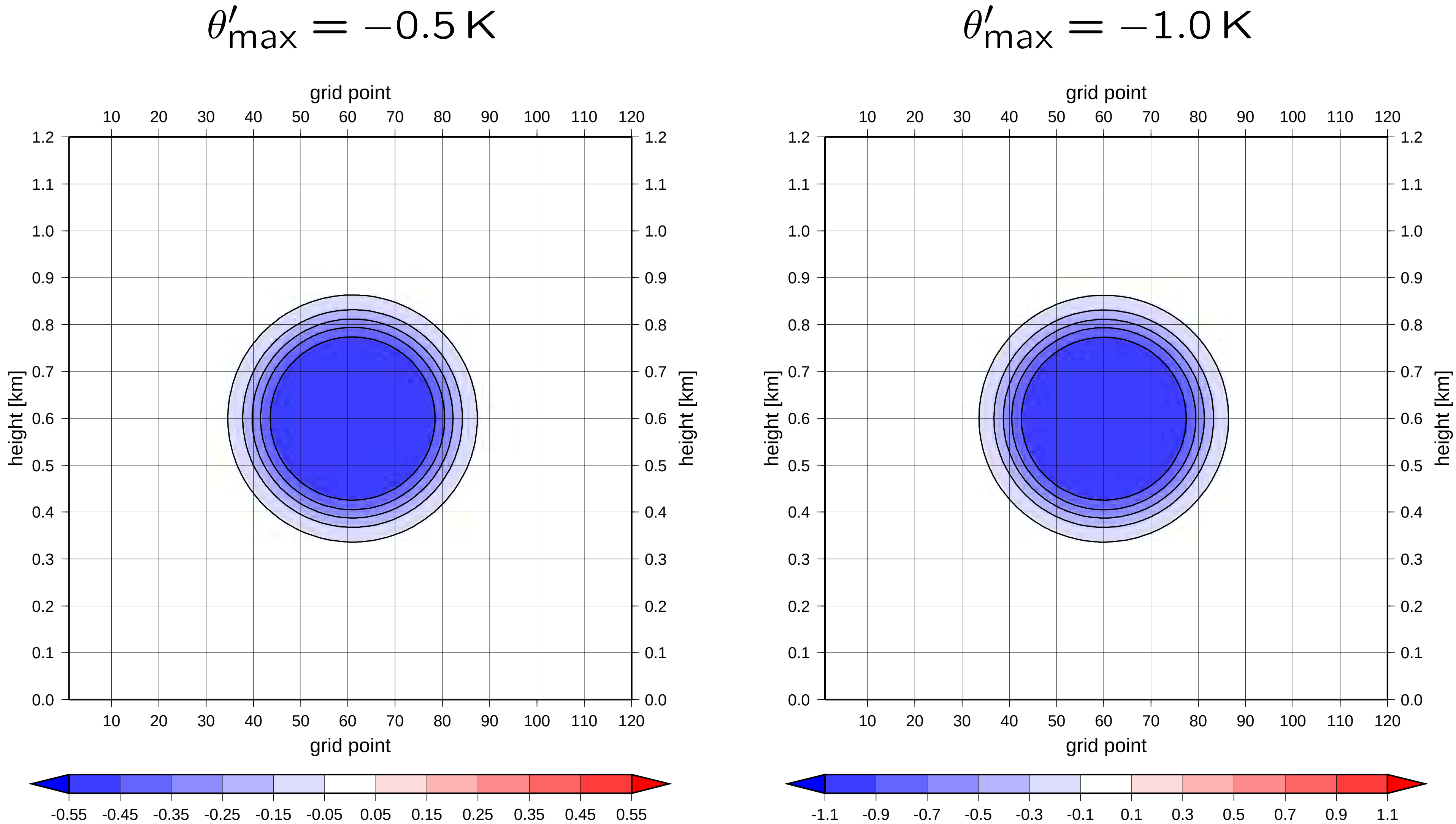
# Non-linearity of bubble flow

- experimental framework:
  - dry and adiabatic atmosphere, fully characterized by state vector $X = (p, \theta, u, v, w)$
  - stationary background state $\overline{X}$ (resting, neutrally stratified with $\overline{\theta} = 300\,\mathrm{K}$)
  - bubble shaped perturbation in initial $\theta$ field
  - no initial perturbation in pressure and velocity fields

