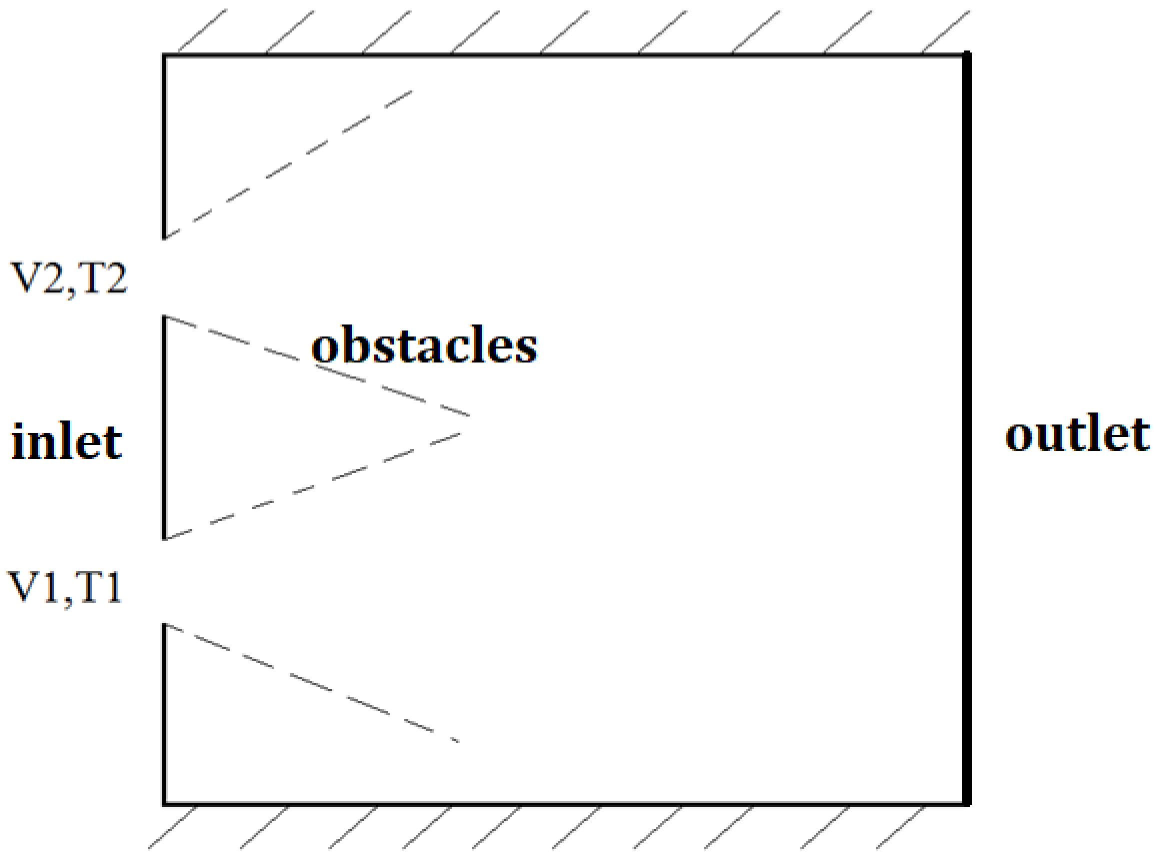
# Physical background



# Mathematical background

$$\frac{\partial U_x}{\partial x} + \frac{\partial U_y}{\partial y} = 0$$

$$\frac{\partial U_x}{\partial t} + U_x \frac{\partial U_x}{\partial x} + U_y \frac{\partial U_x}{\partial y} = -\frac{\partial p}{\partial x} - \frac{1}{\mathrm{Re}}\left(\frac{\partial^2 U_x}{\partial x^2} + \frac{\partial^2 U_x}{\partial y^2}\right)$$

$$\frac{\partial U_y}{\partial t} + U_x \frac{\partial U_y}{\partial x} + U_y \frac{\partial U_y}{\partial y} = -\frac{\partial p}{\partial y} - \frac{1}{\mathrm{Re}}\left(\frac{\partial^2 U_y}{\partial x^2} + \frac{\partial^2 U_y}{\partial y^2}\right) + \frac{Gr}{\mathrm{Re}^2}\theta$$

$$\frac{\partial \theta}{\partial t} + U_x \frac{\partial \theta}{\partial x} + U_y \frac{\partial \theta}{\partial y} = \frac{1}{\mathrm{Pr}\,\mathrm{Re}}\left(\frac{\partial^2 \theta}{\partial x^2} + \frac{\partial^2 \theta}{\partial y^2}\right)$$

