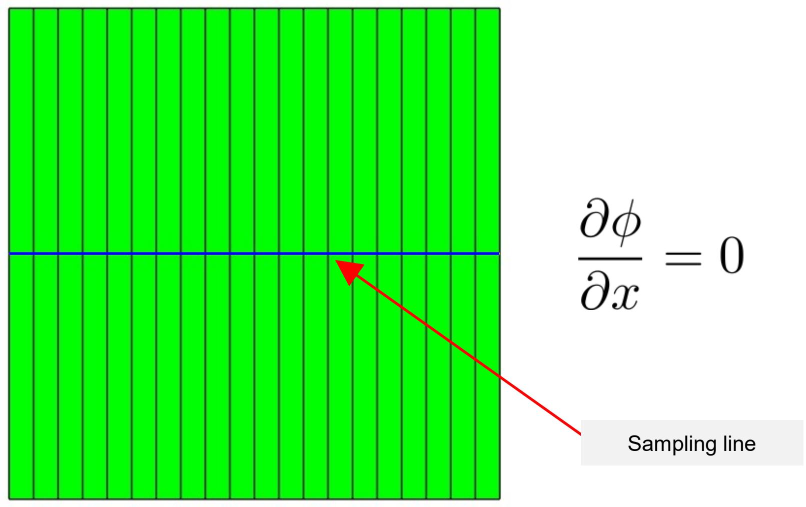
Influence of URF and tolerances on the accuracy and stability

- Let us solve the general transport equation in the following domain,

$$\underbrace{\frac{\partial \rho \phi}{\partial t}}_{\text{Time derivative}} + \underbrace{\nabla \cdot (\rho \mathbf{u} \phi)}_{\text{Convective term}} - \underbrace{\nabla \cdot (\rho \Gamma_{\phi} \nabla \phi)}_{\text{Difussion term}} = \underbrace{S_{\phi}}_{\text{Source term}}$$

$U = 1$

$\phi_{inlet} = 0$



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

$x_{inlet} = 0$ $\quad$ $x_{outlet} = 1$

$S_{\phi} = 1$

Volumetric source term
In the whole domain

$\Gamma_{\phi} = 0$

Diffusion coefficient

Note:
All dimensions are in the SI system (MKS).

Influence of URF and tolerances on the accuracy and stability

- With the given boundary conditions, initial conditions, and physical properties, the general transport equation,

$$\underbrace{\frac{\partial \rho \phi}{\partial t}}_{\text{Time derivative}} + \underbrace{\nabla \cdot (\rho \mathbf{u} \phi)}_{\text{Convective term}} - \underbrace{\nabla \cdot (\rho \Gamma_{\phi} \nabla \phi)}_{\text{Difusion term}} = \underbrace{S_{\phi}}_{\text{Source term}}$$

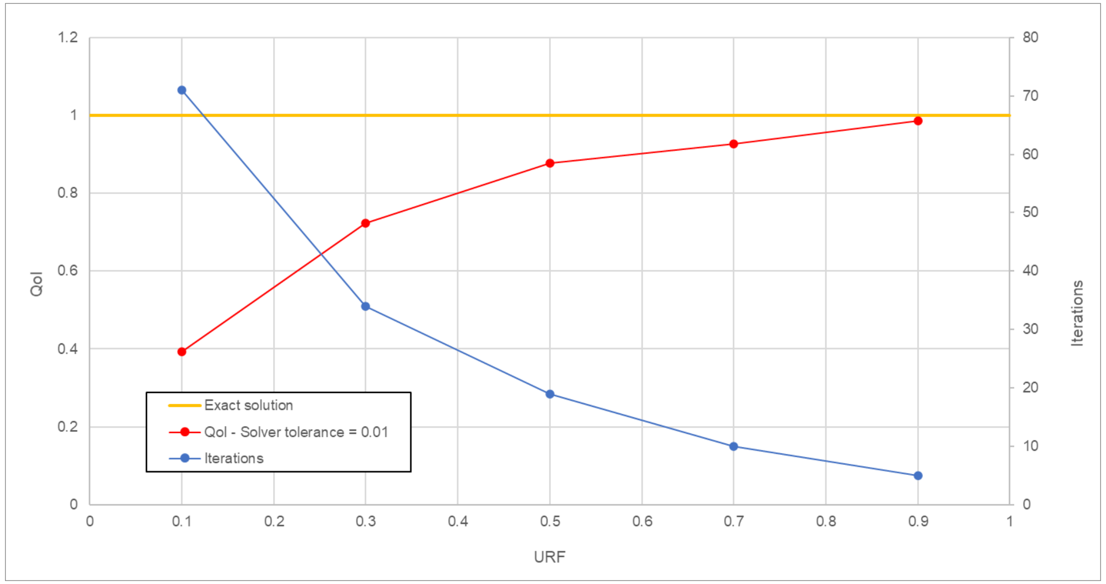
- Reduces to the following governing equation,

