3rd AIAA Sonic Boom Prediction Workshop

Nearfield Cases

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Orlando, Florida

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CFD++ Solver

- Finite volume solver
- Unstructured framework
- RANS equations solved
- Air treated as a calorically perfect gas
- Turbulence models used in this study:
  - Realizable k-ϵ
  - Cubic k-ϵ
  - Spalart-Allmaras (SA) + RC + QCR
  - Menter's SST

Biconvex Shock-Plume Interaction Model

Cases Simulated

1. Three turbulence models tested: realizable k-**ϵ**, cubic k-**ϵ**, and SST models.
2. Mesh convergence study performed with each model and the provided "mixed" mesh family (coarse, medium, and fine).

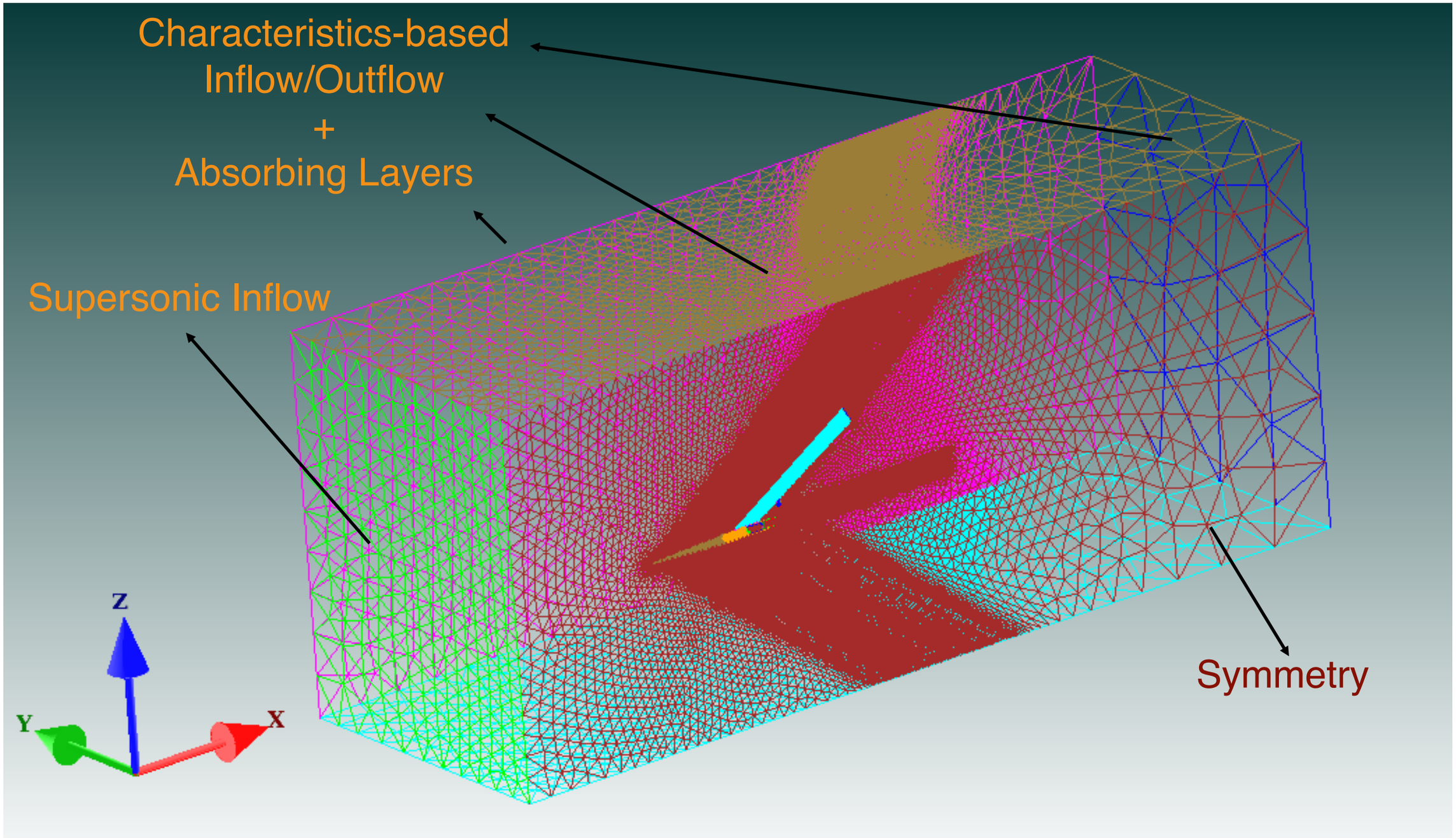
Freestream Conditions

1. Fluid: air treated as a calorically perfect gas

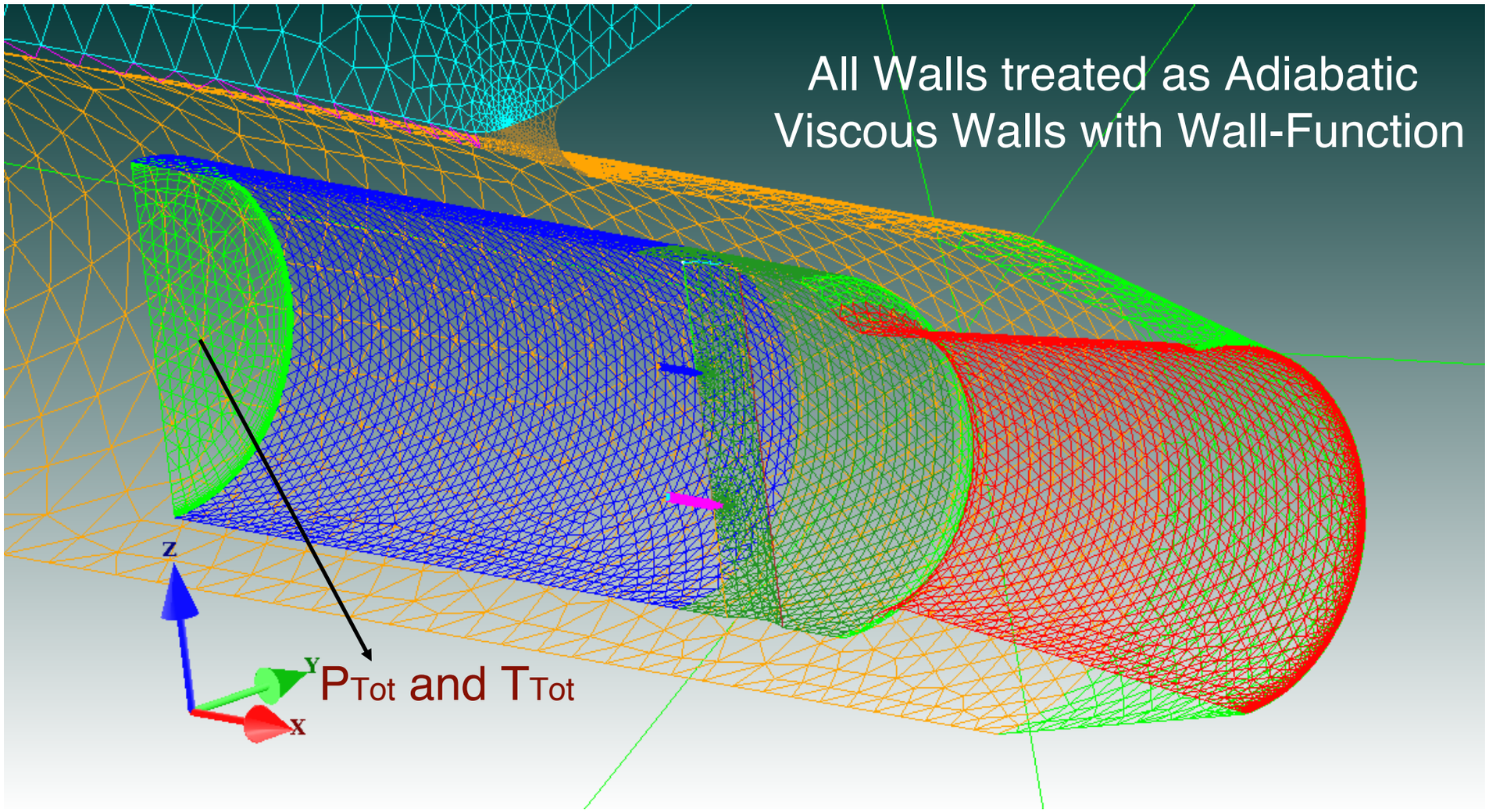
Property	Value
M	1.6
Re ($inch^{-1}$)	376850.0
T (Rankine)	374.0

