Subsiding Shells in Actively Growing Shallow Cumulus clouds: a DNS study

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This study investigates the dynamics of a subsiding shell at the edges of actively growing shallow cumulus clouds. Direct numerical simulations of a small region at the edge of a shallow cumulus cloud is performed to conduct a temporal study of the cloud-environment mixing. A volumetric forcing is introduced in the cloud layer of the two layer numerical setup to simulate an actively growing cloud. Turbulent mixing and evaporative cooling at the cloud edges generate a subsiding shell which grows with time. The shell thickness is observed to increase linearly with time. The shell buoyancy scale remains constant as it thickens and is set by the initial thermodynamics of the cloud and environment. The shell accelerates ballistically with a magnitude defined by the saturation value of the buoyancy of the cloud-environment mixture. Hence the mean velocity is expected to be passive and the shell is buoyancy driven. The shell thickness and the velocity continues to grow indefinitely and could possibly be limited only by the cloud evolution phase and ultimately lifetime.

A self-similar regime is observed after an initial transient. However contrary to classical self similar flows, the Turbulent Kinetic Energy (TKE) budget terms and the velocity moments scale according to the buoyancy and not with the mean velocity. Relations are obtained for the thickness of the shell as a function of time and the minimum velocity within the shell. The values of the shell thickness and velocities obtained using these relations are consistent with the values of a typical shallow cumulus cloud. The entrainment coefficient has been predicted by studying the rate at which the shell thickness increases. This coefficient is a constant for a particular initial state of the cloud and the environment.

Code(s) used: SPARKLE

Time usage on ARCHER (approx. kAU): 20,000

Databases produced (including web link if available):

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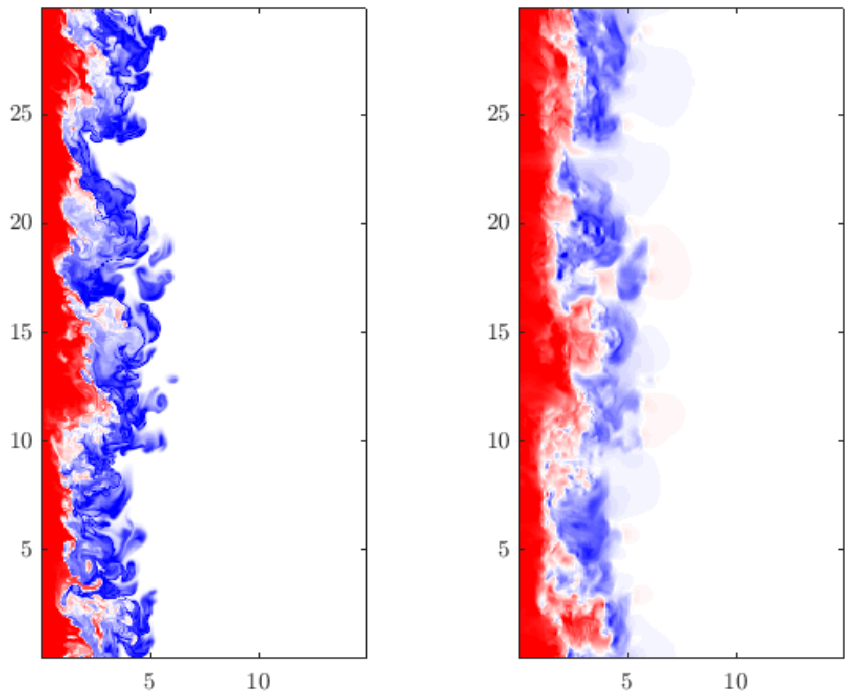

Figure 1: Instantaneous plots of the vertical cross-section of the flow at cloud edge showing the subsiding shell. Left panel shows the evolution of buoyancy and right panel shows the evolution of vertical velocity. Red represents positive values and blue negative values with white representing zero