Shallow cumulus and congestus modes in circulating equilibria of the tropical atmosphere in a two-column RCE model

Nuijens, Louise; Emanuel, Kerry

Publication date
2017

Document Version
Final published version

Published in
Geophysical Research Abstracts (online)

Citation (APA)
Nuijens, L., & Emanuel, K. (2017). Shallow cumulus and congestus modes in circulating equilibria of the tropical atmosphere in a two-column RCE model. *Geophysical Research Abstracts (online)*, *19*, Article EGU2017-9075.

Geophysical Research Abstracts
Vol. 19, EGU2017-9075, 2017
EGU General Assembly 2017

Shallow cumulus and congestus modes in circulating equilibria of the tropical atmosphere in a two-column RCE model

Louise Nuijens (1) and Kerry Emanuel (2)

(1) Delft University of Technology, Delft, Netherlands (louise.nuijens@tudelft.nl), (2) Massachusetts Institute of Technology, Cambridge, USA

Using a two-column radiative-convective equilibrium (RCE) model of a Walker-like overturning circulation, we aim to conceptualize mechanisms that control the depth of convection and precipitation in the subsiding column. The model numerically solves for two-dimensional, non-rotating hydrostatic flow, with parameterized convection, clouds and radiative transfer. A circulation between the columns develops by lowering the sea surface temperature in one column from local RCE, and the circulation is damped by diffusion of momentum in the boundary layer and the model interior. With an increasing SST gradient, convection in the colder column collapses, but to preferred heights near 600 hPa (congestus) and 850 hPa (shallow cumulus), with surface precipitation rates of 1 mm/d respectively 0.5 mm/d.

The more delicate congestus mode is unanticipated, because the model does not include explicit melting (freezing) processes. We will show how the characteristics of precipitation in the deep convection column lead to pronounced moist and dry layers, which through their interaction with radiation, create stable layers and horizontal flows that favor a preferred congestus top in the subsiding column. Furthermore, we will show that congestus modes only emerge when inversions above the mixed-layer can persist against the work of buoyancy waves, notably in simulations with considerable cumulus friction (convective momentum transport) or on large enough horizontal domains.

Lastly, more efficient warm rain formation is shown to raise congestus tops, which tends to slow down the circulation and decrease deep convective precipitation. But the deeper moist congestus layer also reduces low-level radiative cooling, which might pose an energetic constraint on the amount of surface precipitation that congestus can produce.