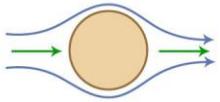
Supplement 6

Comparison of:

Unsteady and steady solvers

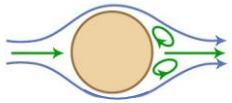
Unsteady physics and steady physics

Vortex shedding behind a cylinder



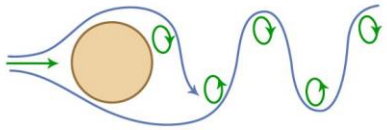
Creeping flow (no separation)
Steady flow

$Re < 5$



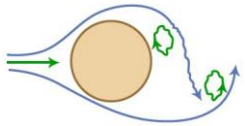
A pair of stable vortices in the wake
Steady flow

$5 < Re < 40 - 46$



Laminar vortex street (Von Karman street)
Unsteady flow

$40 - 46 < Re < 150$

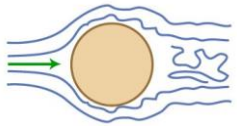


Laminar boundary layer up to the separation point, turbulent wake
Unsteady flow

$150 < Re < 300$

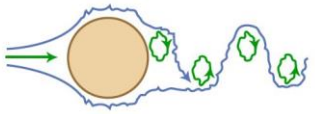
Transition to turbulence

$300 < Re < 3 \times 10^5$



Boundary layer transition to turbulent
Unsteady flow

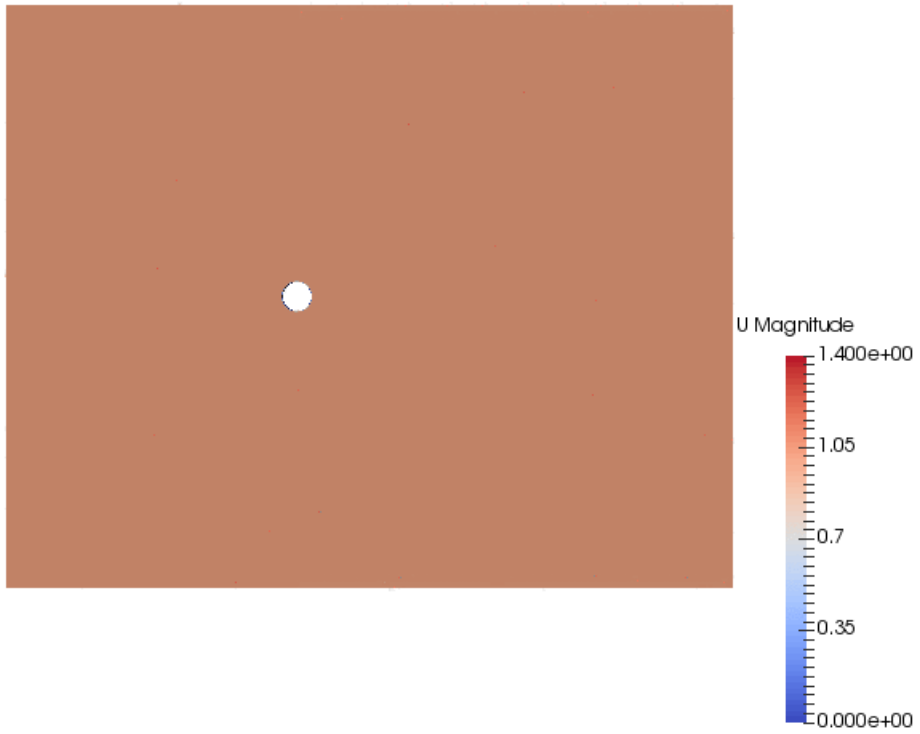
$3 \times 10^5 < Re < 3 \times 10^6$



Turbulent vortex street, but the wake is narrower than in the laminar case
Unsteady flow

