Pattern competition in a narrow horizontal homogeneously heated layer

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Natural Convection: Definition

- Fluid motion induced by small local density differences
- Density differences caused by:
  - Local temperature differences
  - Compositional changes
- The Boussinesq approximation is used to simplify modelling
  - Free convection
  - Difference in inertia is negligible
  - Difference in the local mass is only appreaciable in order to induce motion
  - Therefore, density is only constant in the continuity and momemtum equations with the exception of the gravity term
  - Limit density difference of 1%
  - Only applicable to the body force term
- Time steady range of convection cells

Horizontal Layer

Steady state, laminar, thermal energy models.
Aspect ratio $\left[1:4\sqrt{3}:12\right]$ with $[30:104:180]$ nodes following Ichikawa *et al.* 2006, Physics of Fluids 18, 038101.
Blue Surface: Isothermal Surface
Grey Surface: Adiabatic Surface
Remaining boundaries are periodic
Fluid: Water of Pr ≈ 7
Homogeneous heating is estimated by:

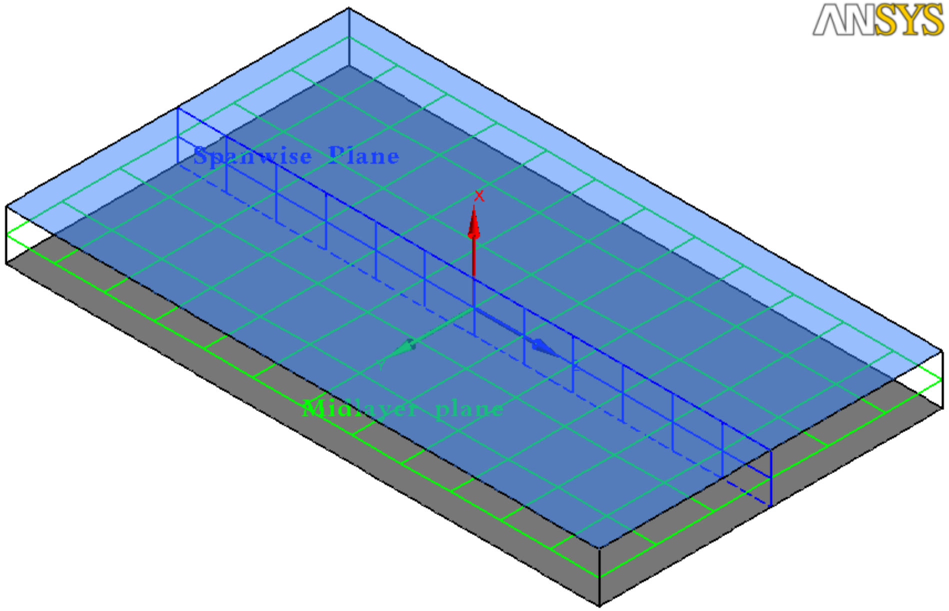
$$S_i = \frac{2k\Delta T}{L^2}$$

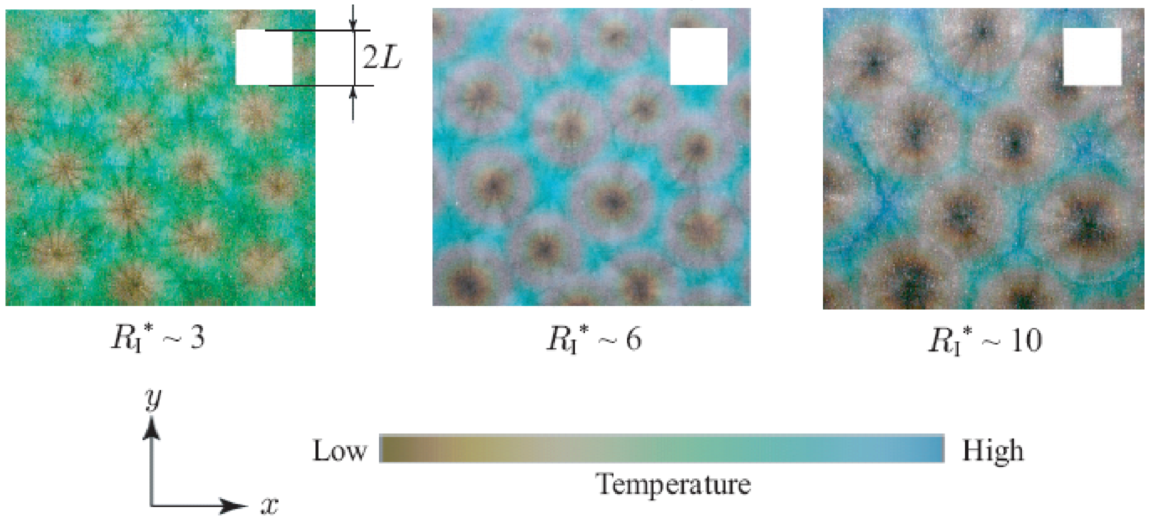
Grashof number is used to define the convection regime:

$$Gr = \mathbf{g}\beta S_i L^5/2\nu^2 k$$

$$\epsilon = \frac{Gr - Gr_c}{Gr_c}$$

$\Delta T = 1K$
$L = 0.0038 \rightarrow 0.012$ m
$Gr = 114 \rightarrow 3522$
$Gr_c \approx 198$

