Tutorials

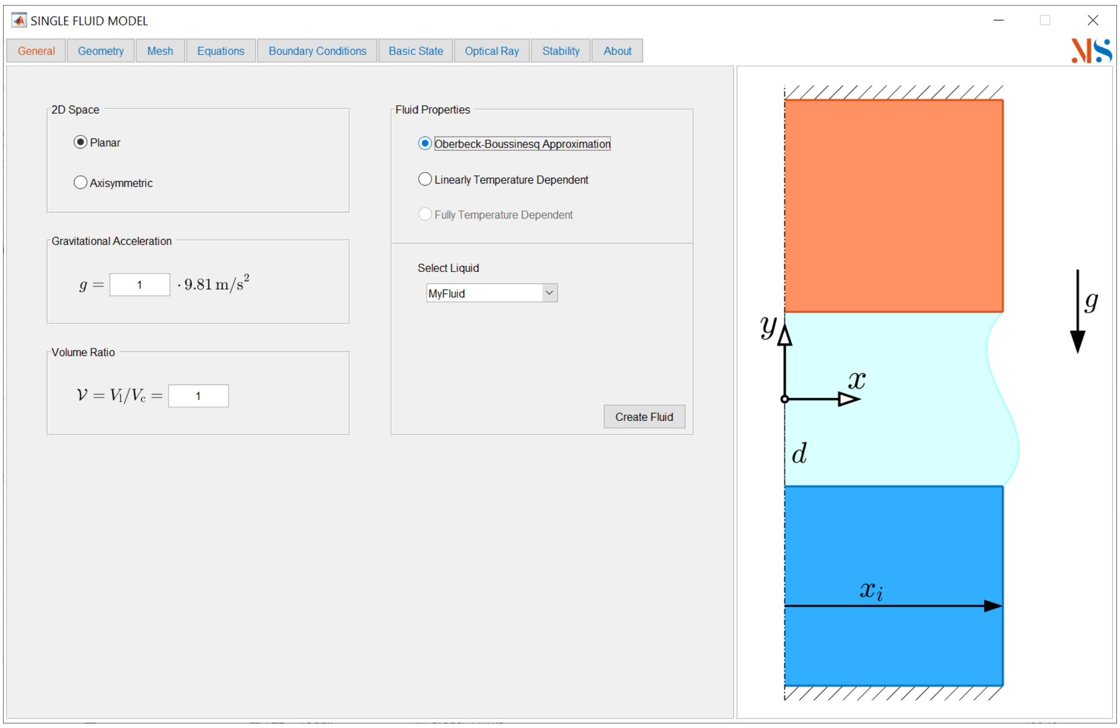
The tutorials presented hereinafter are intended as a guide to the user with the main features implemented in `MaranStable`. The GUI `MaranStable` is started by running the file `main.m` with Matlab 2022 or a more recent version.

1 Rayleigh–Bénard instability

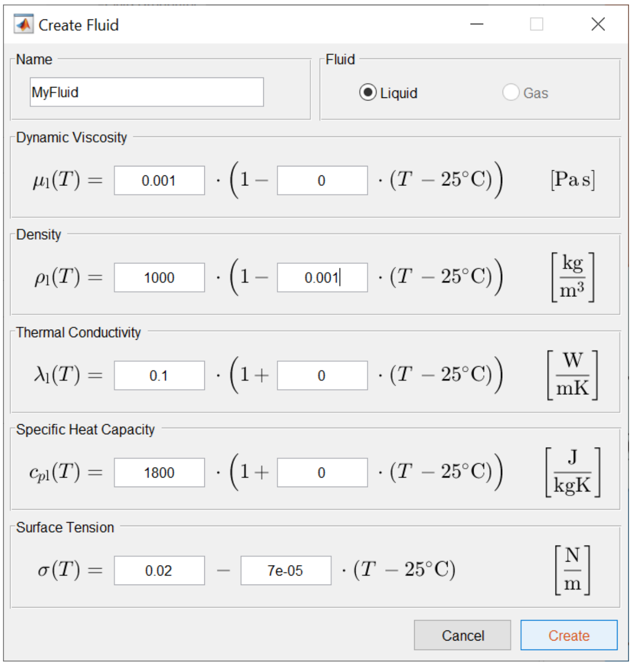
The first tutorial deals with the Rayleigh–Bénard problem, i.e. the instability of a quiescent fluid layer heated from. Here we consider a planar geometry laterally confined by slip walls as a substitute for an infinite layer. This tutorial corresponds to the file `example_1.mat` in the folder `tutorials`.

- Select the single-phase solver

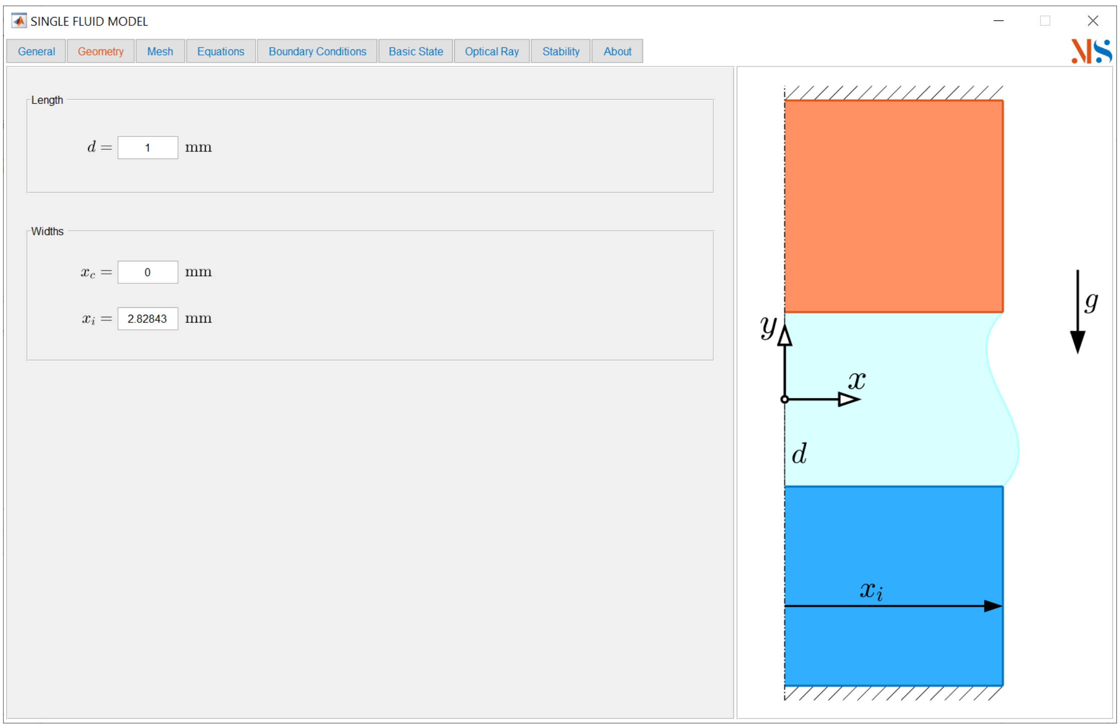
- Set up the planar geometry and the gravitational acceleration. Since we consider a rectangular domain, the volume ratio is set to $\mathcal{V} = 1$. Select the Oberbeck–Boussinesq approximation as physical model.



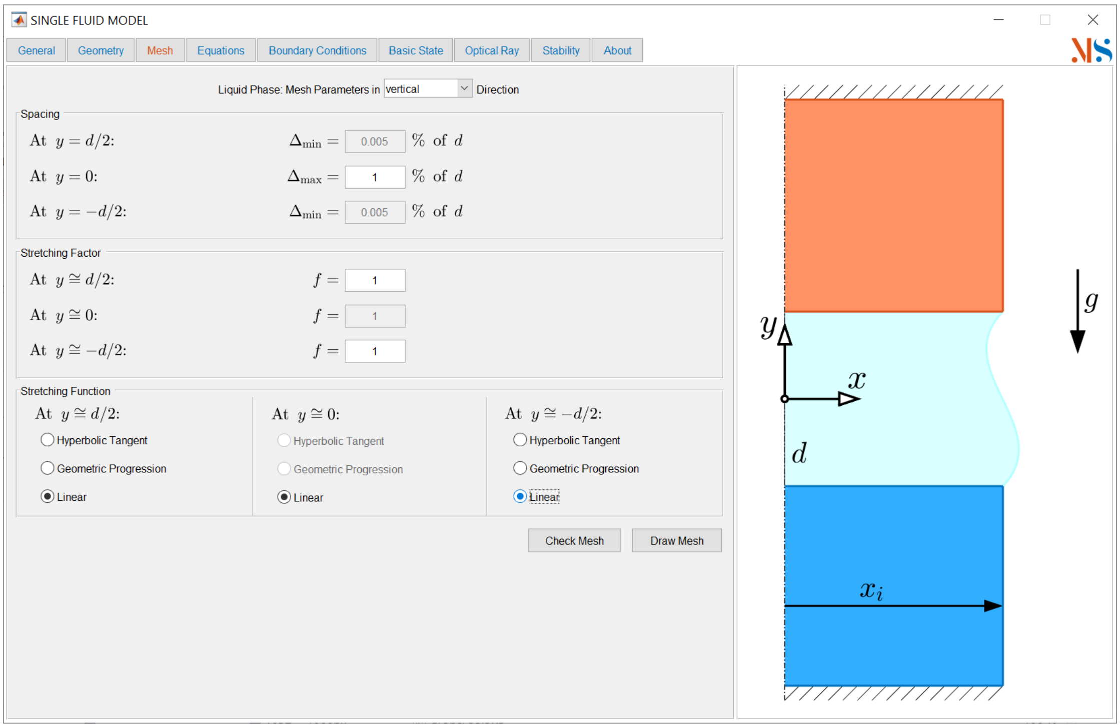
- Set up a new fluid by clicking on `Create Fluid`. The parameters are set as follows. Then click `Create`.

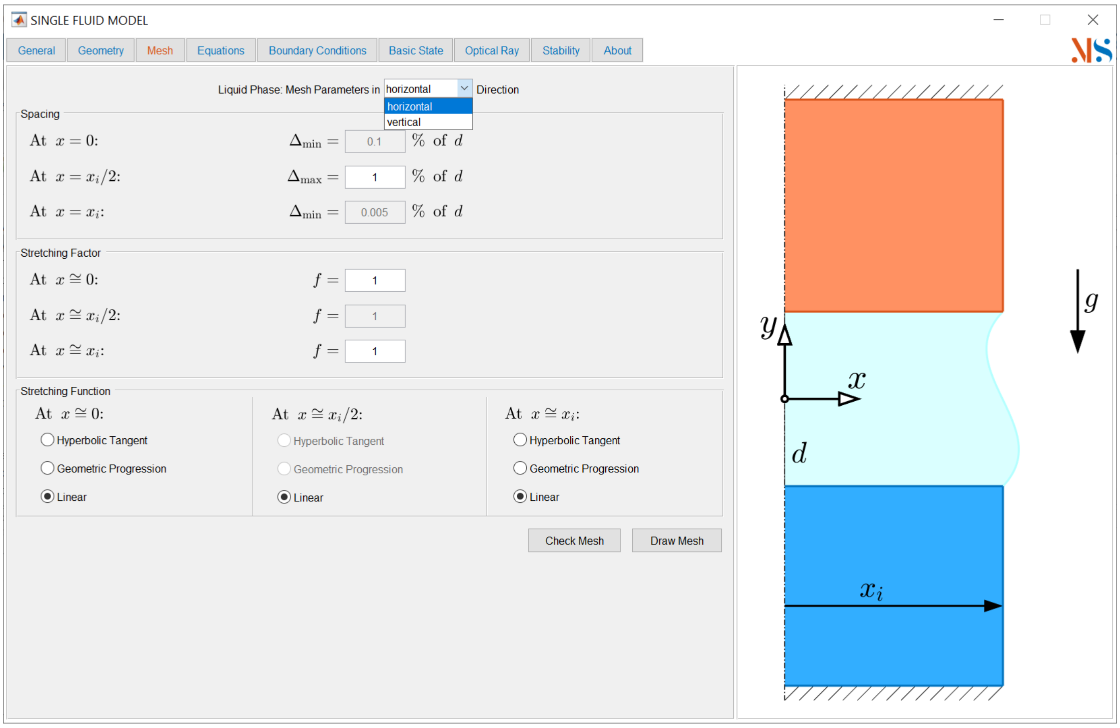


- Set up the planar geometry as follows. The values are selected to coincide with the critical wavelength ($\lambda_c = 2\sqrt{2} = 2.82843$) of the Rayleigh–Bénard instability for free slip on the horizontal boundaries.

