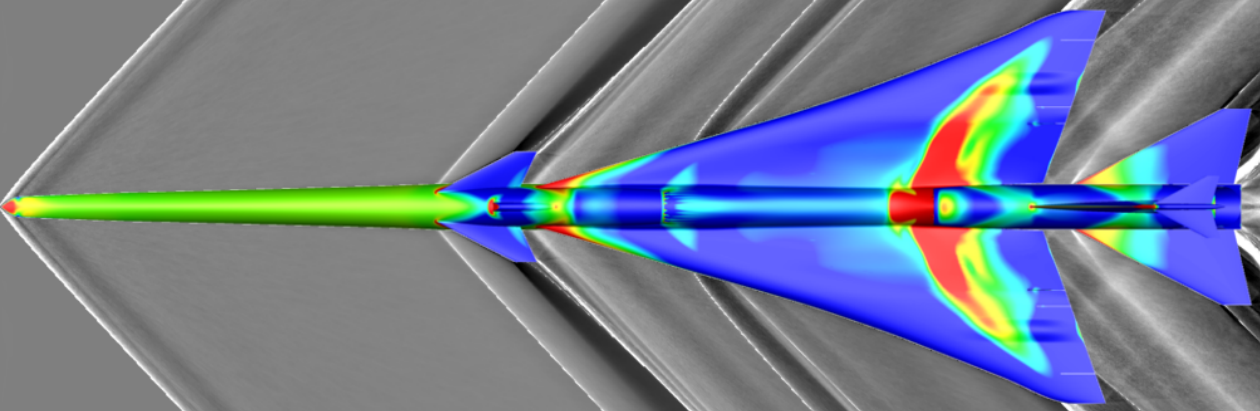
FUN3D Fixed-Grid and Adapted-Grid Nearfield Submissions to the Third AIAA Sonic Boom Prediction Workshop



Look down computational schlieren of C608

Mike Park

Computational AeroSciences Branch

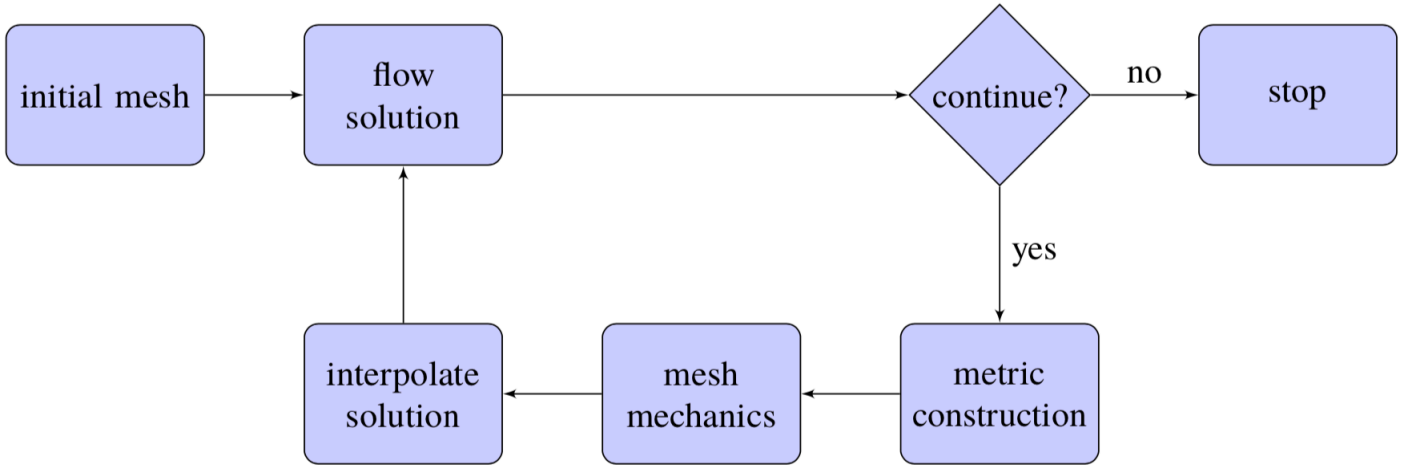
NASA Langley Research Center

FUN3D 13.6 (Biedron et al., NASA TM-2019-220416)