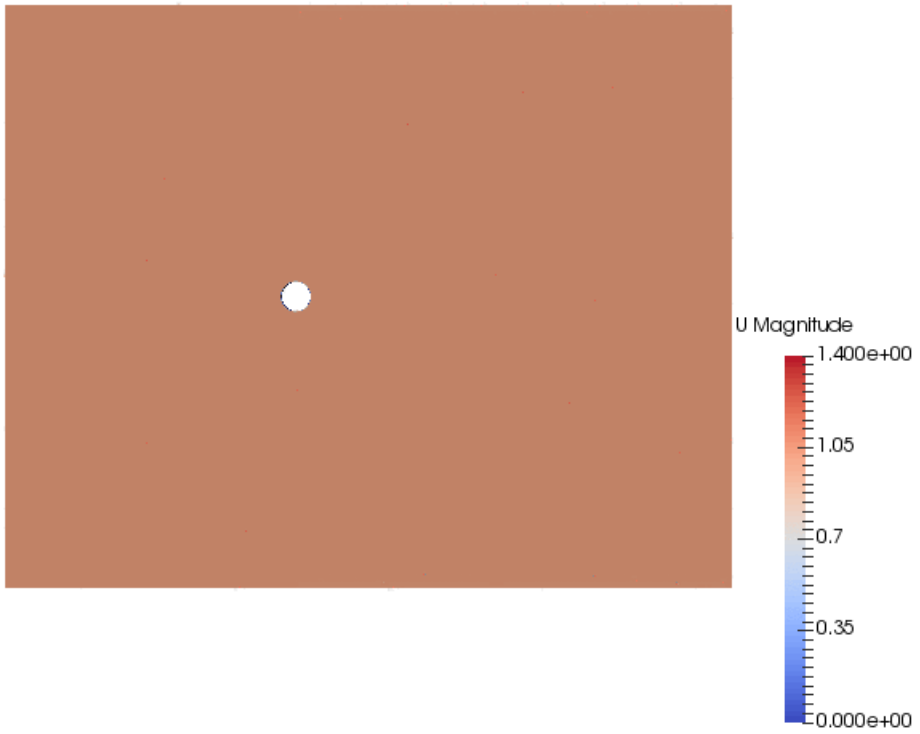
$3 \times 10^6 > Re$

Time: 0.000000

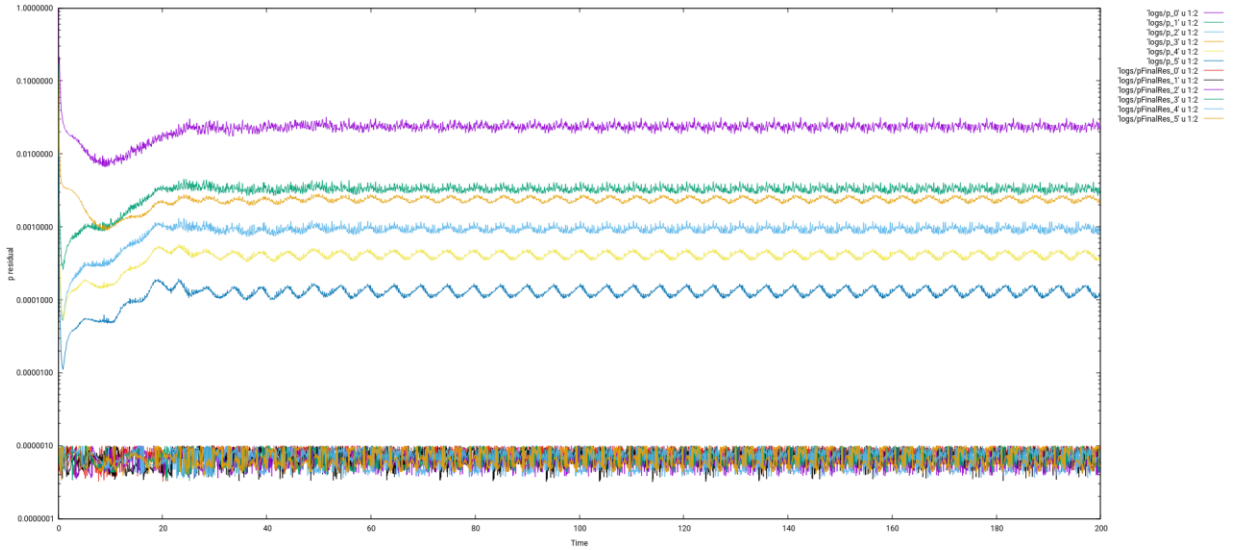


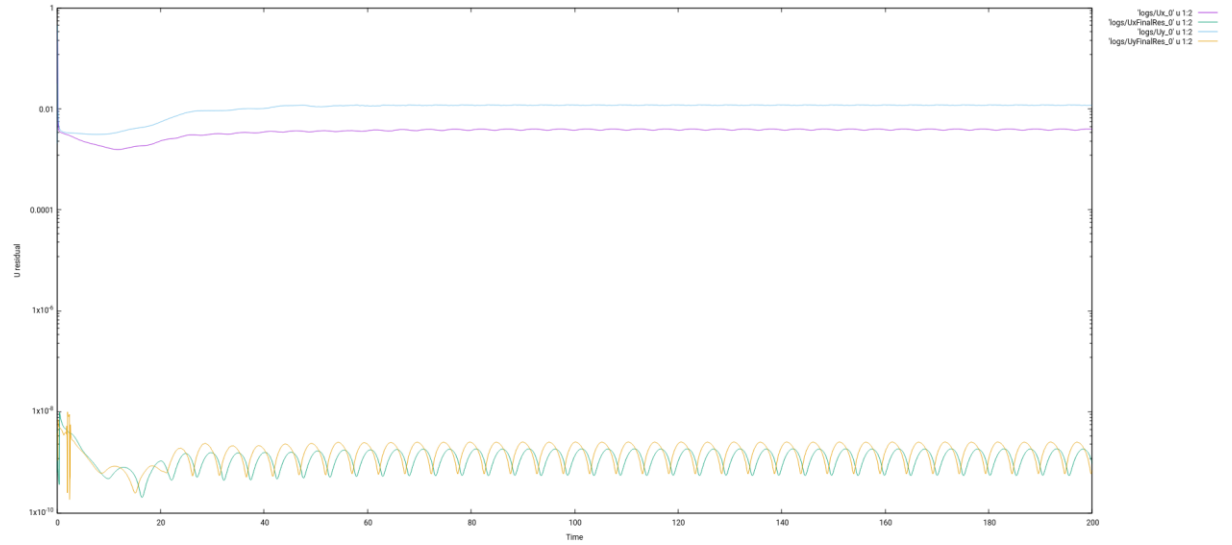
Re = 200
Unsteady physics with **unsteady solver**
Non-uniform initialization