Property	Value
T_{Inf} (K)	207.78
P_{Inf} (Pa)	26266.9
U_{Inf} (m/s)	462.45

Boundary Conditions



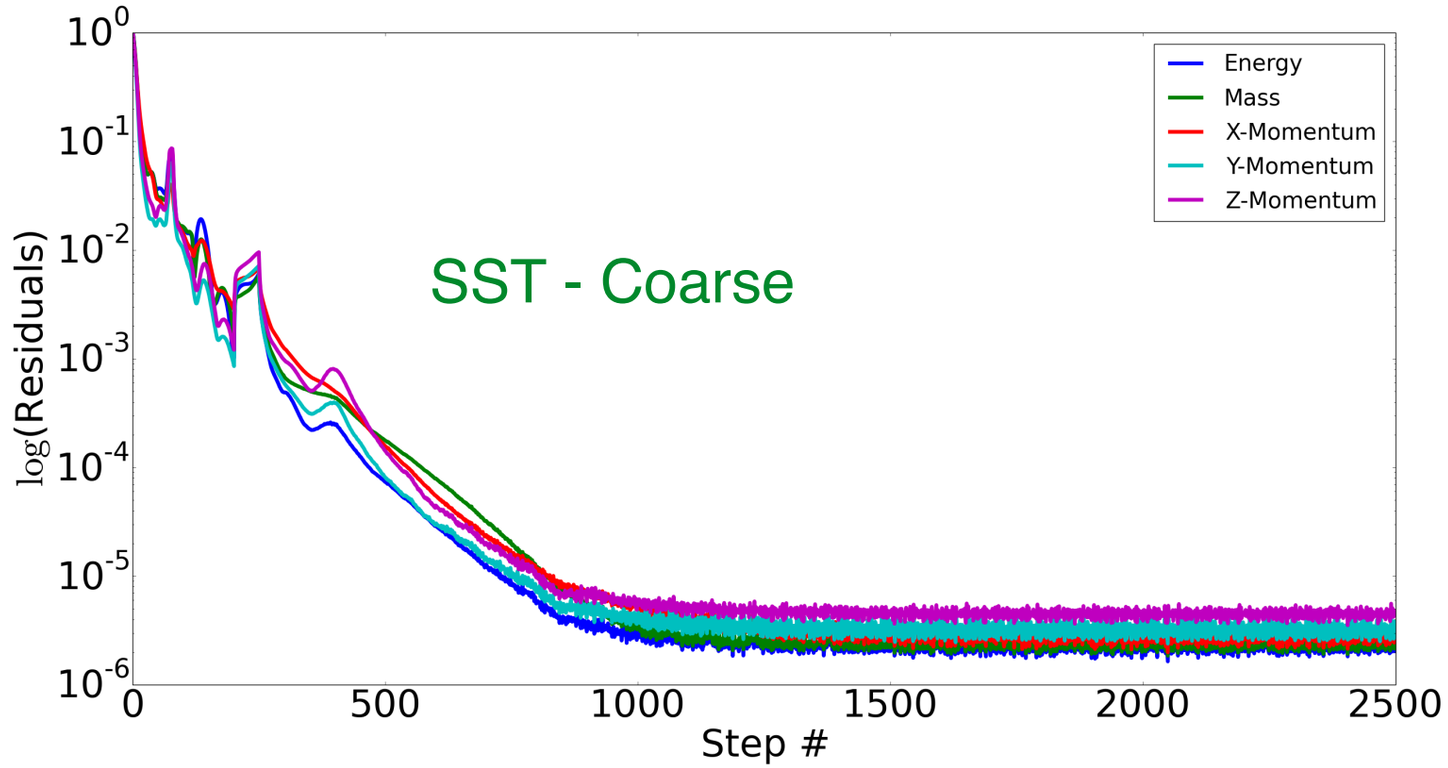
Boundary Conditions

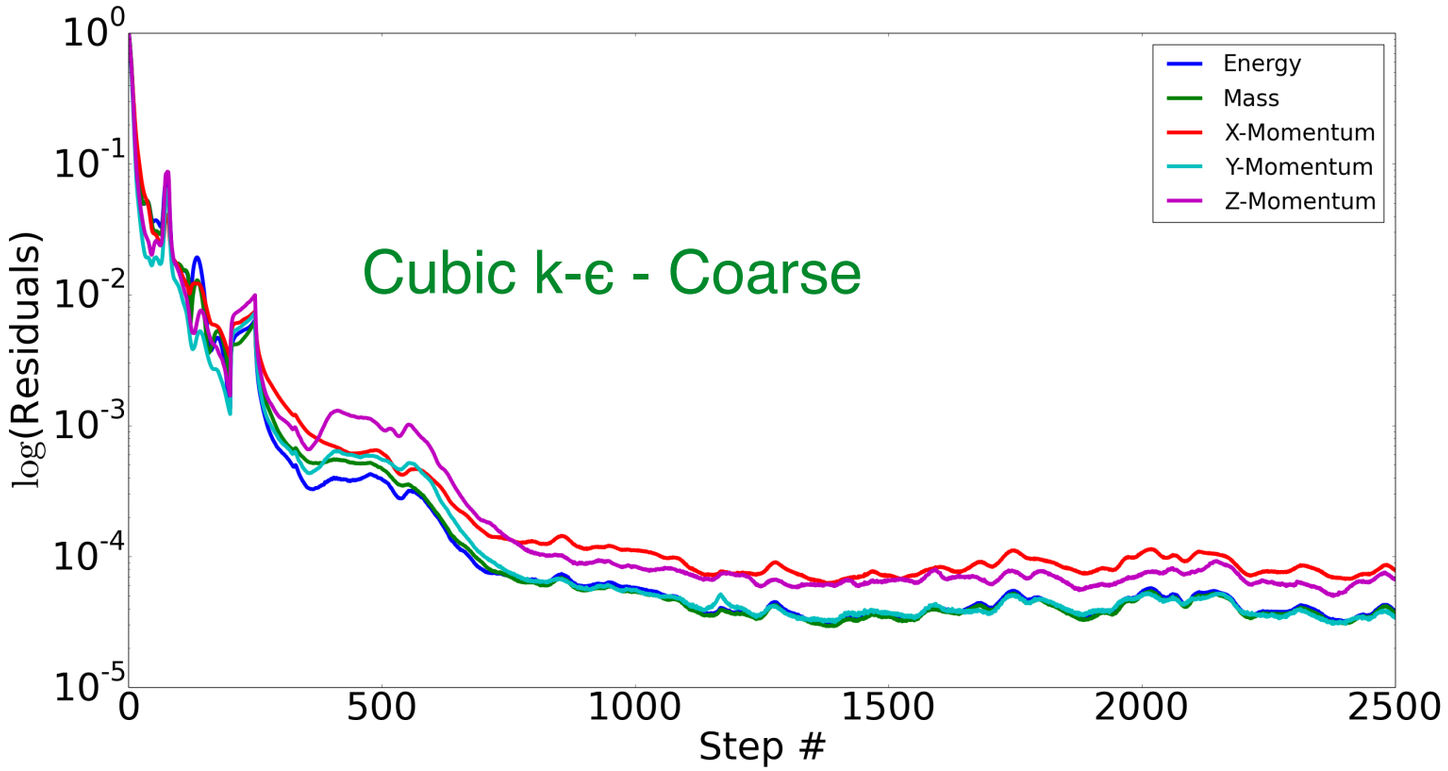


Results

Convergence

1. SST: a decrease of 5-6 orders in magnitude of the residuals
2. Realizable and cubic k-**ϵ**: a decrease of 4-5 orders in magnitude of the residuals





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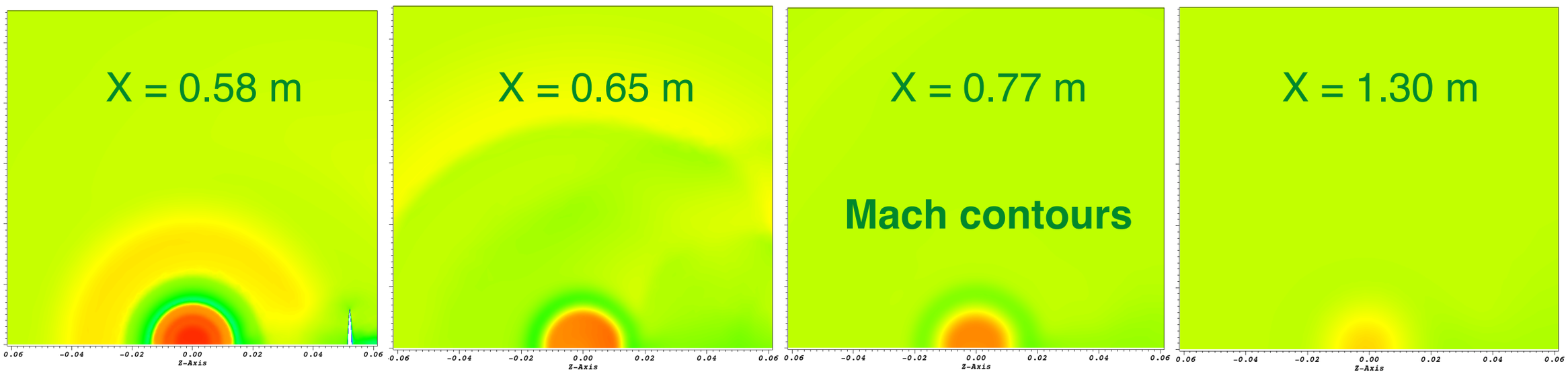
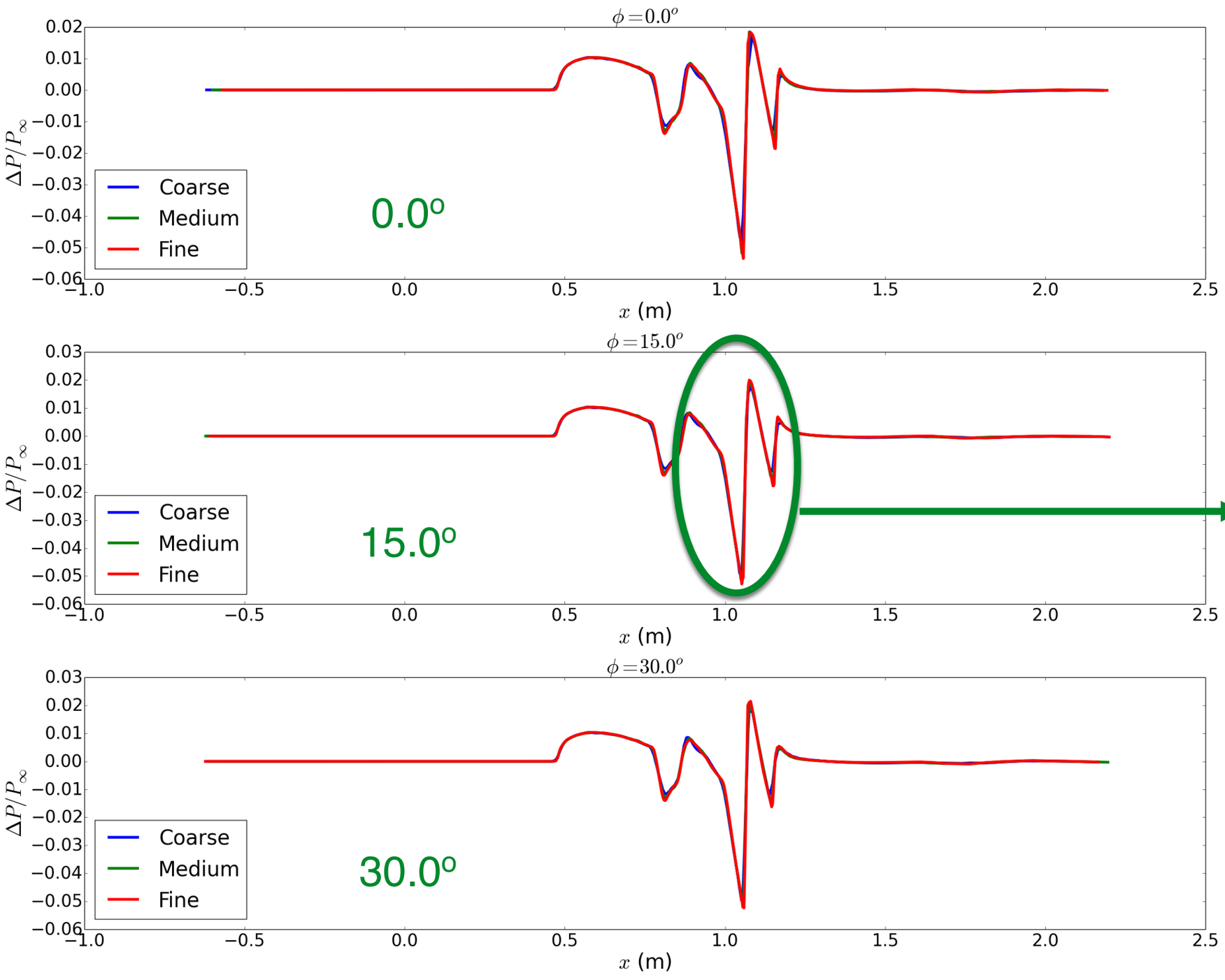
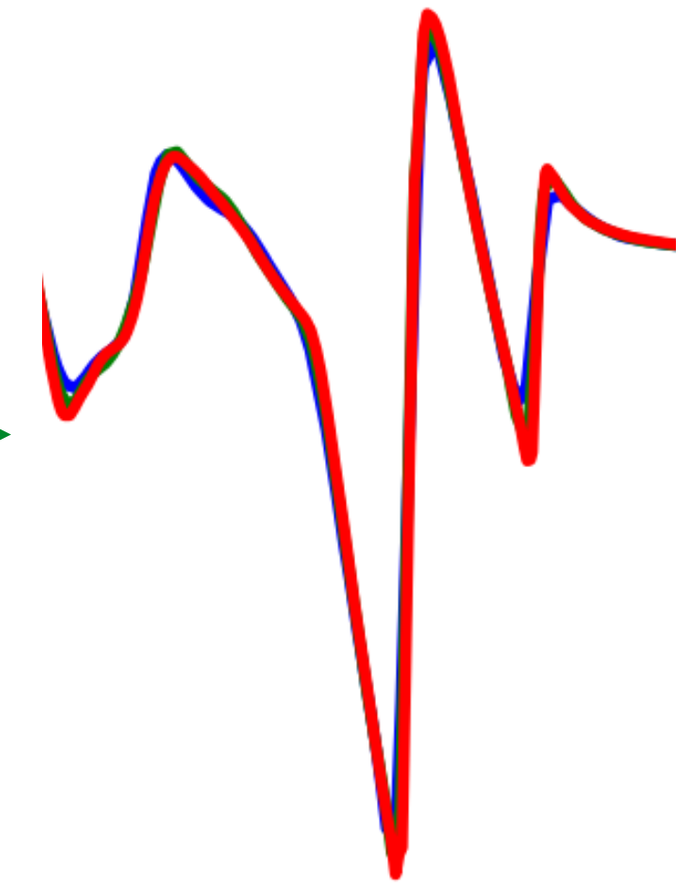
Shock Structure