# Vorticity – Stream function formulation

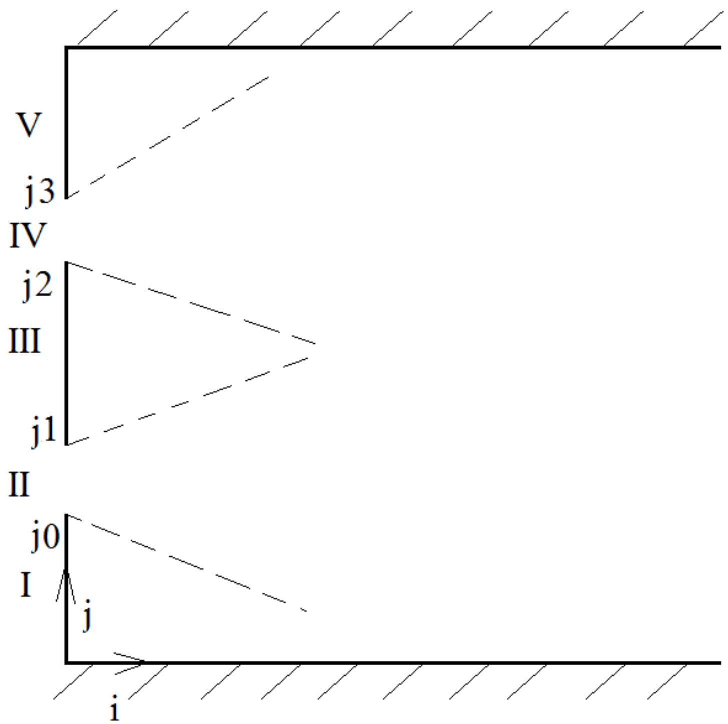
$$U_x = \frac{\partial \psi}{\partial y}; U_y = -\frac{\partial \psi}{\partial x}$$

$$\Omega = \frac{\partial U_x}{\partial y} - \frac{\partial U_y}{\partial x} = \frac{\partial^2 \psi}{\partial x^2} + \frac{\partial^2 \psi}{\partial y^2}$$

$$\frac{\partial \Omega}{\partial t} + U_x \frac{\partial \Omega}{\partial x} + U_y \frac{\partial \Omega}{\partial y} = \frac{1}{\mathrm{Re}}\left(\frac{\partial^2 \Omega}{\partial x^2} - \frac{\partial^2 \Omega}{\partial y^2}\right) + \frac{Gr}{\mathrm{Re}^2}\frac{\partial \theta}{\partial x}$$

# Boundary conditions

$$\frac{\partial \theta}{\partial x} = 0; U_x = 0; \psi = \psi(j3)$$




$$\frac{\partial}{\partial x} = 0$$

$$\frac{\partial \theta}{\partial x} = 0; U_x = 0; \psi = 0$$

$$I.U_x = 0; \theta = 0; \psi = 0$$

$$II.U_x = 0; \theta = 1; \psi = y - y_0$$

$$III.U_x = 0; \theta = 0; \psi = \psi(j1)$$

$$IV.U_x = 1; \theta = 0; \psi = y - y_2 + \psi(j2)$$

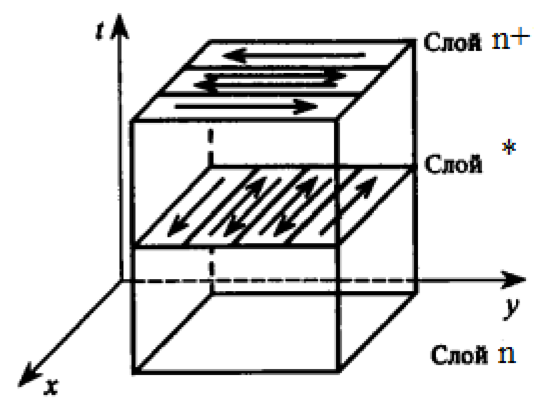
$$V.U_x = 0; \theta = 0; \psi = \psi(j3)$$