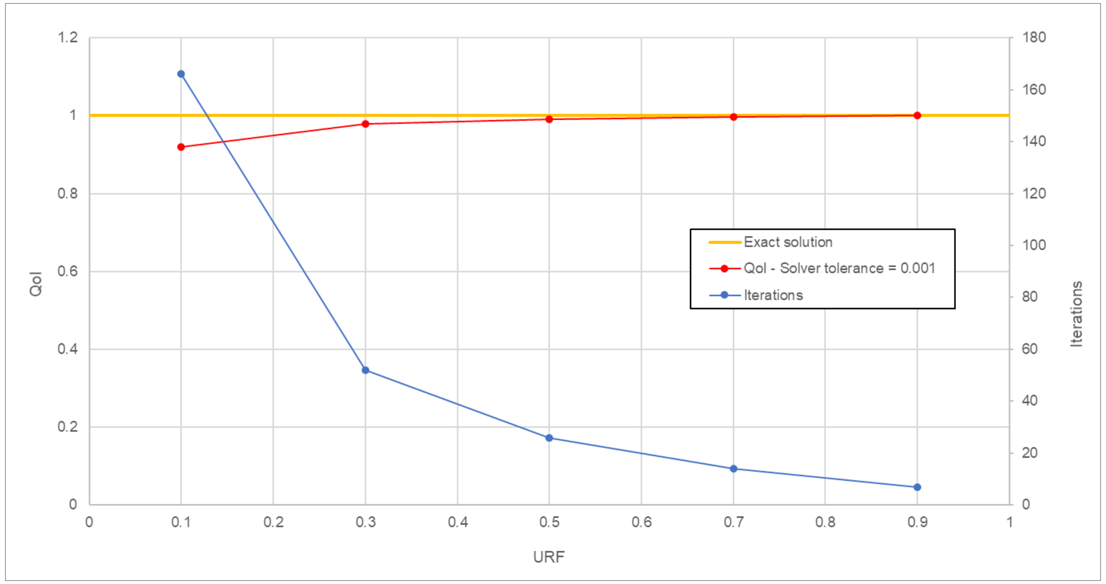
$$\frac{\partial \phi}{\partial x} = 1$$

- That has the following analytical solution,

$$\phi_x = x$$

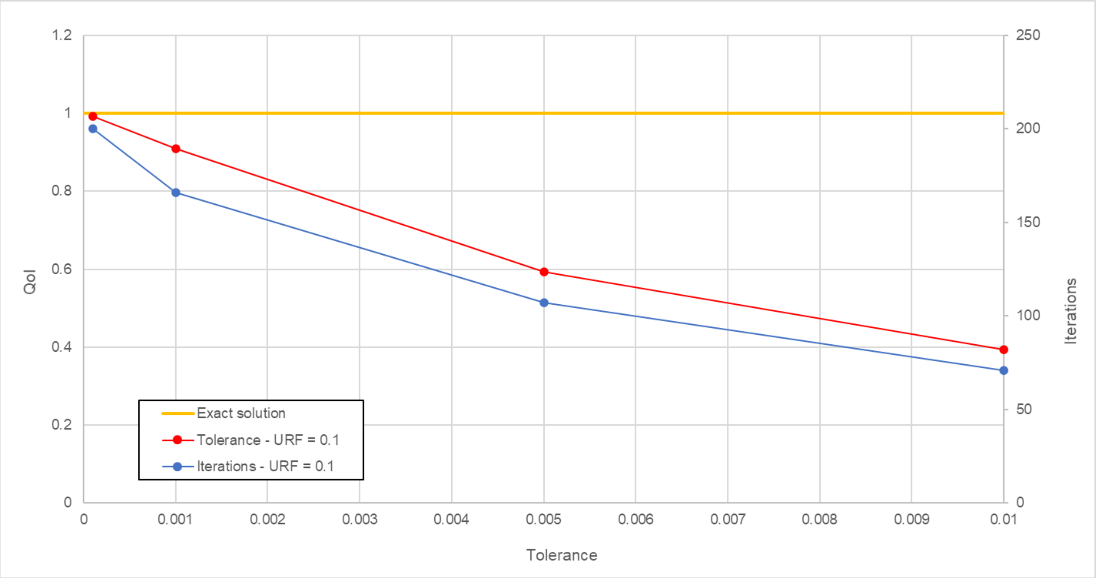
Influence of URF and tolerances on the accuracy and stability

