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Mesoscale dynamics protect trade-cumulus clouds from mixing-induced desiccation

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Shallow trade cumulus clouds cool the planet and fuel the large-scale circulation. Their unknown response to climate change is a major source of uncertainty in climate projections. Differing changes in cloudiness near the base of the cumulus layer with warming control the spread in simulated trade cumulus cloud feedbacks in models, with high climate sensitivity models showing a strong negative coupling between lower-tropospheric mixing and cloudiness. However, such a *mixing-desiccation* mechanism has never been tested with observations. Here we present novel measurements of the convective mass flux, cloud fraction and relative humidity at cloud base from the recent EUREC^{4}A field campaign and find the dynamical control of cloudiness through the mass flux to overwhelm the thermodynamic response to humidity. Because the mesoscale vertical velocity controls the mass flux as much as entrainment does, the mass flux ends up being uncorrelated to relative humidity, which opposes the mixing-desiccation hypothesis. The magnitude, variability, and coupling of mass flux and cloudiness differs drastically between climate models and the EUREC^{4}A observations. Models that have particularly strong trade cumulus feedbacks tend to exaggerate the dependence of cloudiness on humidity rather than the mass flux, and also exaggerate variability in cloudiness. The process-based constraints presented here render those strongly positive trade cumulus feedbacks unrealistic, for the first time supporting and explaining a weak trade cumulus feedback at the relevant process scale.