- in linear regime, doubling of initial perturbation $X'(t_0)$ doubles the response $X'(t)$

- animation shows that this is not the case for bubble flow, as soon as longer evolution times are concerned

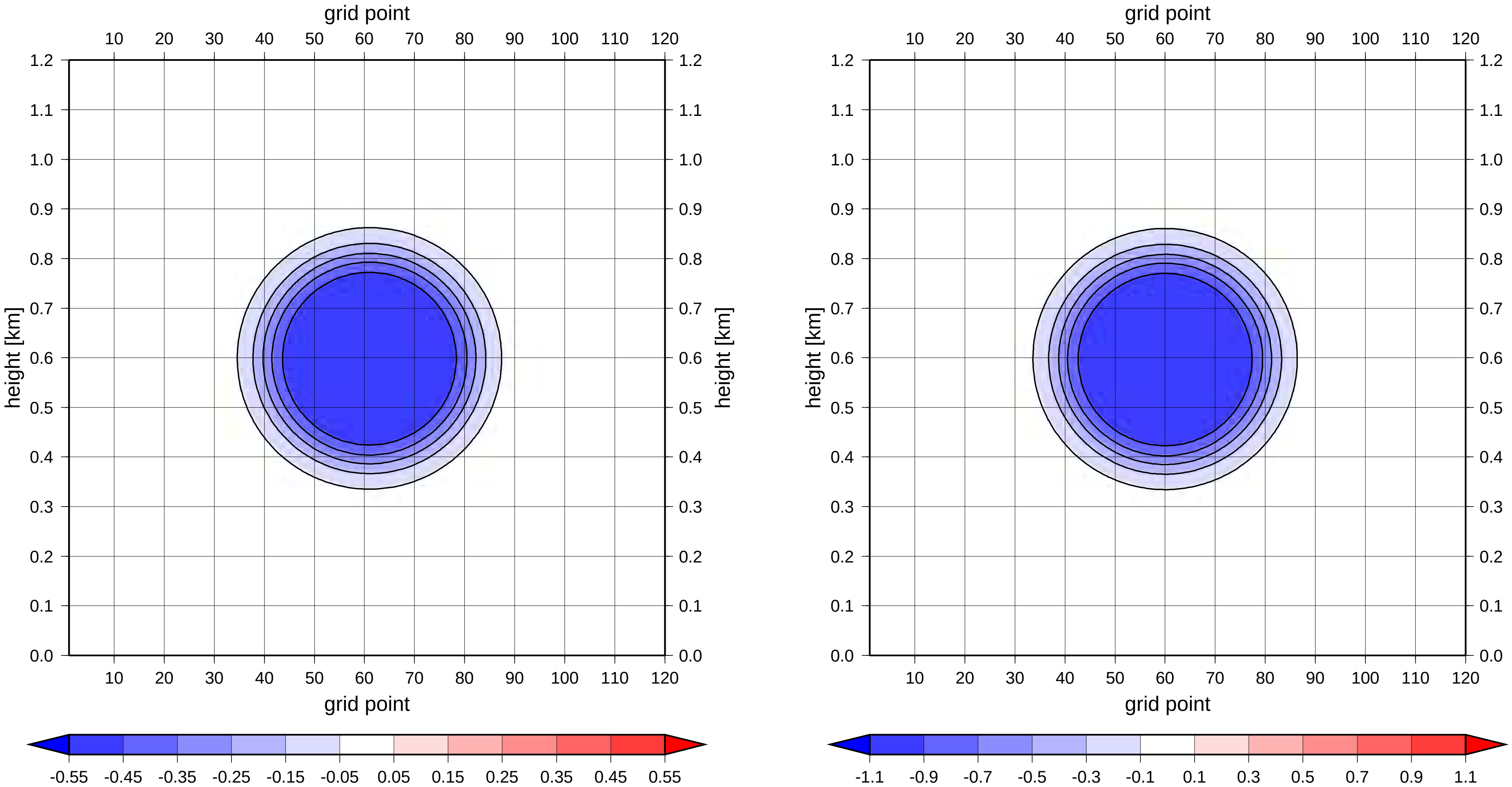
# perturbation of potential temperature $\theta'$




