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Observational evidence of key factors controlling shallow cumulus cloud fields

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Climate models exhibit a large spread in their tropical shallow cumulus response to global warming and would hence benefit from stronger observational constraints. Earlier studies on shallow cumulus either used moderate resolution satellite data or were limited to a small number of high-resolution scenes. Our study utilizes an extensive dataset of high-resolution ASTER imagery to investigate the dependence of shallow cumulus macrophysical and organizational properties on large-scale meteorological conditions.

We show that increased surface wind speed leads to deeper and horizontally larger clouds, in agreement with a proposed mechanism gleaned from large eddy simulations. In addition, we find that cloud fields are organized into different spatial patterns in low wind speed and high wind speed situations. Wind shear, on the other hand, appears to play a minor role. Closely related to the wind speed is the Bowen ratio, the ratio of the surface heat fluxes. Recent modelling studies also suggest that the Bowen ratio strongly controls the distribution shape of cloud-base mass flux, which is related to cloud size. From observational data we can confirm a relation between the Bowen ratio and the shape of the cloud size distribution. In contrast, the lower tropospheric stability and the large-scale vertical velocity seem to set the frame for shallow cumulus clouds to develop, but have only minor effects on the cloud size distribution.