An experimental analogue of moist convection

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Large scale motions of the lower part of the atmosphere (the troposphere) are partly due to moist convection. In this type of convection, the source of buoyancy is the latent heat released by condensation of water droplets. This type of convection is very different from the classical Rayleigh-Bénard case : the heating is internal and associated to a saturation threshold. Strong and localised updrafts appear whereas downdrafts are slow and more diffuse [1]. A correct parametrisation of the lateral scales associated to moist convection is one of the key ingredients for correct mid and long term climate forecasts.

Yet, the full dynamic of such a complex system is barely accessible to 3D direct numerical simulations in large aspect ratio domains. We built an experimental analogue of moist convection to identify the important physical processes behind these complex atmospheric motions.

Inspired by the simple model of moist convection derived by Vallis et al. [2] and the experimental study of conditional instability by Krishnamurti [3] we reproduced the key ingredients of moist convection in the laboratory. Our experimental setup is a rectangular tank filled with water, stratified in temperature. A pH indicator (bromothymol blue) is dissolved, it is yellow at low pH and blue at high pH. A DC power supply applies a constant voltage between the copper plate at the bottom and the grid of stainless steel wire at the top. This voltage induces the water electrolysis at both electrodes : the water close to the top one becomes more acidic and the water close to the bottom one becomes basic hence blue. A sodium lamp placed at the top heats internally the basic (blue) fluid which rises in the stratified ambient because of buoyancy. Simultaneously it mixes, dilutes, becomes more acid, and turns yellow once pH becomes lower than a given threshold around 7. Hence the main ingredients of moist convection, including internal heating, the competition between mixing and increasing buoyancy, and the existence of a threshold in buoyancy production, are reproduced.

The analytical modelling of our system shows the similarities between our setup and the moist convection model of Vallis et al.[2] The system is also studied with linear stability analysis and direct numerical simulations using the pseudospectral solver Dedalus [4].

Références

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