- Node-based finite-volume solver for mixed-element grids
- Blended upwind and central difference
  - **Roe** and low-dissipation Roe flux functions
  - **van Albada (with heuristic pressure switch)** and Barth-Jespersen limiter
- Spalart-Allmaras (SA) turbulence model
- Implicit solution advancement scheme with approximate convective Jacobians and explicitly specified CFL ramping

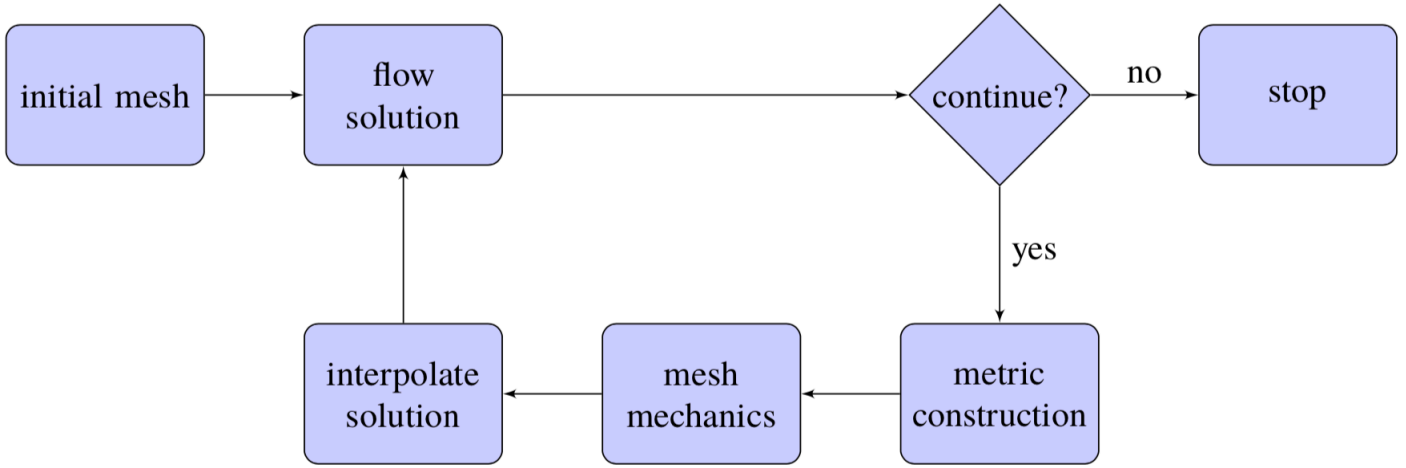
Adapted grids

- Multiscale metric (Alauzet and Loseille, JCP 229(3), 2010)
- Hessian reconstructed from Mach with local scaling to control interpolation error of smooth and nonsmooth features



Adapted grids

- *refine* grid adaptation mechanics for volume, boundary layer, and surface grid
  - OpenCSM (AIAA 2013-0701)
  - EGADS (AIAA 2012-0683)
  - EGADSlite (AIAA 2018-1401)