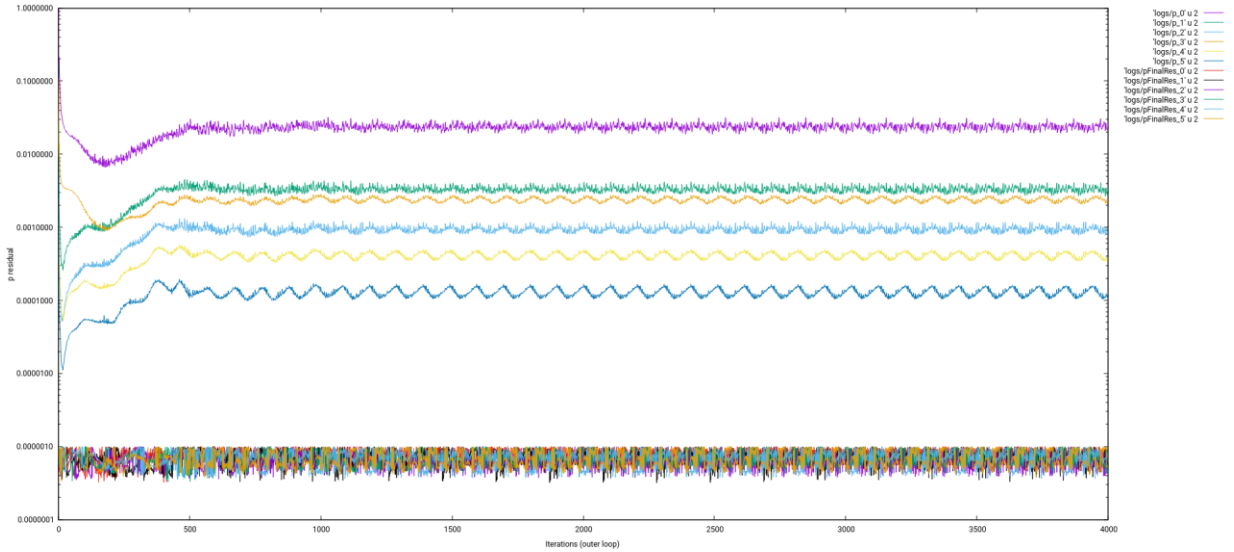
Iteration: 0.000000

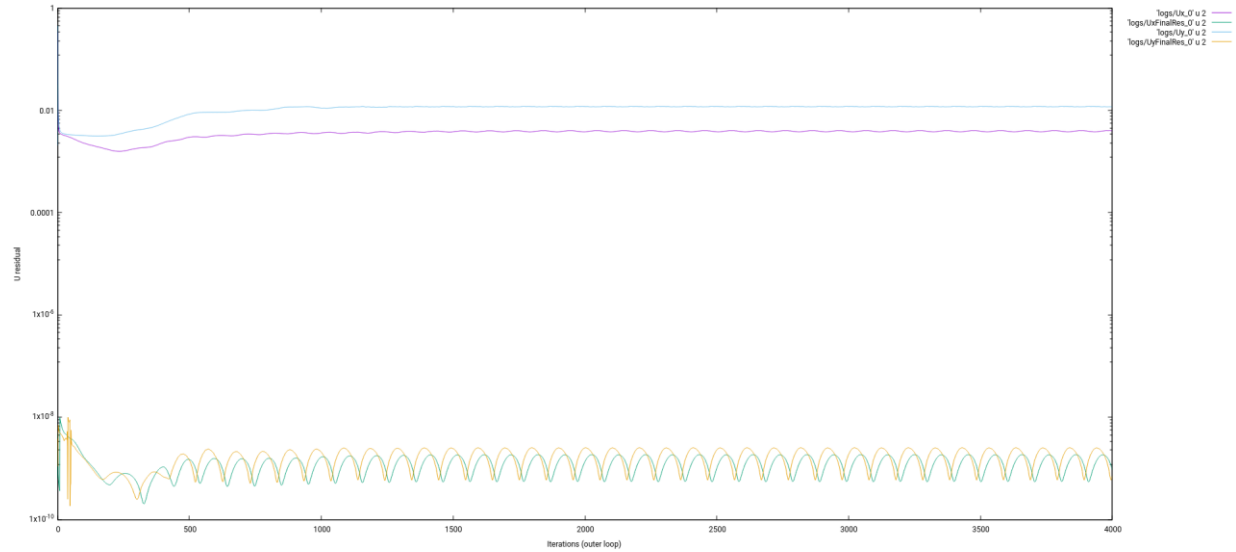


Re = 200
Unsteady physics with **steady solver**
Non-uniform initialization

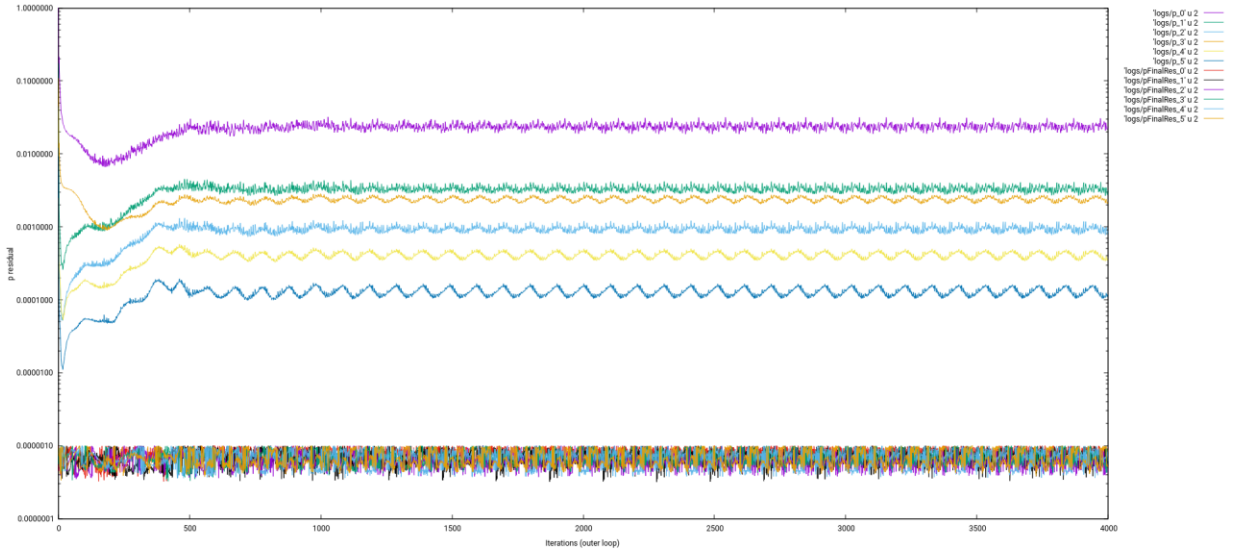


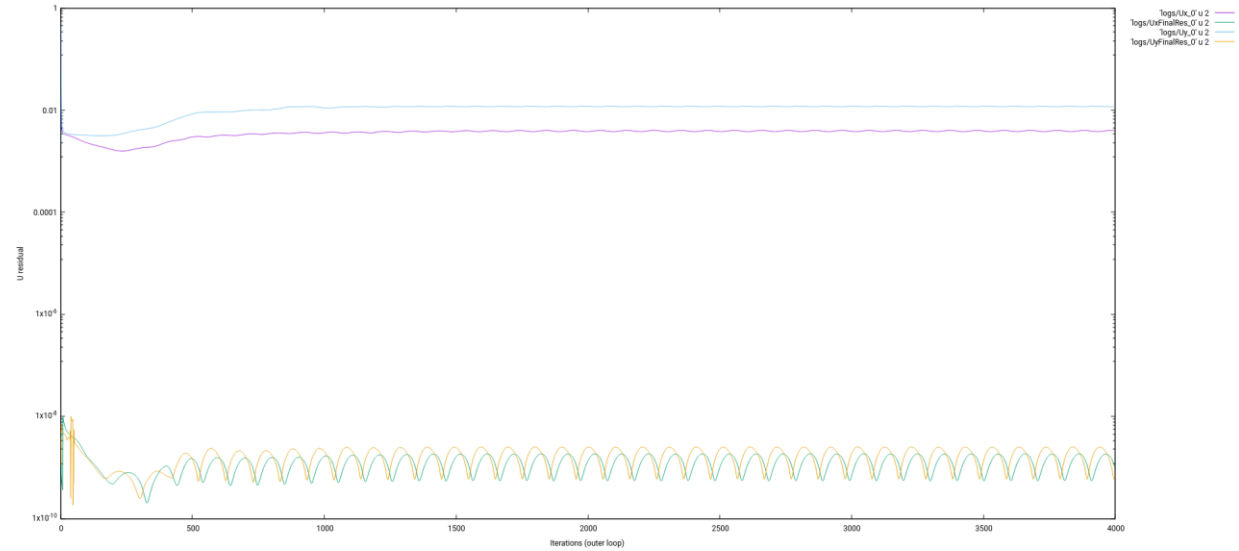


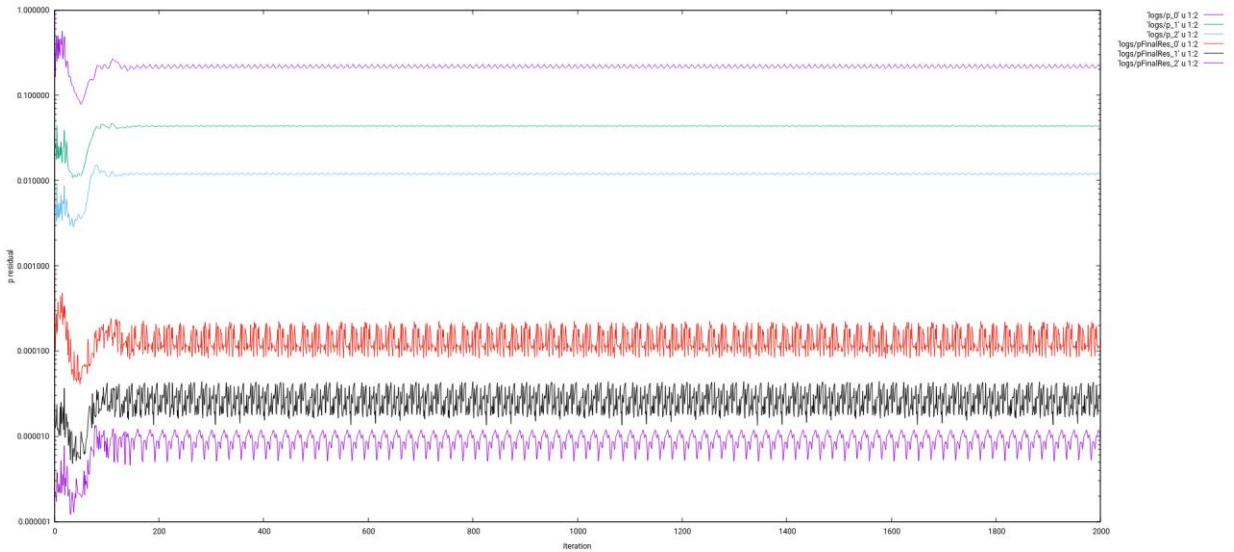


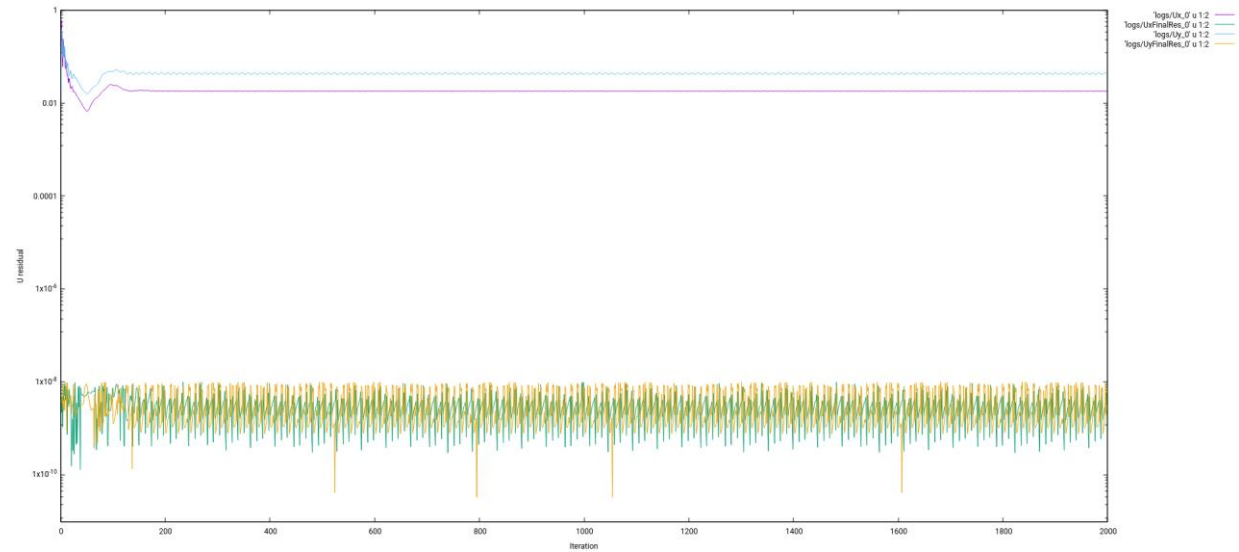


Unsteady solver residuals – Top row: residuals in function of time. Bottom row: residuals in function of iteration number.