$\Delta x = \Delta z = 10\,\mathrm{m},\ t = 0\,\mathrm{s}$

perturbation of potential temperature $\theta'$

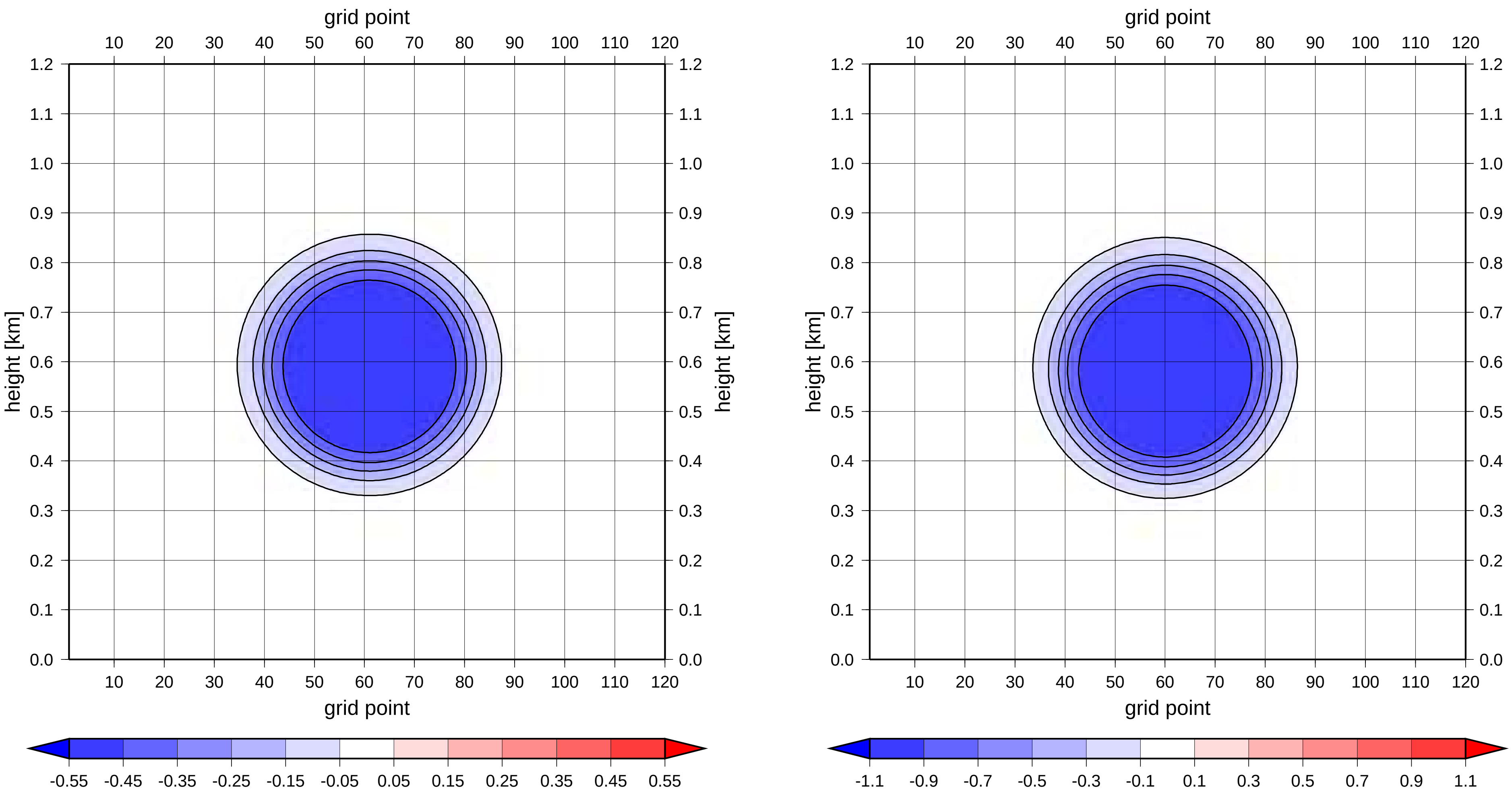
$\theta'_{\mathrm{max}} = -0.5\,\mathrm{K}$ $\qquad$ $\theta'_{\mathrm{max}} = -1.0\,\mathrm{K}$