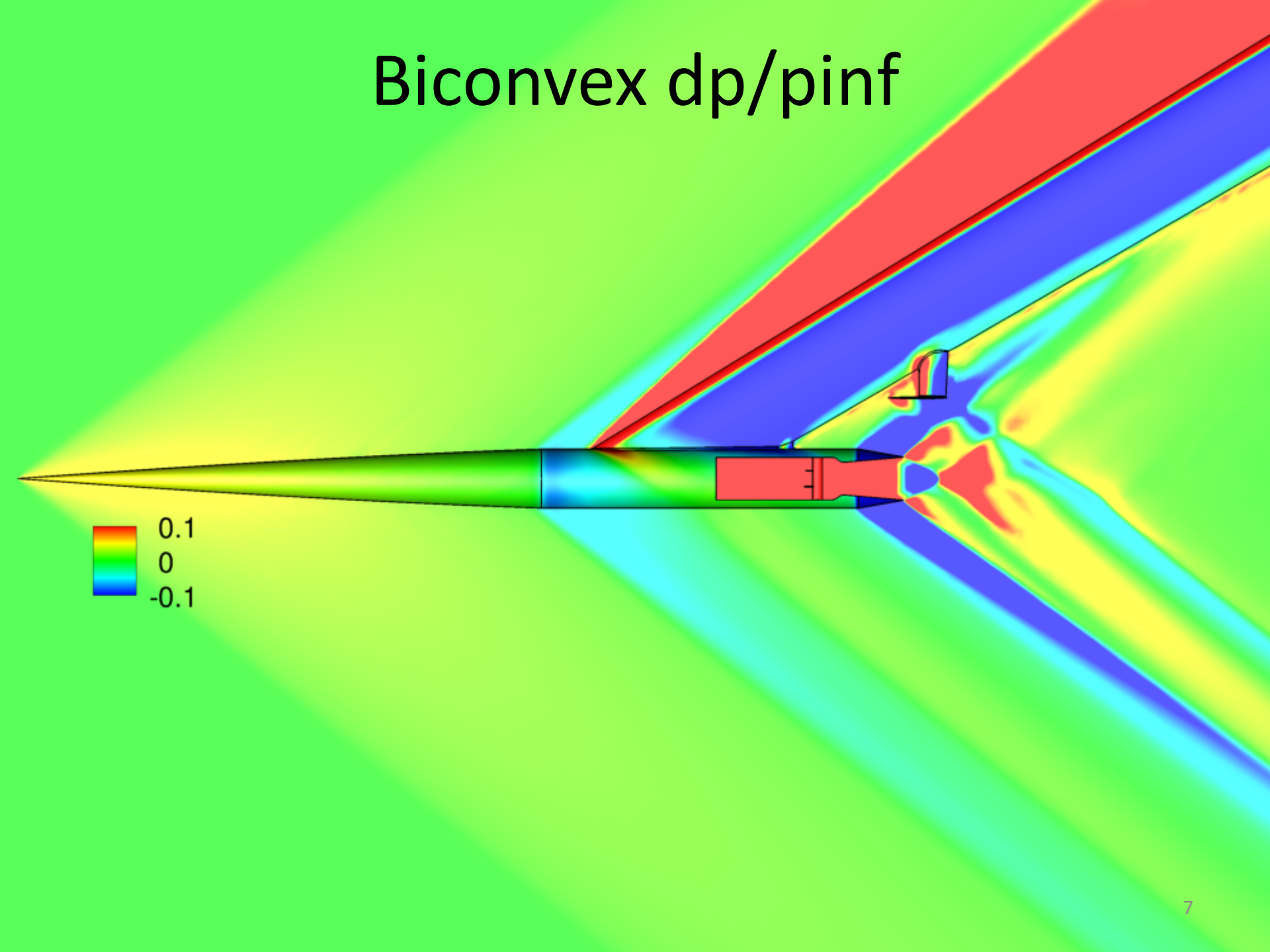
Resources

- NASA Langley mid-range computing facility
  - SGI ICE Altix Cluster
- FUN3D
  - 16 to 640 core jobs limited by number of free cores and queue sizes
  - Adapted grids O(100K) to O(10M)
  - Workshop-provided grids 0(1M) to O(100M)
  - Few minutes to a few hours