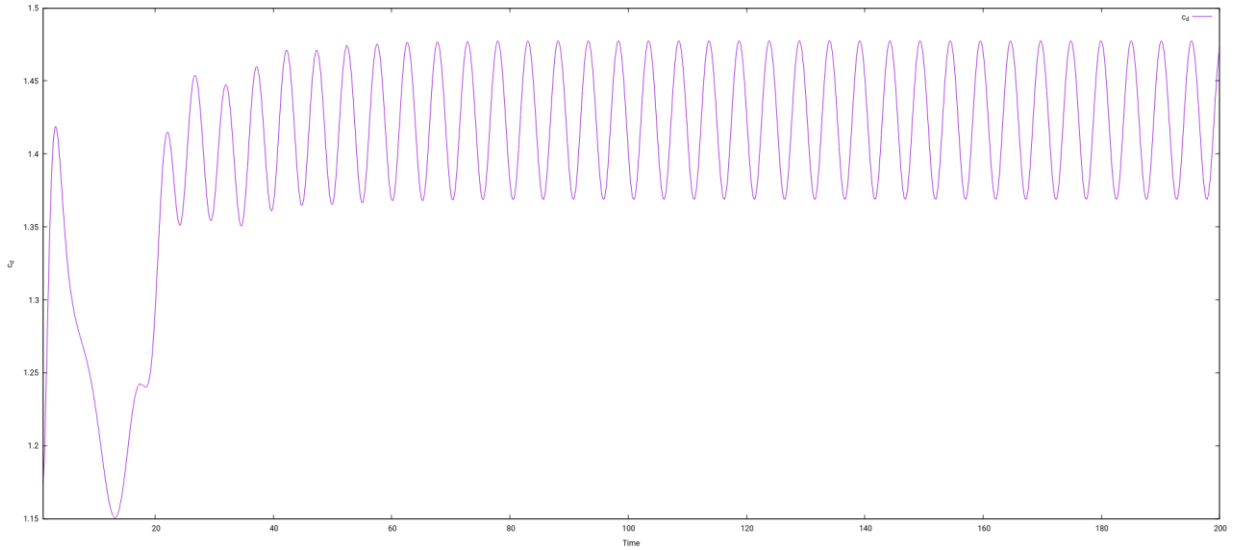


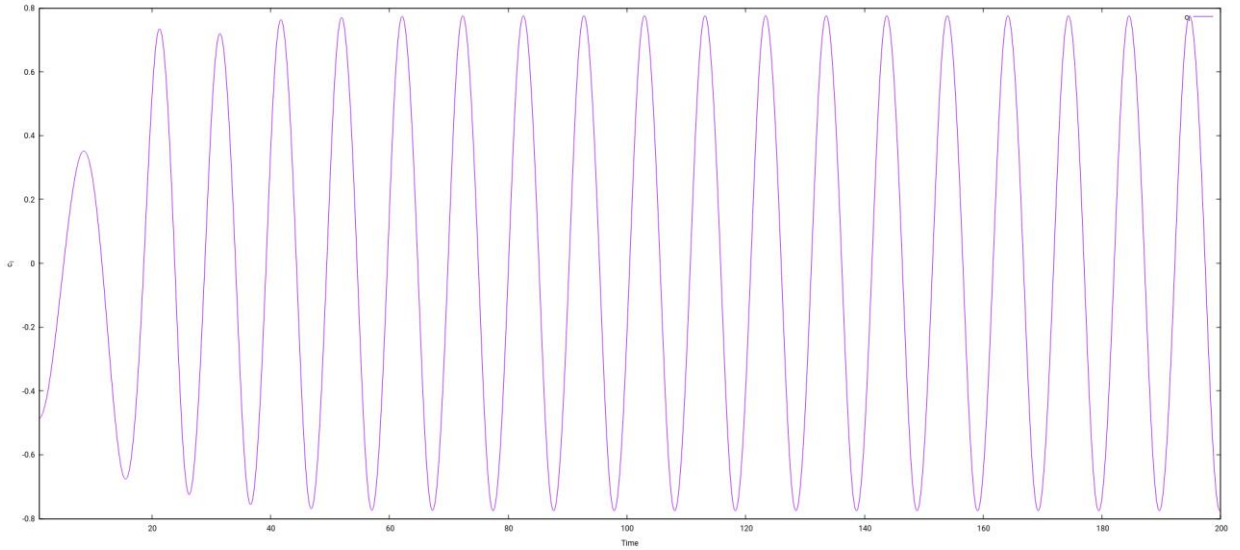


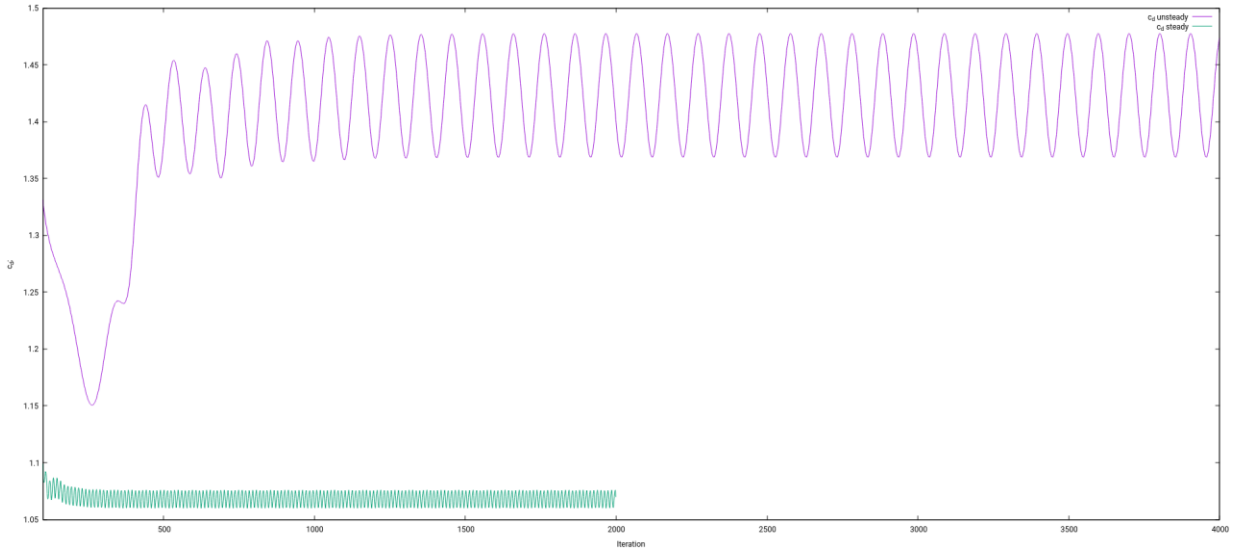


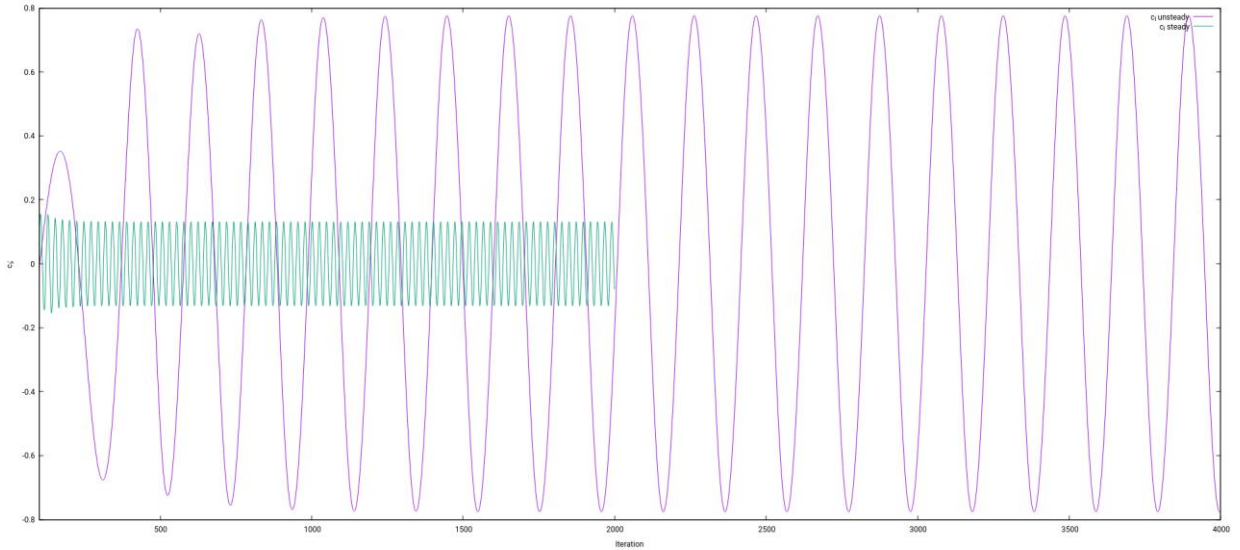


Comparison of unsteady solver residuals (top row) and steady solver residuals (bottom row)