$$y = (j-1)\vartriangle y; y_n = (jn-1)\vartriangle y; n = 0,3$$

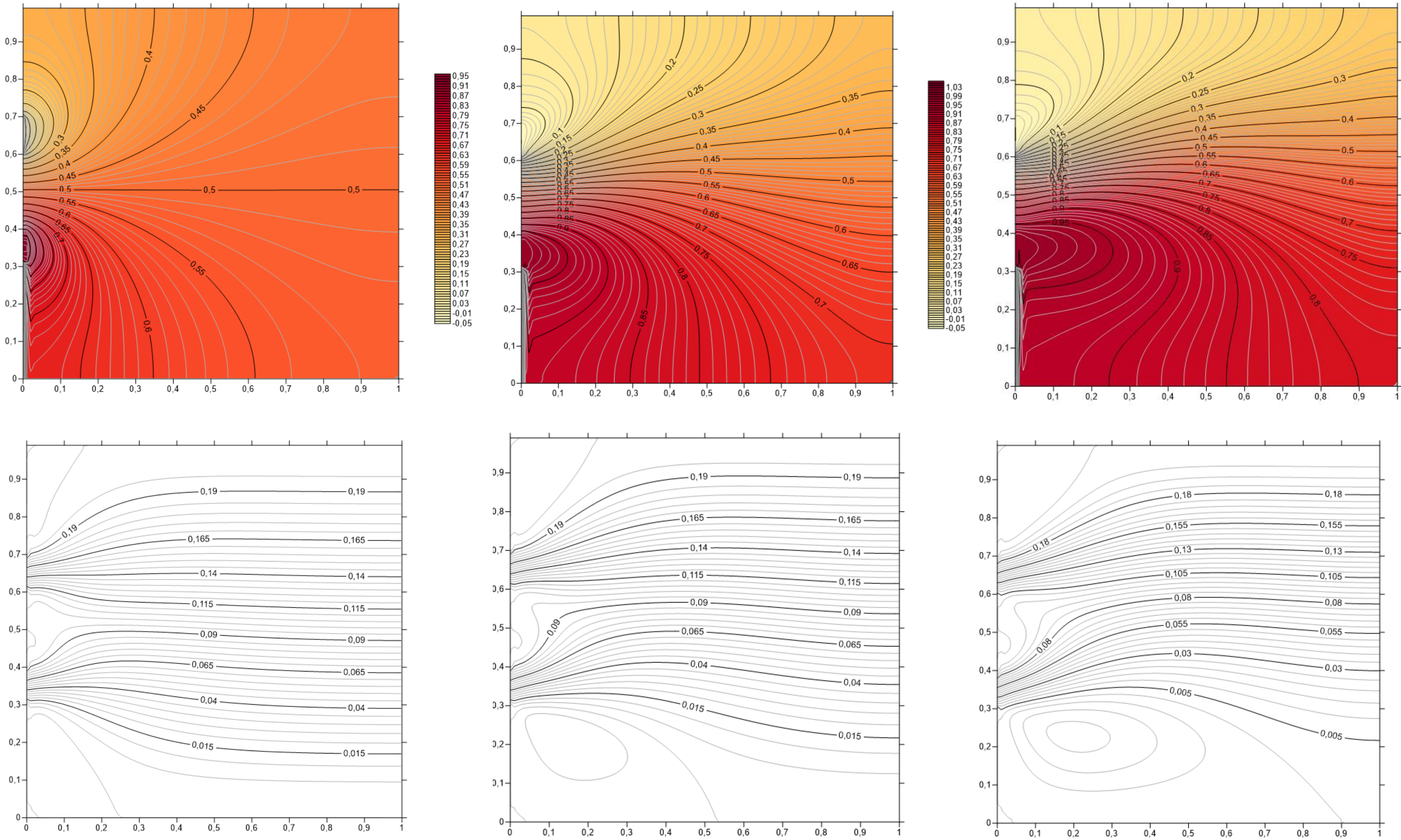
# Local one-dimentional scheme

$$\frac{\theta_{ij}^{*}-\theta_{ij}^{n}}{\vartriangle\tau}+(U_x\frac{\partial\theta}{\partial x})_{ij}^{*}=\frac{1}{\Pr\mathrm{Re}}(\frac{\partial^2\theta}{\partial x^2})_{ij}^{*}$$