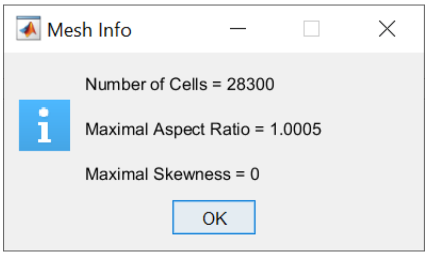


- Set up the mesh as shown below (both horizontal and vertical coordinates must be discretized). You can change the discretization parameters if a finer resolution is needed.

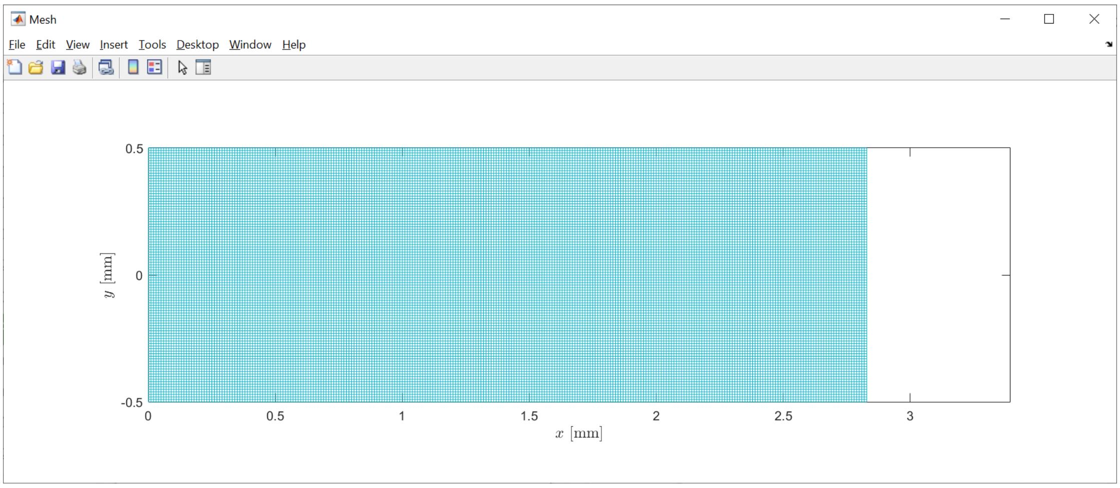




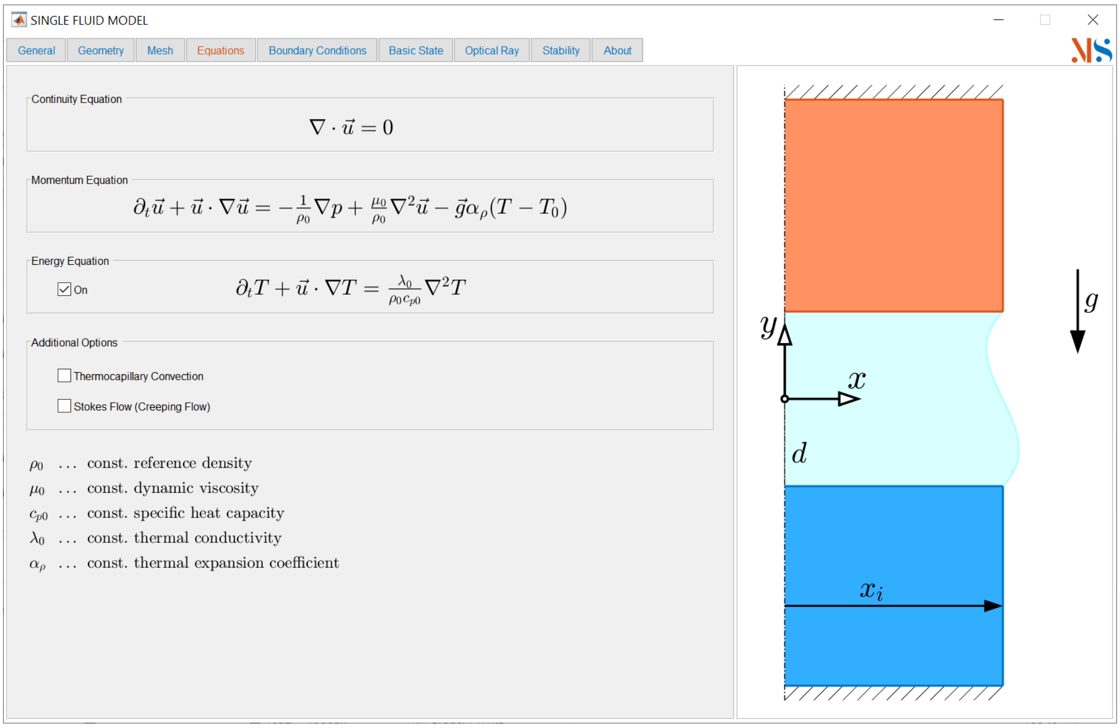
- Click on `Check Mesh`



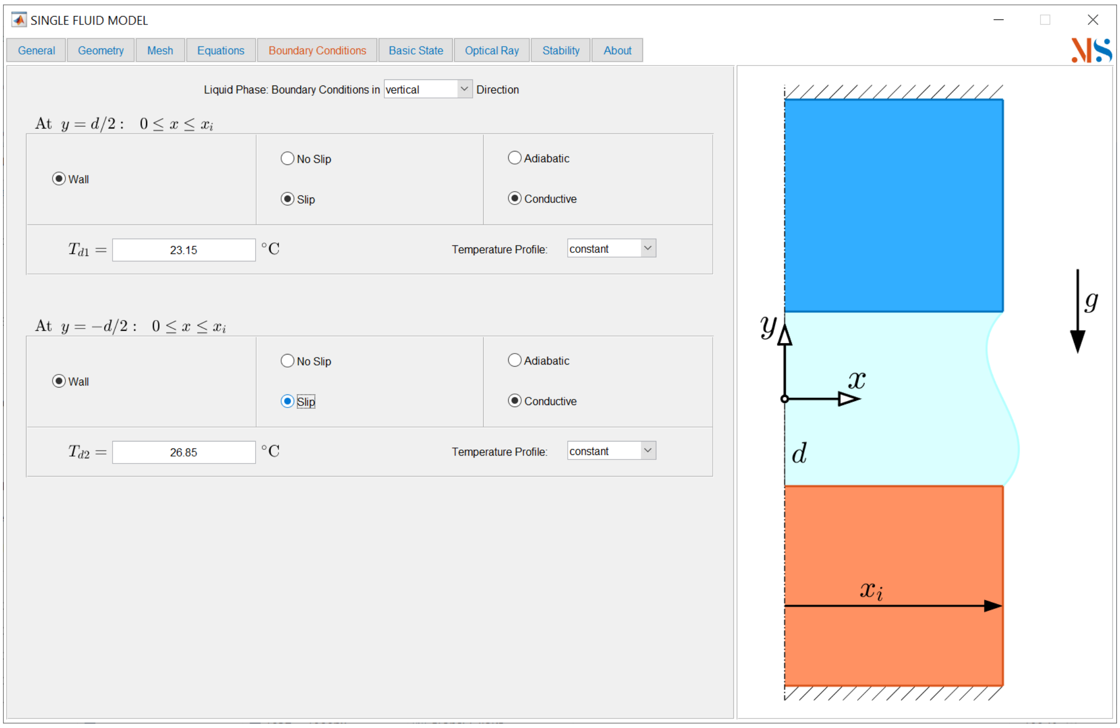
- Visualize the mesh by clicking `Plot Mesh`

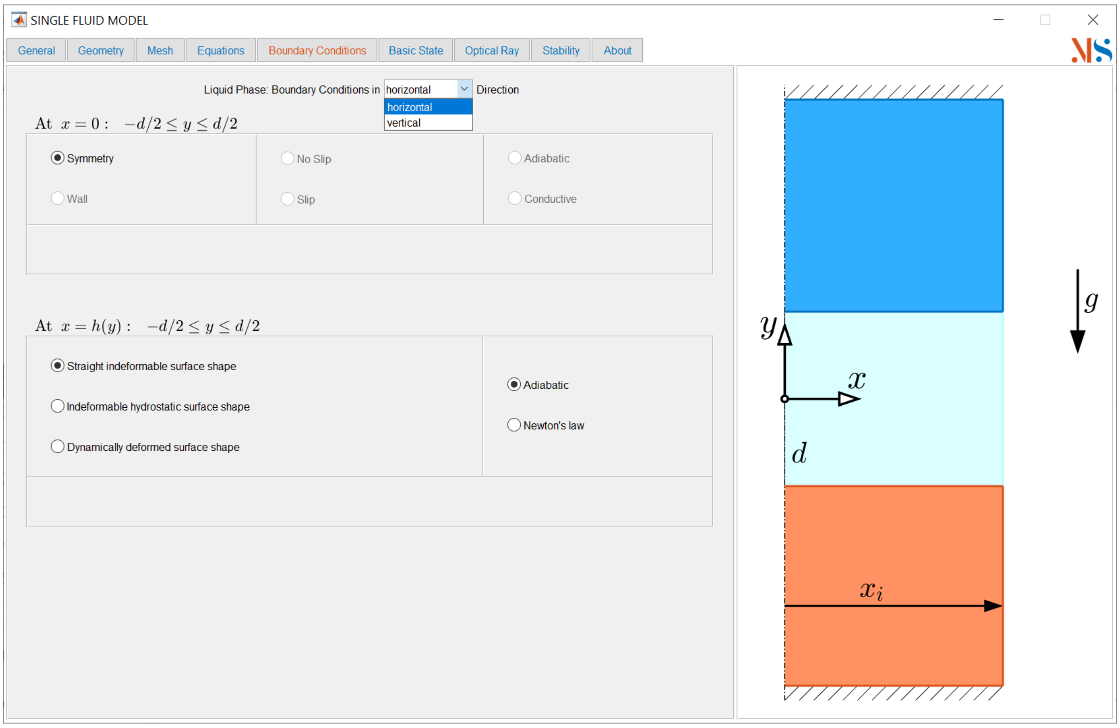


- Leave the energy equation enabled and pay attention to unticking the thermocapillary convection.

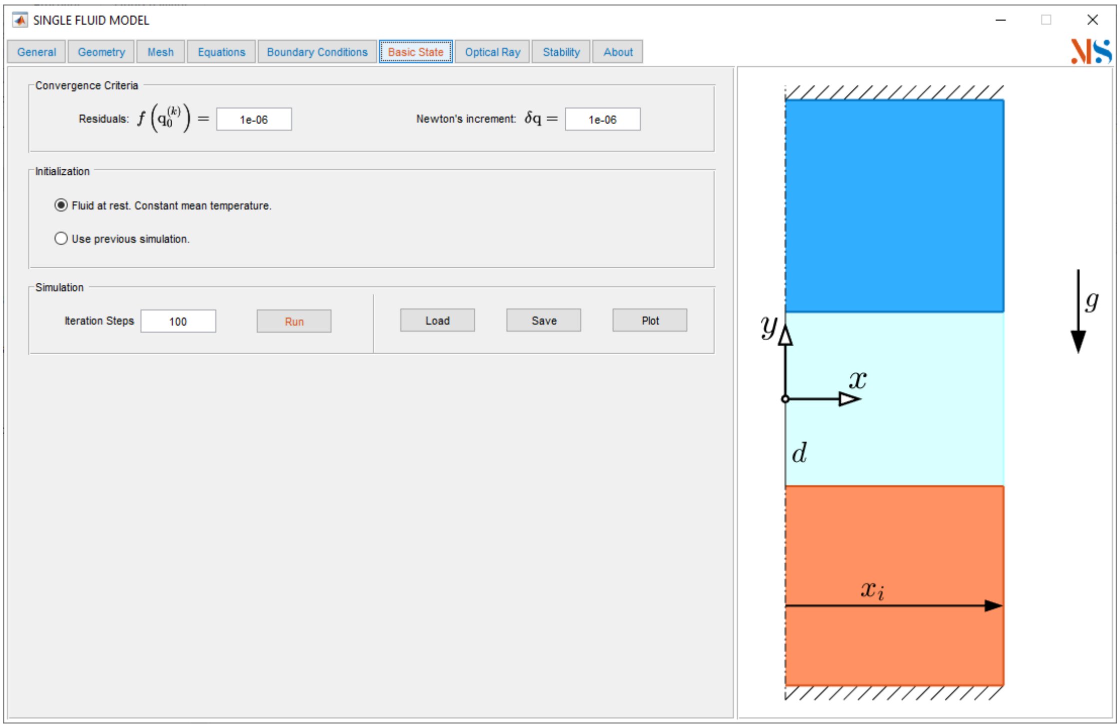


- Set the boundary conditions in the horizontal and vertical directions. Prohibit surface deformations by ticking the box `Straight indeformable surface shape`.