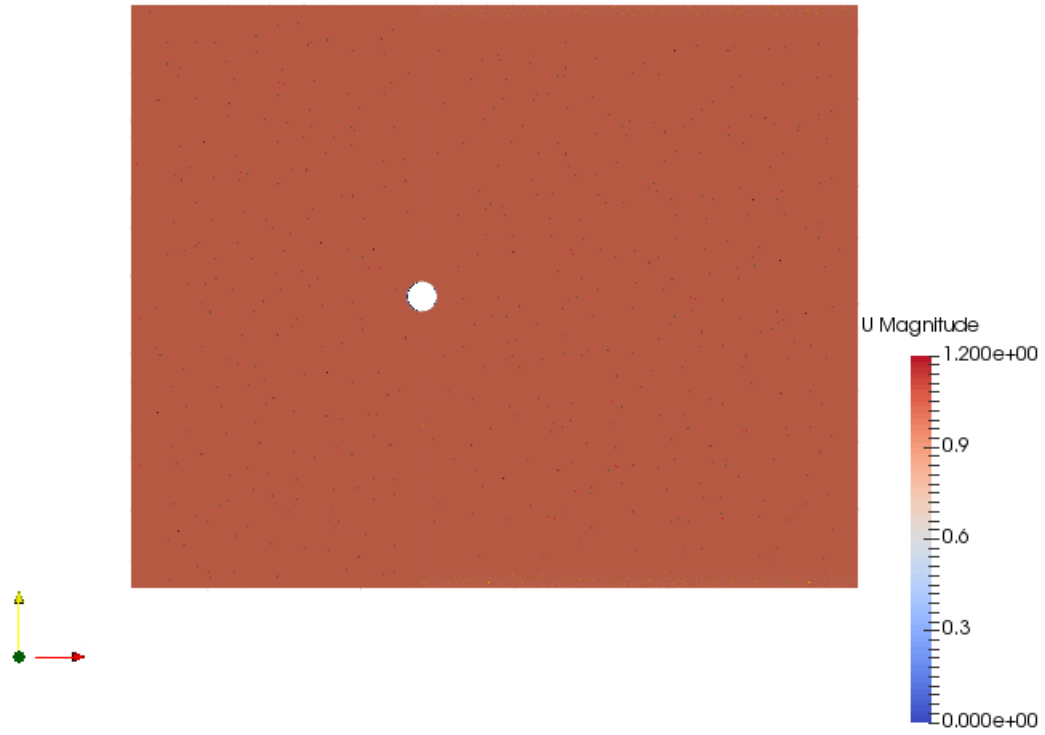






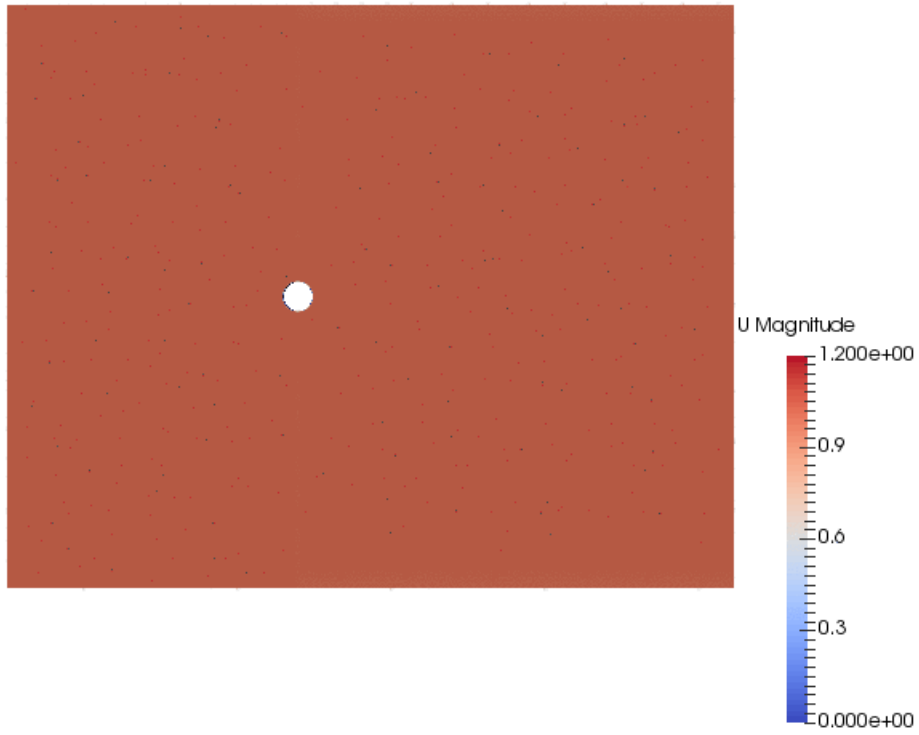
Unsteady solver QoI in function of time (top row) – Comparison of unsteady and steady solvers QoI in function of iterations (bottom row)