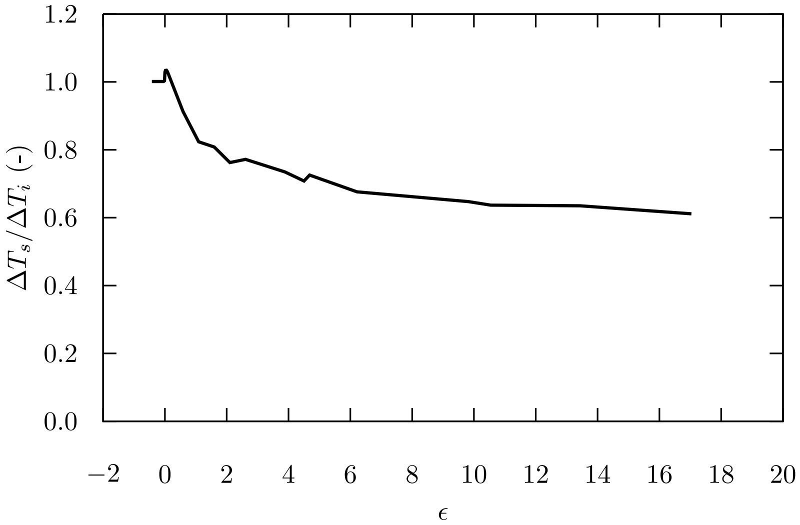




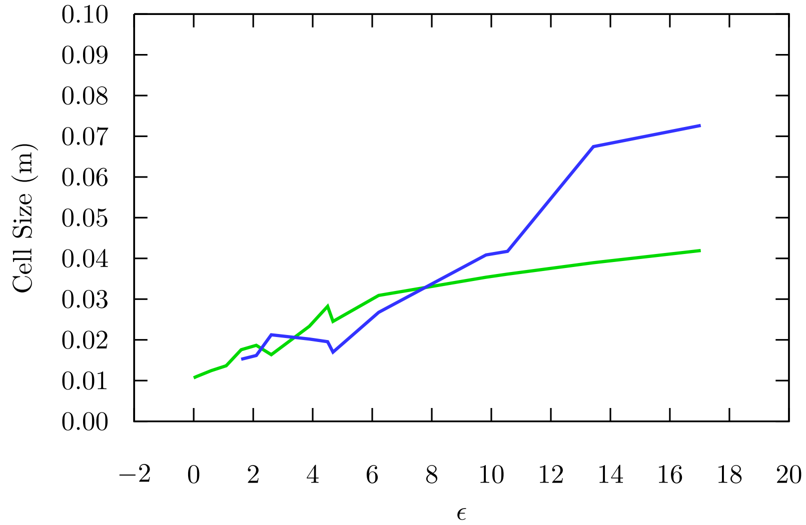
Tasaka *et al*, Journal of Physics: Conference Series **14** (2005) 168179

Profiles of parameters as $Gr = 114 \rightarrow 3522$

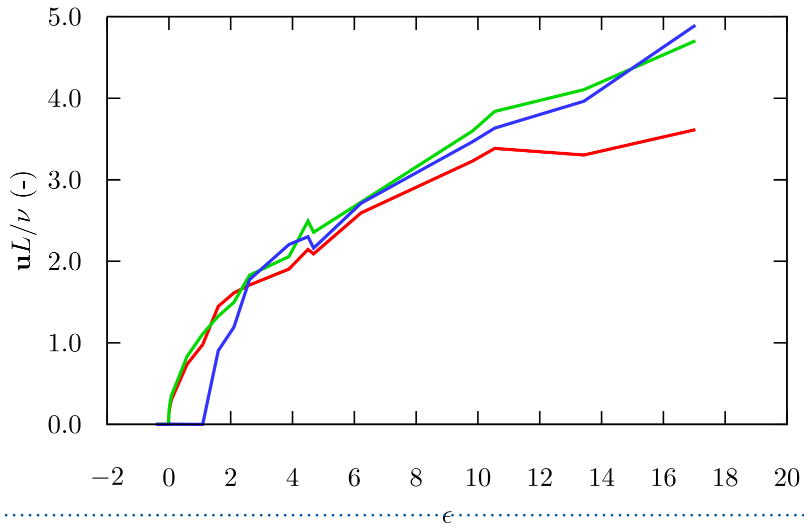
Temperature difference where $\epsilon = (Gr - Gr_c)/Gr_c$



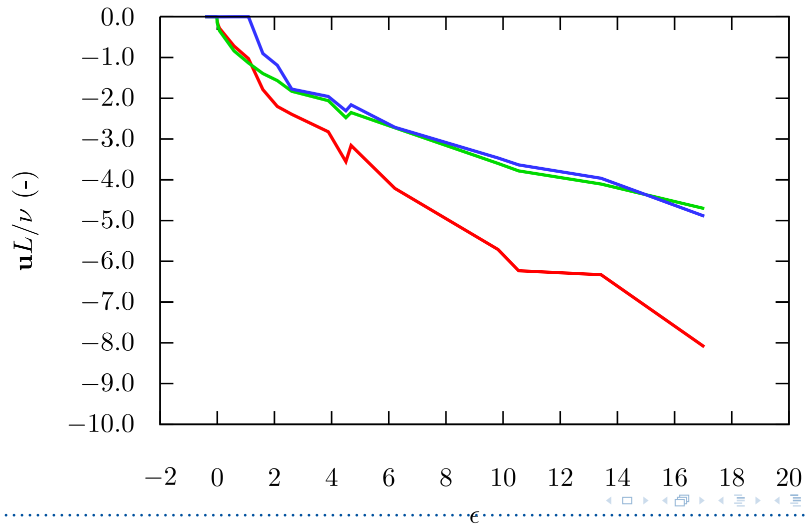
Convection cell size (y: green; z: blue;)



