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The Rainy-Bénard model: Convective organisation and equilibria in a simple framework.

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We have constructed an extension of the Rayleigh–Bénard model of convection, to include latent heating due to the condensation of water vapour in clouds. Condensation occurs whenever specific humidity exceeds saturation (a nonlinear function derived from the Clausius-Clapeyron relation), and leads to heating. Condensed water is removed from the system and hence there is no evaporation. The system captures the nonlinearities between saturated (cloudy) and unsaturated (clear-air) thermodynamics.

A new non-dimensional number, related to the latent heating, is defined. An analytical steady-state ("drizzle") solution exists, in which diffusion of moisture maintains a saturated atmosphere, and condensation heating balances diffusive cooling. Time-dependent numerical solutions are also shown. For low Rayleigh number, Ra, steady-state flows occur, with "chimneys"of narrow convective clouds separated by broad regions of clear-sky descent. With increasing Ra the solutions become unsteady, with transient clouds and active gravity waves. This behaviour will be explored through matching of conserved quantities in the cloudy and clear parts of the domain, and through consideration of the mean, limiting states. The results will be related to "meteorological" parameters, to explore how the simple system can shed light on the origins of equilibria and instabilities in the atmospheric environment.

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