$$\frac{\theta_{ij}^{n+1}-\theta_{ij}^{*}}{\vartriangle\tau}+(U_y\frac{\partial\theta}{\partial x})_{ij}^{n+1}=\frac{1}{\Pr\mathrm{Re}}(\frac{\partial^2\theta}{\partial x^2})_{ij}^{n+1}$$

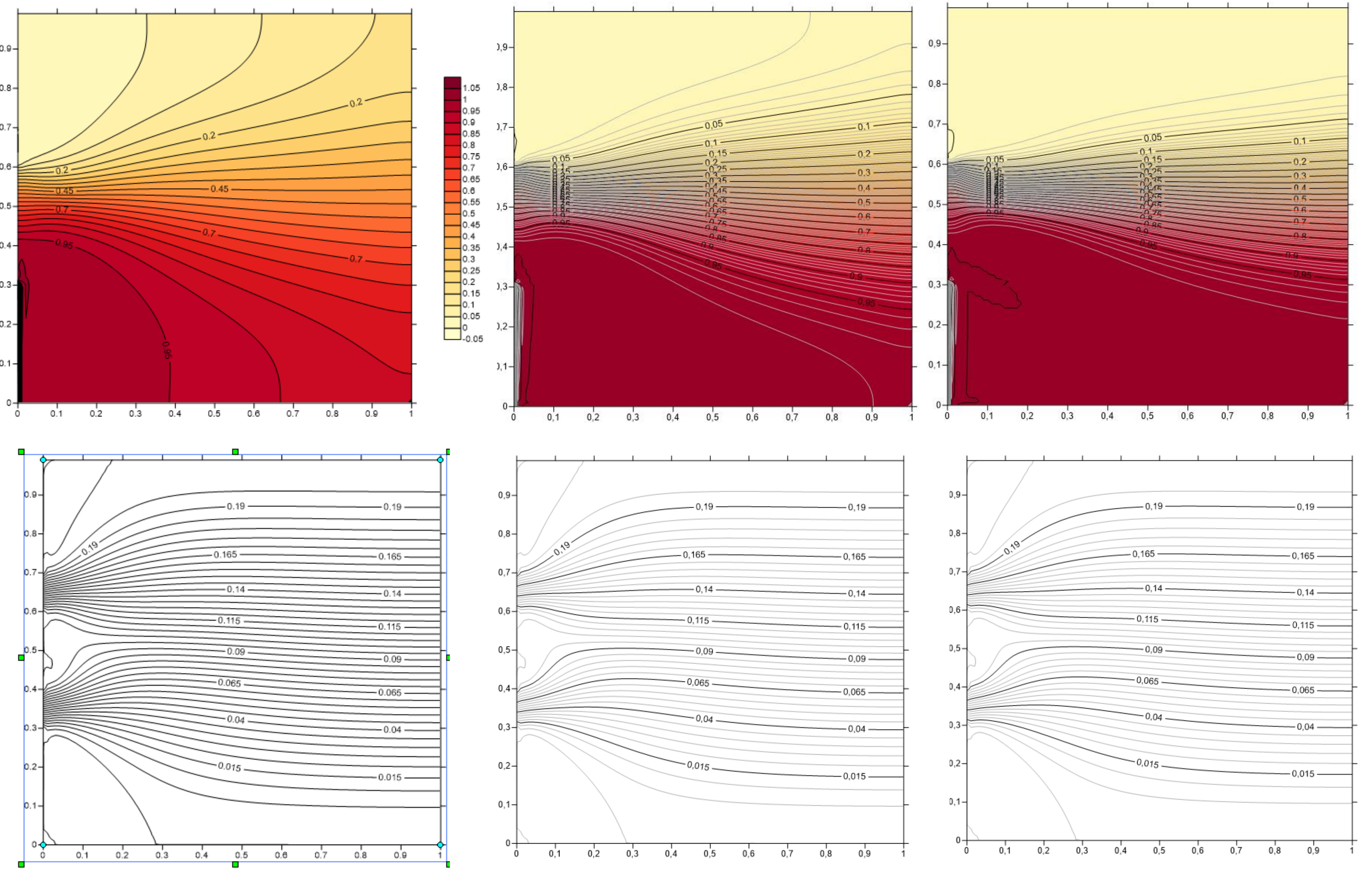


**Pr=1 Gr=0**



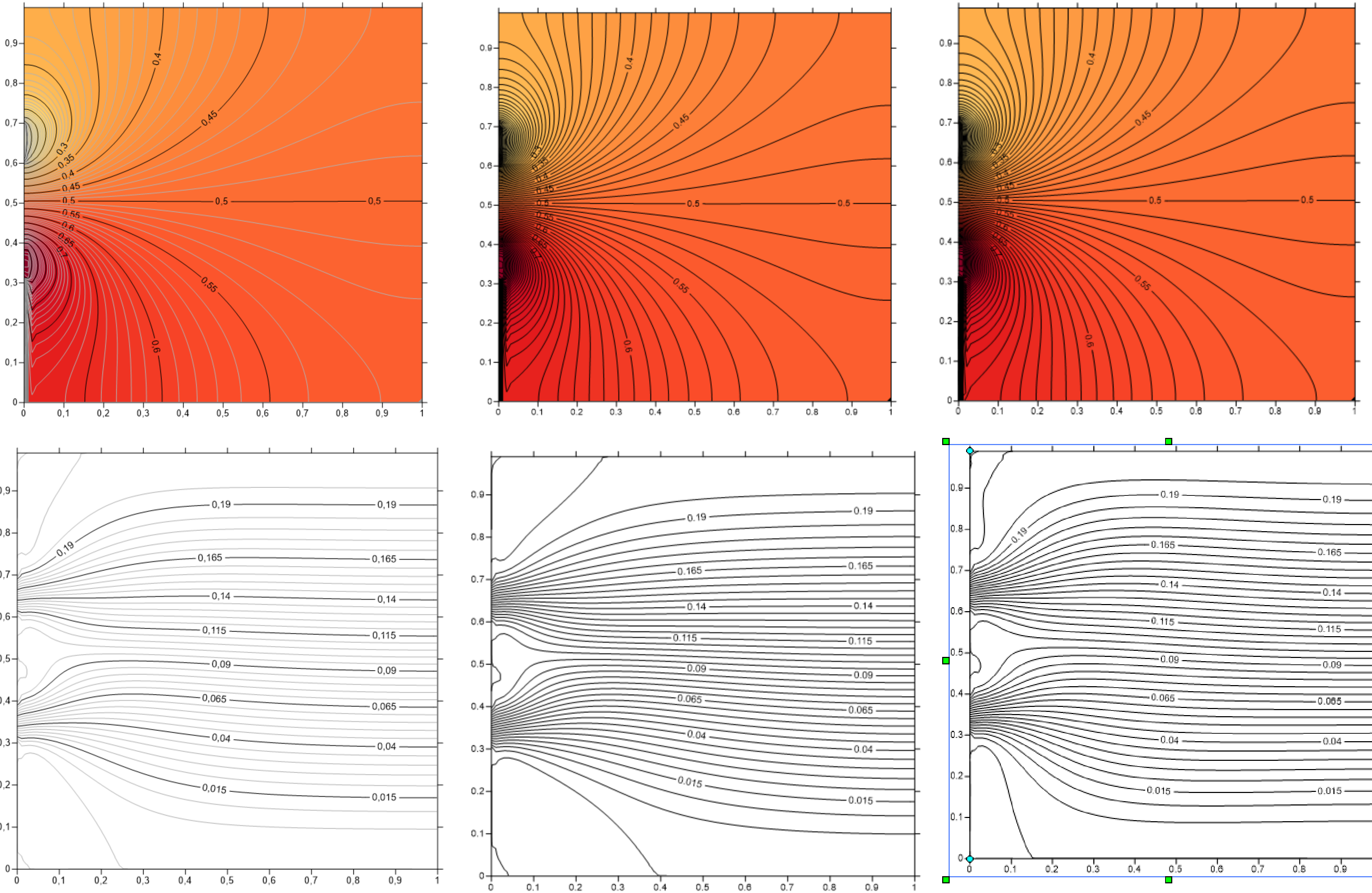
Re=1 Re=50 Re=80

Re=10 Gr=0



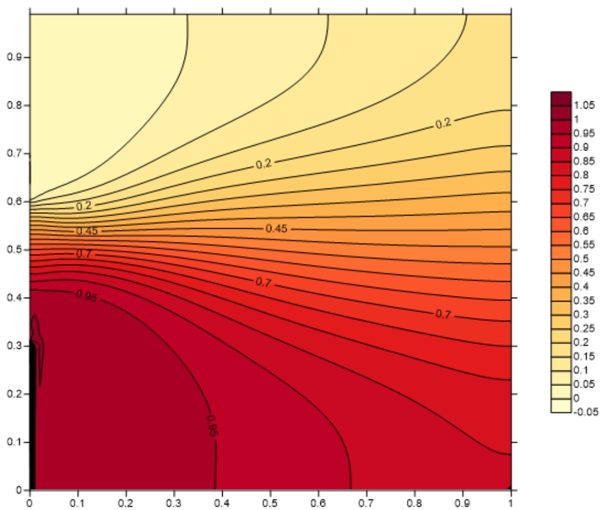

Pr=10 Pr=30 Pr=50

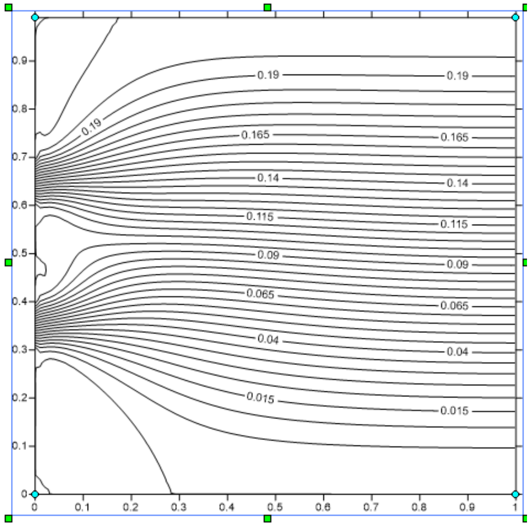
