice microphysical processes in mixed-phase clouds, resulting in reduced conversion efficiencies of liquid water to ice and precipitation, and yielding an enhanced reservoir of cloud liquid water. Hence, in climate models, the suppression of ice-phase microphysics that deplete cloud liquid water is a key mechanism of the LWP increase with warming and of the associated negative shortwave cloud feedback in cold clouds.

In support of these findings, we show the existence of a very robust positive relationship between monthly-mean LWP and temperature in CMIP5 models and observations in mixed-phase cloud regions only. In models, the historical LWP sensitivity to temperature is a good predictor of the forced global warming response poleward of about 45°, although models appear to overestimate the LWP response to warming compared to observations. Historical cloud optical depth–temperature relationships are shown to provide an observational constraint on the modeled cloud feedback, and support the prediction of a negative cloud feedback at high latitudes. Because optical thickening with warming is supported by simple temperature-dependent mechanisms and dominates over cloud amount changes, we conclude that the shortwave cloud feedback is very likely negative in mid to high latitudes.