Geophysical Research Abstracts
Vol. 19, EGU2017-12514, 2017
EGU General Assembly 2017

Conceptual model of a shallow circulation induced by low-level radiative cooling

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Studies of radiative convective equilibrium in idealised domains have shown that low-level radiative cooling is important in forcing the organisation of convection. This cooling, maximising at the top of the boundary layer (BL), is thought to drive a divergent low-level flow that both enhances subsidence in the non-convecting areas and transports moist static energy into convecting areas. A comprehensive interpretation of the role of low-level radiative cooling in driving the organisation of convection is currently limited by a poor understanding of how low-level radiative cooling, in particular in connection with a BL flow, induces such a secondary circulation and which parameters influence its structure and strength.

In this study, we use bulk concepts and idealised large-eddy simulation to investigate to what extent radiative cooling in the lower atmosphere in non-convecting areas can induce a secondary circulation that is important in determining the structure in regions of deep convection. The bulk model suggests that heterogeneous radiative BL cooling causes a circulation induced by pressure deviations between the area of weak radiative BL cooling and the area of strong radiative BL cooling. Including a feedback of the induced circulation on the BL in a two-column model, leads to a new equilibrium in which a weakened horizontal BL flow of about 1 m/s is maintained for radiative BL cooling rates stronger than -2 K/day. Such a circulation strength is comparable to a shallow circulation caused by surface temperature differences of a few Kelvins. Spatial differences in radiative BL cooling should therefore be considered as a first-order effect for the formation of shallow circulations.