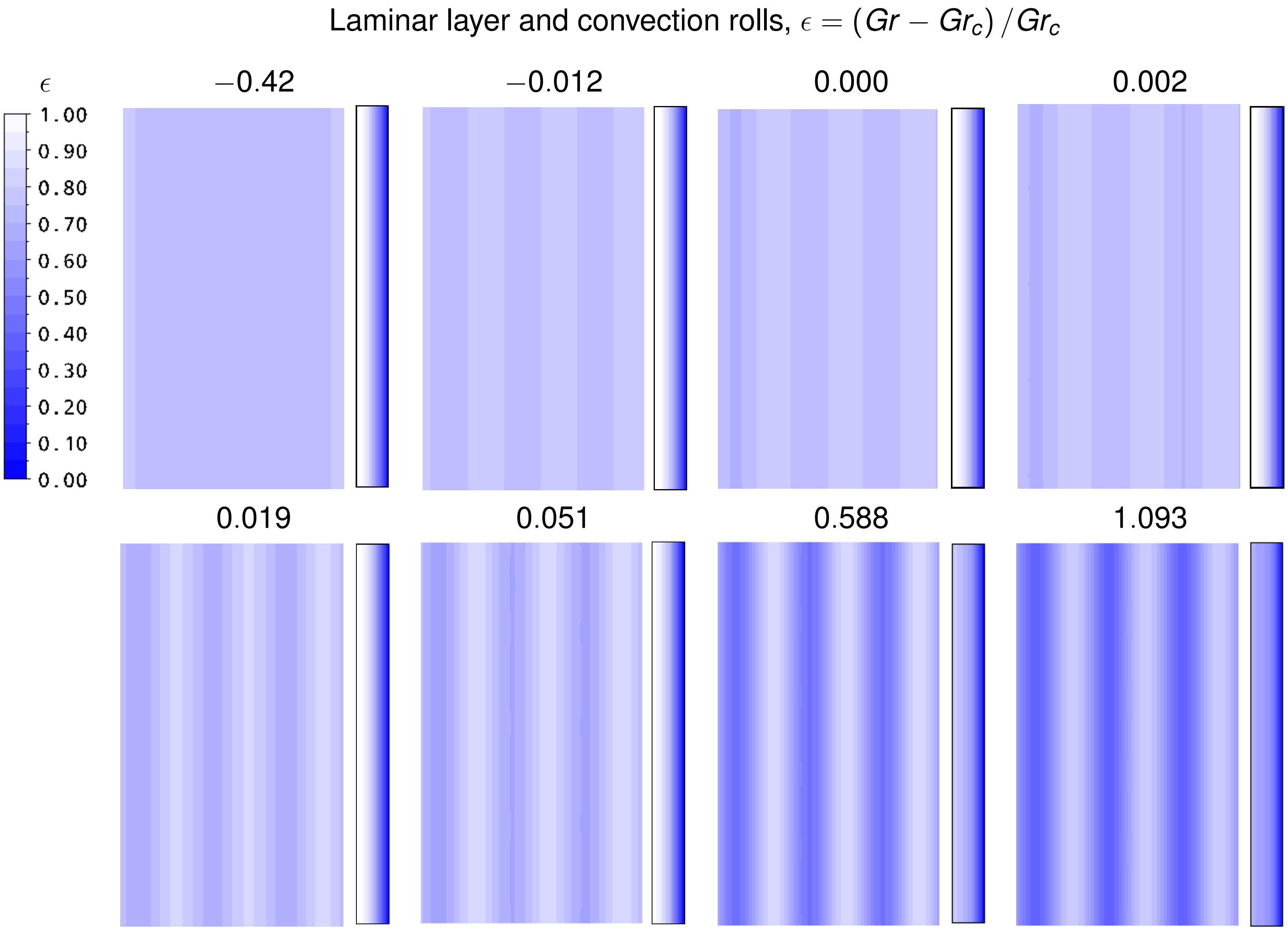
Velocity components, maximum (u: red; v: green; w: blue;)



Velocity components, minimum (u: red; v: green; w: blue;)

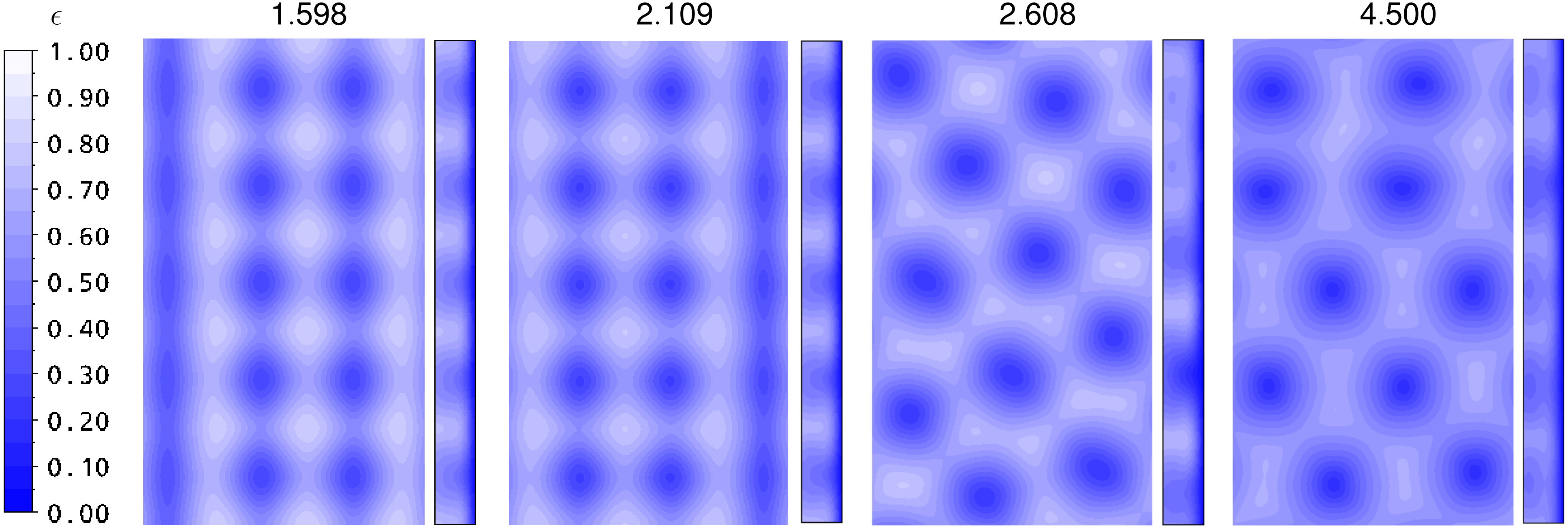


Contours of temperature as $Gr = 114 \rightarrow 413$ (1)