Density gradient contours
SST - Coarse

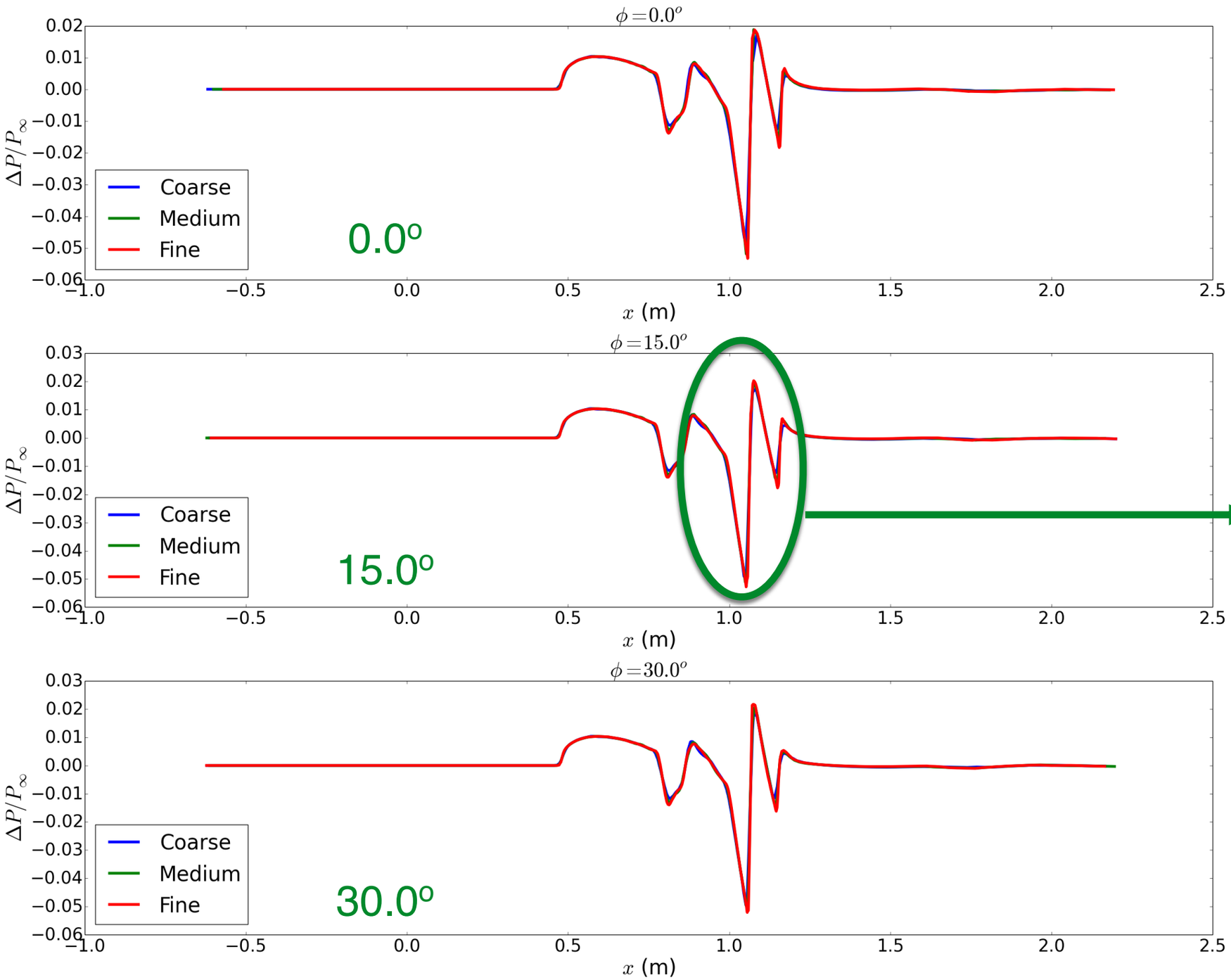


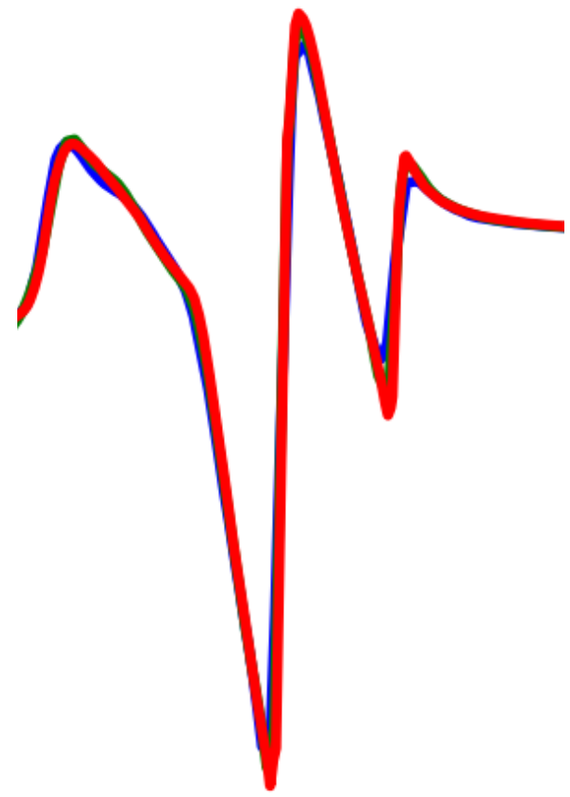
Grid Refinement - Cubic k-ϵ



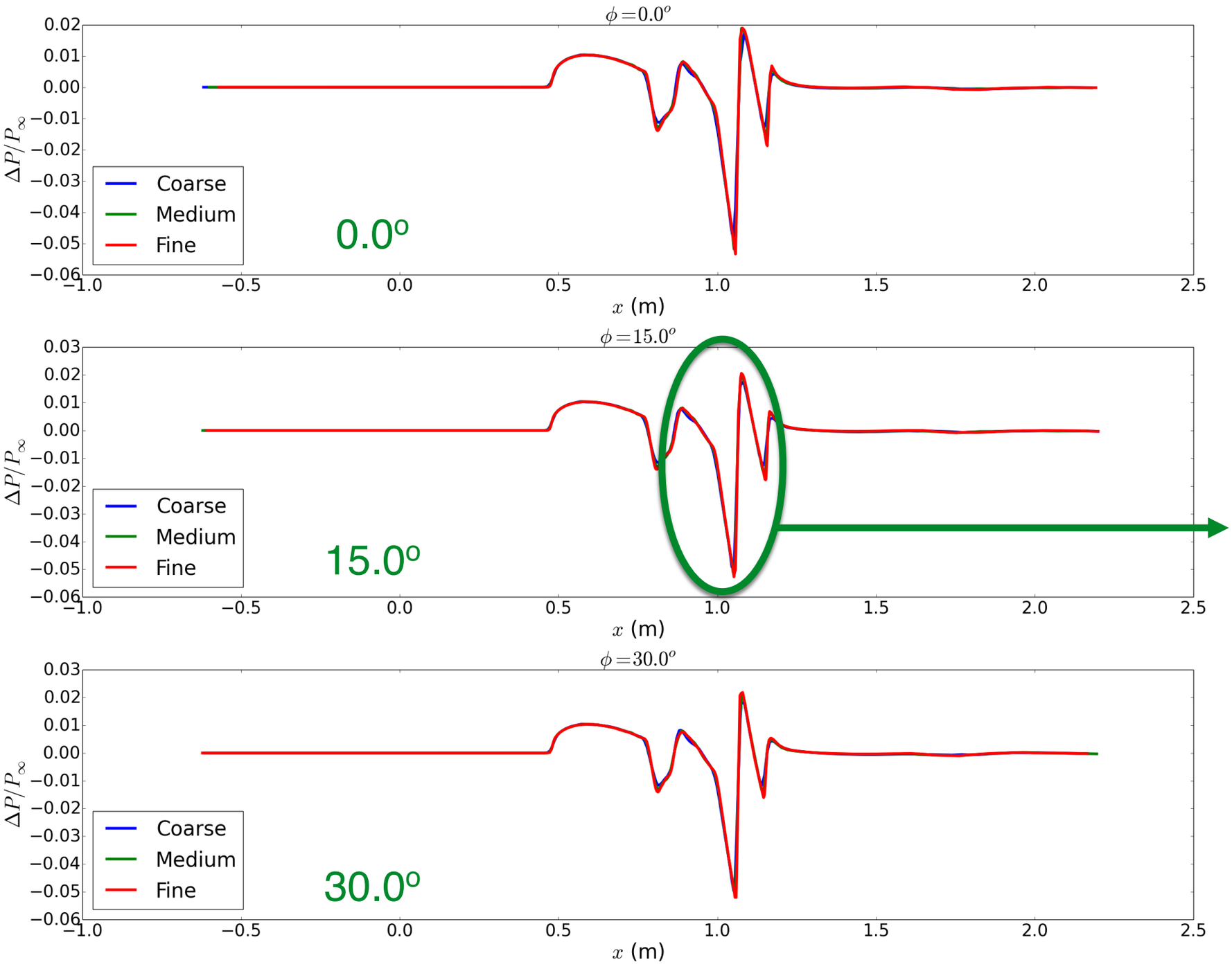


Grid Refinement - Realizable k-ϵ

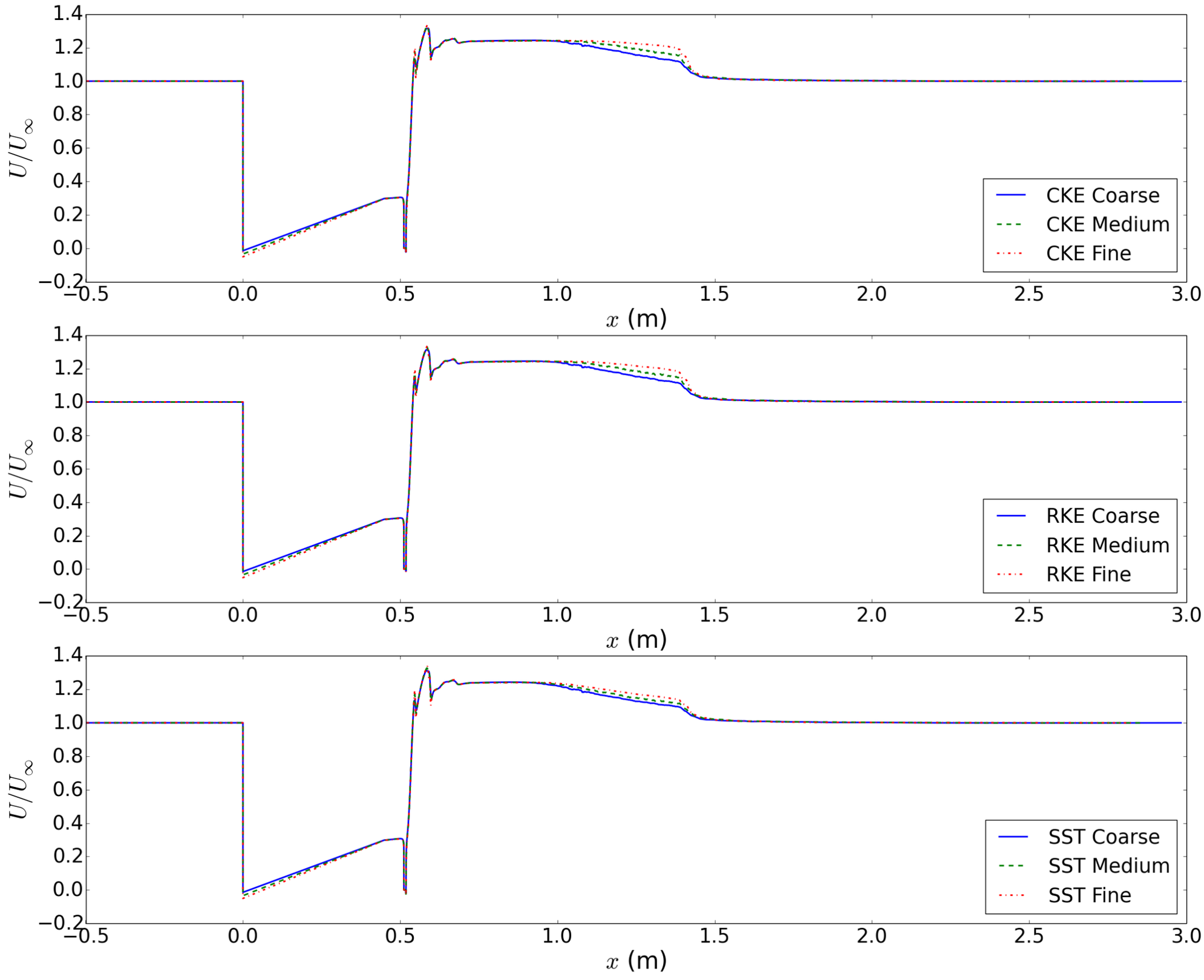




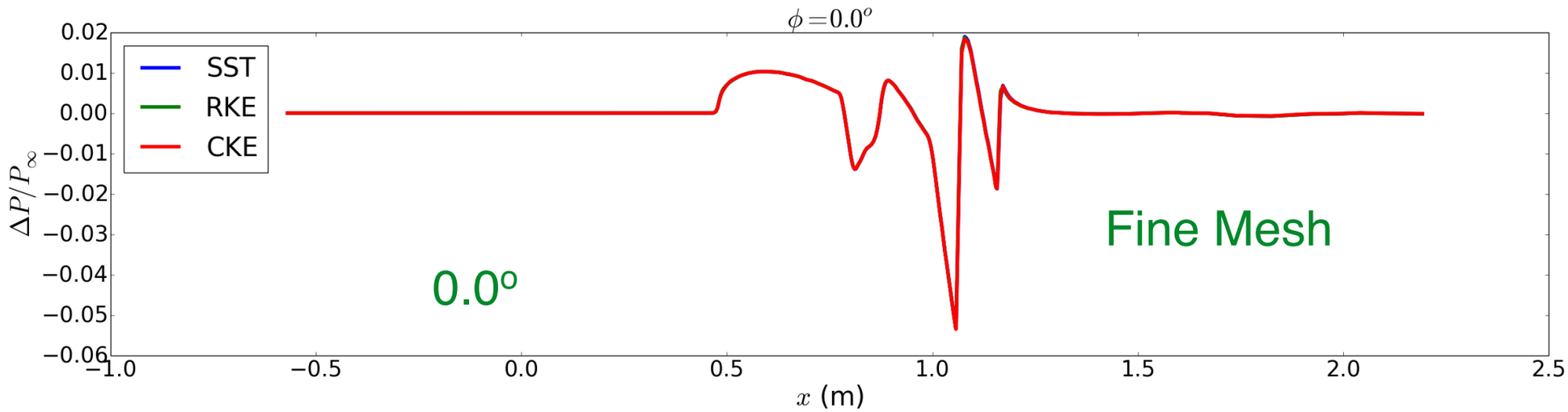
Grid Refinement - SST

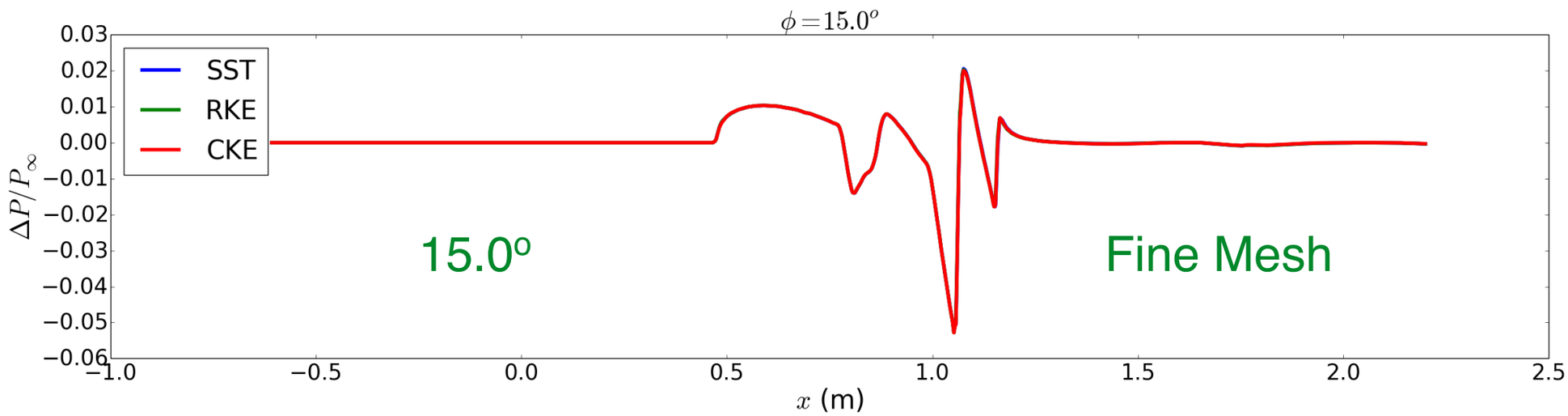