$\Delta x = \Delta z = 10\,\mathrm{m},\ t = 20\,\mathrm{s}$

# perturbation of potential temperature $\theta'$

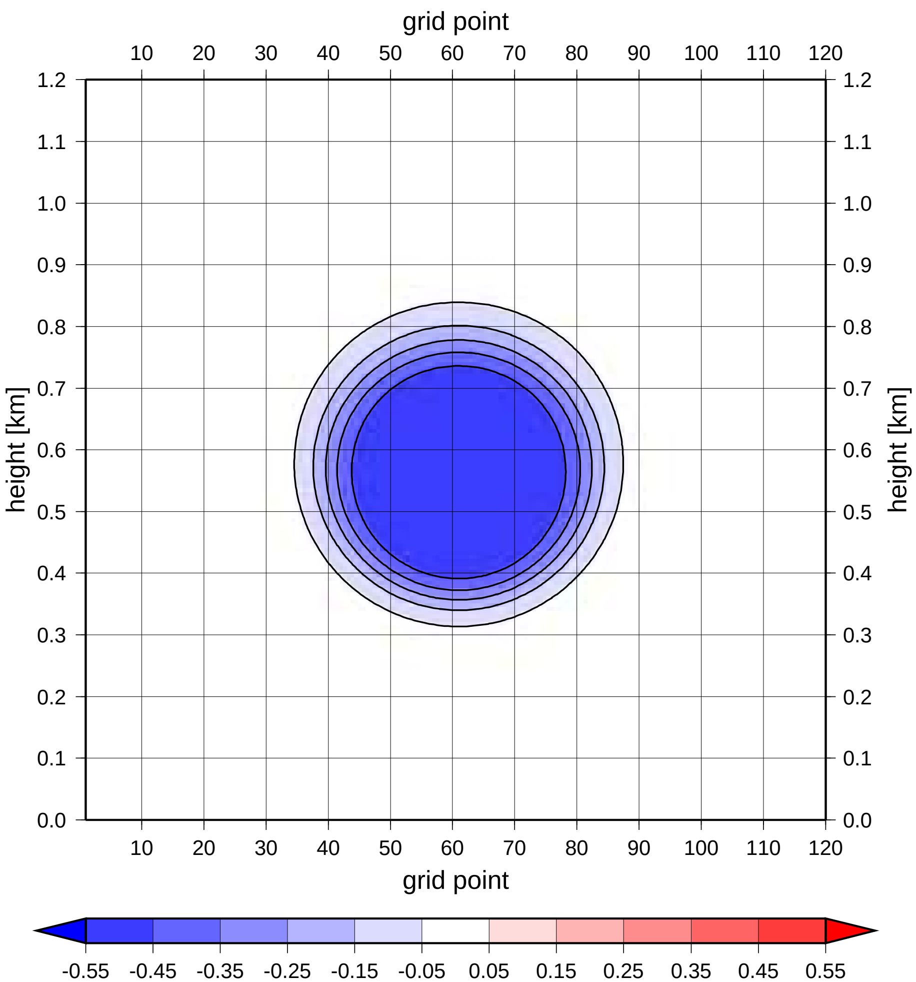
$\theta'_{\text{max}} = -0.5\,\text{K}$ $\theta'_{\text{max}} = -1.0\,\text{K}$