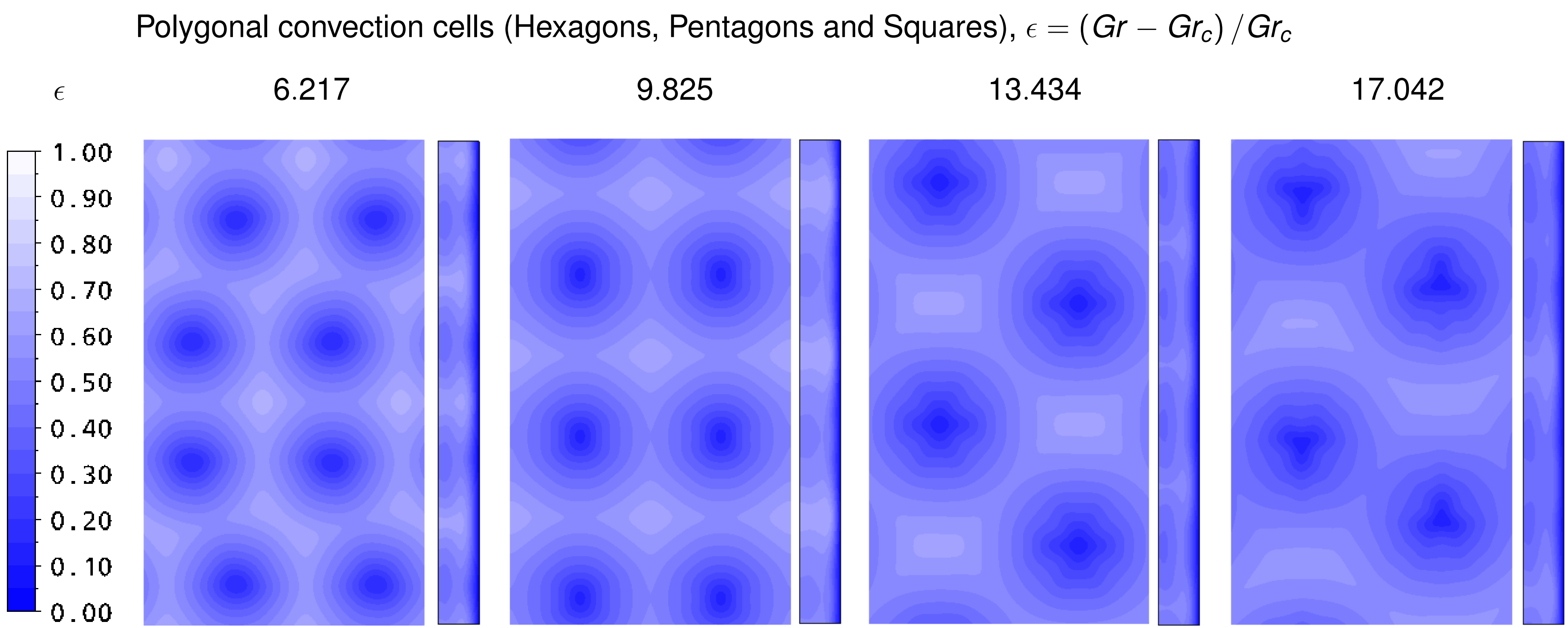


Contours of temperature as $Gr = 513 \rightarrow 1087$ (2)

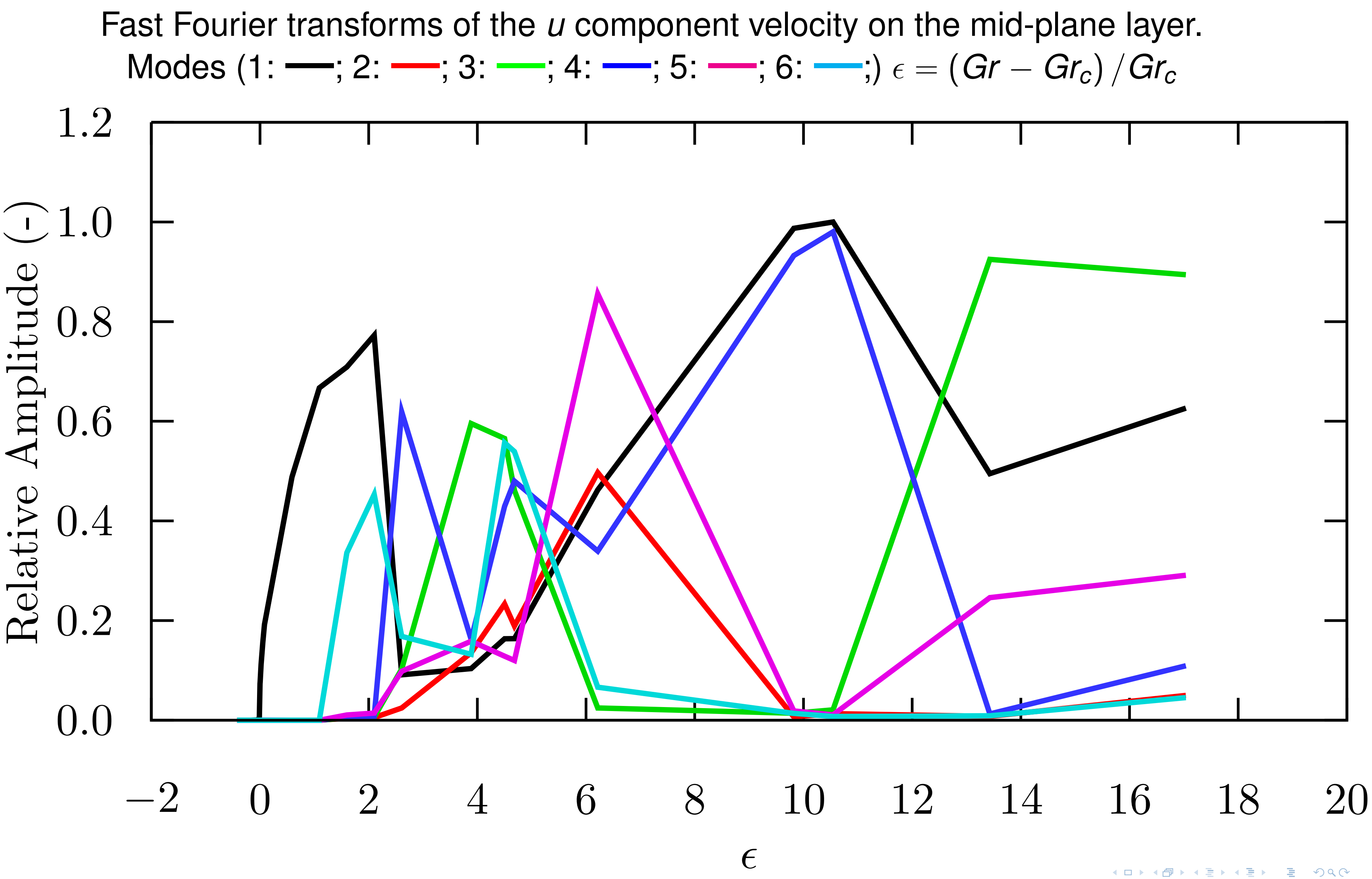
Polygonal convection cells (Hexagons, Pentagons and Squares), $\epsilon = (Gr - Gr_c)\,/\,Gr_c$