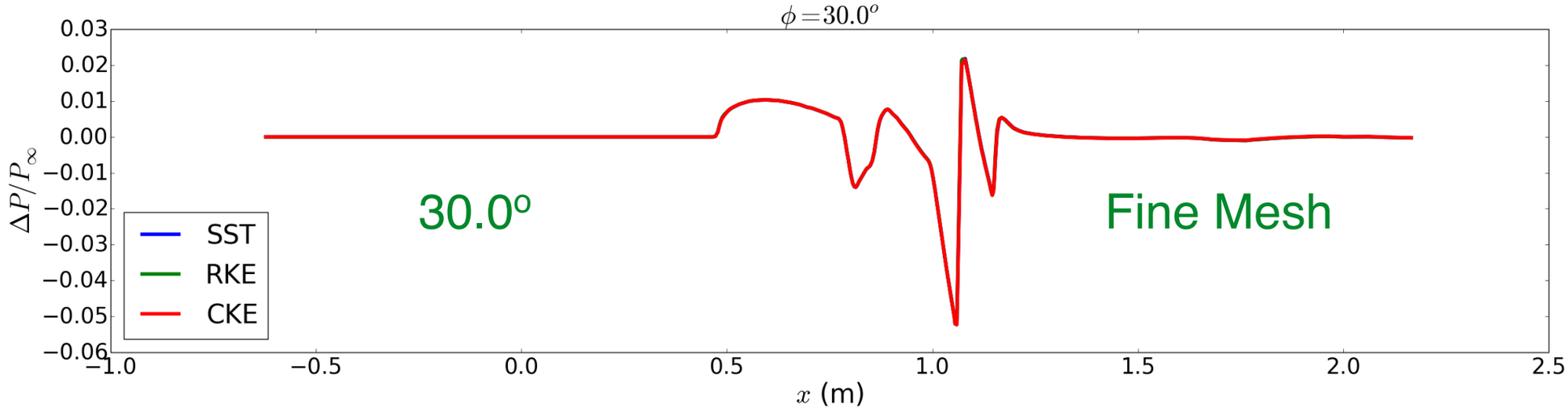
Grid Refinement - Centerline X-Velocity



Turbulence Models Effects







C608 Low Boom Flight Demonstrator

Cases Simulated

1. Three turbulence models tested: Spalart-Allmaras (SA), SA+RC+QCR, and SST models.
2. Mesh convergence study performed with each model and the provided "mixed" mesh family (Coarse040, Coarse050, Coarse064, Coarse080, Coarse100, and Coarse128).