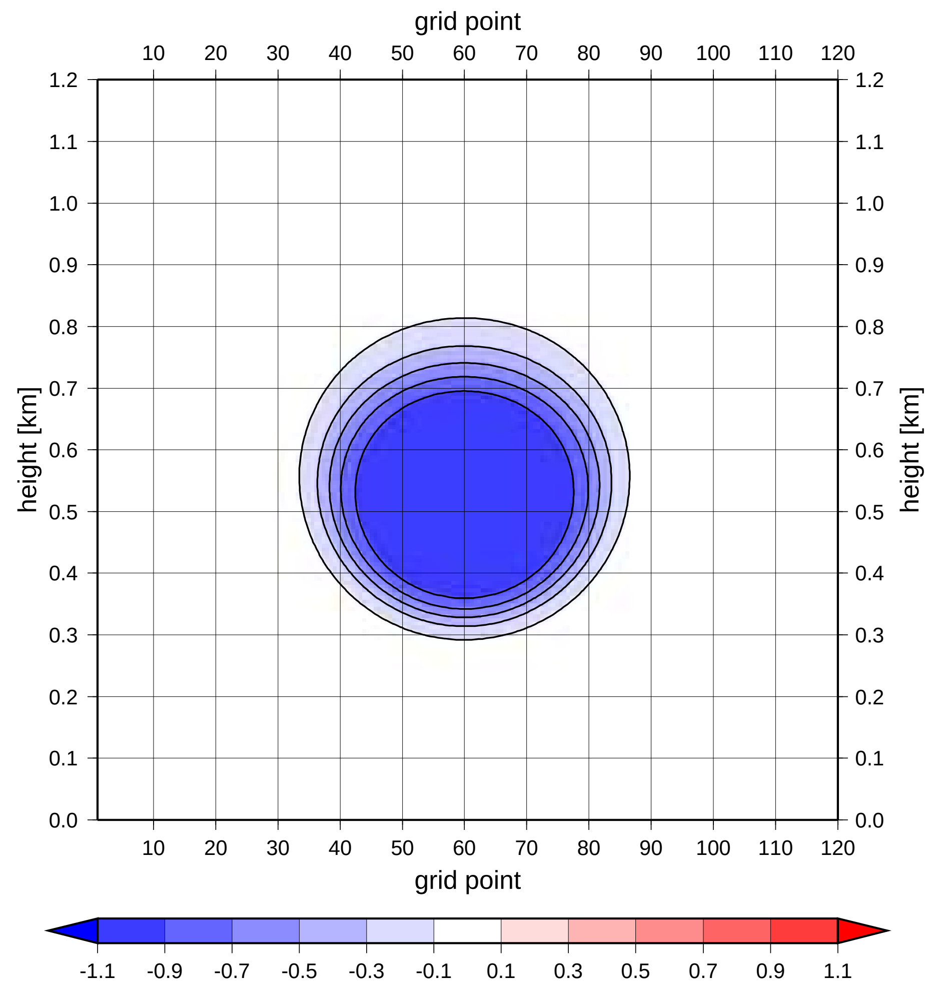

$\Delta x = \Delta z = 10\,\text{m},\ t = 50\,\text{s}$

# perturbation of potential temperature $\theta'$