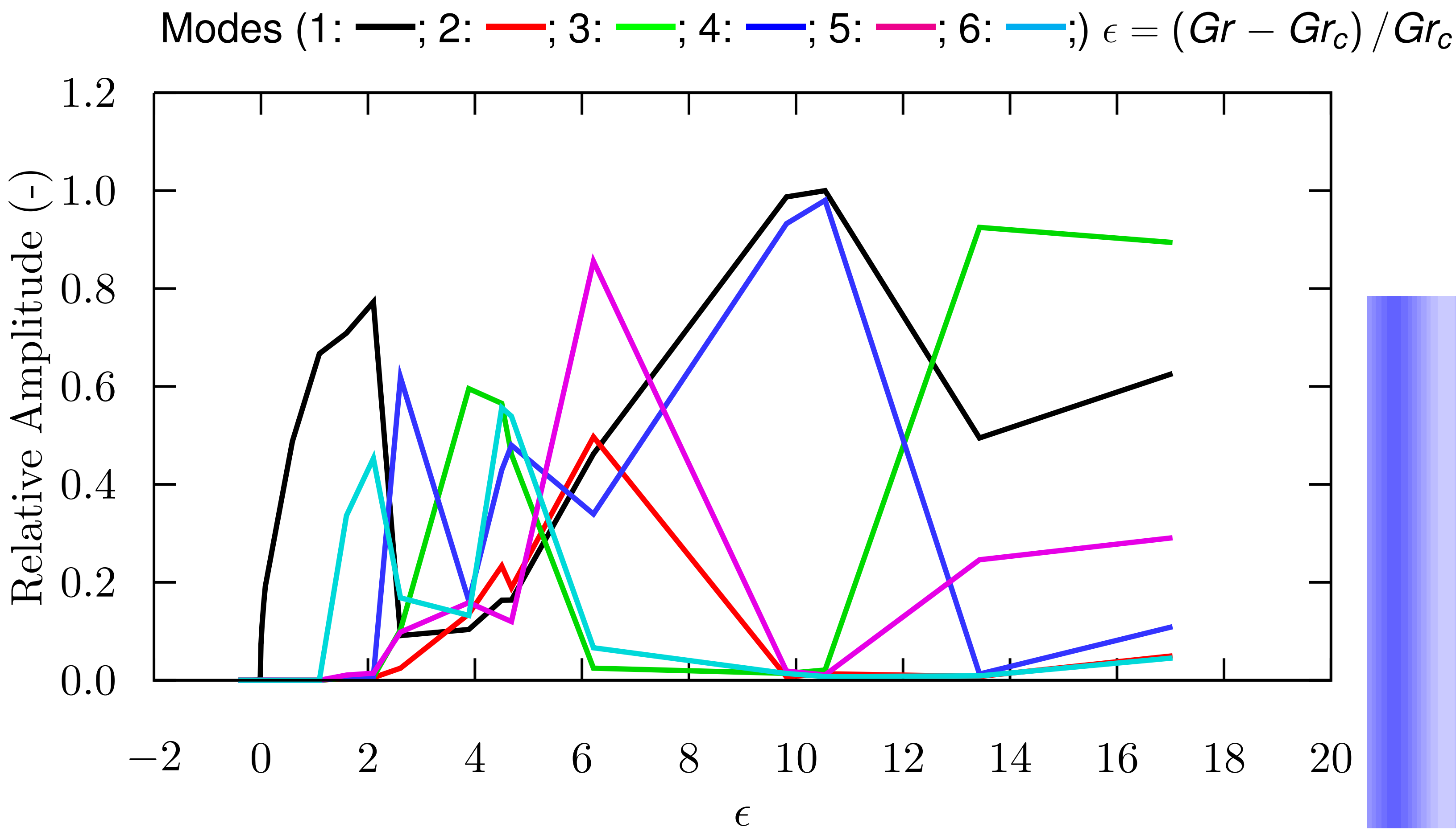
Contours of temperature as $Gr = 1426 \rightarrow 3522$ (3)

