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Composited structure of shallow cumulus clouds

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The normalized distributions of thermodynamic and dynamical variables both within and outside shallow clouds are investigated through a composite algorithm using large eddy simulation of the BOMEX case. The normalized magnitude is maximum near cloud center and decreases outwards. While relative humidity (RH) and cloud liquid water (q_l) decrease smoothly to match the environment, the vertical velocity, virtual potential temperature (θ_v) and potential temperature (θ) perturbations have more complicated behaviour towards the cloud boundary. Below the inversion layer, θ_v becomes negative before the vertical velocity has turned from updraft to subsiding shell outside the cloud, indicating the presence of a transition zone where the updraft is negatively buoyant. Due to the downdraft outside the cloud and the enhanced horizontal turbulent mixing across the edge, the normalized turbulence kinetic energy (TKE) and horizontal turbulence kinetic energy (HTKE) decrease more slowly from the cloud center outwards than the thermodynamic variables. The distributions all present asymmetric structures in response to the vertical wind shear, with more negatively buoyant air, stronger downdrafts and larger TKE on the downshear side. We discuss several implications of the distributions for theoretical models and parameterizations. Positive buoyancy near cloud base is mostly due to the virtual effect of water vapor, emphasising the role of moisture in triggering. The mean vertical velocity is found to be approximately half the maximum vertical velocity within each cloud, providing a constraint on some models. Finally, products of normalized distributions for different variables are shown to be able to well represent the vertical heat and moisture fluxes, but they underestimate fluxes in the inversion layer because they do not capture cloud top downdrafts.