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Interrogating the influence of shallow convective mixing on low-level clouds with observations and simulations of stable water isotopes

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Low-cloud feedbacks contribute large uncertainties to climate projections and estimated climate sensitivity. A key physical process modulating low-cloud feedbacks is shallow convective mixing between the boundary layer and the free troposphere. However, there are challenges in acquiring observational estimations of shallow convective mixing with global coverage. To this end, we propose a novel approach to constraining convective mixing using stable water vapor isotope profiles from satellite retrievals. We demonstrate that the vertical gradient of water vapor δD between the boundary layer and free troposphere can be used to track shallow convective mixing, especially over the trade-wind regions. We also evaluate this metric of shallow convective mixing against the EUREC4A experiment data and isotope-enabled climate model experiments. Analyzing isotopes in water vapor alongside low-cloud properties from satellite retrievals, we find that low-cloud fraction appears insensitive to convective mixing in trade cumulus regions. Our results suggest that satellite-derived observations of the relationship between shallow convective mixing and low-cloud are regionally-dependent, and strong shallow convective mixing is associated with moistening of the free troposphere in the tropics. The new estimations of low-cloud properties and their relationship with changes in convective mixing using water isotopes house potential to improve the simulation of low-cloud feedbacks in numerical simulations. To this end, we use satellite-derived estimates of mixing to validate and tune the isotope enabled Community Atmosphere Model (iCAM5, iCAM6), and explore how using water isotopes as a target field changes atmospheric circulation globally. Finally, we explore how these adjustments in iCAM change estimates of climate sensitivity.