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Gravity wave breaking and mixing in a three-dimensional model of deep convection

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It is generally accepted that deep convection is an important source of atmospheric gravity waves. Numerous modelling studies, and some observational studies, have begun to elucidate the mechanisms responsible for their generation, and the general properties of the wave spectrum. Recent studies have highlighted the importance of background flow conditions in effectively filtering the wave spectrum. These processes strongly affect the wave propagation and inhibit much of the generated spectrum of waves from propagating vertically. Part of this wave filtering involves the breakdown of gravity waves through interactions with critical layers. This wave breakdown induces turbulence and mixing on scales less than the dominant wavelength of the gravity waves. The turbulence has important consequences for commercial aviation, and may play an import role in causing vertical mixing of atmospheric constituents like water vapour and ozone.

In this paper, we present new results detailing high-resolution three-dimensional simulations of the evolution of deep convection, the generation of gravity waves, and the subsequent breakdown of these waves in the lower-stratosphere. These simulations resolve the clouds, the waves, and part of the turbulence cascade induced by the wave breakdown. We show that the presence of moderate vertical wind shear can cause this wave breakdown by inducing a critical layer. Furthermore, it will also be shown that the cloud-induced circulations, such as the relatively strong cloud top outflow, cause the height of the critical layer to be reduced substantially from its background altitude. The effect of this nonlinear interaction is strong mixing due to gravity wave breaking very close to the cloud top. Estimates of the turbulence, and fluxes induced by the mixing will also be presented, as well as comparisons with previous two-dimensional results.