Studies of moist Rayleigh-Bénard convection in a Galerkin model

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ABSTRACT

The transition to turbulence and resulting localized convective patterns in Rayleigh-Bénard convection with phase changes are studied in a Galerkin-model. The underlying equations of motion rely on a simplified scheme to represent the effect of phase transition on the buoyancy of the fluid in order to study the dynamics of convective clouds in a idealized setting. We show that the transition to moist convection can significantly differ from the classical dry Rayleigh-Bénard case. The moist Rayleigh-Bénard problem is determined by two non-dimensional Rayleigh numbers, one characterizing the stability of unsaturated parcels and the other of saturated, or cloudy, parcels. Two different parameter regimes can be identified, one where the box is completely filled with clear, dry air in the equilibrium and the other completely filled with cloudy air. For the range of Rayleigh numbers investigated here and for sufficiently large aspect ratios, we find that convection appears first in form of a stationary single plume of mostly upward moving cloudy air surrounded by an extended unsaturated region dominated by slow subsidence. Moist convection is thus highly localized in space and asymmetric with respect to the vertical direction. The transition region is studied here through a systematic decrease of the stability of the unsaturated parcels, starting in the first regime and then switching to the second. If the stable stratification of dry air is too strong every perturbation relaxes to the quiescent equilibrium. When stable stratification is decreased, some perturbations can trigger a convection, others return to the quiescent equilibrium. We studied this feature statistically and concluded that two attractors coexist in phase space at the same parameters with a very complex shaped boundary between the attracting domains. With the help of a edge tracking algorithm we found an edge state between both attractors that is a periodic orbit. If the stability of the dry air is further decreased one enters the second parameter regime in which every perturbation eventually reaches a convective state. At the beginning of the range, an interesting recharge-discharge convection can be observed. When the stable background stratification of the dry air is further reduced or the aspect ratio of the layer at fixed parameter set is enhanced, moist convection starts to become time-dependent and eventually turbulent. We also discuss parallels and differences to the transition to turbulence in wall-bounded plane shear flows.

REFERENCES

[1] Olivier Pauluis, Jörg Schumacher *Idealized moist Rayleigh-Benard convection*, Comm. Math. Sci. **8**, 295-319, 2010.

[2] Thomas Weidauer, Olivier Pauluis, Jörg Schumacher *Rayleigh-Bénard convection with phase changes in a Galerkin model*, submitted to Phys. Rev. E.