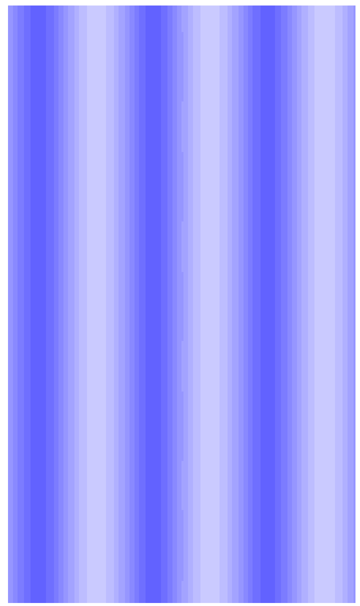


Profiles of Fourier space modes over $Gr = 114 \rightarrow 3522$

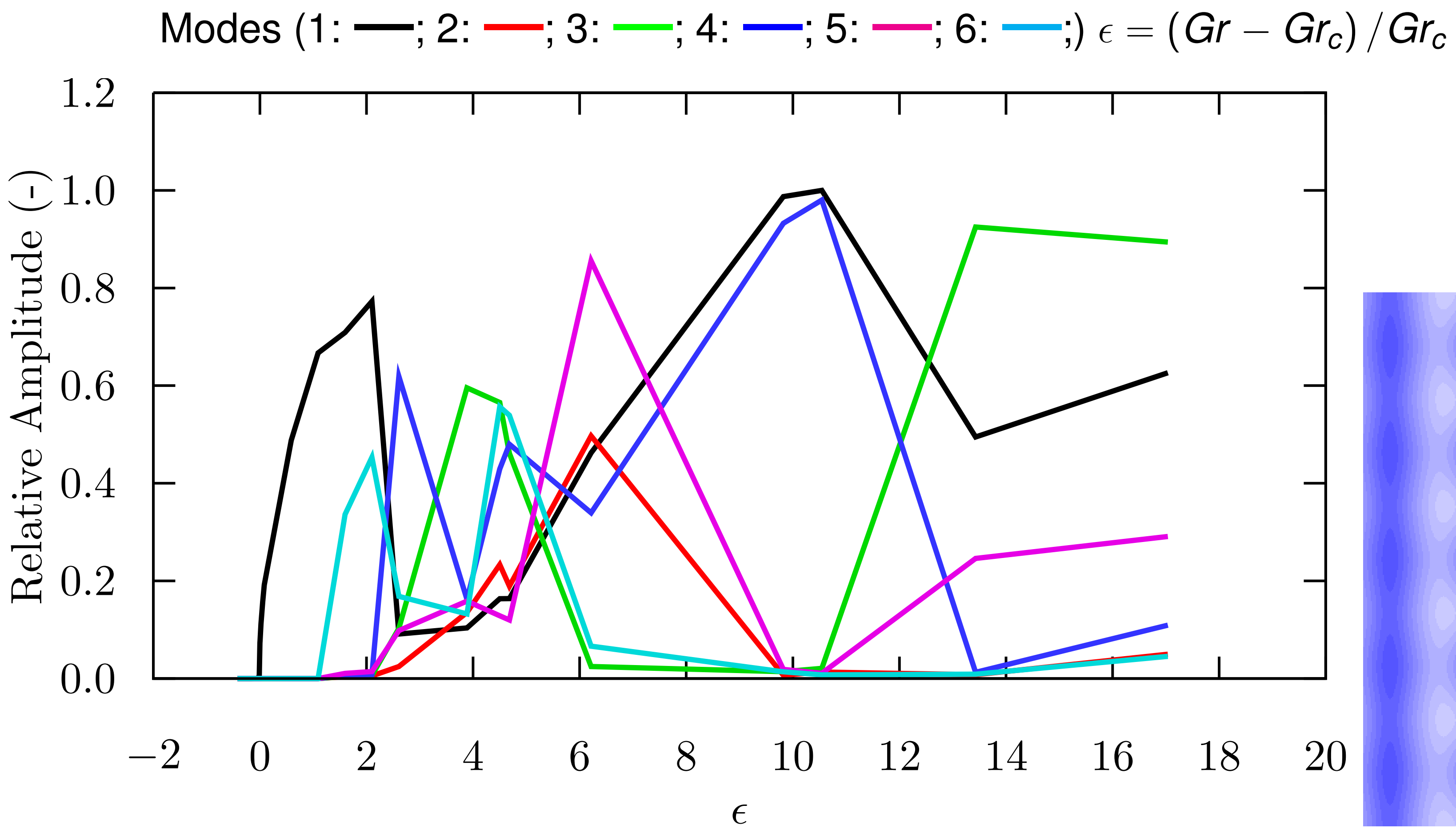


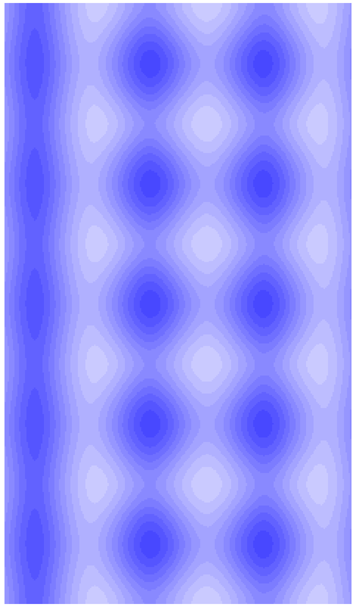
Profiles of Fourier space modes over $Gr = 114 \rightarrow 3522$; Rolls



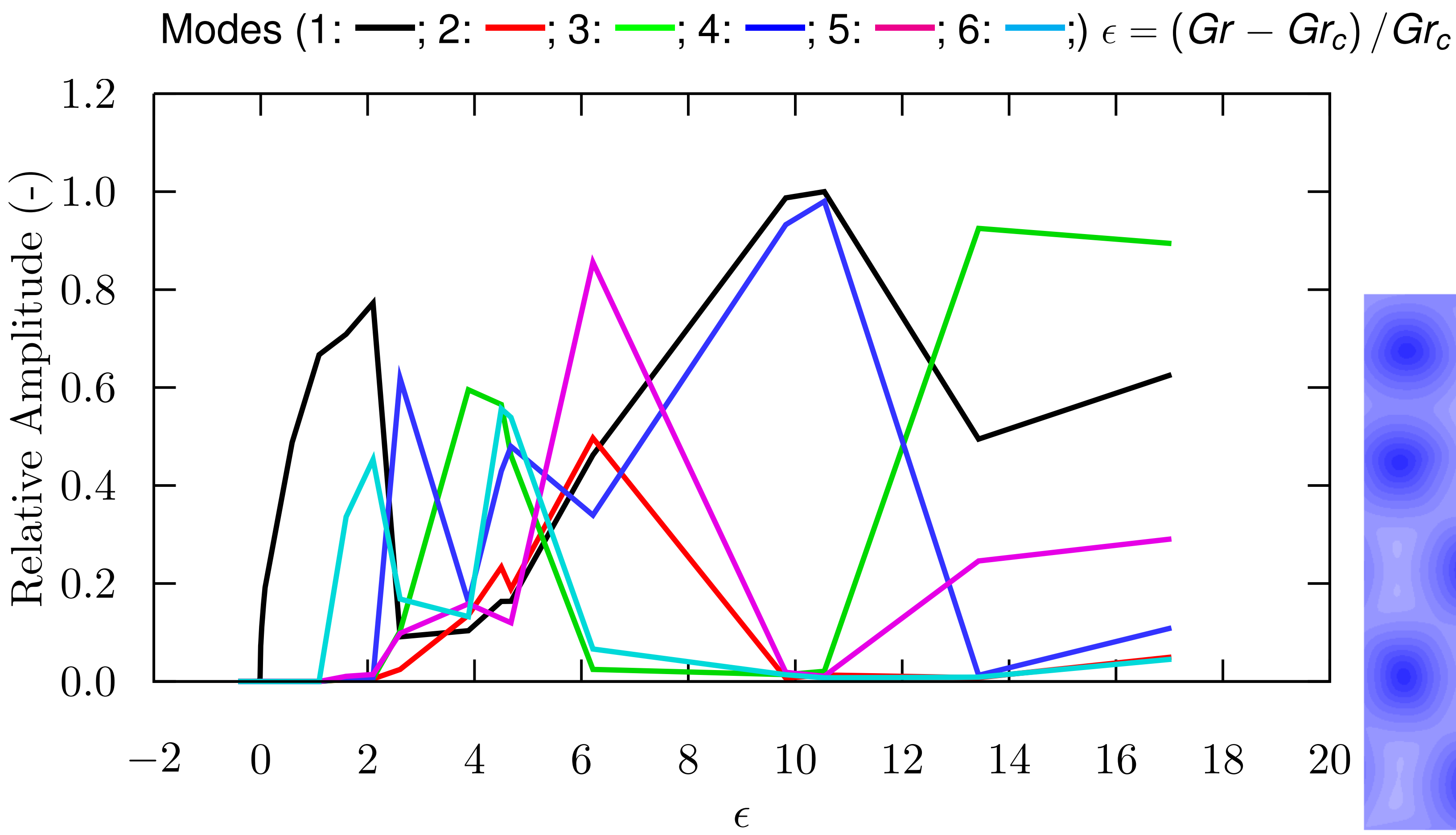


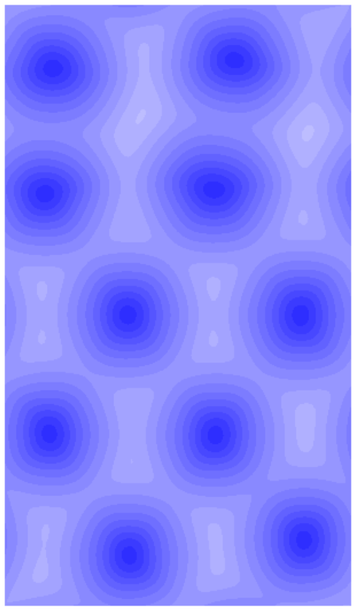
Profiles of Fourier space modes over $Gr = 114 \rightarrow 3522$; First Square State