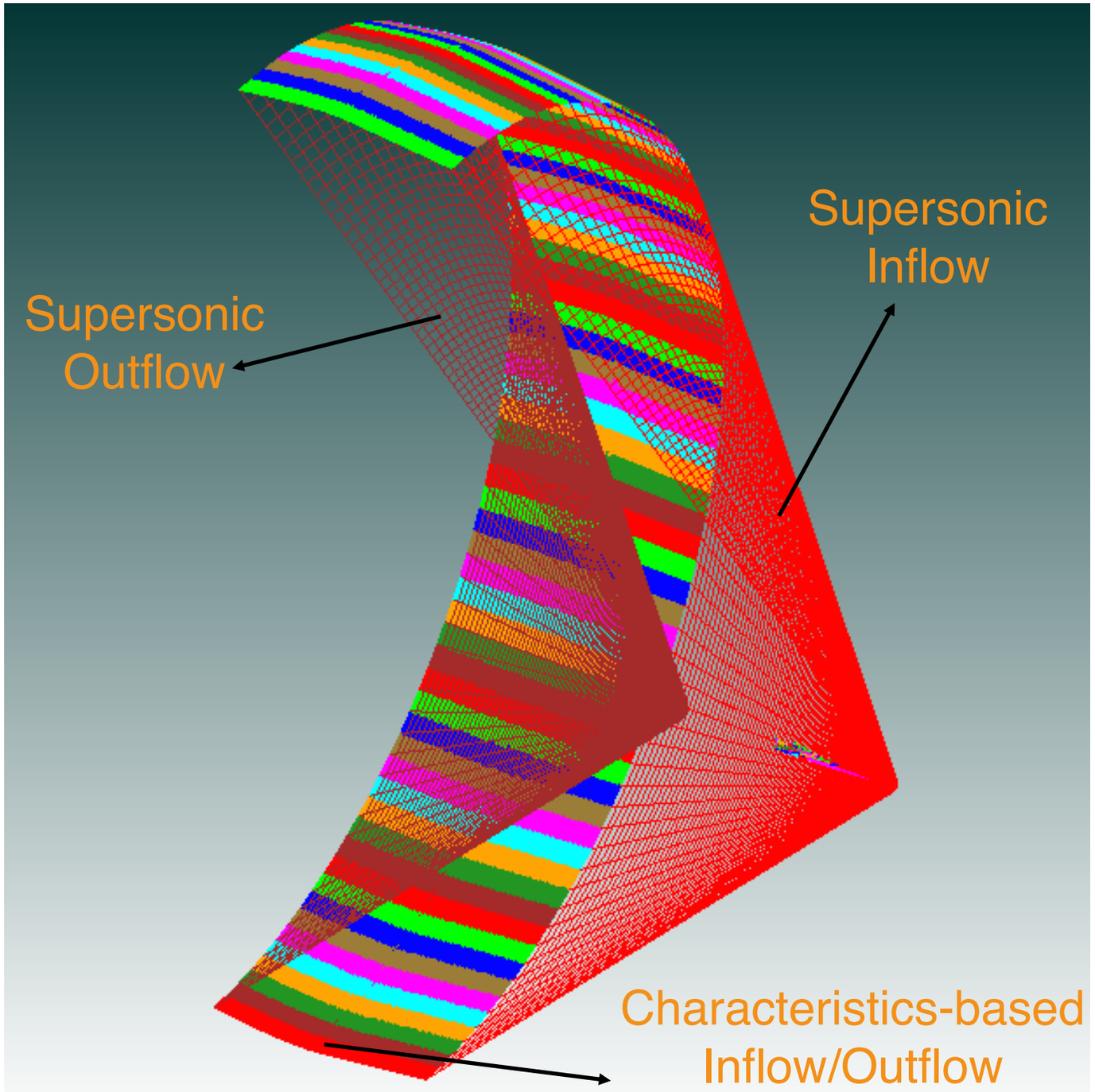
Freestream Conditions

1. Fluid: air treated as a calorically perfect gas
2. U.S. Standard Atmosphere 1976 used for freestream specification

Property	Value
M	1.4
Altitude (ft)	53200.0

Property	Value
T_{Inf} (K)	216.65
P_{Inf} (Pa)	10008.75
U_{Inf} (m/s)	413.19

Boundary Conditions

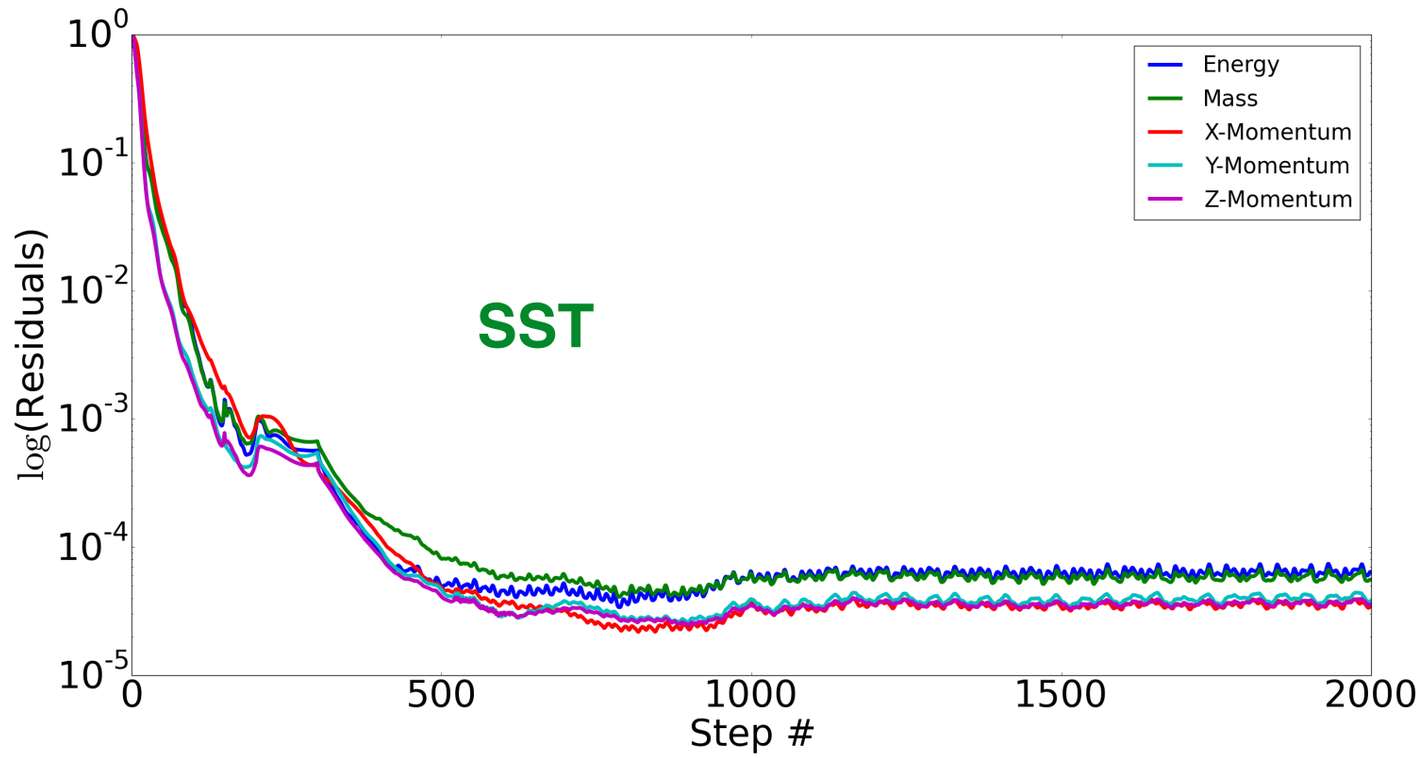


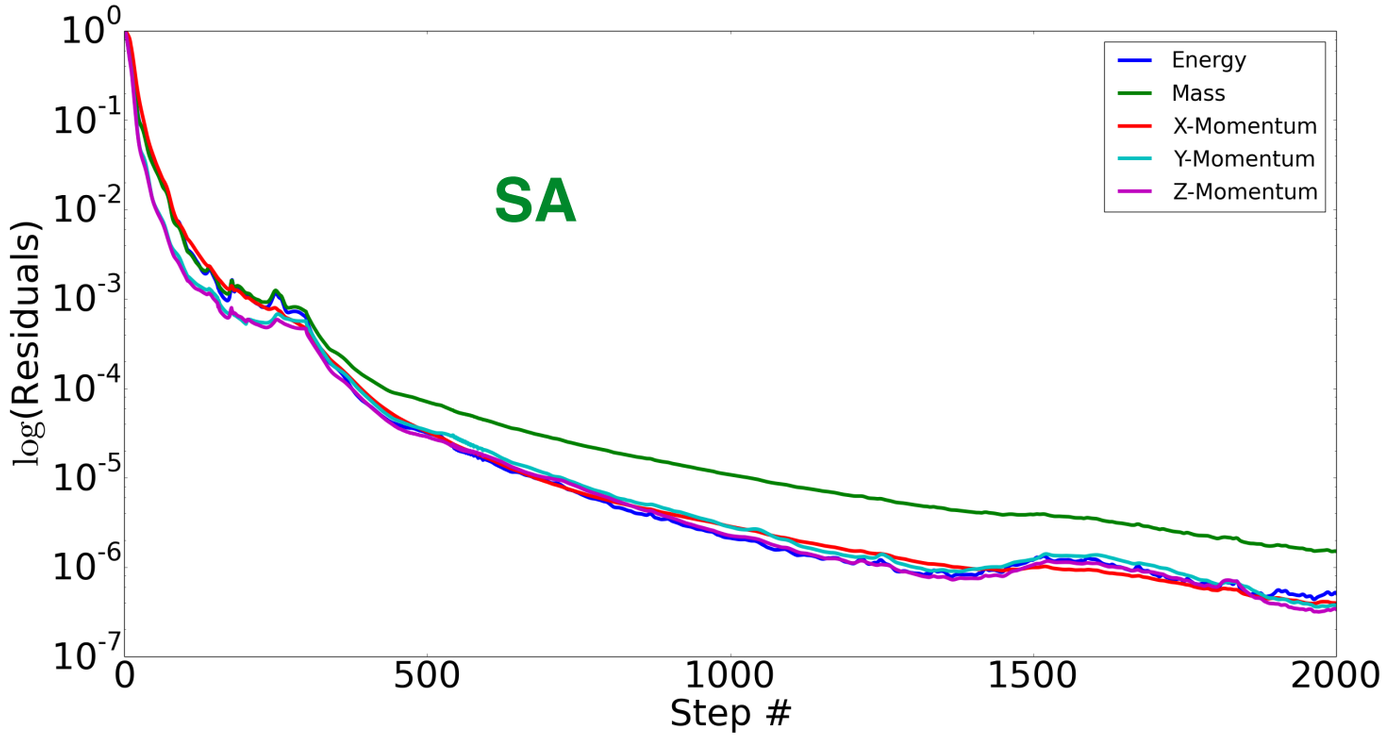
1. All walls treated as adiabatic viscous surfaces with solve-to-wall methodology
2. As recommended in the guidelines, reservoir boundary conditions prescribed for engine plenum and bypass surfaces
3. As recommended in the guidelines, back pressure boundary conditions imposed at the engine fan and environmental control system (ECS) faces