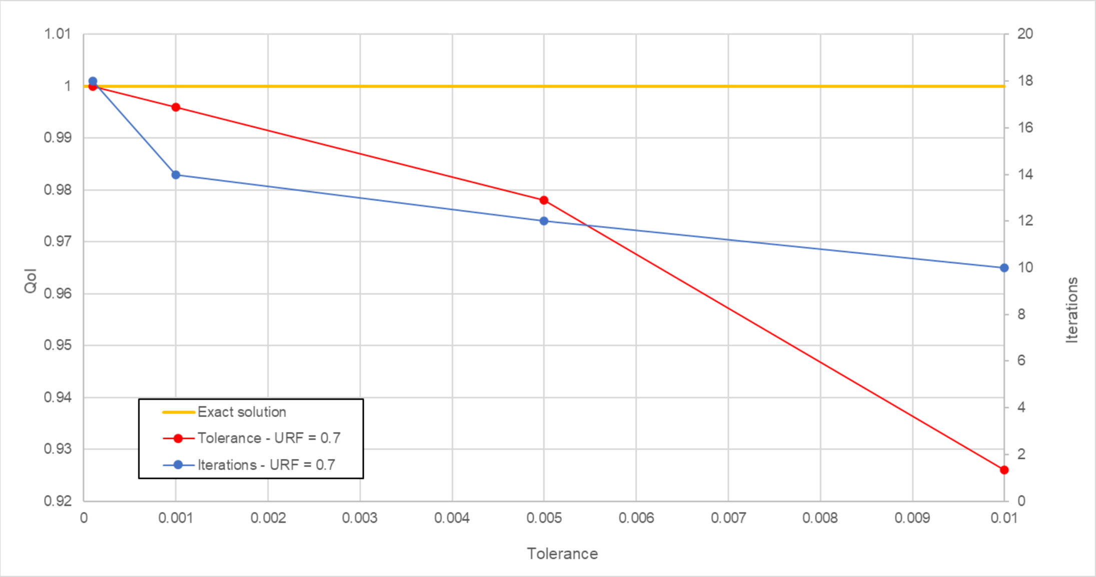




- In this example, the quantity of interest (QoI) is a bounded quantity.
- In this case, the QoI cannot be larger than one (the analytical solution).
- Large URFs have fast convergence rate but the solution might become unbounded or oscillatory.
- Instead, if we use low URFs, the solution is very stable (bounded and non-oscillatory).
- However, the convergence rate is very slow.
- A tolerance in the order of 0.01 is just a pretty picture.
- Acceptable accuracy can be obtained with a tolerance level in the order of 0.001 and lower.
- In general, to increase the accuracy we need to use low tolerances.
- Choosing URF is a compromise between accuracy, convergence rate, and stability.
- In some cases, if you use large URF (more than 0.7), the solution becomes a little bit oscillatory or unbounded.
- Unbounded solutions are not desirable in CFD.