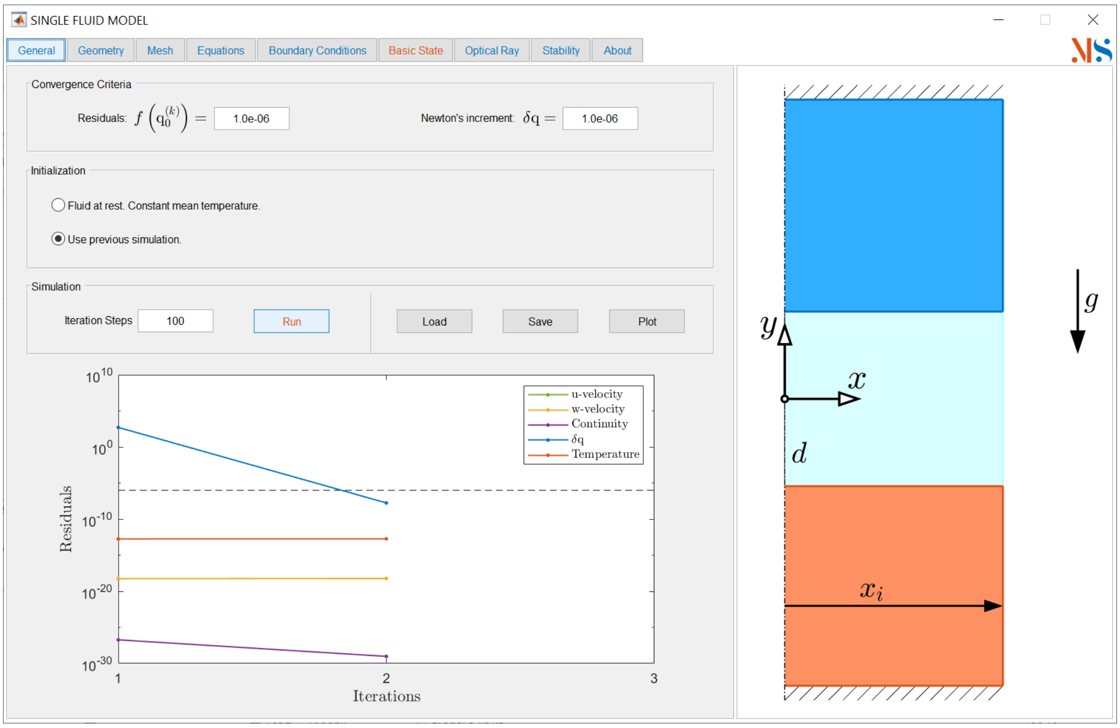




- Set the tolerances of the residuals for the Newton solver and the solution increments.

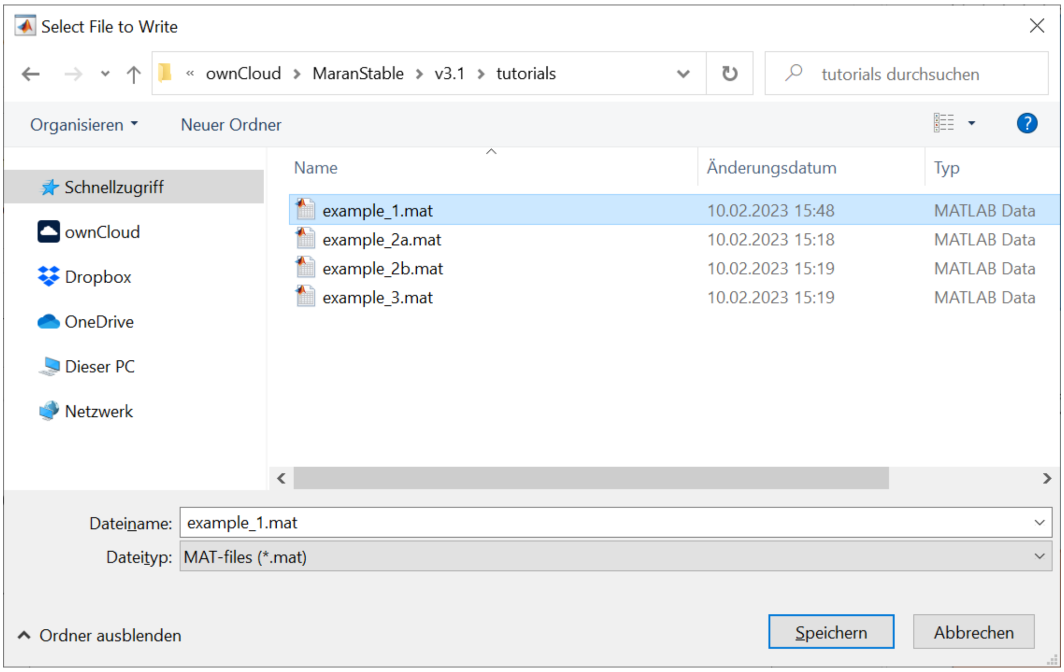


- Solve the basic state by clicking on `Run`.

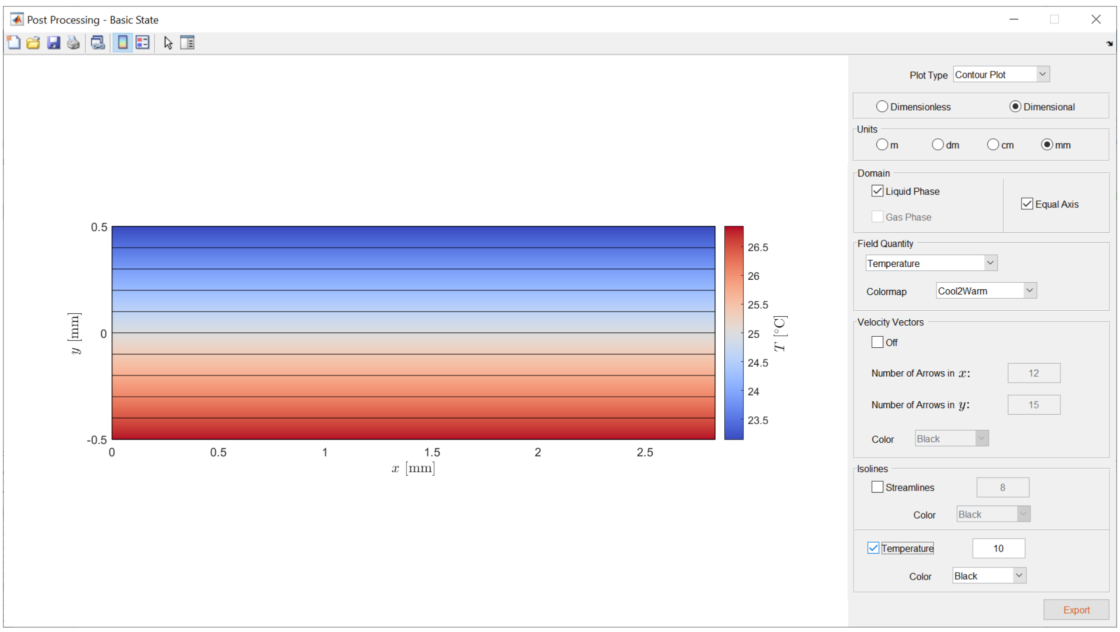


- Upon convergence, `MaranStable` will provide the message:

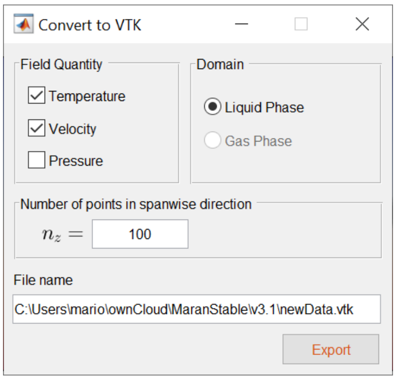
- Click on `Save` to store the converged basic state just computed.



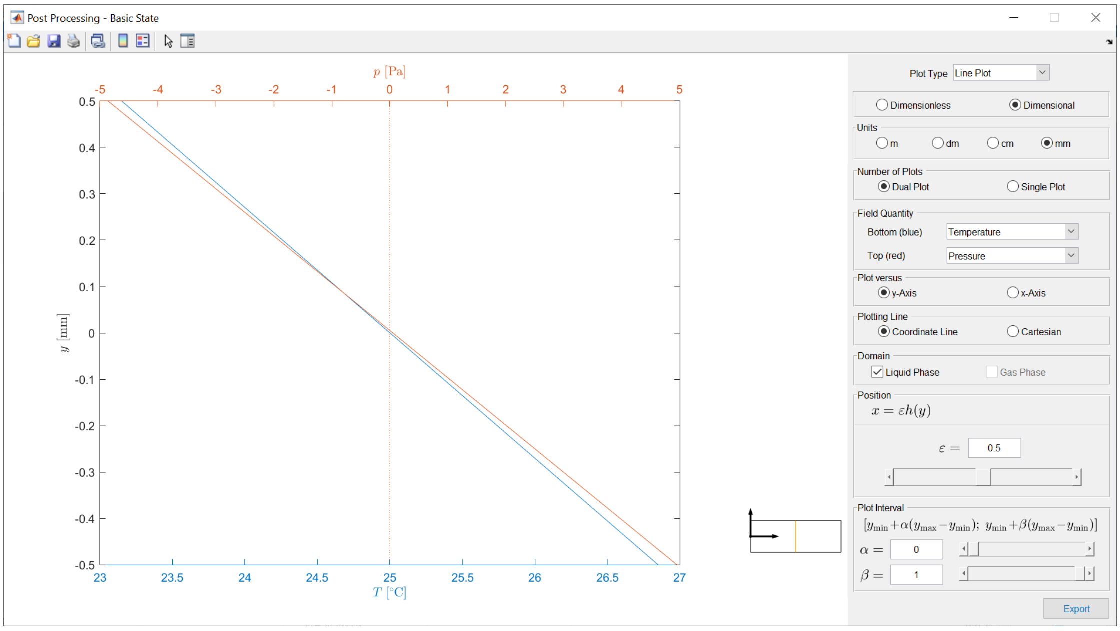
- Click on `Plot` to visualize the basic state. Choose the desired field quantity and enable or disable velocity vectors and/or isolines.



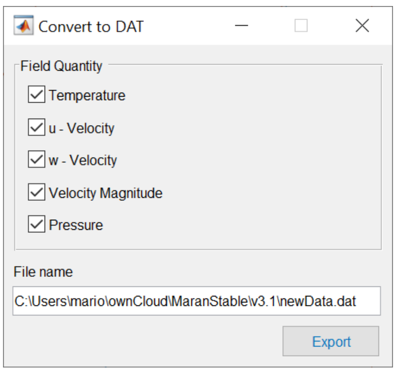
- Click on `Export` to export the solution in vtk format (compatible with ParaView).



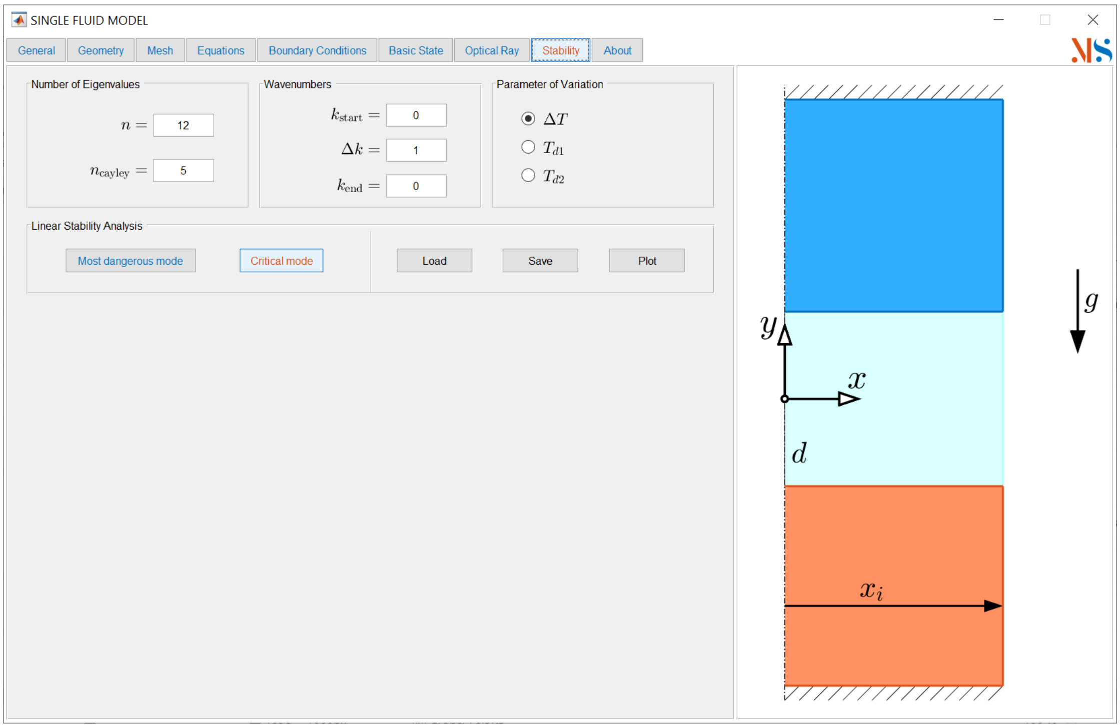
- Change the plot type to `Line Plot` and change the position (location at which the data are evaluated, yellow line) to $\varepsilon = 0.5$ to visualize the temperature and pressure at the vertical midplane.