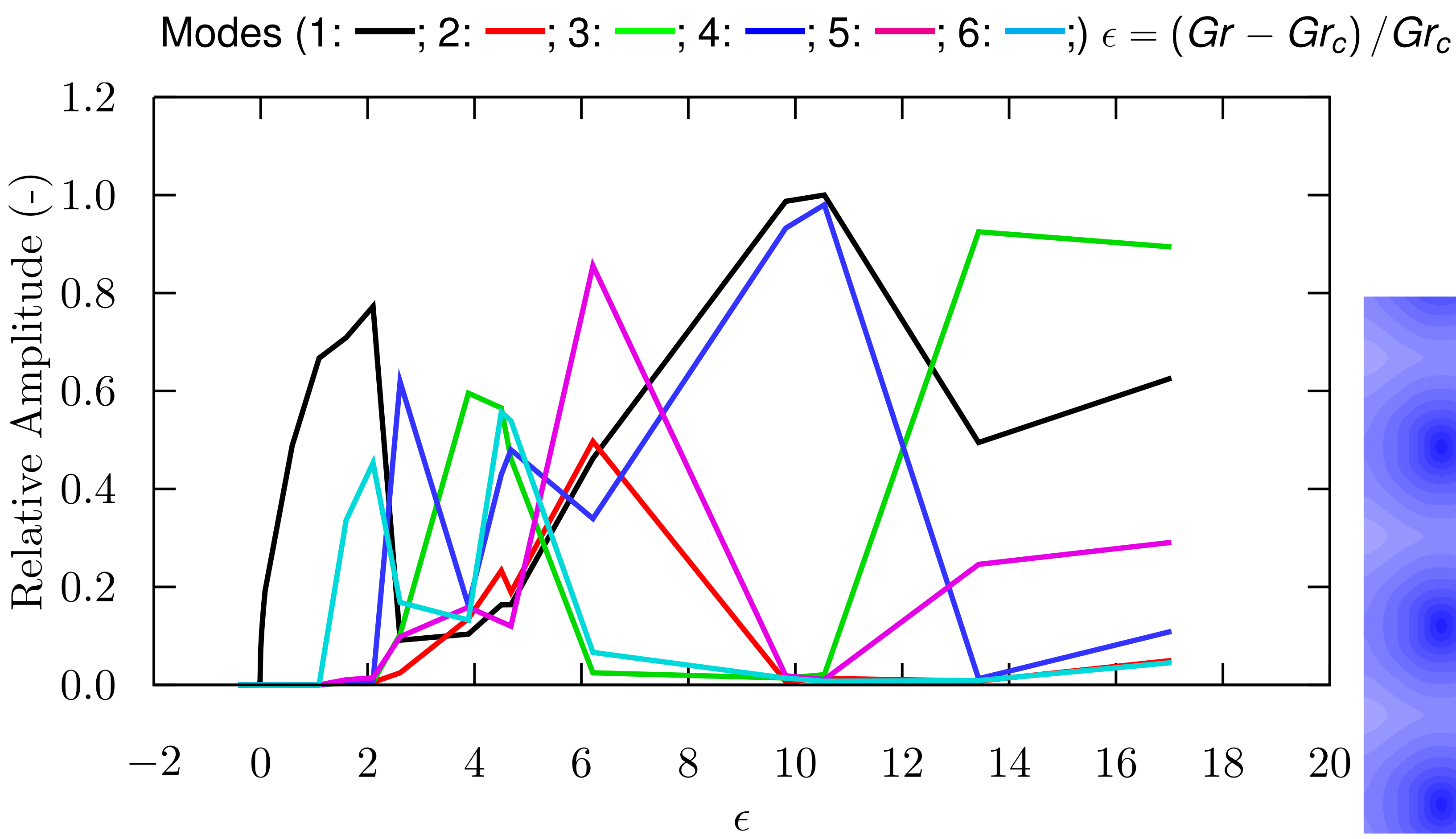


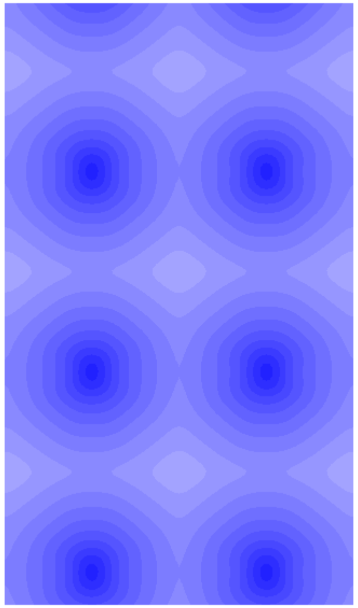
Profiles of Fourier space modes over $Gr = 114 \rightarrow 3522$; Mixed Hexagonal and Pentagonal States



