

# Boundary layer evolution in turbulent Rayleigh-Bénard convection

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## Abstract

We present a fluid dynamics video which illustrates the dynamics of the velocity field in the boundary layer in a turbulent Rayleigh-Bénard convection flow. The data are obtained from direct numerical simulation.

## 1 Video Description

When a gas or fluid in a cylindrical cell of height  $H$  and diameter  $D$  is cooled from above and heated from below turbulent convection is triggered provided that the temperature difference between top and bottom plates is sufficiently large. Crucial for the deeper understanding of the mechanisms of turbulent heat transport is the analysis of the physics in the tiny boundary layers at the top and bottom [1]. The video shows the dynamics of velocity field in the thermal boundary layer. Data are obtained from direct numerical simulations of the Boussinesq equations (see [2] for further details). The computational grid is given in cylindrical coordinates and contains  $N_r \times N_\phi \times N_z = 513 \times 1153 \times 861$  grid points. The simulation parameters are Prandtl number  $Pr = 0.7$ , Rayleigh number  $Ra = 3 \times 10^{10}$  and aspect ratio  $\Gamma = D/H = 1$ .

The movie shows at first the horizontal plane in which the streaklines are seeded. We display the temperature distribution and observe a skeleton of hot sheet-like thermal plumes which turns from color into gray. This

seeding plane is at about the thermal boundary layer thickness above the hot bottom plate. The streaklines are colored with respect to the velocity magnitude (blue=minimum, red=maximun). The evolution of the streaklines gives us an impression about the large-scale circulation which always builds up in a confined cell [3]. The second part of the Video highlights the merging of two plume events close to the side wall. Our simulations show that the detachment of thermal plumes is accompanied by the formation of mini-tornados as they are shown here in the merging process. This zoom demonstrates clearly the locally fluctuating and three-dimensional dynamics in the boundary layer. The implications for the boundary layer dynamics at even higher Rayleigh numbers and a transition to turbulence need to be explored in the future.

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## References

- [1] R. Verzicco, *Boundary layer structure in confined turbulent thermal convection*, J. Fluid Mech. **706**, 1 (2012).
- [2] N. Shi, M. S. Emran and J. Schumacher, *Boundary layer structure in turbulent Rayleigh-Bénard convection*, J. Fluid Mech. **706**, 5 (2012).
- [3] F. Chillà and J. Schumacher, *New perspectives in turbulent Rayleigh-Bénard convection*, Eur. J. Phys. E **35**, 58 (2012).