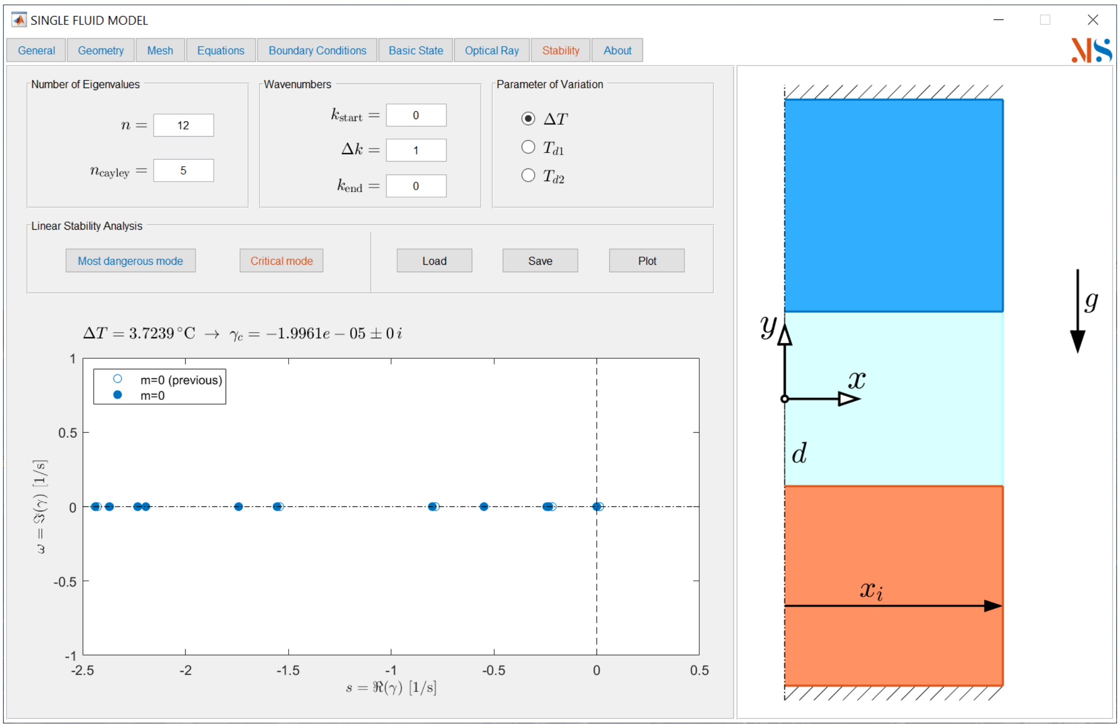
- Click on `Export` to export the solution in dat format (compatible with Xmgrace, Matlab, Excel, etc.).



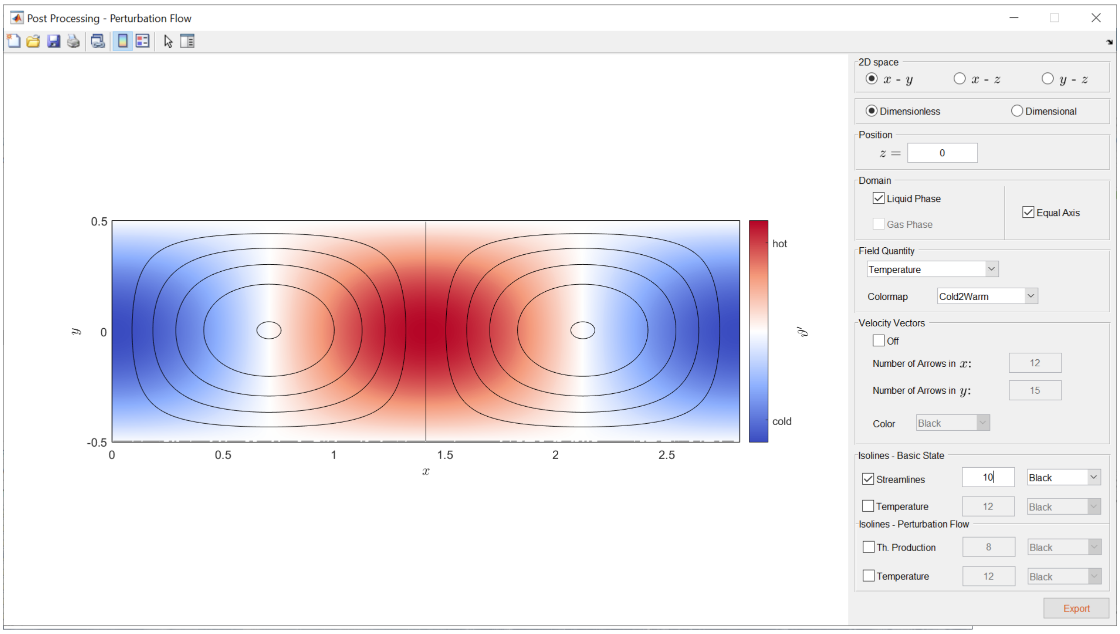
- Set up the parameters for carrying out the stability analysis. The wave number k corresponds to the homogeneous z-direction. Note: Here this is a different direction for the wavelength λ_c above, which was in the y-direction.



- Solve the linear stability analysis by clicking on `Critical Mode`. Here it arises for $k = 0$ which corresponds to a single pair (one wavelength in y direction selected above) of straight convection rolls which are infinitely extended in the z direction.



- Click on `Plot` to visualize the most critical mode

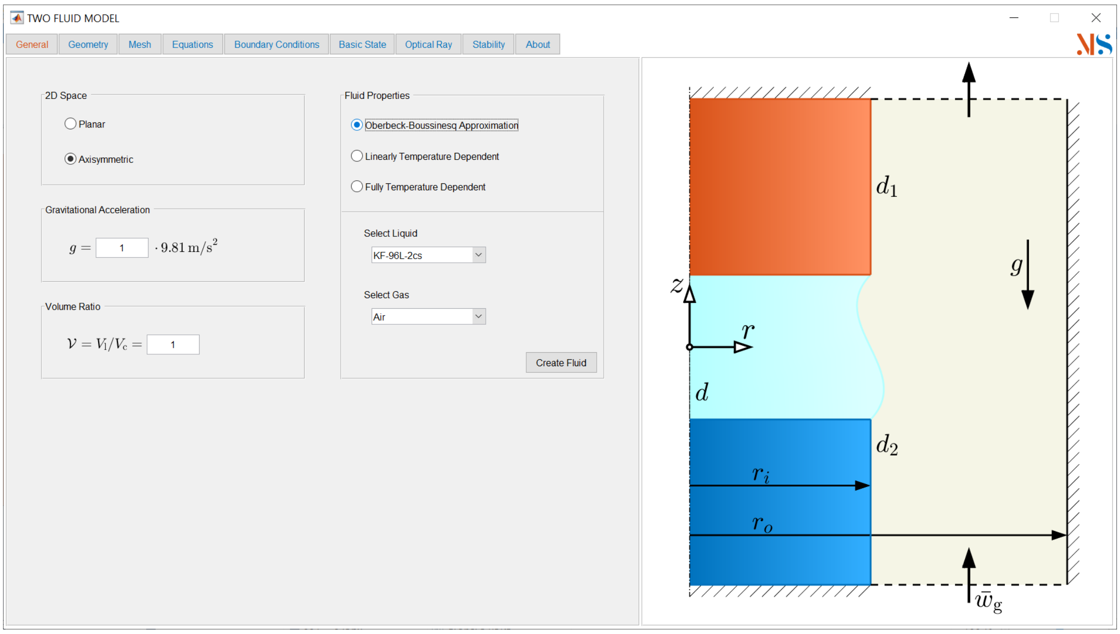


2 Instability of thermocapillary flow

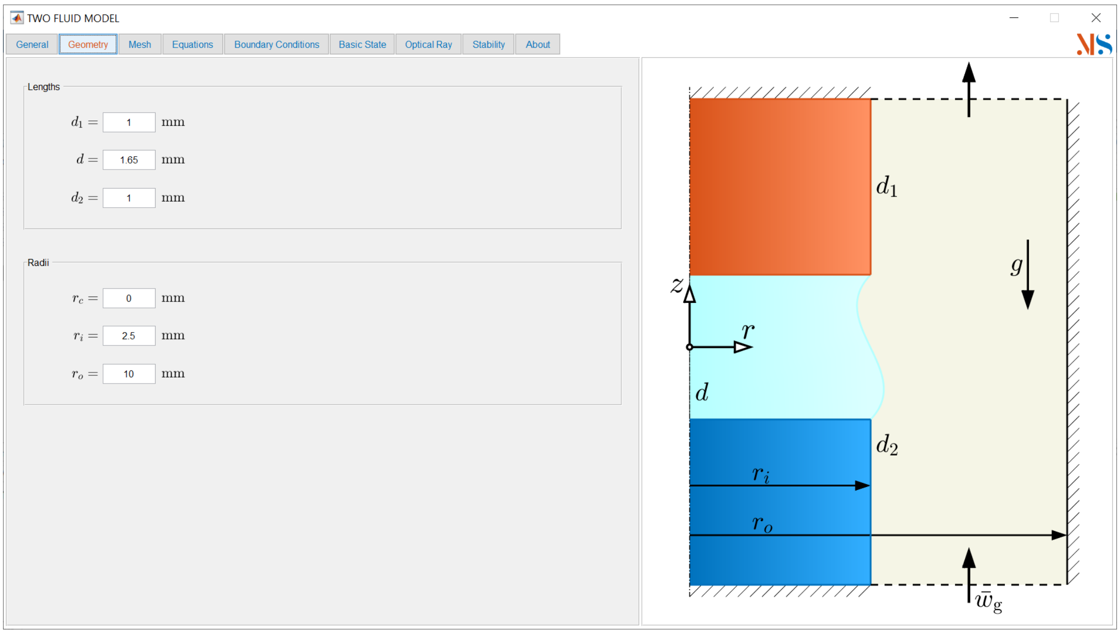
The second tutorial deals with thermocapillary instability in a cylindrical droplet of silicone oil surrounded by air. Both, the liquid and the gas are assumed to be Boussinesq fluids. This tutorial corresponds to the file `example_2a.mat` in the folder `tutorials`. Its counterpart with fully temperature-dependent properties is stored in the file `example_2b.mat`.