Results

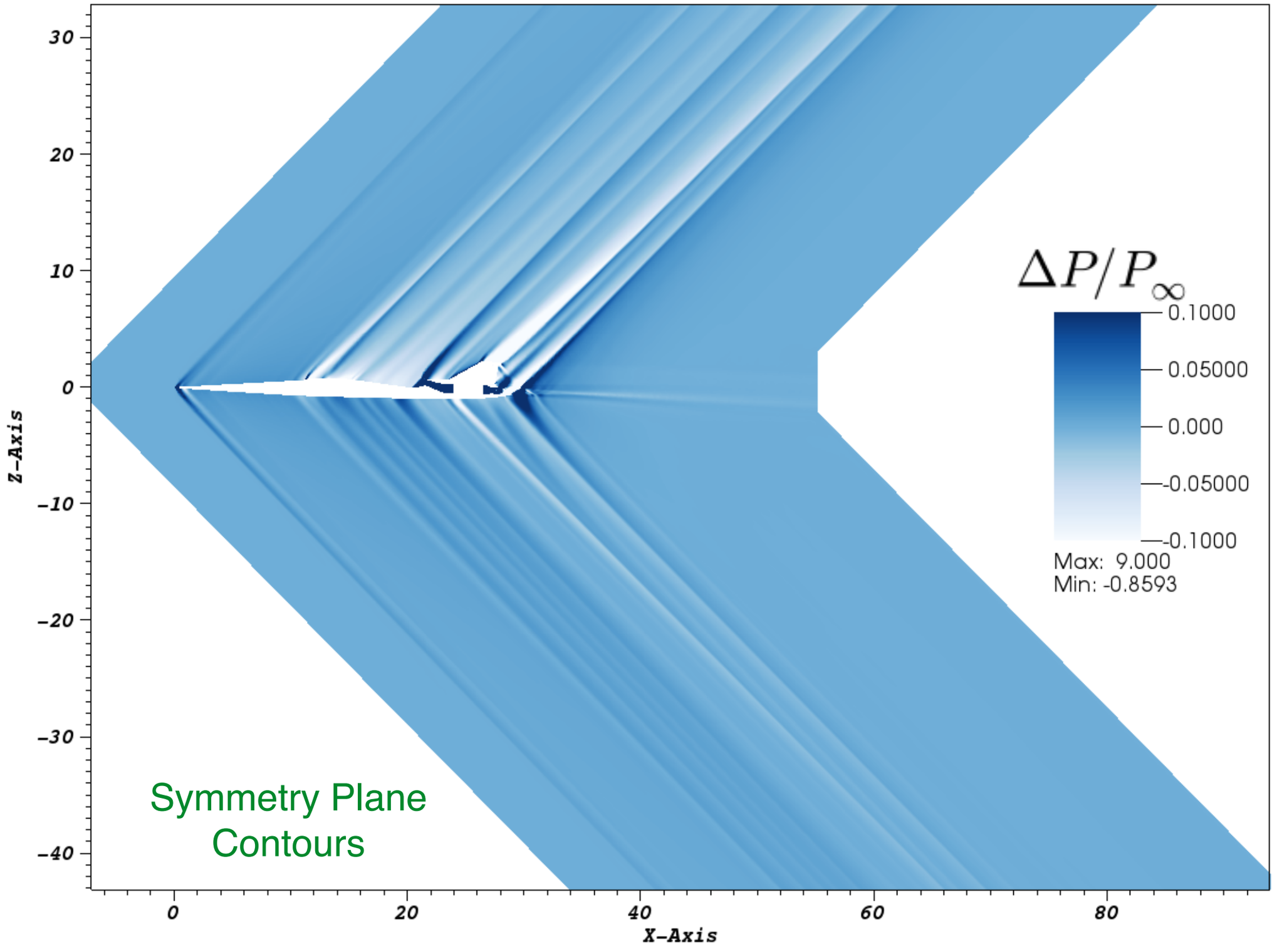
Convergence

- SST: a decrease of 4-5 orders in magnitude of the residuals
- SA and SA+RC+QCR: a decrease of 6-7orders in magnitude of the residuals