Influence of URF and tolerances on the accuracy and stability





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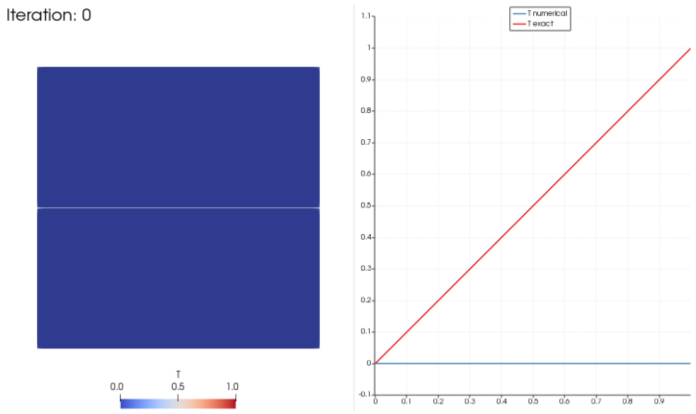
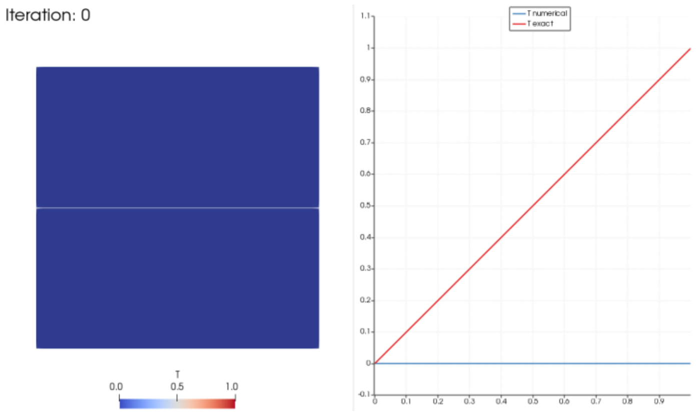
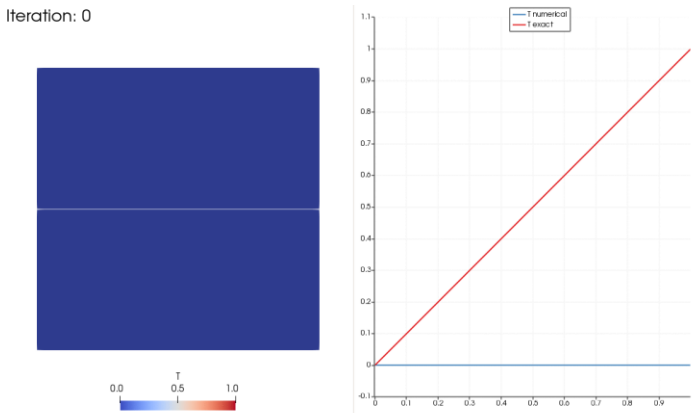
Influence of URF and tolerances on the accuracy and stability



URF 0.1
Tolerance 0.01
www.wolfdynamics.com/training/OF_WS2020/figs/f5.gif



URF 0.5
Tolerance 0.01
www.wolfdynamics.com/training/OF_WS2020/figs/f6.gif



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Tolerance 0.001
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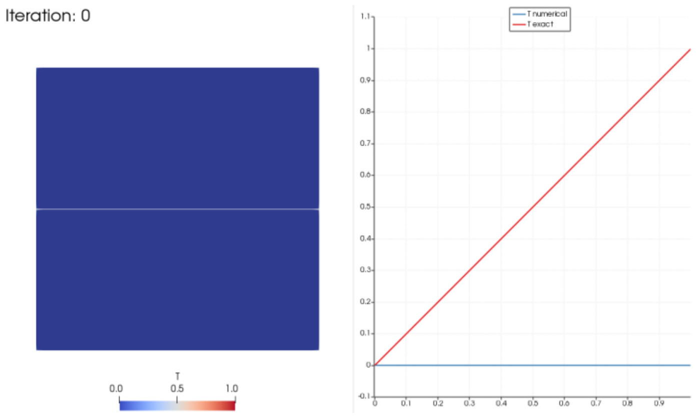

URF 0.7
Tolerance 0.0001
www.wolfdynamics.com/training/OF_WS2020/figs/f8.gif