- Select the two-phase solver

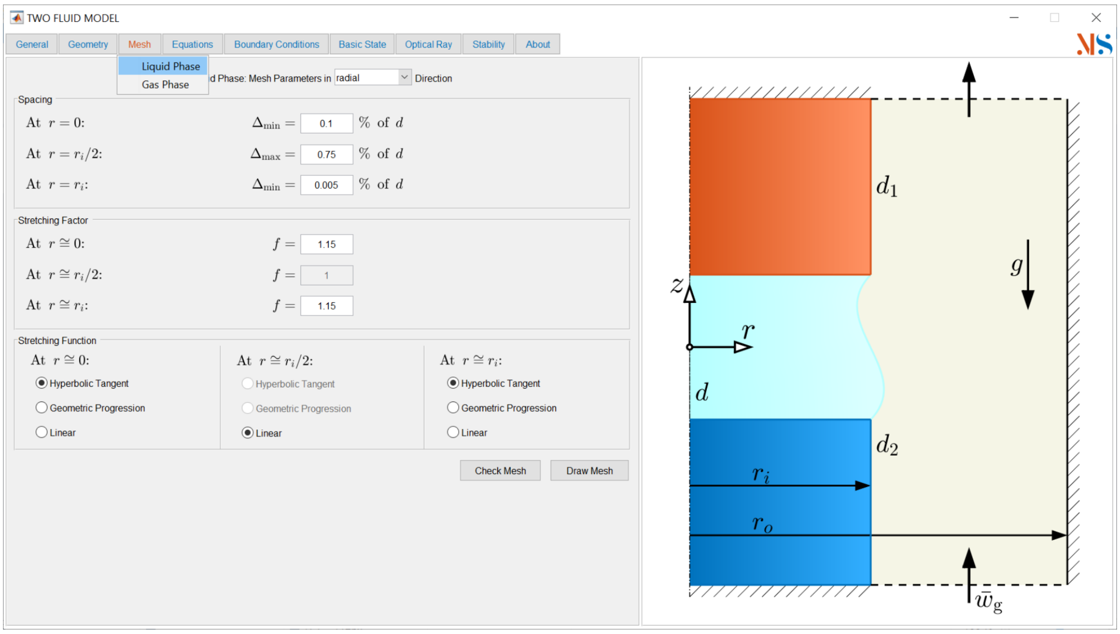
- Set up the axisymmetric geometry and the gravity acceleration. The volume ratio is set to 1 and a 2cSt-silicon oil is considered. Select the Oberbeck–Boussinesq approximation

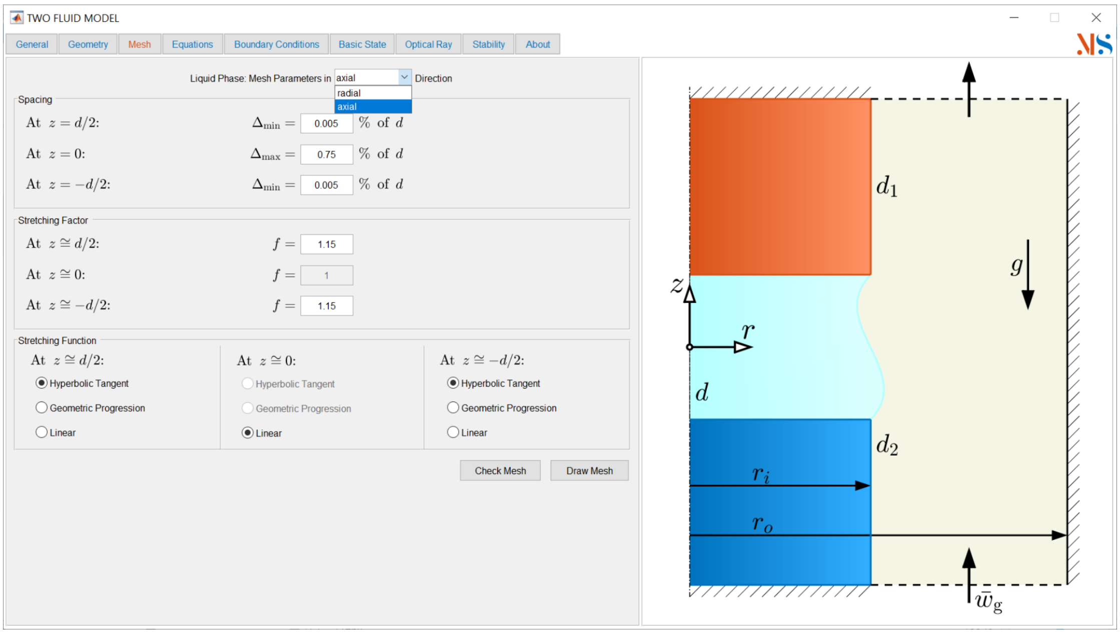


- Set up the cylindrical geometry as follows. The values are selected to coincide with the ones reported in Stojanović et al. (n.d.).

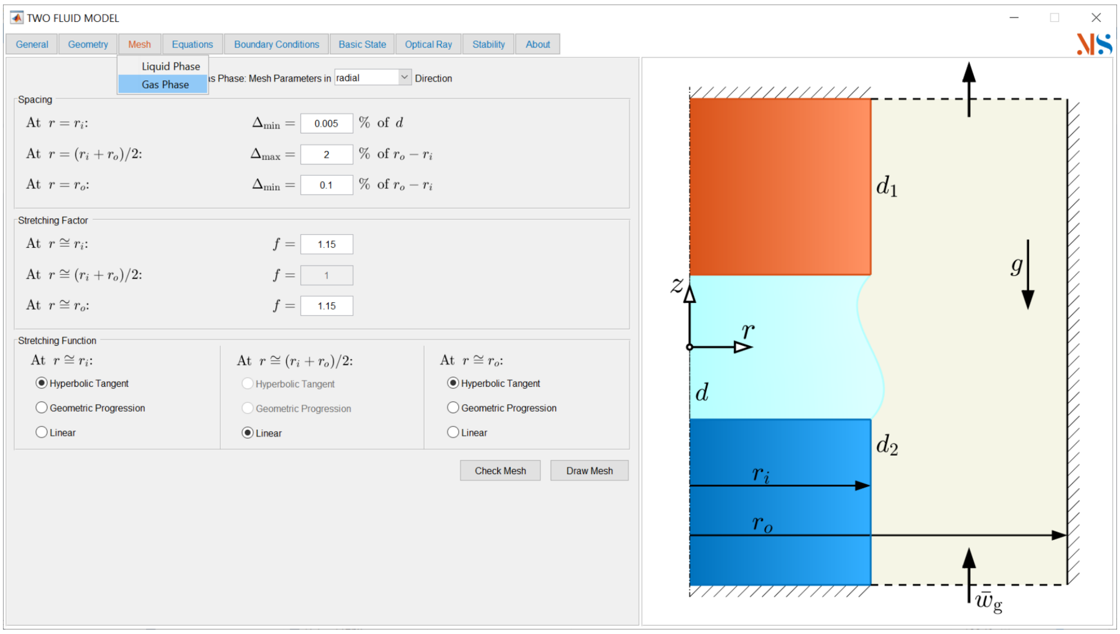


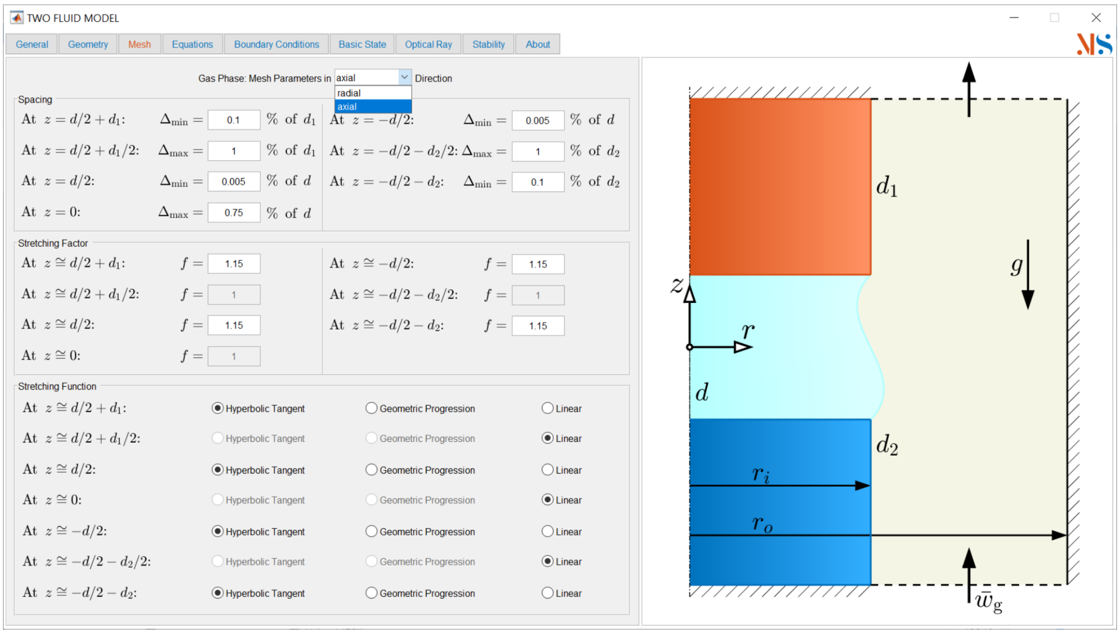
- Set up the mesh for the liquid phase by clicking on `Mesh` and `Liquid Phase`. Define the parameters for both radial and axial coordinates.



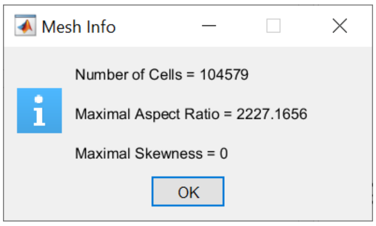


- Set up the parameters for the gas phase in an analogous manner for both radial and axial coordinates.

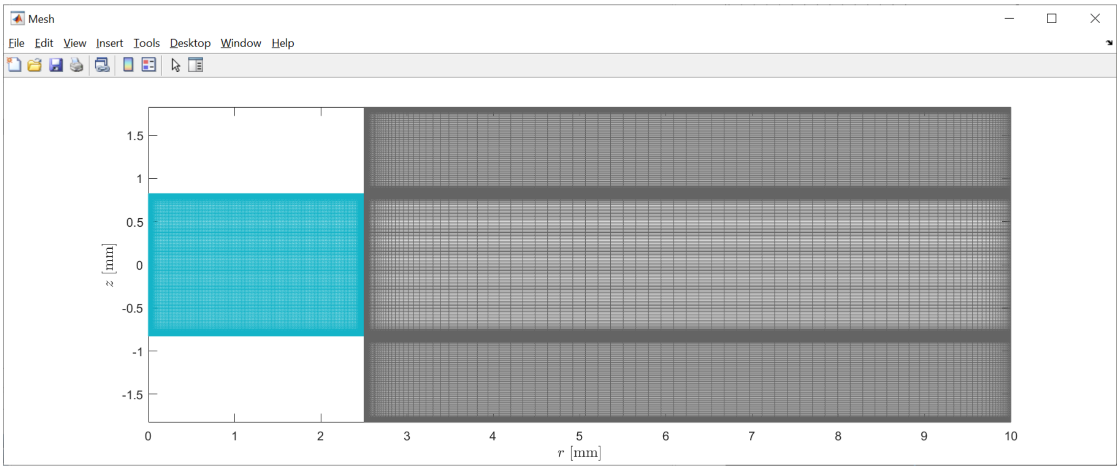




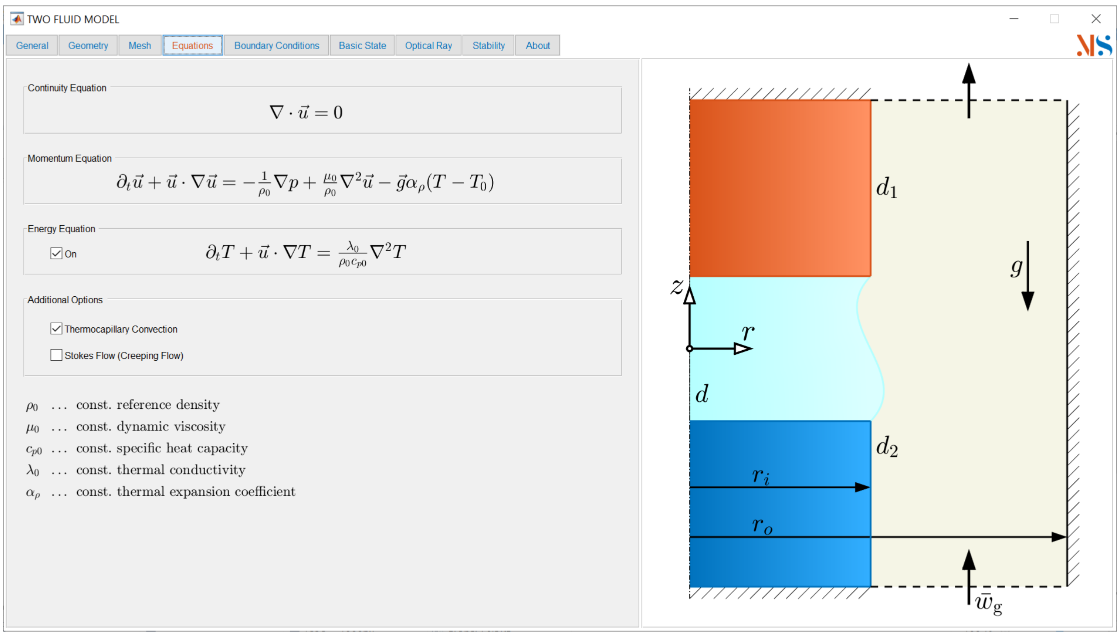
- Click on `Check Mesh`



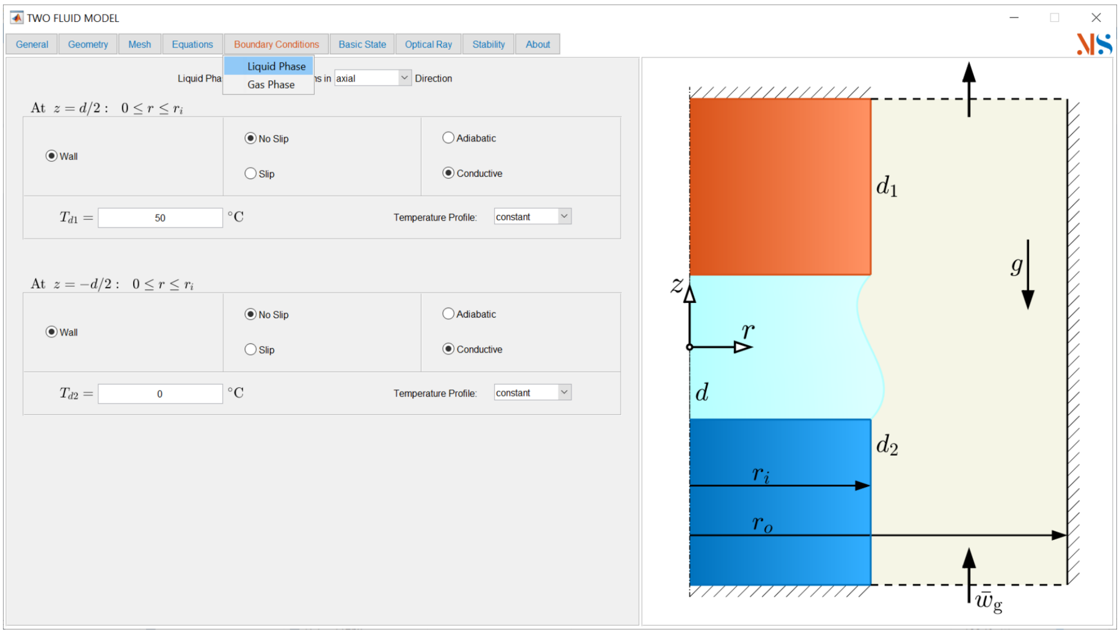
- Visualize the mesh by clicking `Plot Mesh`

