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Impact of circulation on tropical cloud feedbacks in cloud resolving models

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Uncertainty in the response of clouds to warming remains a significant barrier to reducing the range in projected climate sensitivity. A key question is to what extent cloud feedbacks can be attributed to changes in circulation, such as the strengthening or weakening of ascent or changes in the areas of convecting vs subsiding air. Previous research has shown that, in general circulation models (GCMs), the 'dynamic' component of the cloud feedback – that which is due to changes in circulation rather than changes in the thermodynamic properties of clouds (Bony et al., 2006) – is generally small (Byrne and Schneider, 2018). An open question, however, is whether this extends to models at cloud resolving resolutions that explicitly simulate deep convection.

Here, we utilize simulations from the Radiative-Convective Equilibrium Model Intercomparison Project (RCEMIP, Wing et al., 2018, 2020) to quantify the impact of circulation on tropical cloud feedbacks. RCE is a simple idealisation of the tropical atmosphere and we focus on simulations in a long channel configuration with uniform sea surface temperatures of 295, 300 and 305K. The dynamic component of the total cloud feedback is substantial for this suite of cloud resolving models (CRMs), and is driven by circulation changes and nonlinearity in the climatological relationship between clouds and circulation. The large spread in dynamic component across models is linked to the extent to which convection strengthens and narrows with warming. This strengthening/narrowing of convective regions is further linked to changes in clear-sky radiative cooling and mid-tropospheric static stability in subsiding regions.