Time: 0.000000

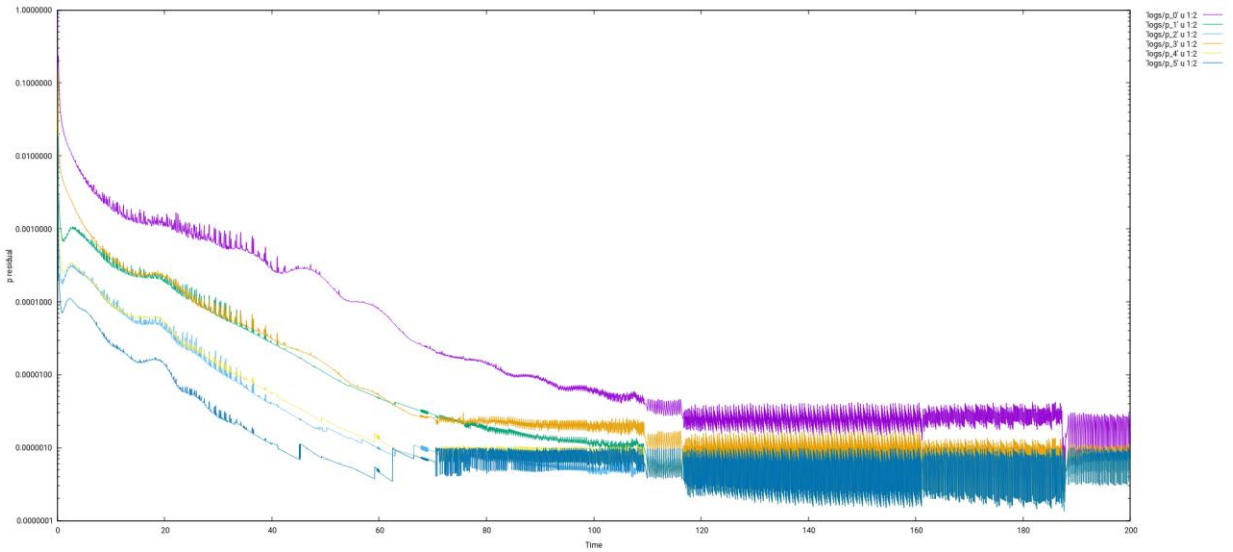


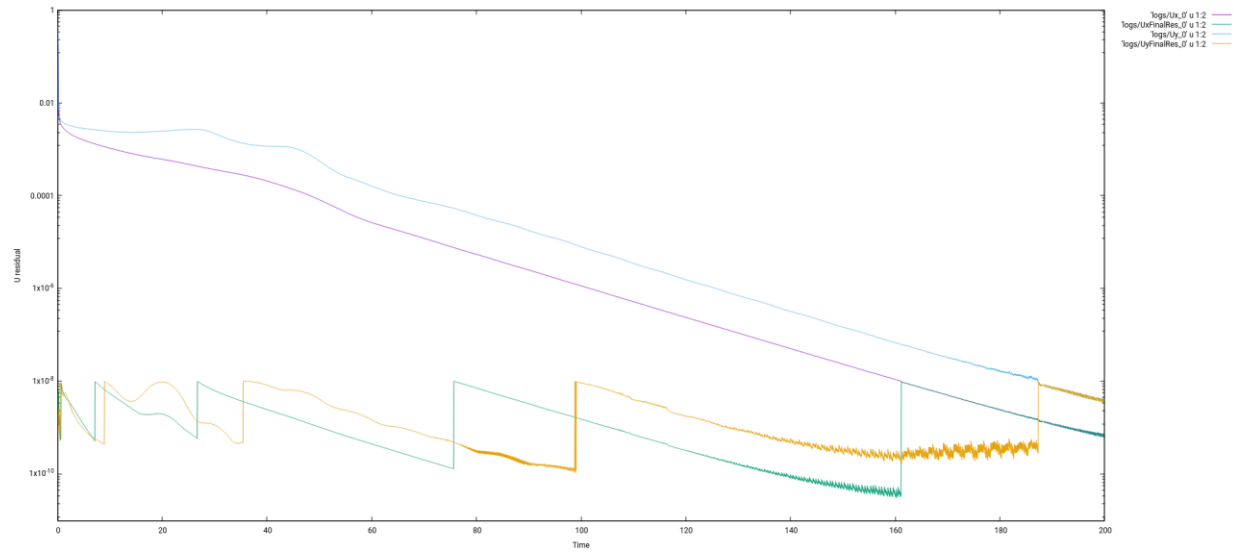
Re = 20
Steady physics with **unsteady solver**
Non-uniform initialization