$\theta'_{\mathrm{max}} = -0.5\,\mathrm{K}$



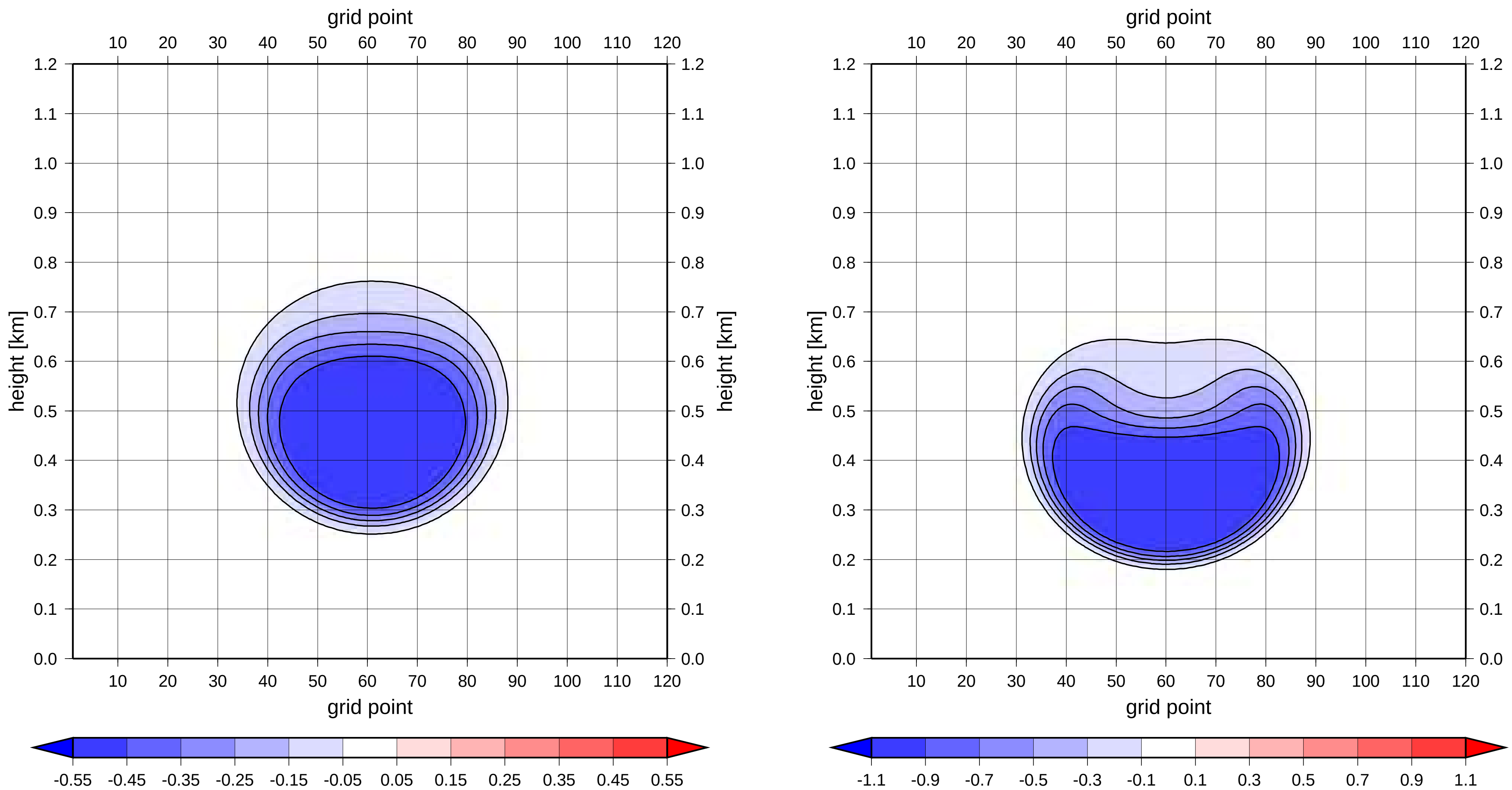

$\theta'_{\mathrm{max}} = -1.0\,\mathrm{K}$