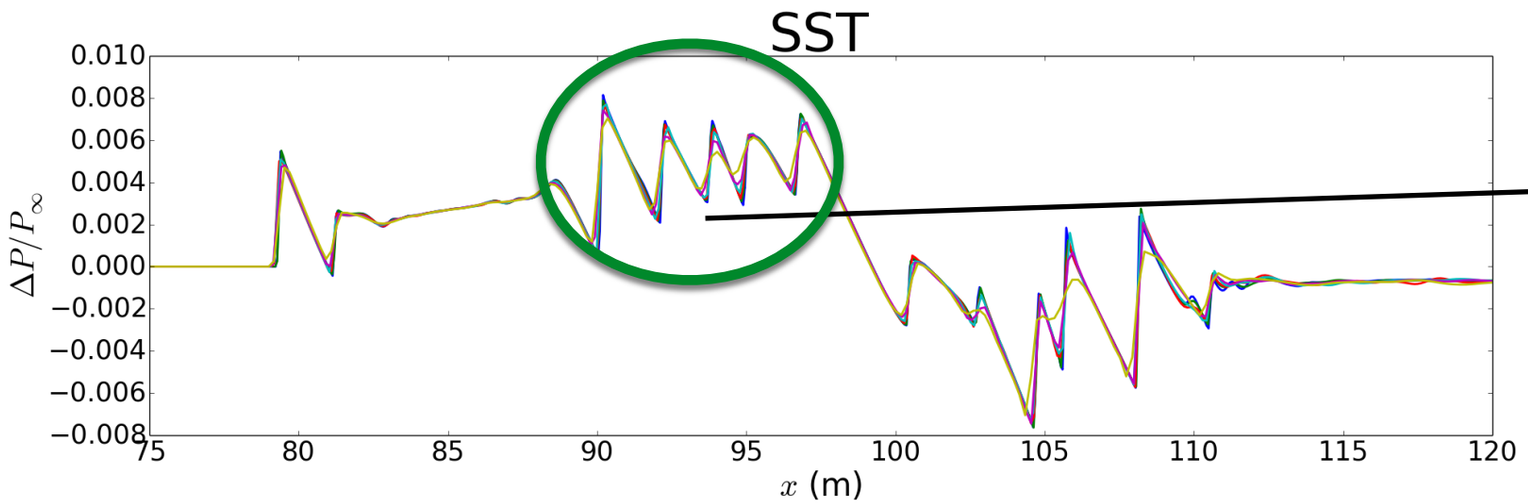


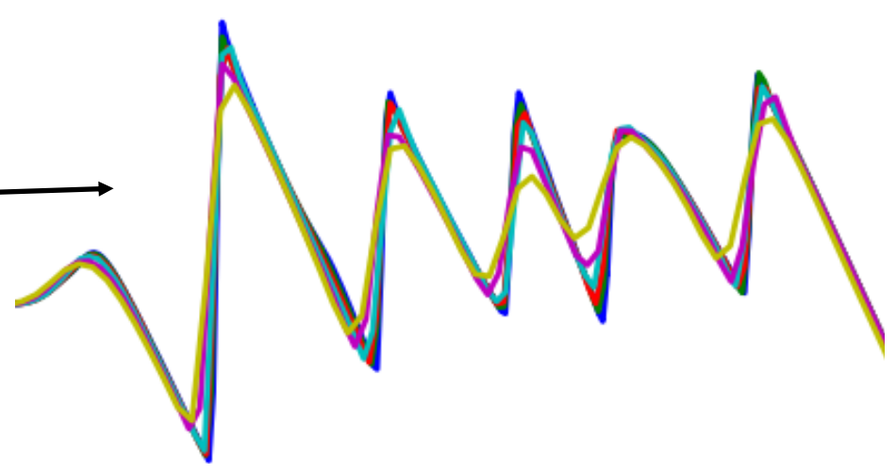


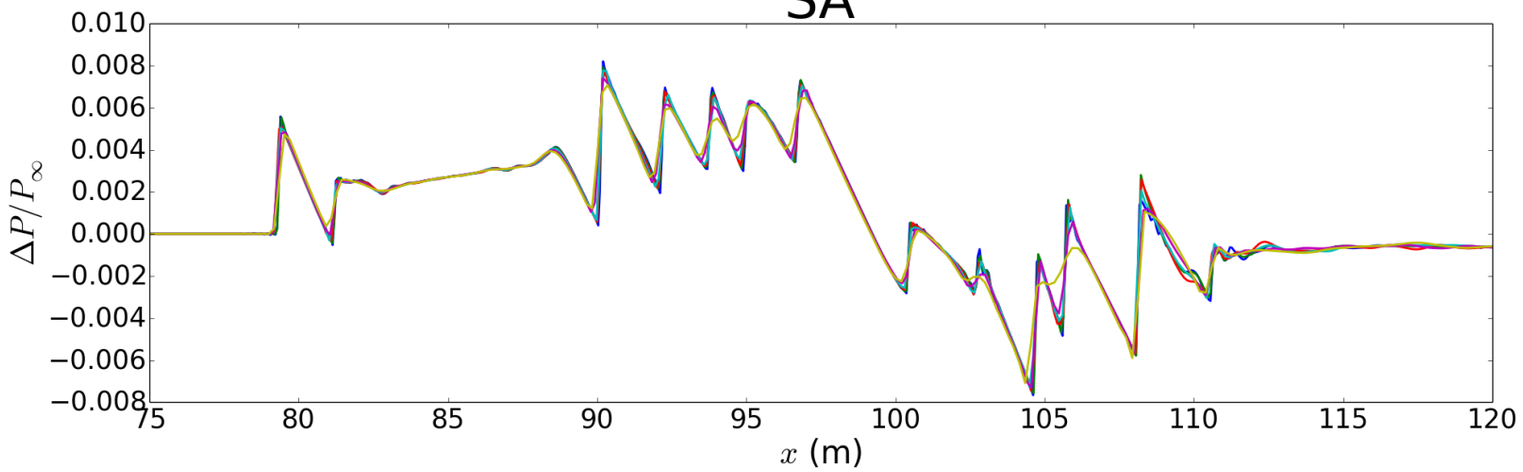
Flow Pattern

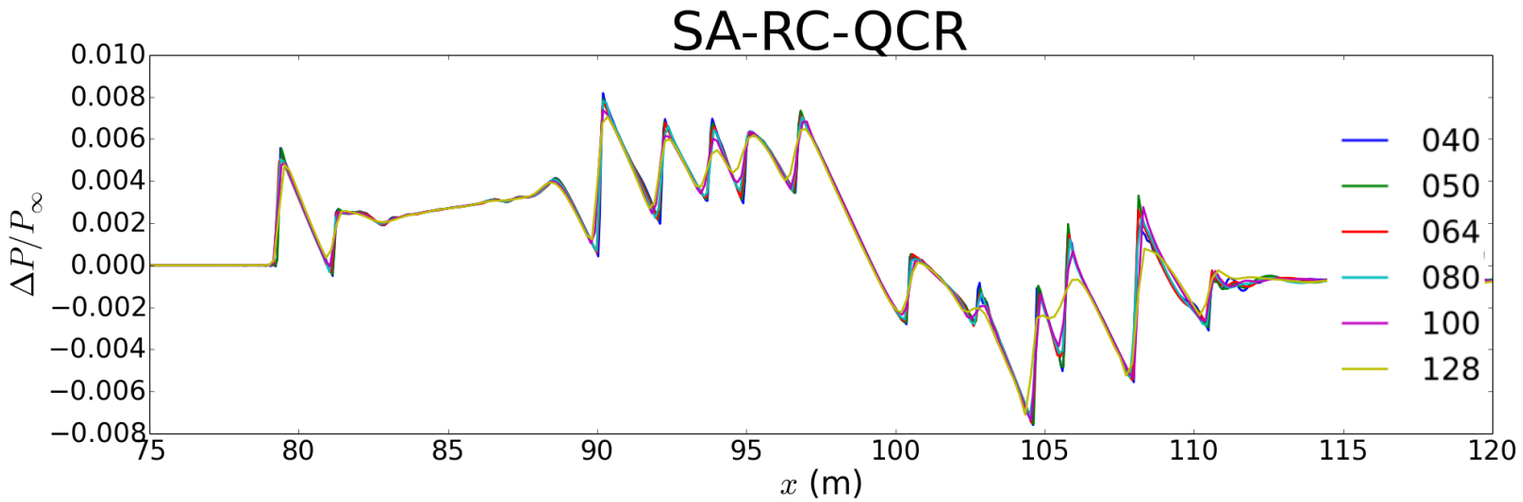


Grid Refinement - H/L = 3.0 and Phi = 0.0°



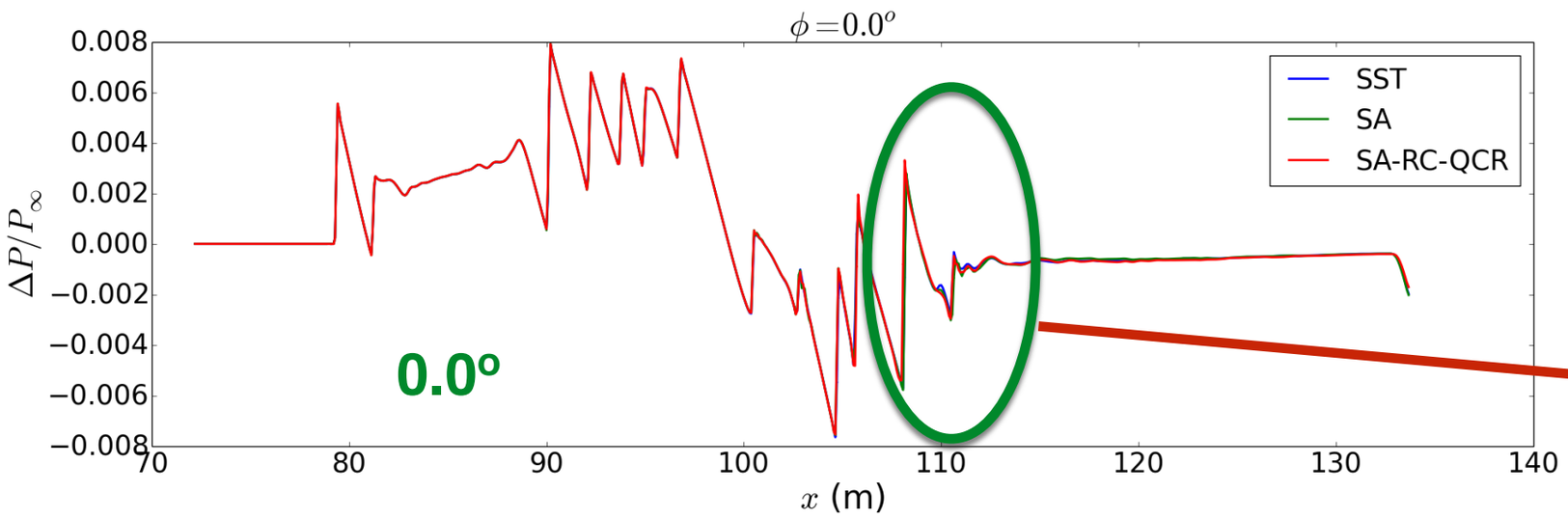


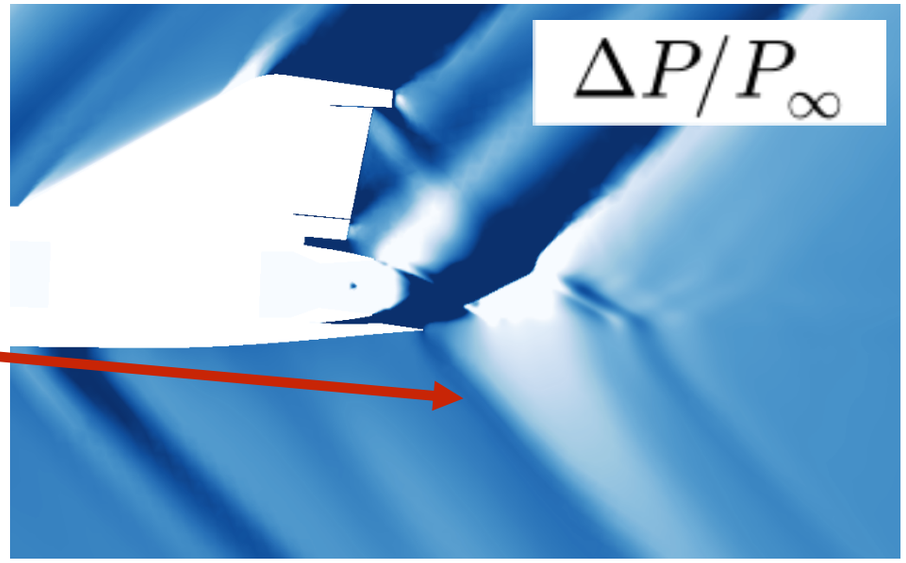


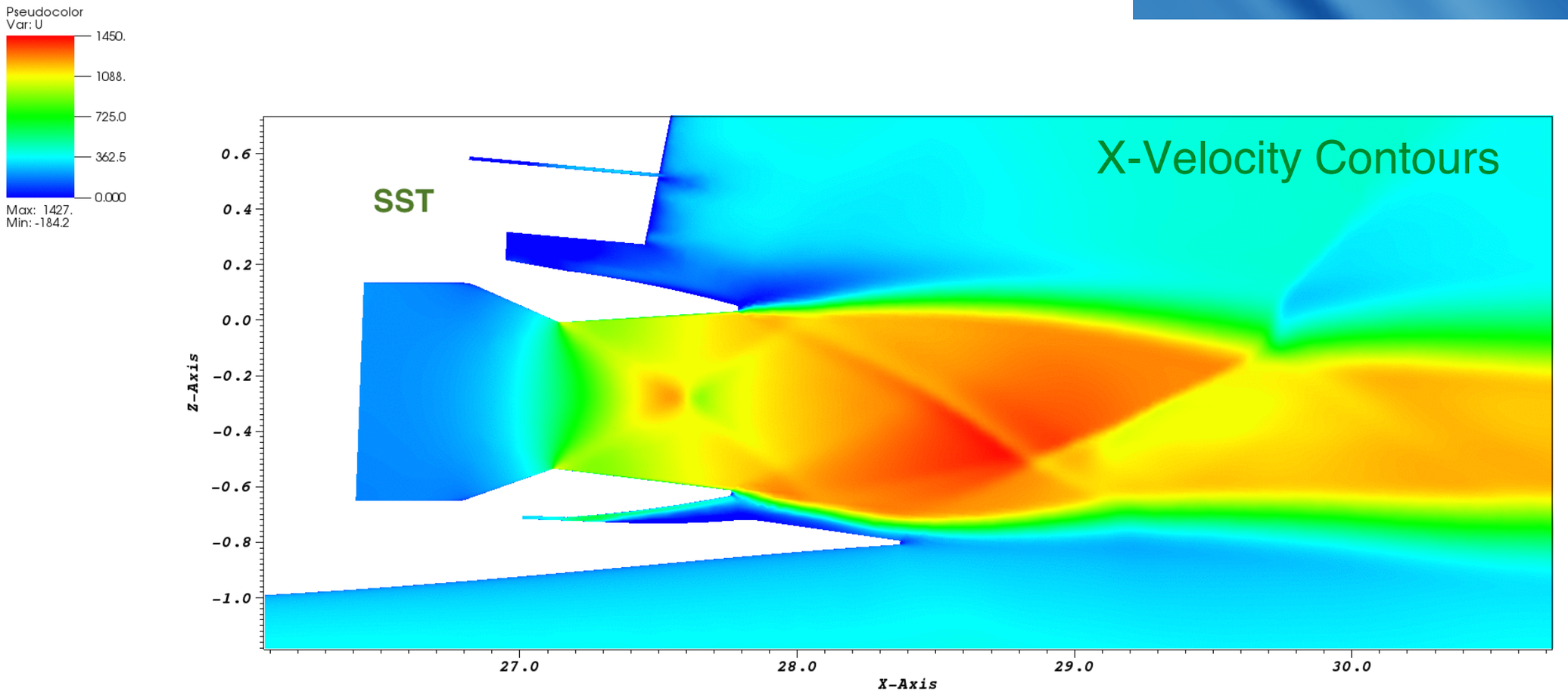


- Peak definitions refined with increase in refinement
- Shock locations remain the same
- As expected, weaker shocks more prominent at higher resolutions