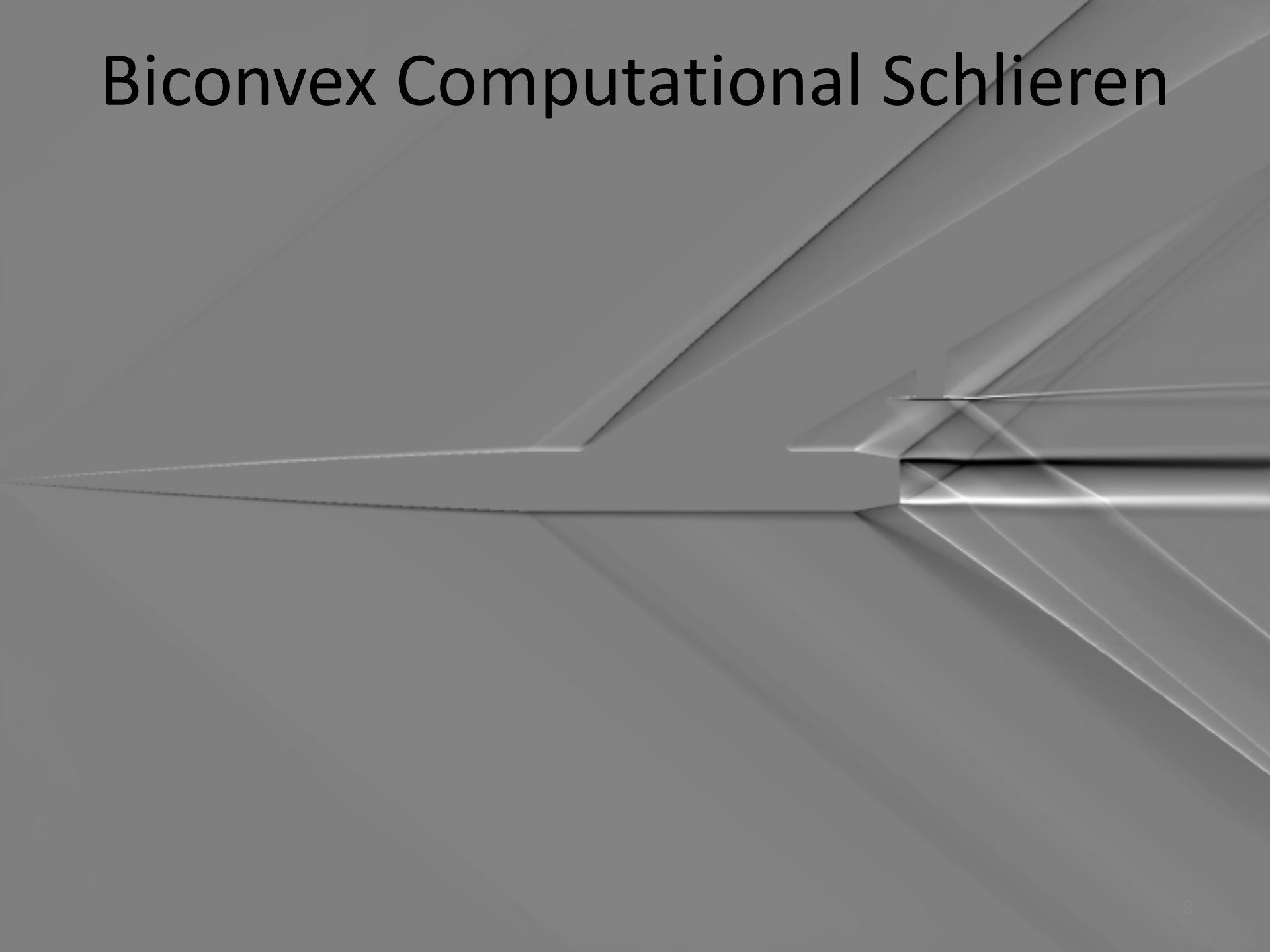
Biconvex Cases

- Workshop-provided tetrahedral grids
  - SA nonlinear divergence on mixed-element grids where the model struct meets the Biconvex support
- Tetrahedral grids adapted to control Mach number interpolation error
- Reynolds number sensitivity on tetrahedral Biconvex grids
  - Experiment and 22% higher workshop values