$$\Delta x = \Delta z = 10\,\mathrm{m},\ t = 100\,\mathrm{s}$$

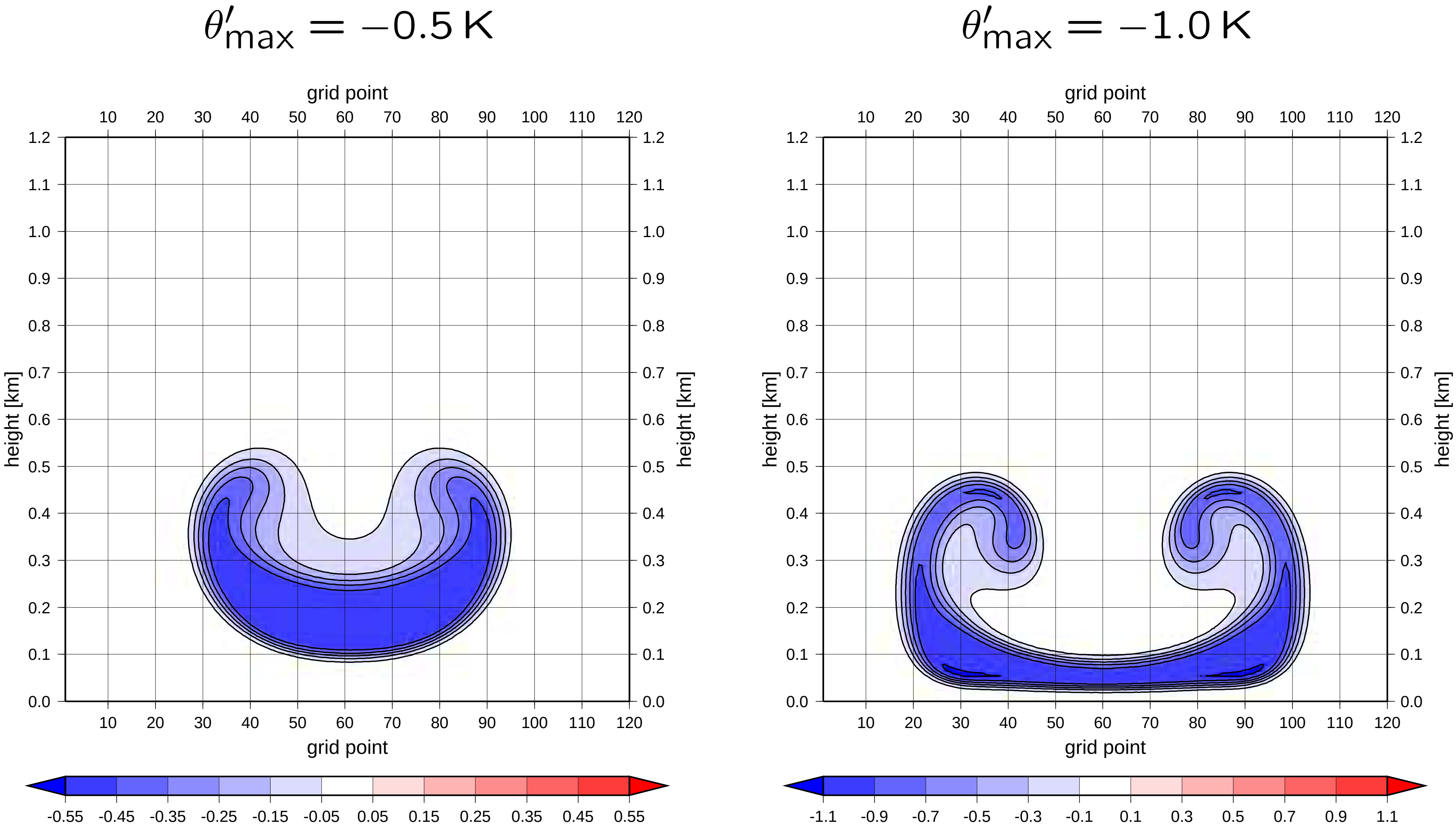
perturbation of potential temperature $\theta'$