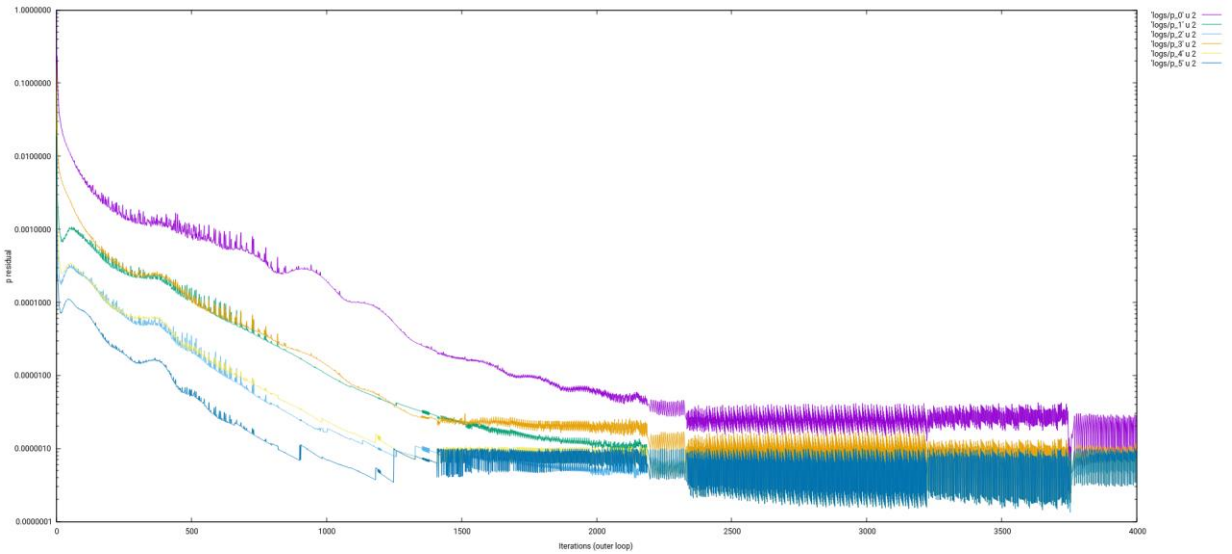
Iteration: 0.000000

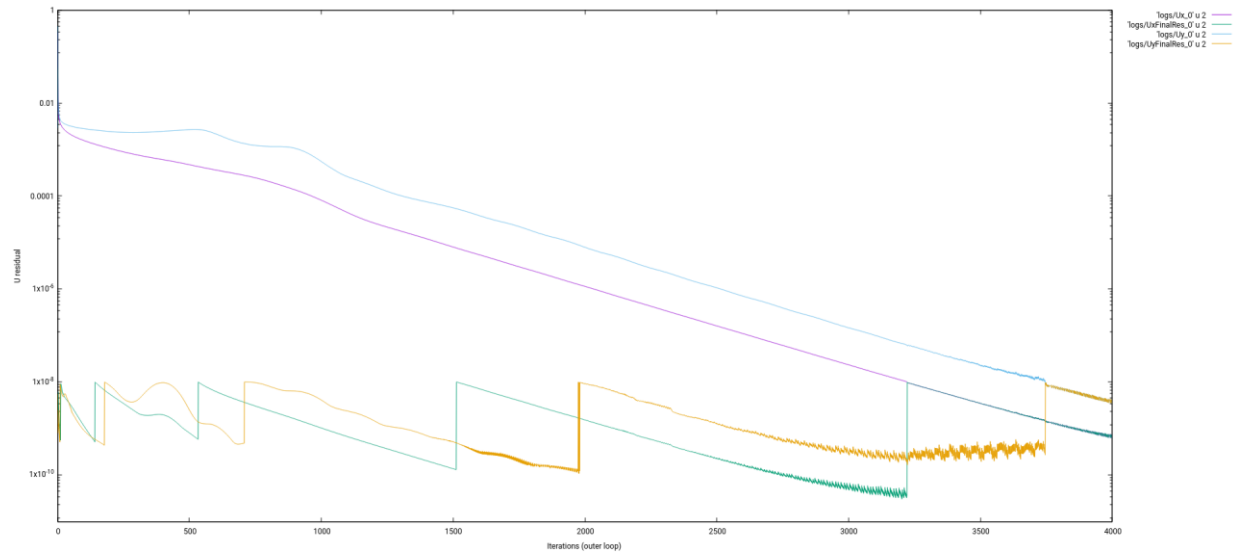


Re = 20
Steady physics with **steady solver**
Non-uniform initialization

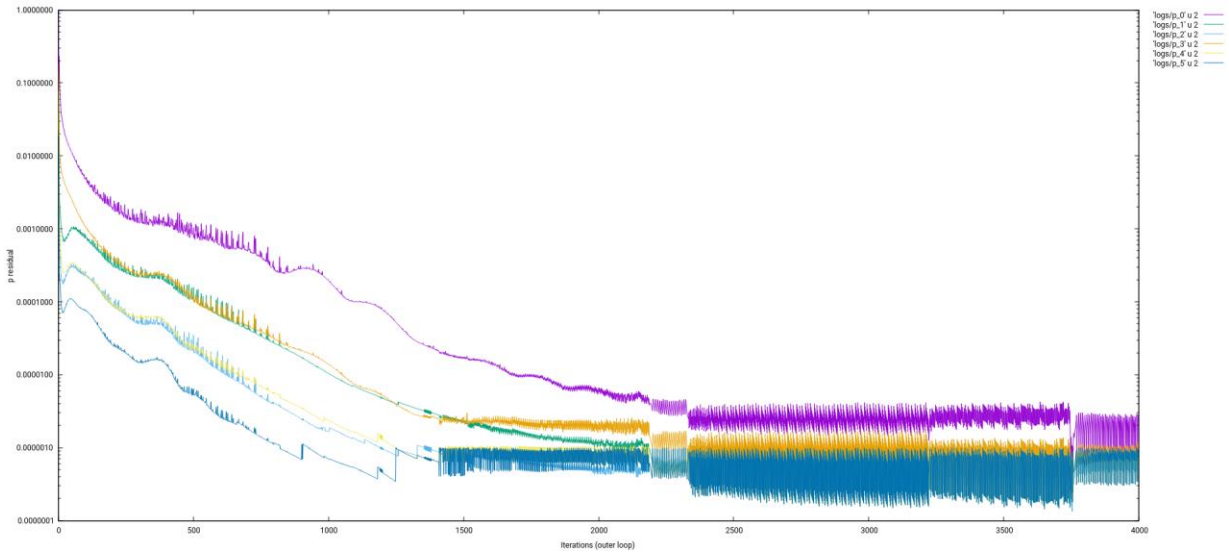


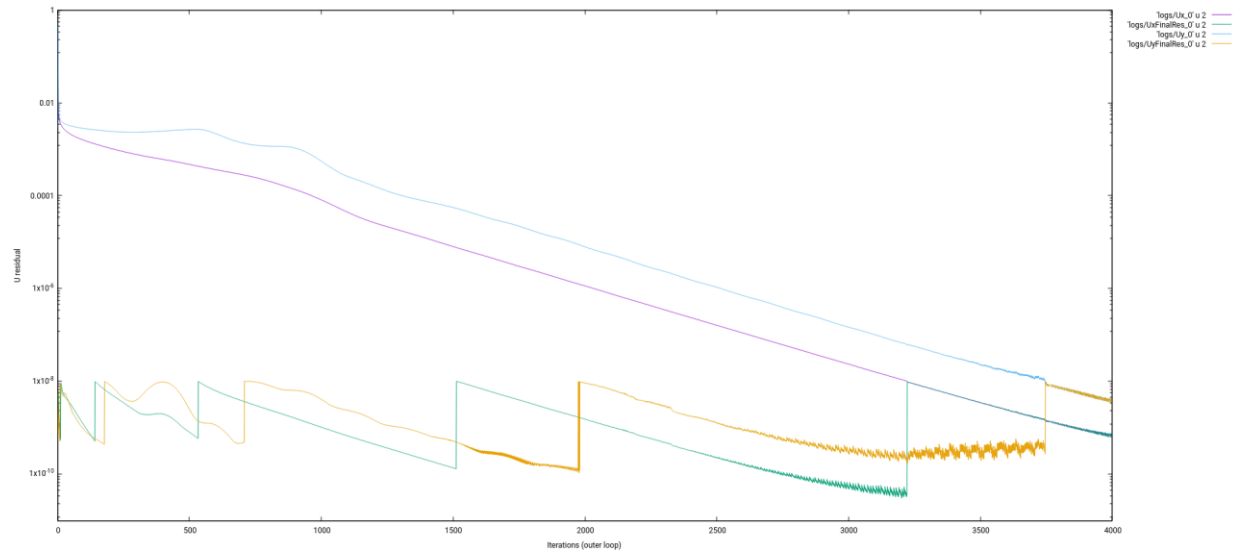


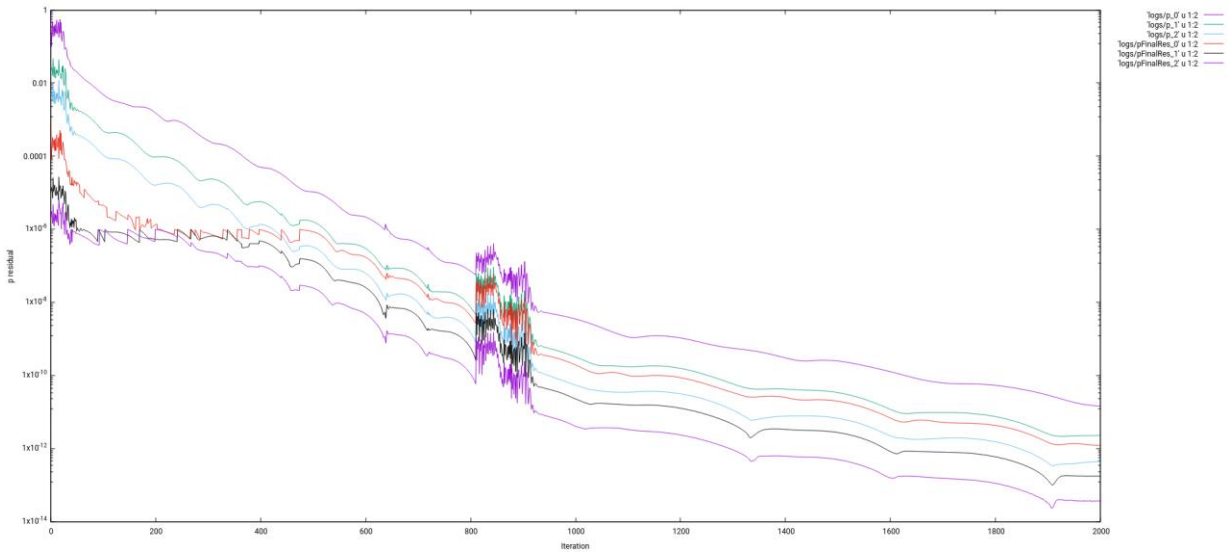


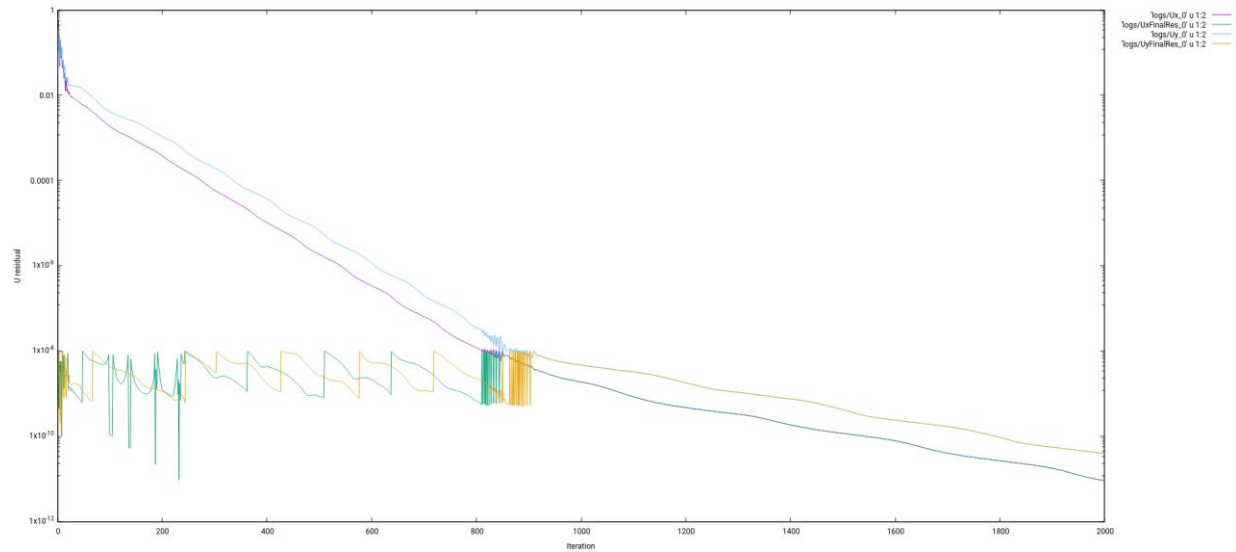


Unsteady solver residuals – Top row: residuals in function of time. Bottom row: residuals in function of iteration number.

