

# Transition to chaos of natural convection between two infinite differentially heated vertical plates

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## Configuration

- Isothermal plates
- Boussinesq approximation
- DNS (Spectral method)

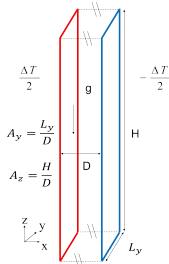


Figure 1: Study domain

## 1st bifurcation

- 1 Supercritical pitchfork bifurcation  $\implies$  four steady 2D corotating rolls
- 2 Analytically derived Ginzburg-Landau Model

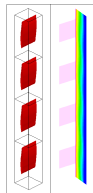


Figure 2: (a) Vorticity iso-surface  $\Omega_y = 3.2$  (b) Temperature contours at two vertical planes  $x=0.0245$  and  $y=0.9677$   $Ra = 6000$

$$\frac{\partial A}{\partial t} = \sigma(Ra - Ra_c)A + \eta \frac{\partial^2 A}{\partial z^2} - lA^2 A^*$$

$$\sigma = 7.67 \times 10^{-5}, \eta = 0.112, l = 20.5$$

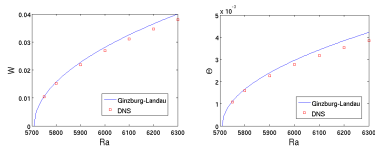


Figure 3: Comparison between DNS and GLM. Left: vertical velocity amplitude; Right: temperature amplitude

## Subsequent bifurcations

- 2nd bif. : supercritical pitchfork bif.  $\Rightarrow$  3D pattern
- 3rd bif. : supercritical Hopf bif.  $\Rightarrow$  3D oscillatory pattern
- subsequent bif. : period-doublings  $\Rightarrow$  chaos

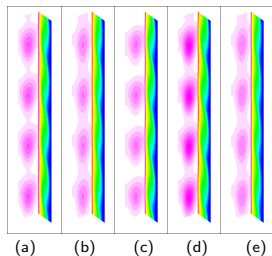


Figure 4: Temperature iso-contours at two vertical planes  $x=0.0245$  and  $y=0.9677$ : (a)  $Ra = 11000$  (b)-(e)  $Ra = 11500$  (b)  $t=2001$ , (c)  $t=2010$ ; (d)  $t=2020$ ; (e)  $t=2029$

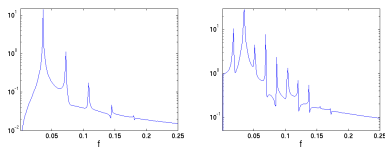


Figure 5: Temporal Fourier spectrum of the temperature at a point in the boundary layer next to the hot wall. Left:  $Ra = 11500$ ; Right:  $Ra = 12200$

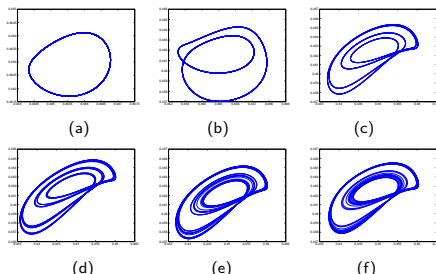


Figure 6: Phase portraits at different  $Ra$ . Abscissa: temperature at the point  $(0.038, 0.097, 6.98)$ ; ordinate: temperature at the point  $(0.038, 0.097, 6.54)$ . (a)  $Ra = 12000$  (b)  $Ra = 12100$  (c)  $Ra = 12300$  (d)  $Ra = 12310$  (e)  $Ra = 12315$  (f)  $Ra = 12320$