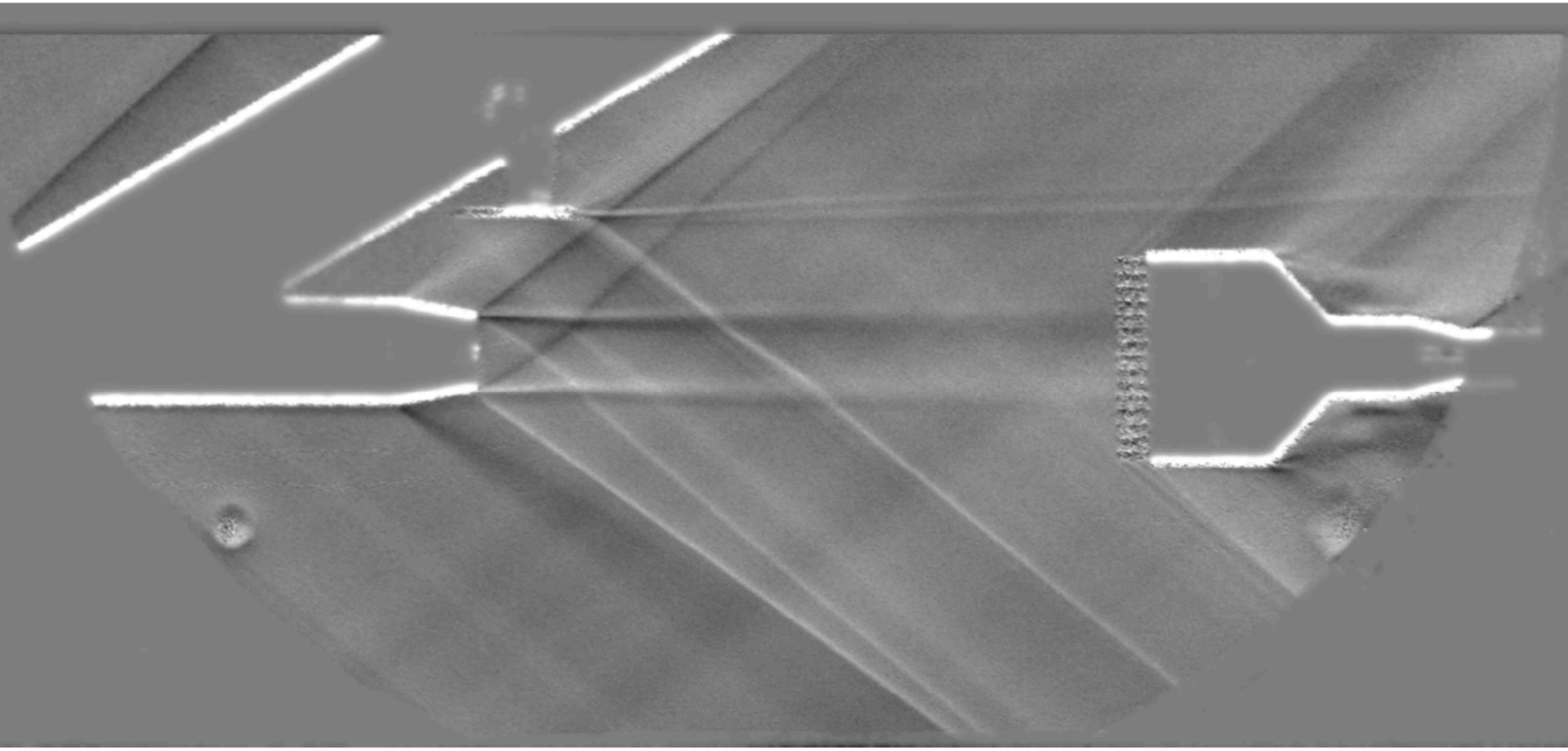
Biconvex dp/pinf