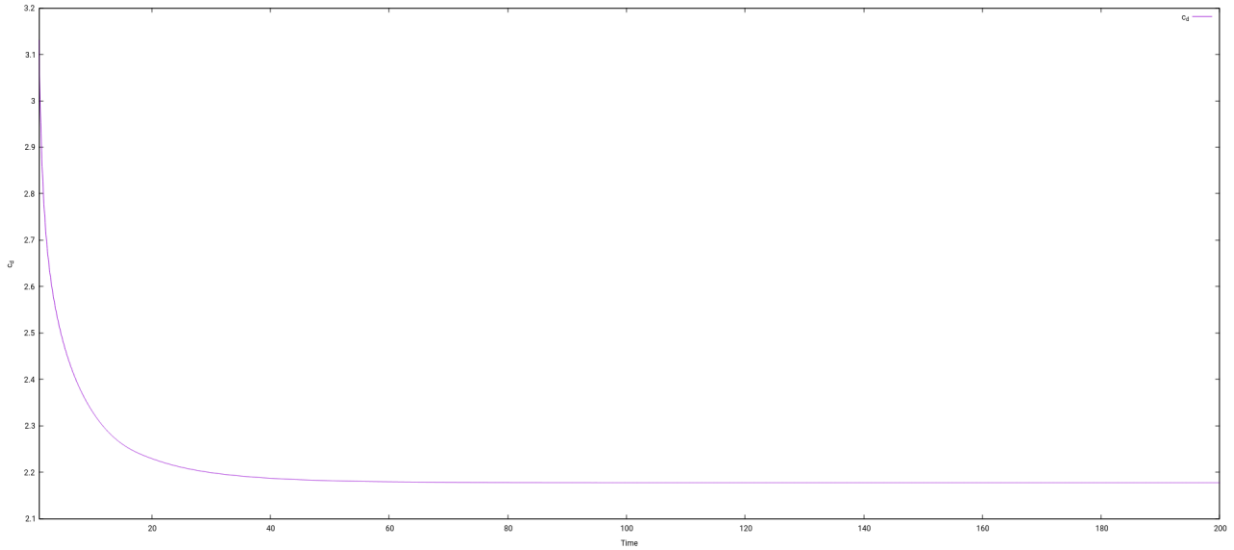


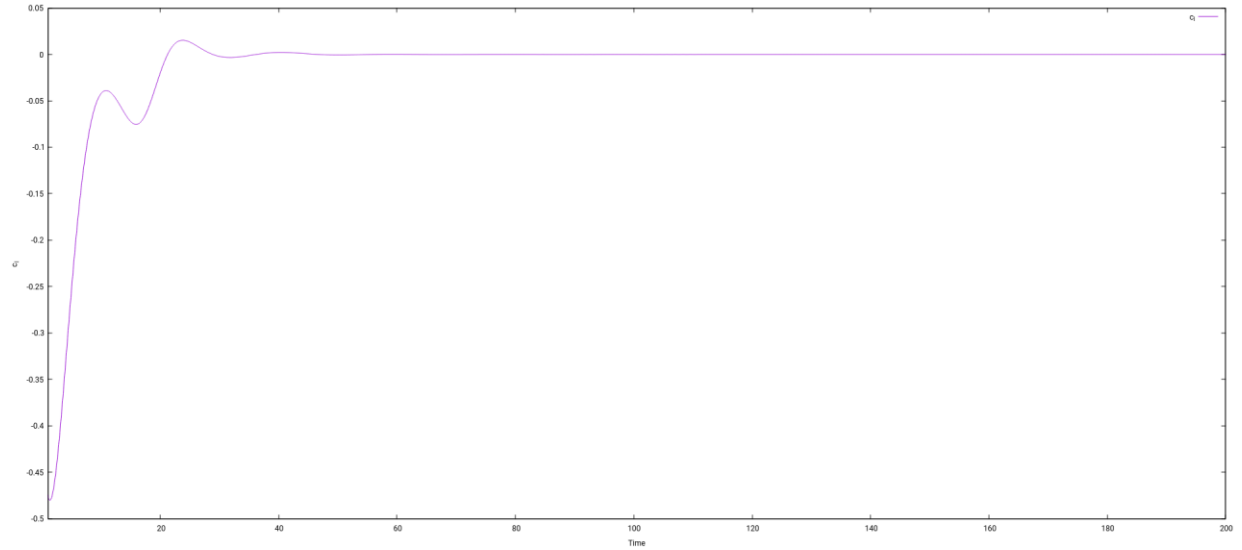


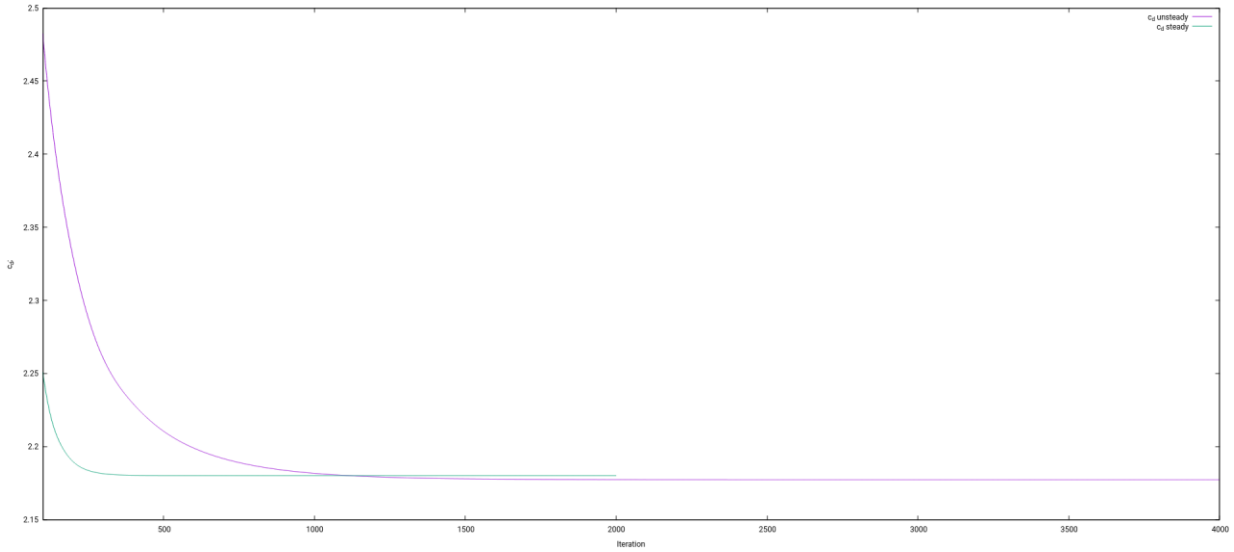


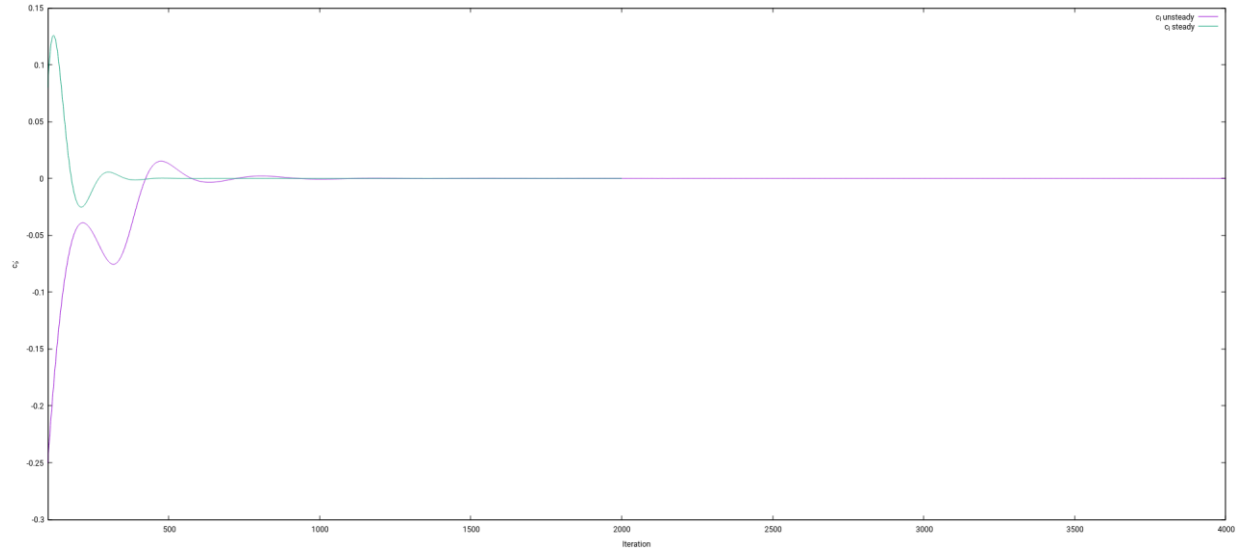


Comparison of unsteady solver residuals (top row) and steady solver residuals (bottom row)









Unsteady solver QoI in function of time (top row) – Comparison of unsteady and steady solvers QoI in function of iterations (bottom row)