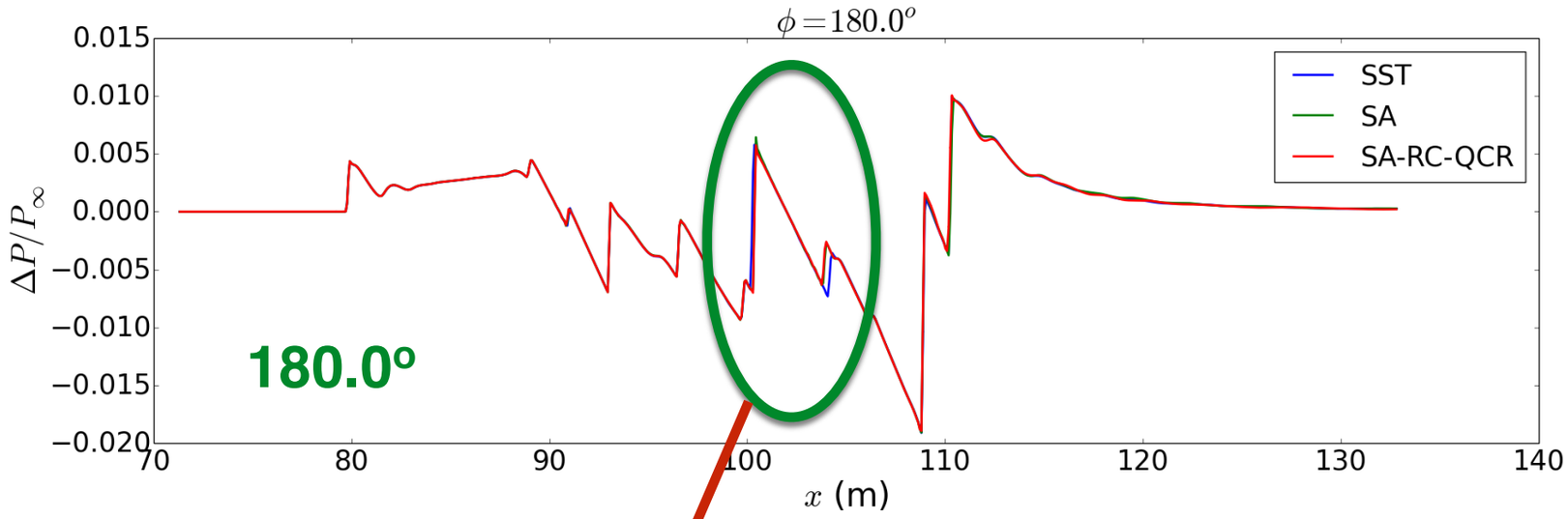
SST vs SA vs SA+RC+QCR

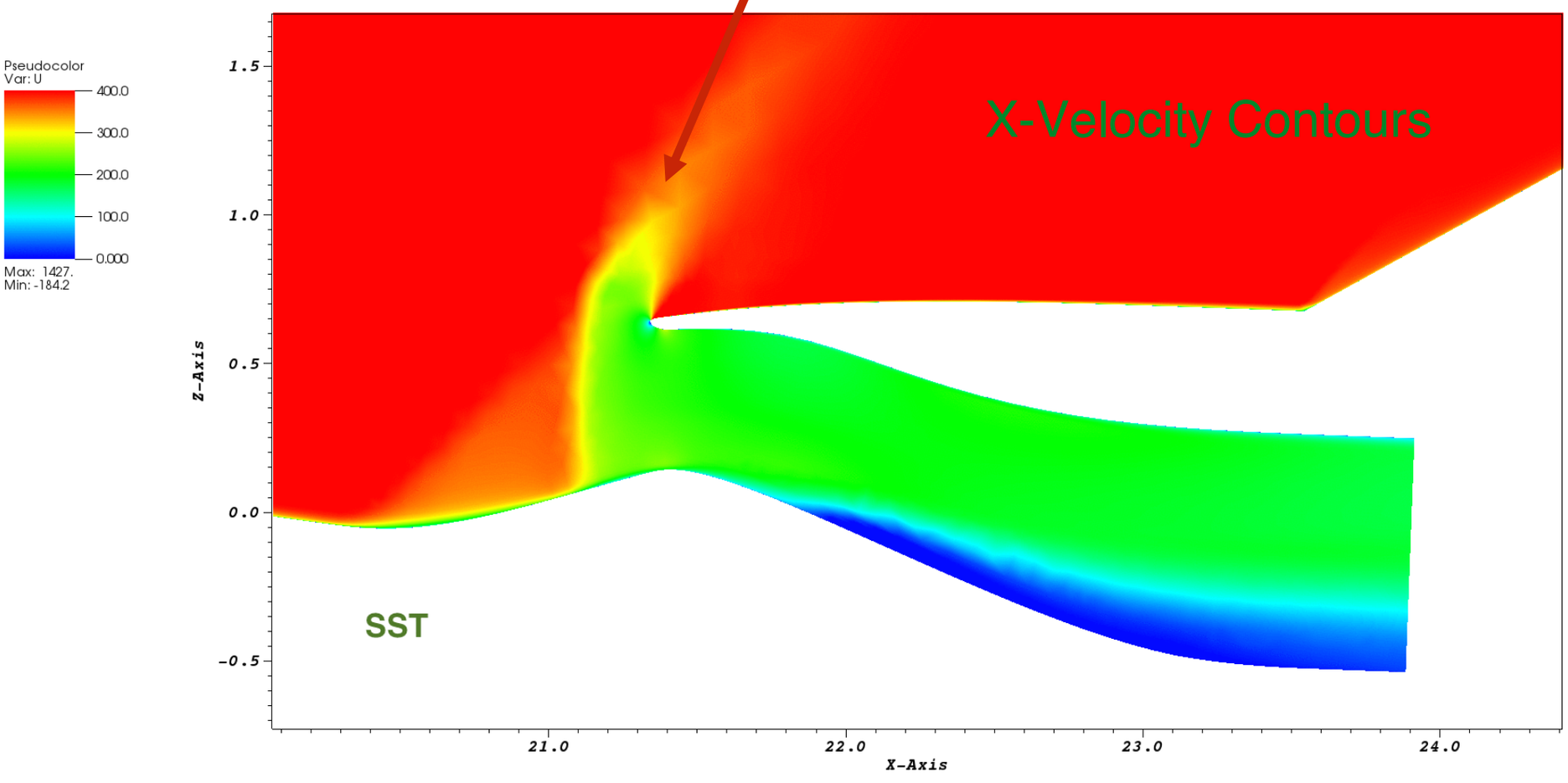






SST vs SA vs SA+RC+QCR





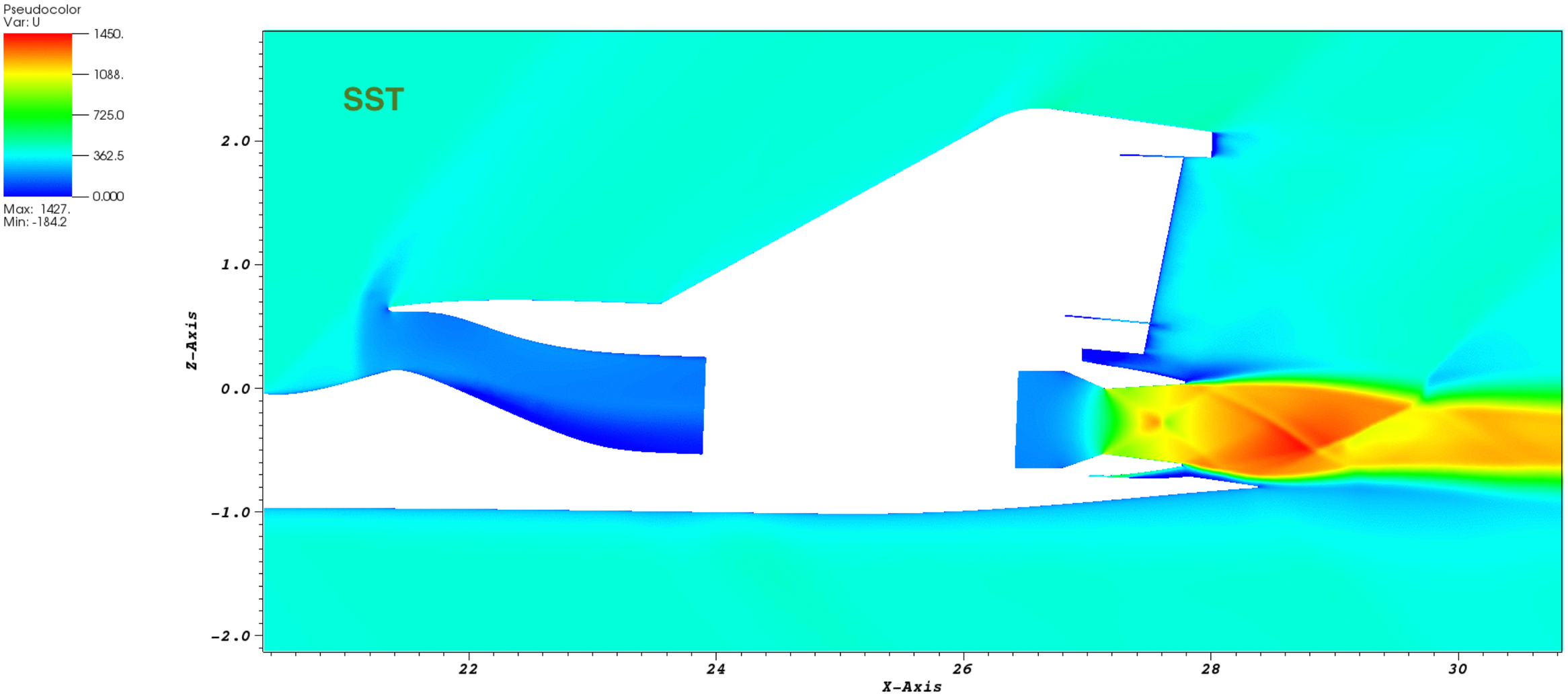
Conclusions

1. Simulated both test cases with CFD++
2. Grid convergence studies:
    - Not achieved for the biconvex shock-plume interaction problem with the provided mesh family
    - Achieved for the low-boom flight demonstrator experiment with the provided mesh family
3. Turbulence models effects studied:
    - Effect of turbulence models minimal on the biconvex shock-plume interaction problem
    - Effect more significant on the low-boom flight demonstrator experiment

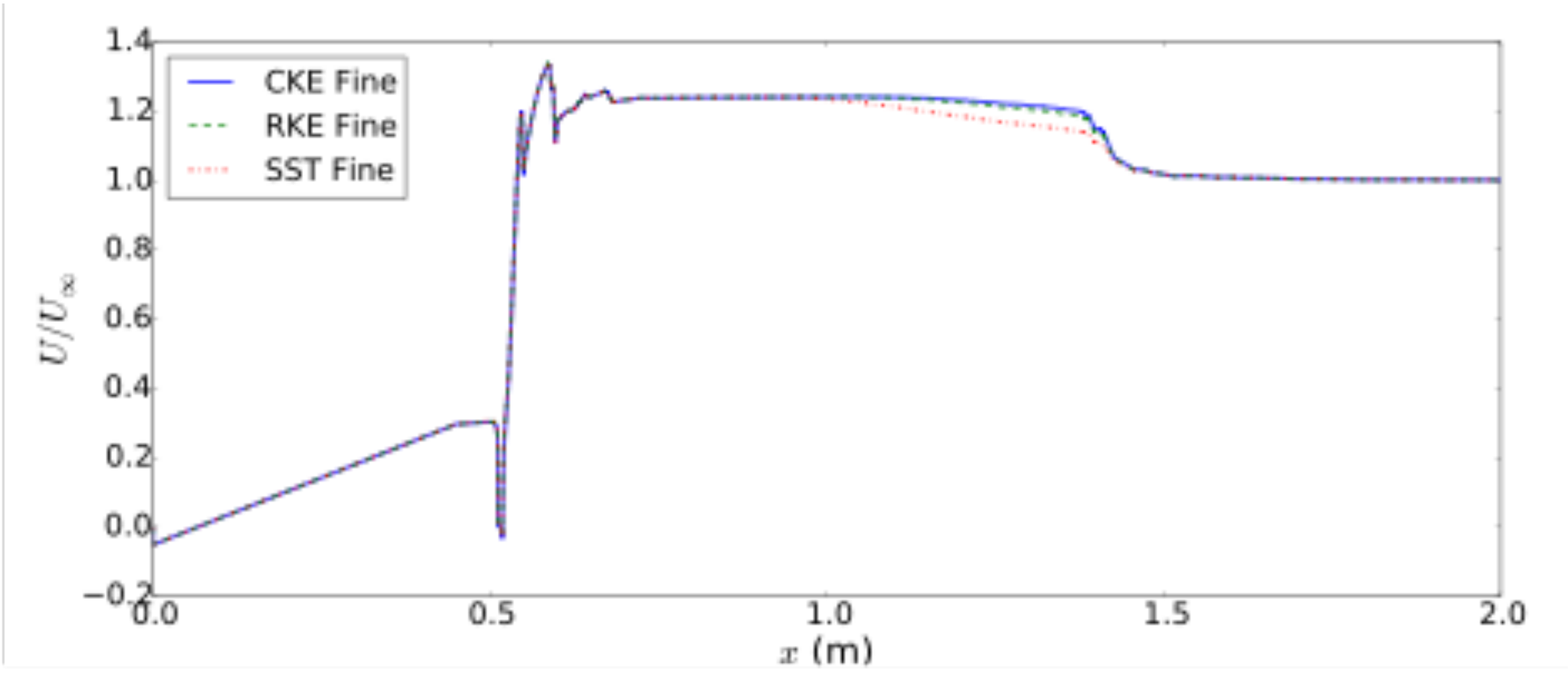
Thank You

Backup Slides

Flow Patterns - Turbulence Models



Turbulence Models Effects



Centerline X-Velocity

SST vs SA vs SA+RC+QCR