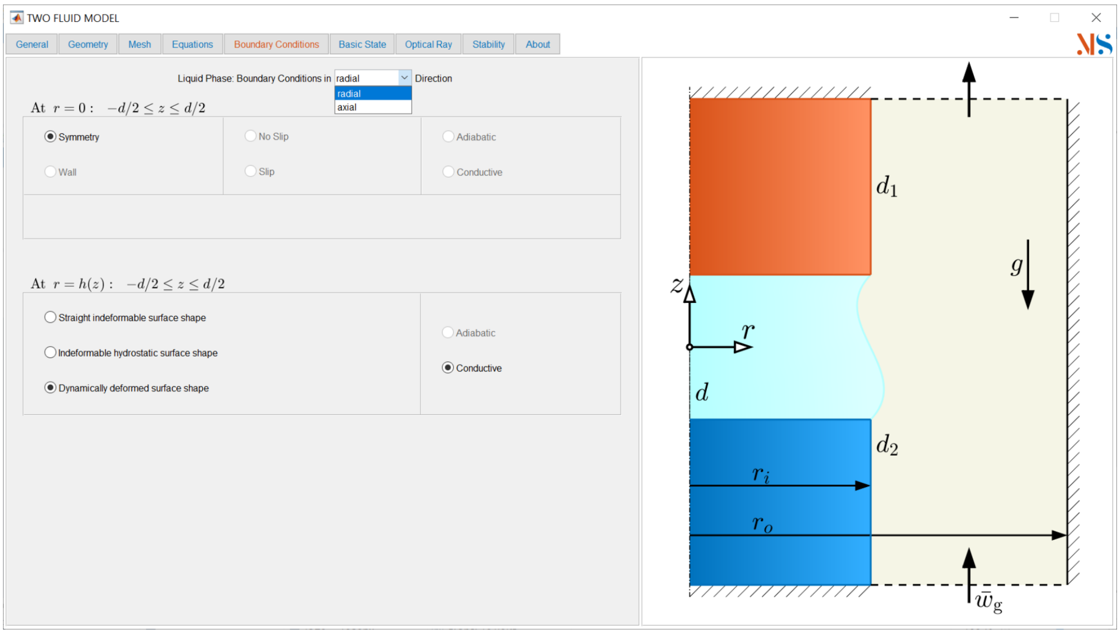


- Select the equations to solve by keeping active the energy equation and the thermocapillary convection.

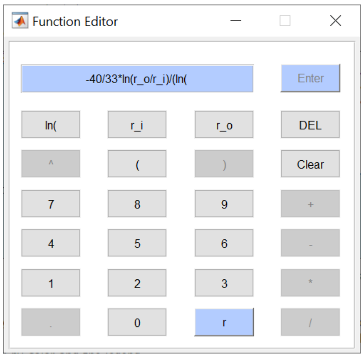


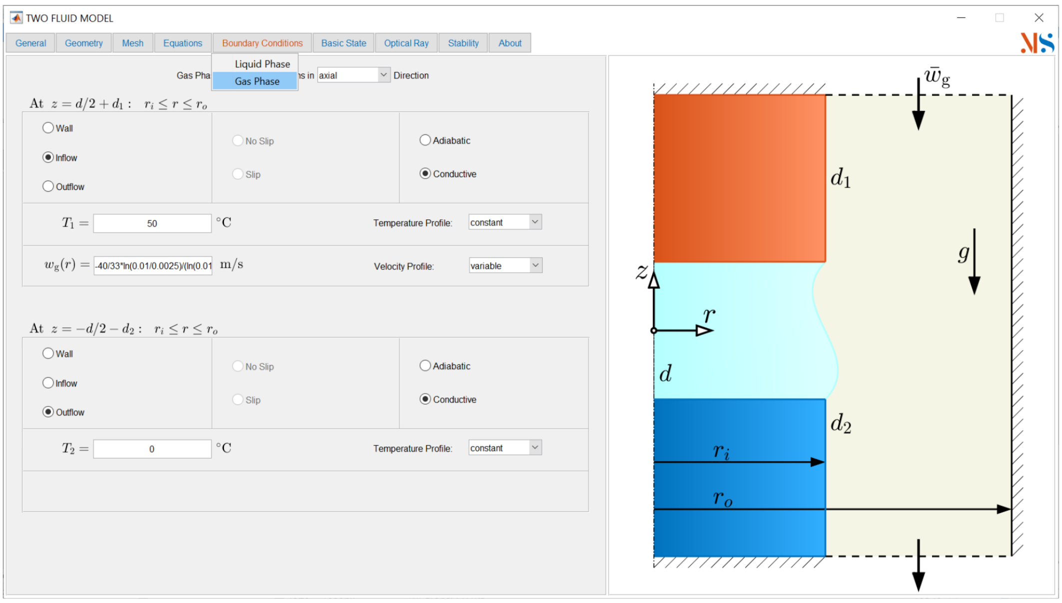
- Set the boundary conditions in the radial and axial directions for the liquid phase. Pay attention to including dynamic surface deformation.

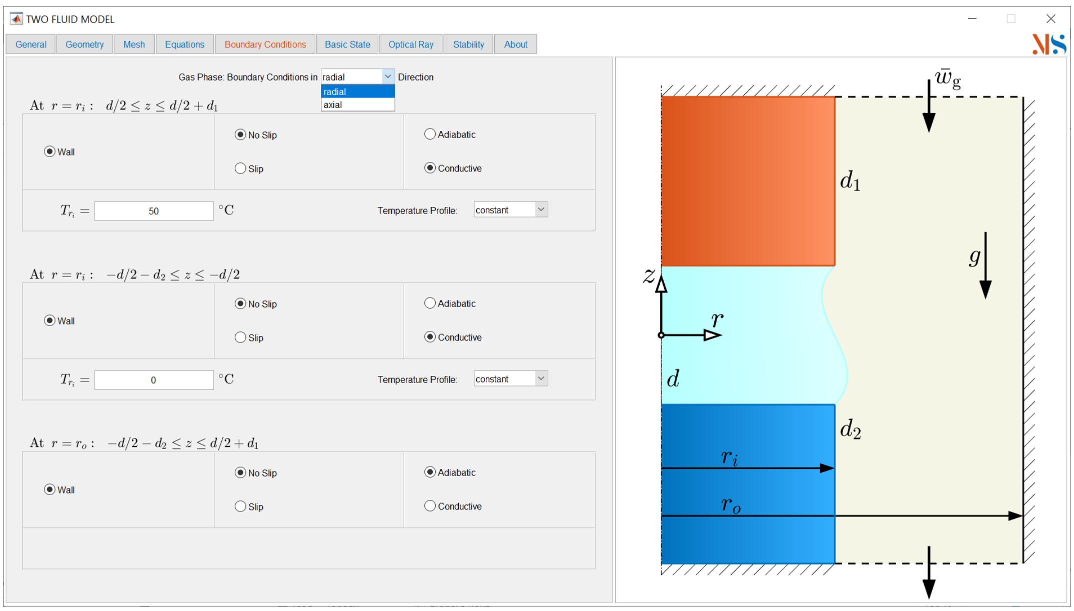




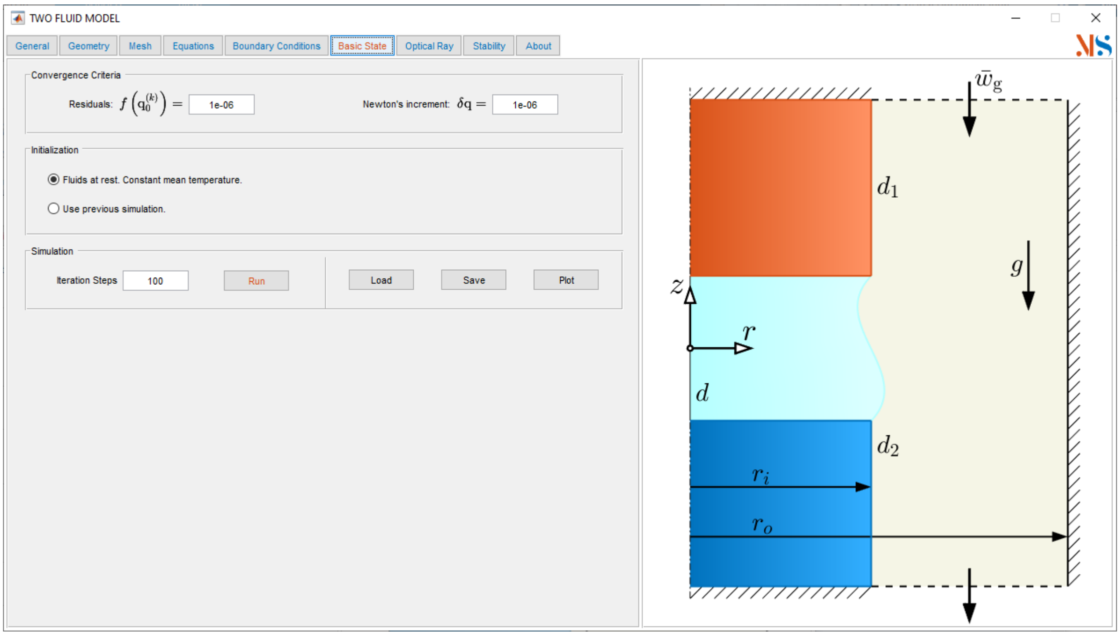
- Set the boundary conditions in the radial and axial directions for the gas phase. Select `variable` in the popup menu for the velocity profile. Use the function editor to prescribe a fully developed profile for $w_g(r)$. The implemented profile is fully developed with a mean inlet velocity of $\bar{w}_g = -(20/33)\,\mathrm{m/s}$ (Joseph, 1976).



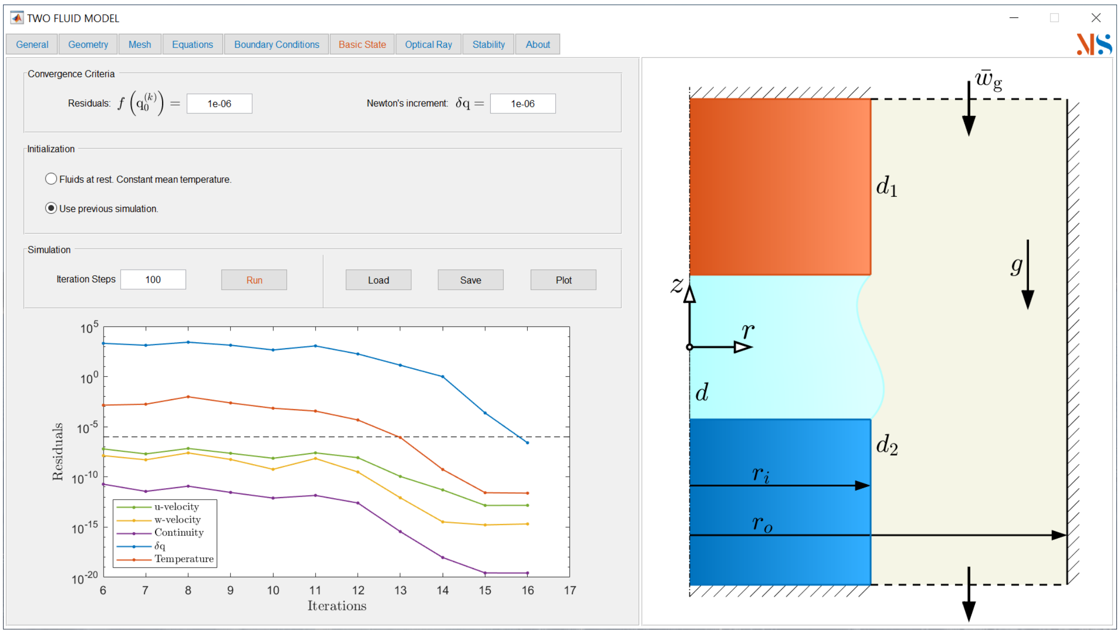




- Set the tolerances of the residuals for the Newton solver and the solution increments.