# Re=1Pr=1



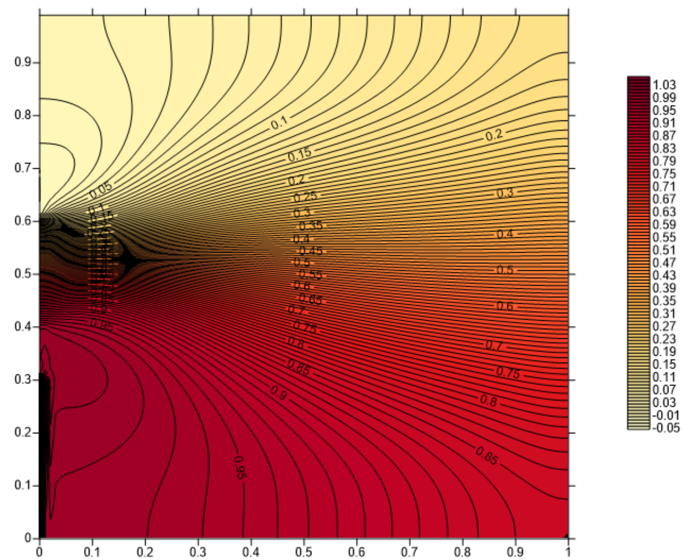

Gr=0 Gr=100 Gr=-100

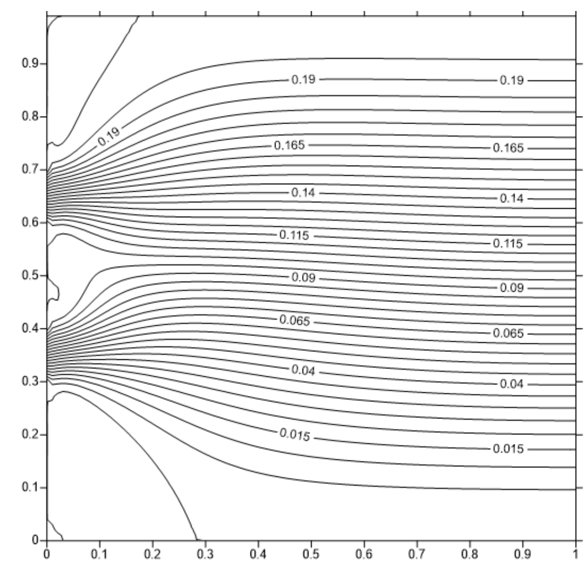
# Re=10 Pr=10 Gr=0





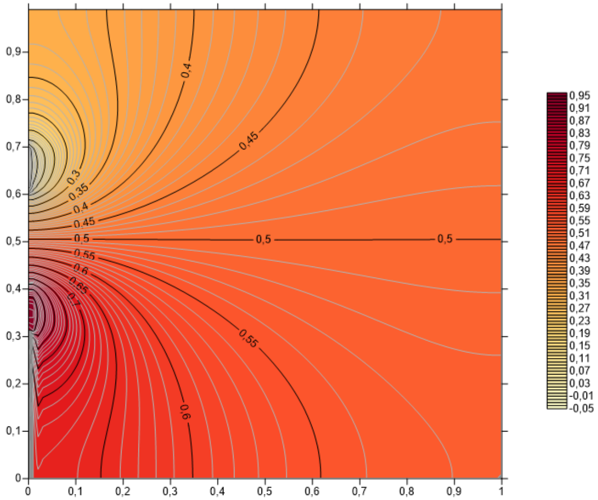
Ux1=1 Ux2=1