$\theta'_{\mathrm{max}} = -0.5\,\mathrm{K}$ $\theta'_{\mathrm{max}} = -1.0\,\mathrm{K}$




$$\Delta x = \Delta z = 10\,\mathrm{m},\ t = 200\,\mathrm{s}$$

perturbation of potential temperature $\theta'$

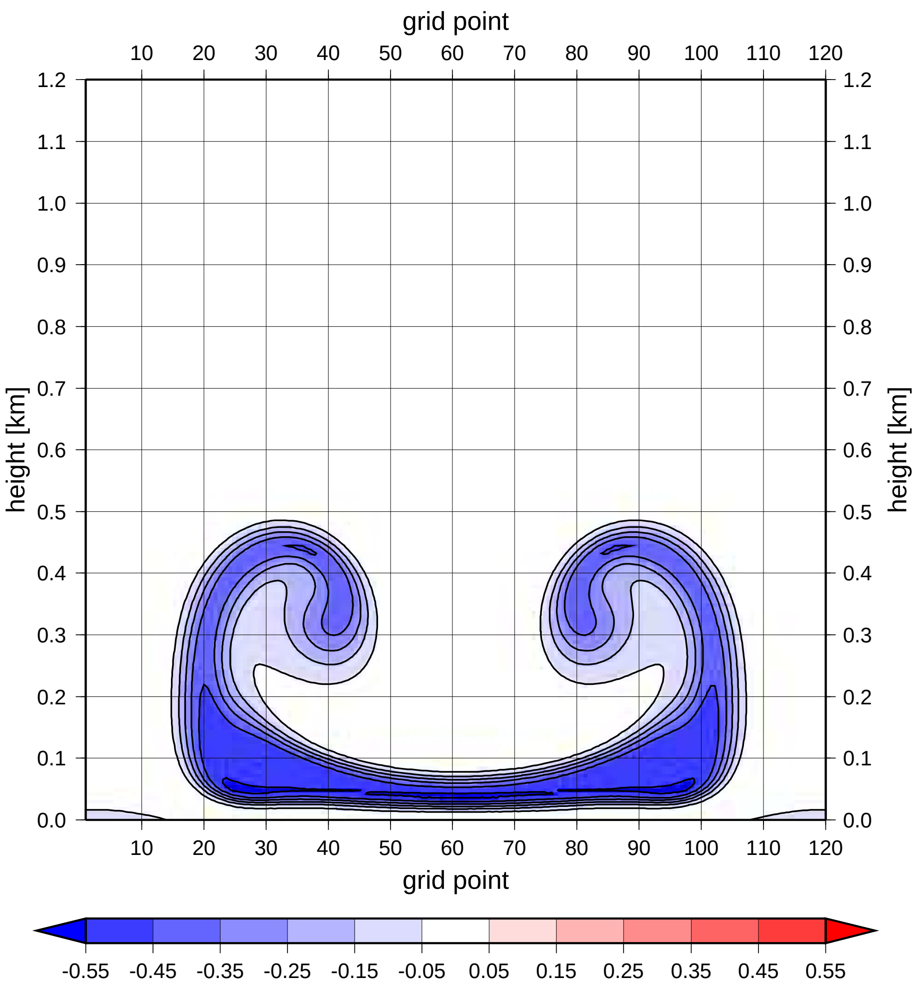


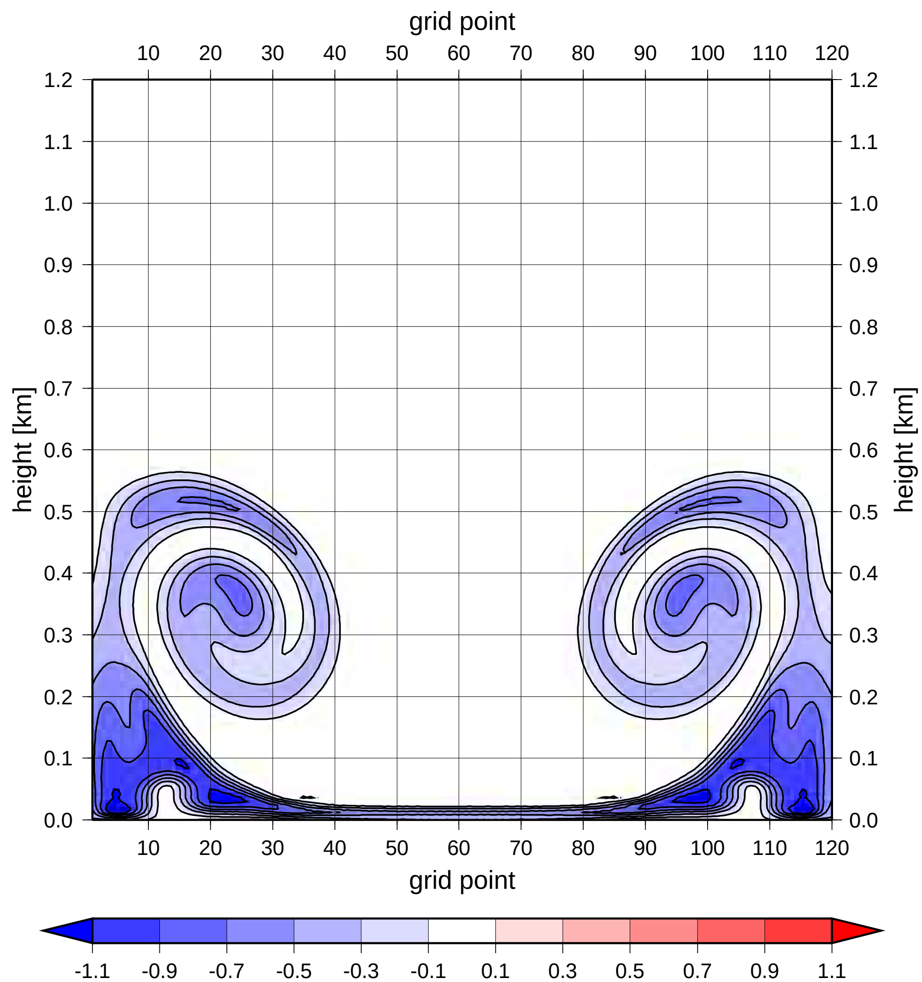

$\Delta x = \Delta z = 10\,\mathrm{m},\ t = 400\,\mathrm{s}$

perturbation of potential temperature $\theta'$

$\theta'_{\mathrm{max}} = -0.5\,\mathrm{K}$

$\theta'_{\mathrm{max}} = -1.0\,\mathrm{K}$




$$\Delta x = \Delta z = 10\,\mathrm{m},\ t = 600\,\mathrm{s}$$