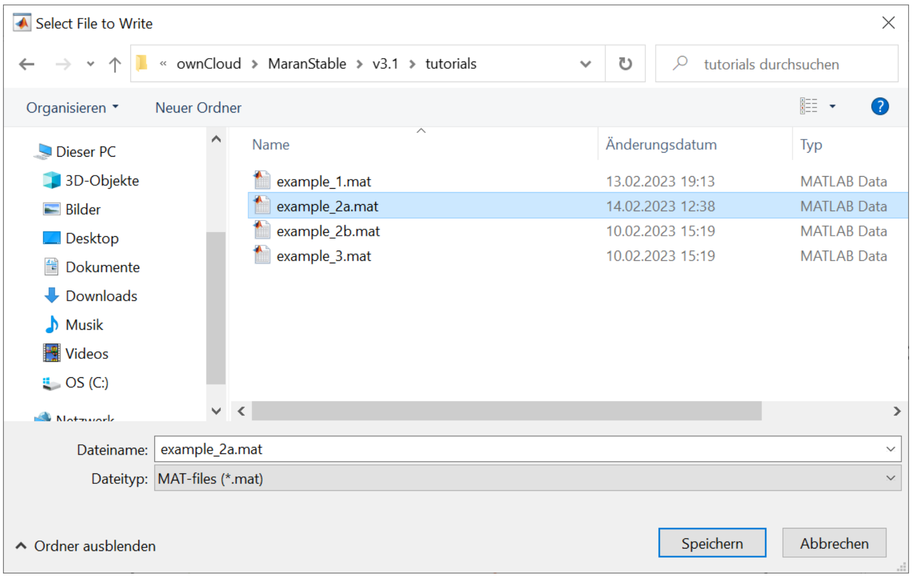


- Solve the basic state by clicking on `Run`.

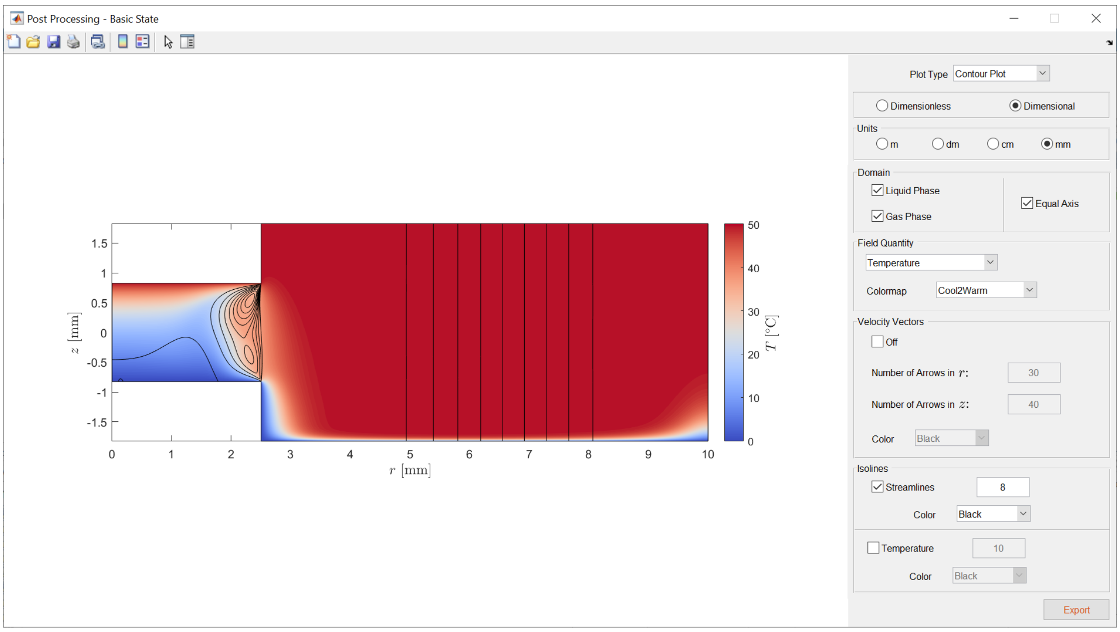


- Upon convergence, `MaranStable` will provide the message:

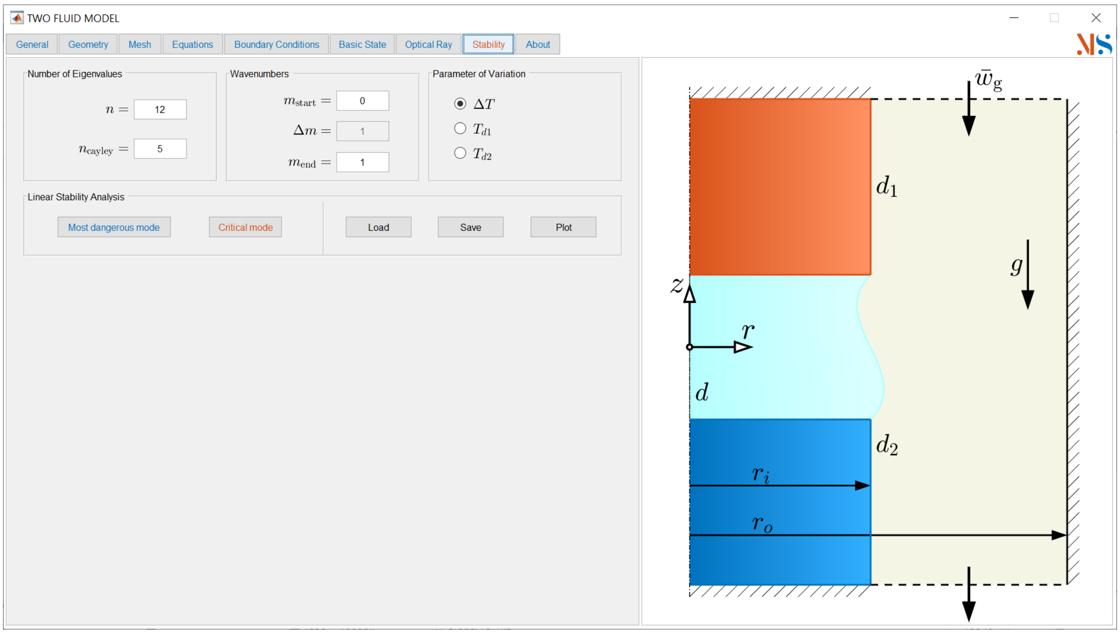
- Click on `Save` to store the converged basic state just computed.



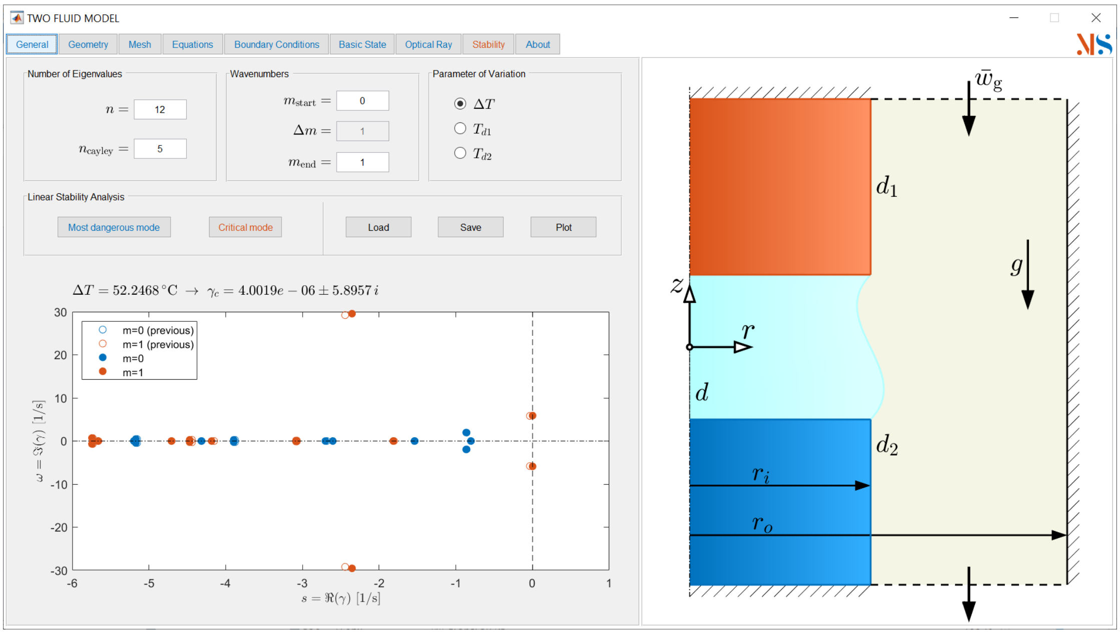
- Click on `Plot` to visualize the basic state.



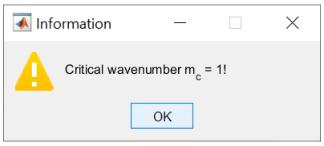
- Set up the parameters for carrying out the stability analysis.



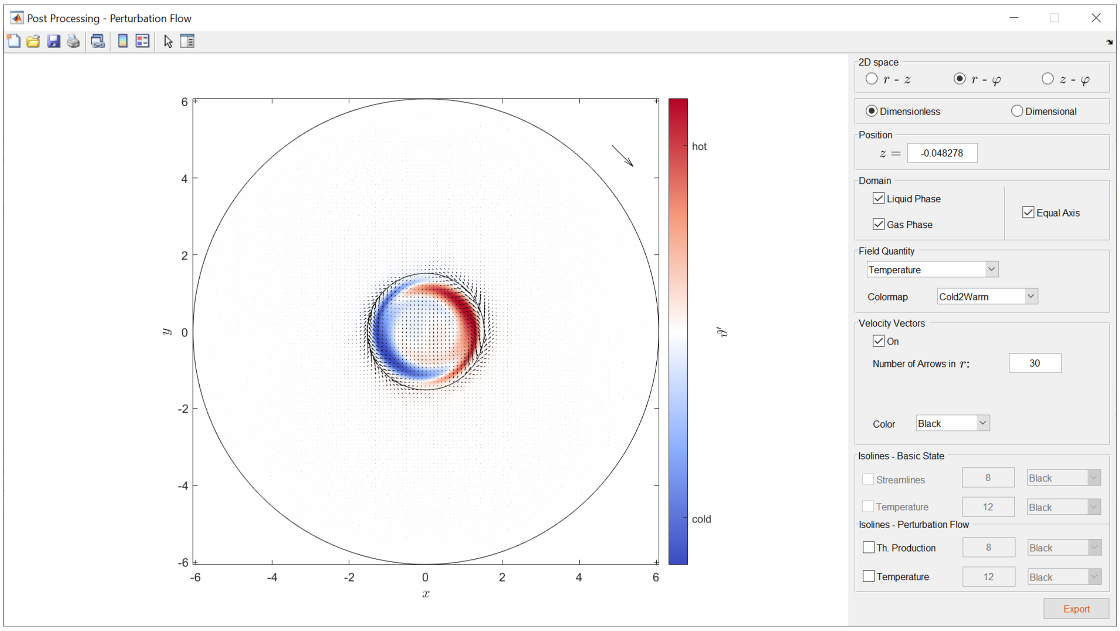
- Solve the linear stability analysis by clicking on `Critical Mode`.