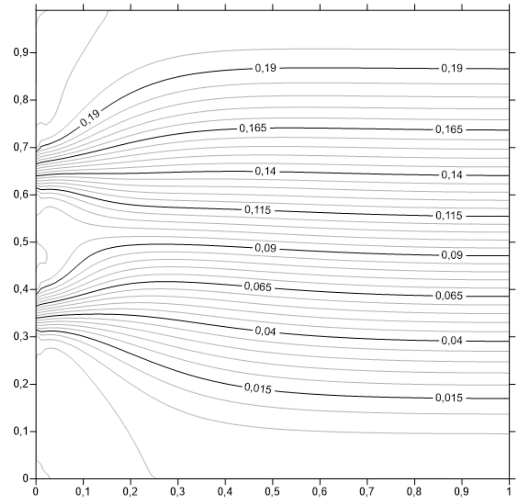




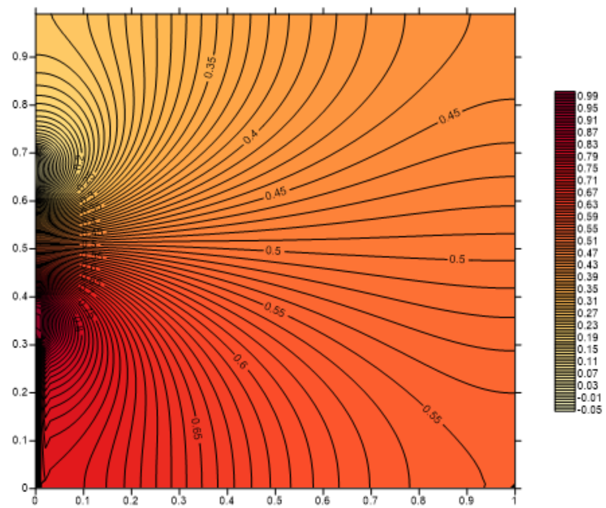
Ux1=1 Ux2=0.5

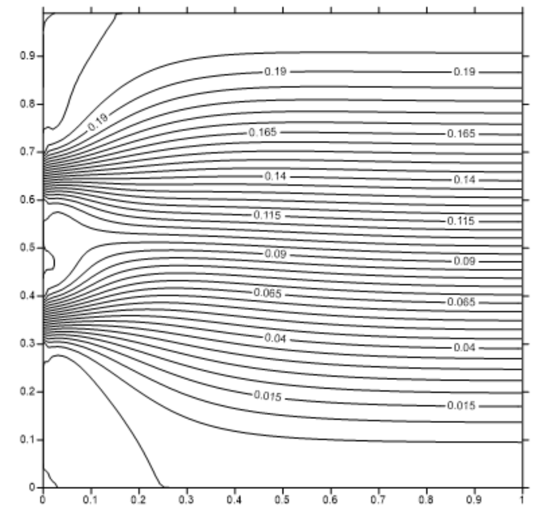
# Re=1 Pr=10 Gr=0



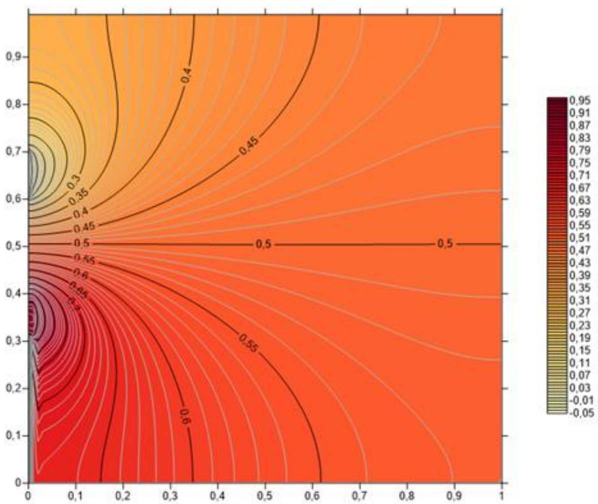