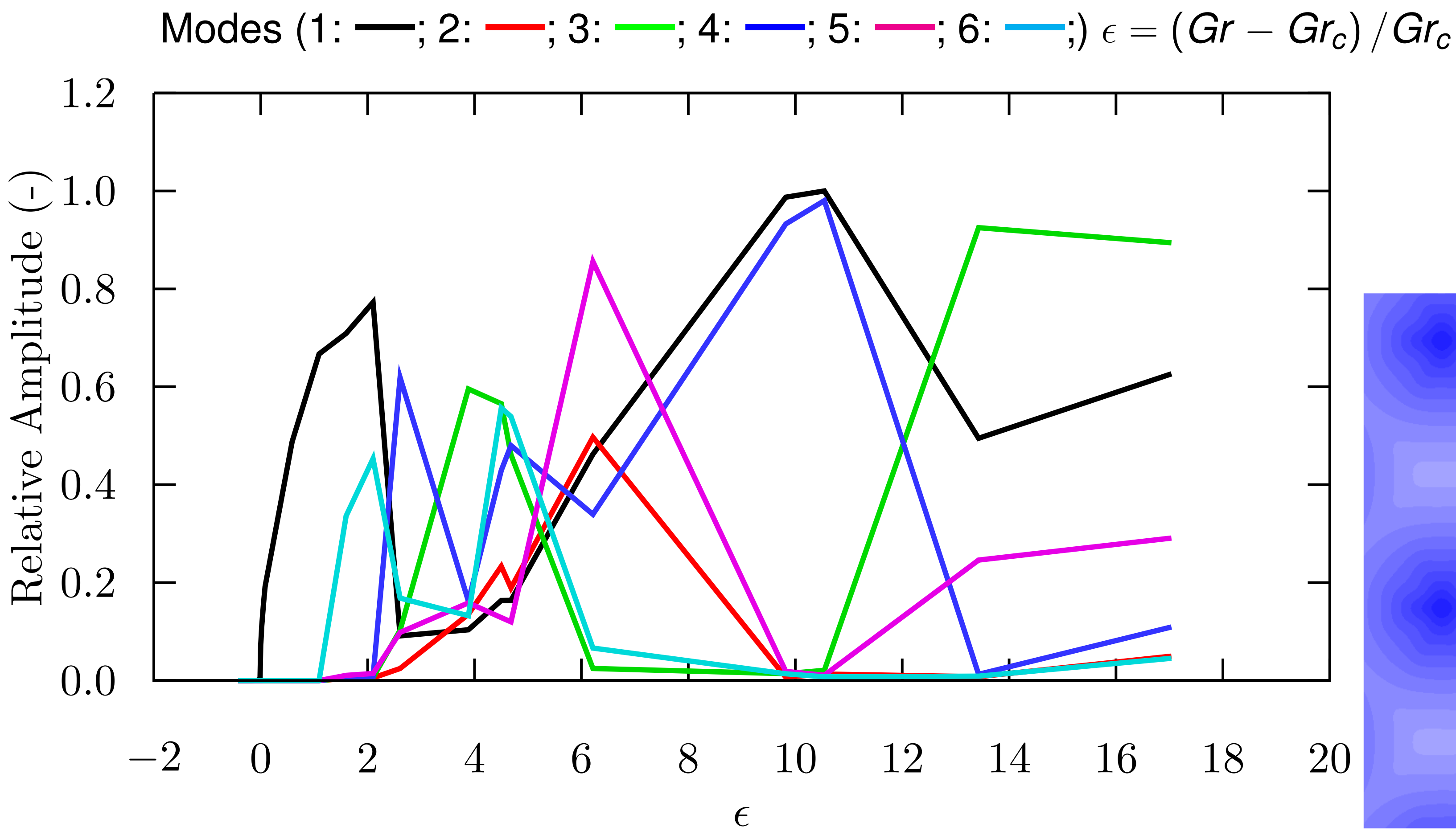


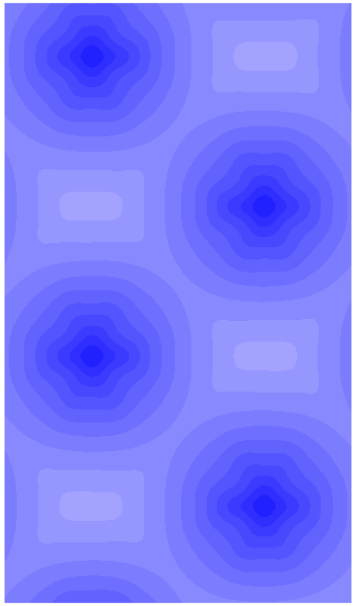
Profiles of Fourier space modes over $Gr = 114 \rightarrow 3522$; Second Square State





Profiles of Fourier space modes over $Gr = 114 \rightarrow 3522$; Third Square State





Discussion

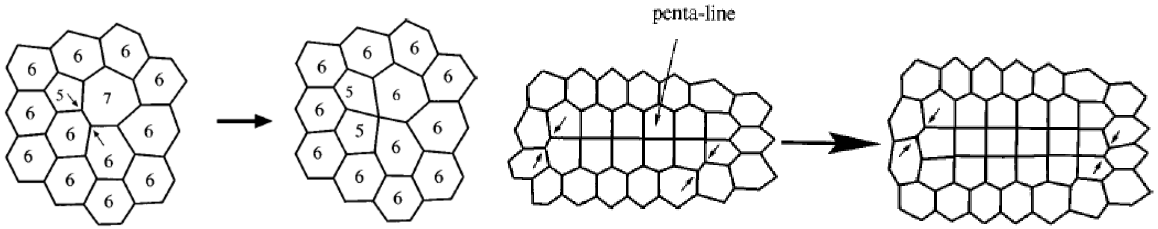
Preferential mode of stability are hexagonal cells as temperature influences the material properties

However, development of stable circulation cells has the following sequence for increasing layer depth

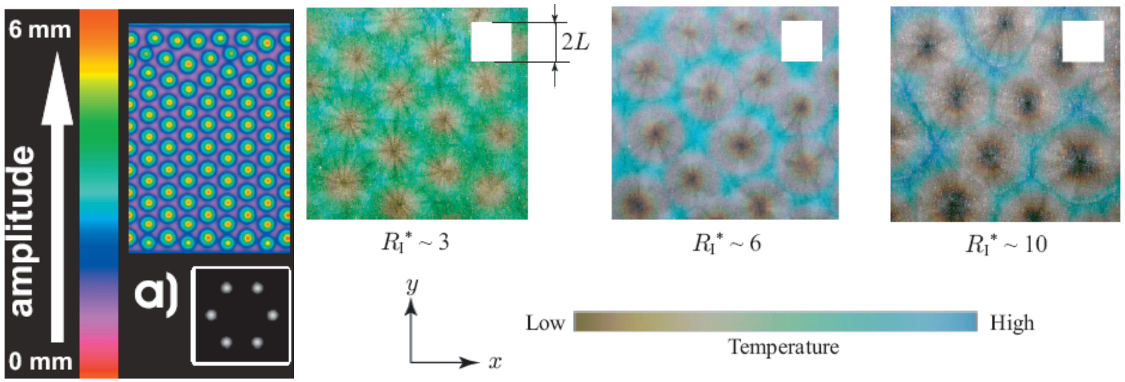
- rolls
- squares
- hexagons and pentagons
- squares
- deformed squares
- transient circulation cells

Further work would examine

- fix the layer depth and increase the temperature to test against Tasaka *et al.* (2005)
- symmetric boundary conditions to test against Groh *et al.* (2007)



Thiele and Eckert, Physical Review E **58**, (1998) 3458-3468



Groh *et al.*, Physical Review E **76**, (2007) 055301(R) & Tasaka *et al.*, Journal of Physics: Conference Series **14** (2005) 168179