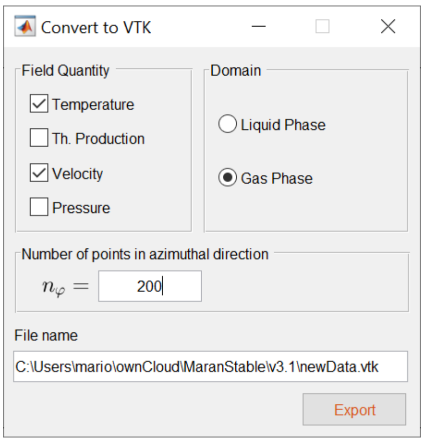
- Once the linear stability analysis is finished, `MaranStable` will provide the message:



- Click on `Plot` to visualize the most critical mode and select $r - \varphi$ in the 2D-space box.



- Export the critical mode in vtk format by clicking on `Export`. Select the field quantities to be exported and the domain (liquid or gas). Increase the number of nodes in the azimuthal direction, if necessary.



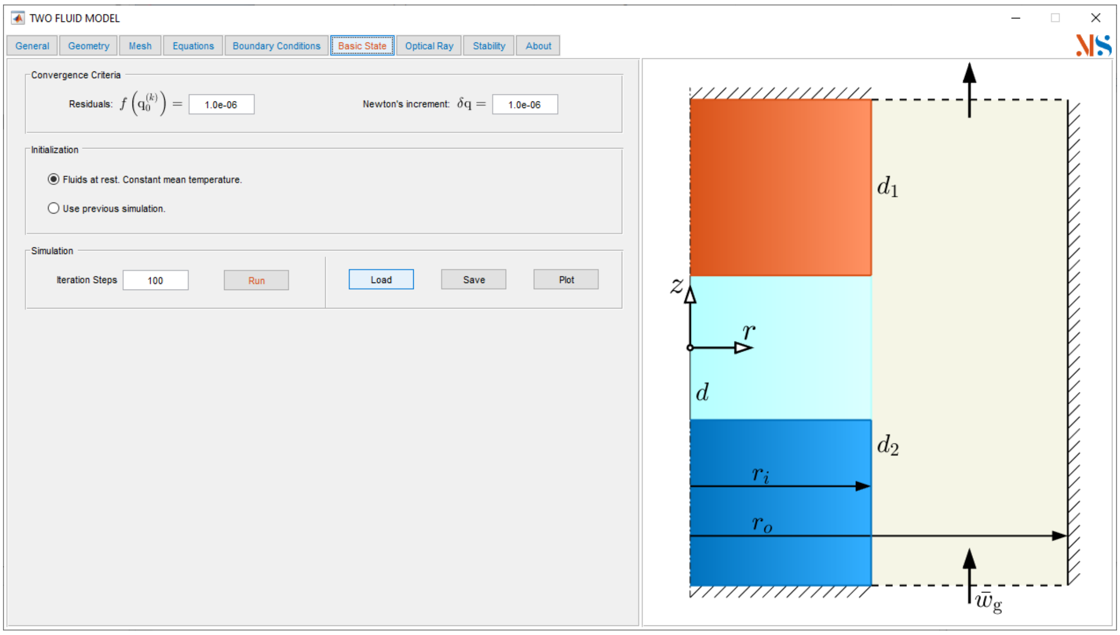
Please note that for the counterpart `example_2b.mat`, computing the basic state for $\Delta T = 50\,\mathrm{K}$ with the initialization 'Fluids at rest. Constant mean temperature.' will run into an error because of the higher-order nonlinearity of the NS3 equations. To circumvent this problem, first compute the basic state with e.g. $\Delta T = 30\,\mathrm{K}$ ($T_{\mathrm{hot}} = 40°\mathrm{C}$, $T_{\mathrm{cold}} = 10°\mathrm{C}$). After the basic state has been computed, change the boundary conditions to $\Delta T = 50\,\mathrm{K}$ and use the just computed flow field as initialization.

3 Optical ray tracing

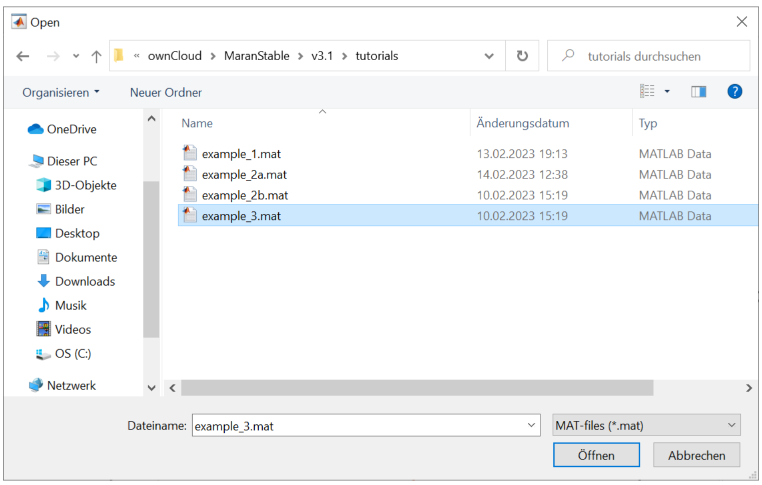
The third tutorial deals with tracing an optical ray in a temperature-dependent index of refraction $\mathcal{N}(T)$. This tutorial corresponds to the file `example_3.mat` in the folder `tutorials`.

- Select the two-phase solver

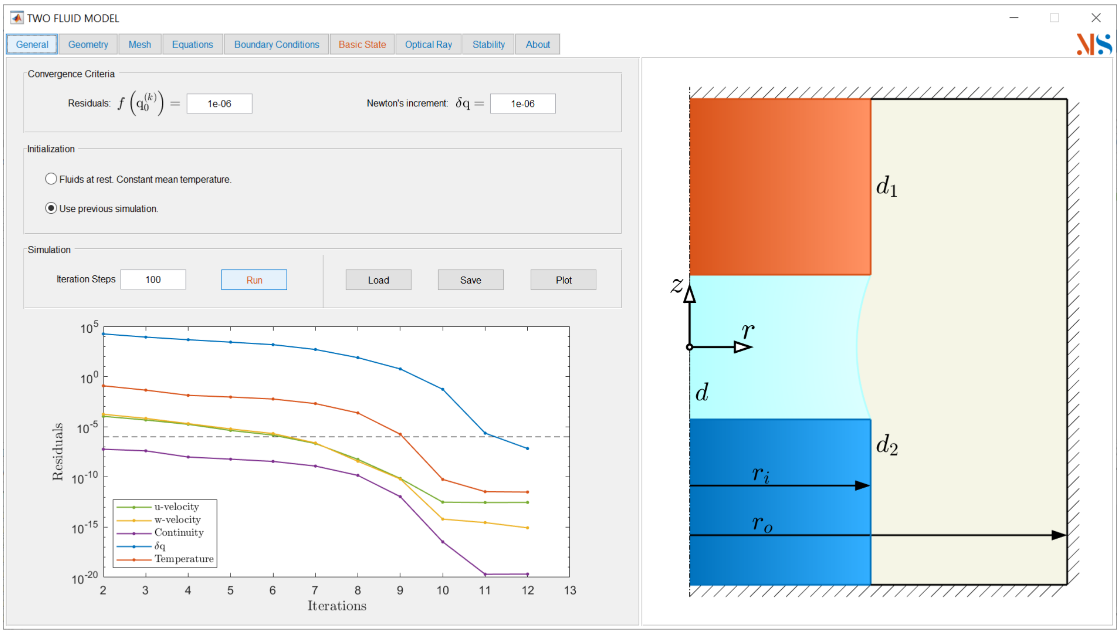
- Select the tab `Basic State`



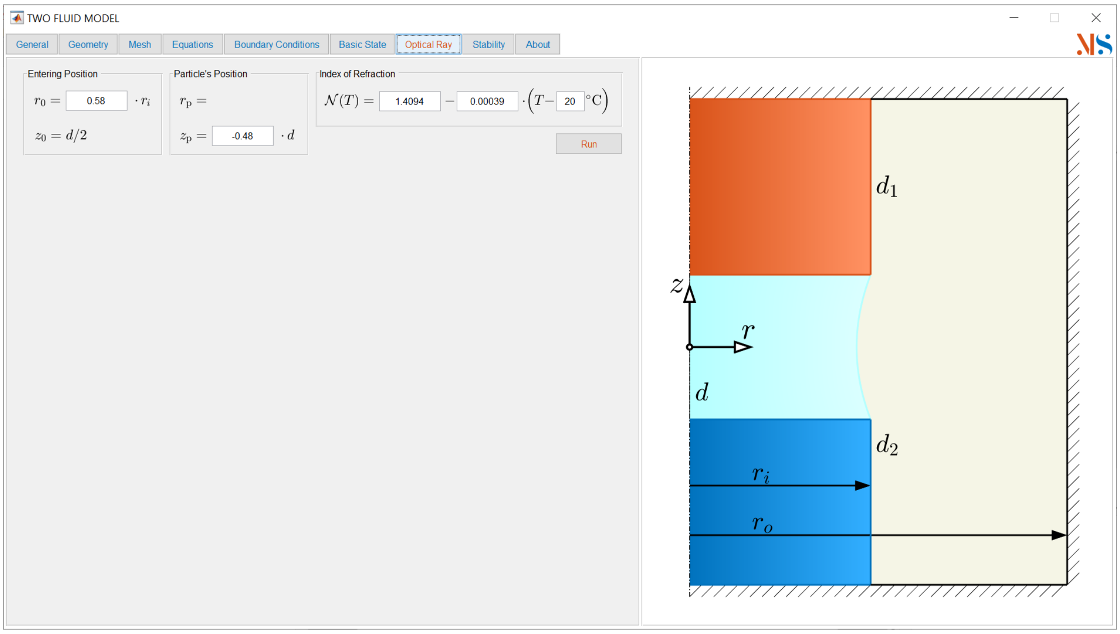
- Load the pre-defined case file.



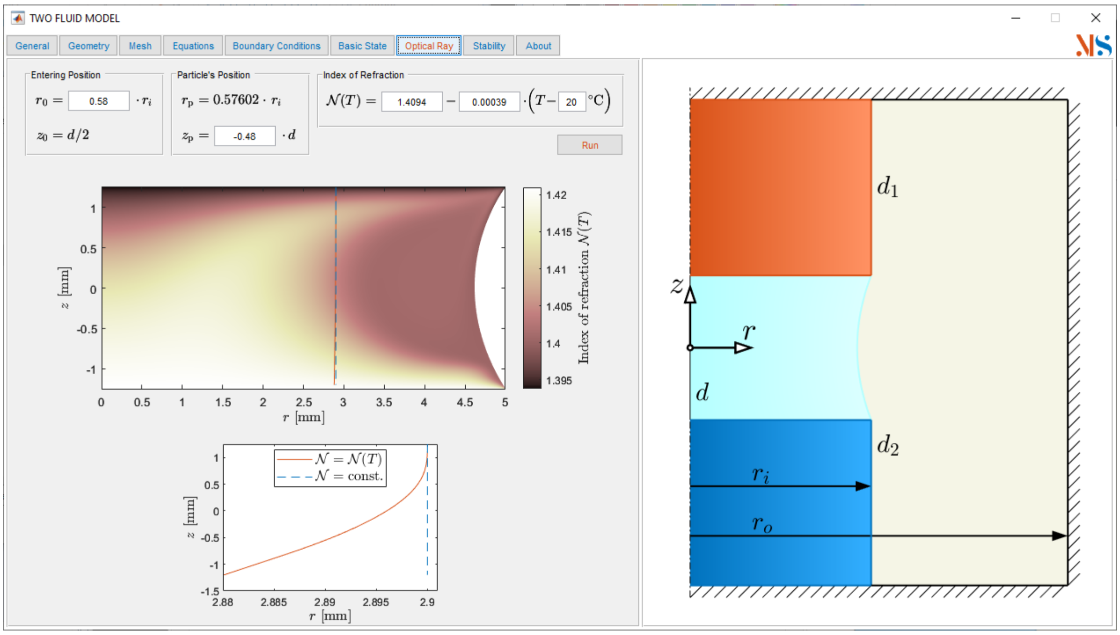
- Click on `Run` to compute the basic state.



- Set up the ray tracing parameters including the location of the ray entering the domain and the temperature dependence of the refractive index $\mathcal{N}(T)$. Leave the default refractive index $\mathcal{N}(T)$ unchanged if dealing with silicone oils (He et al., 2016).



- Click on `Run` to compute the optical ray tracing.



References

He, J., Liu, W. and Huang, Y.-X. (2016), 'Simultaneous determination of glass transition temperatures of several polymers', *PLoS ONE* **11**, 0151454 (12pp).

Joseph, D. D. (1976), *Stability of Fluid motions I*, Vol. 27 of *Springer Tracts in Natural Philosophy*, Springer, Berlin, Heidelberg.

Stojanović, M., Romanò, F. and Kuhlmann, H. C. (n.d.), 'High-Prandtl-number thermocapillary liquid bridges with dynamically deformed interface: Effect of an axial gas flow on the linear stability'. In preparation.