Ux1=1 Ux2=1

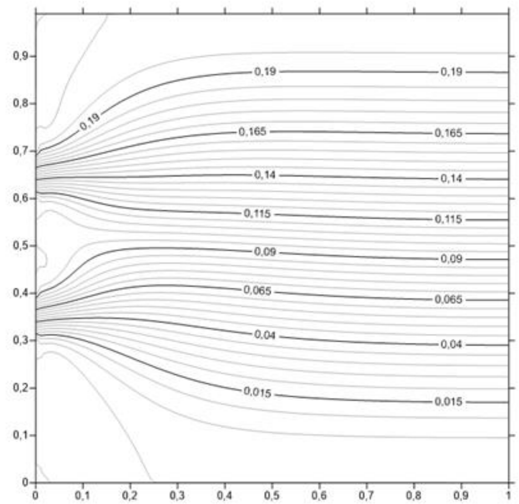


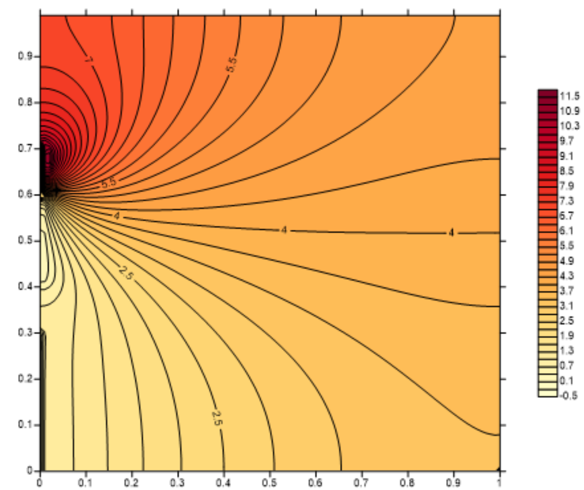

Ux1=1 Ux2=0.5

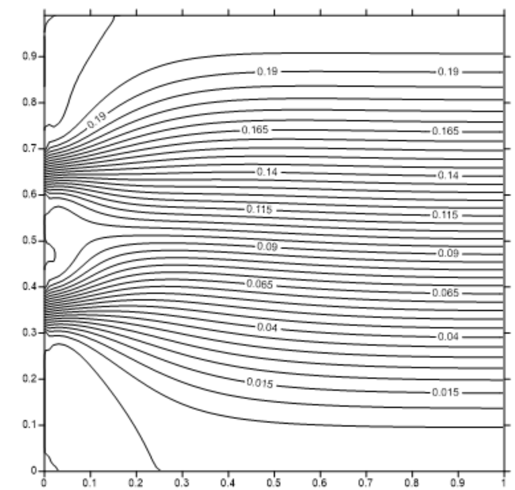
# Re=1 Pr=10 Gr=0





θ1=1 θ2=0





θ1=0 θ2=1