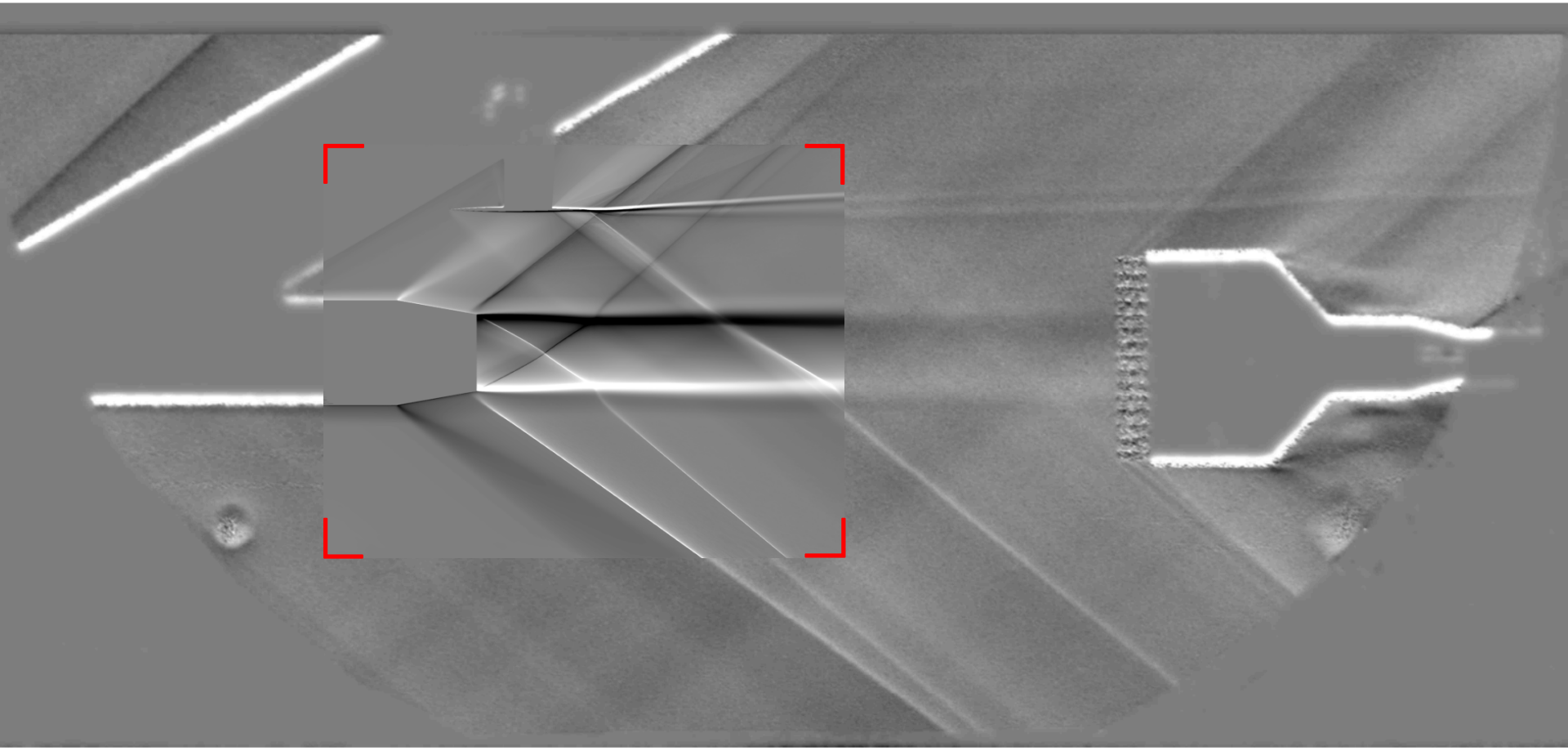
Biconvex Computational Schlieren



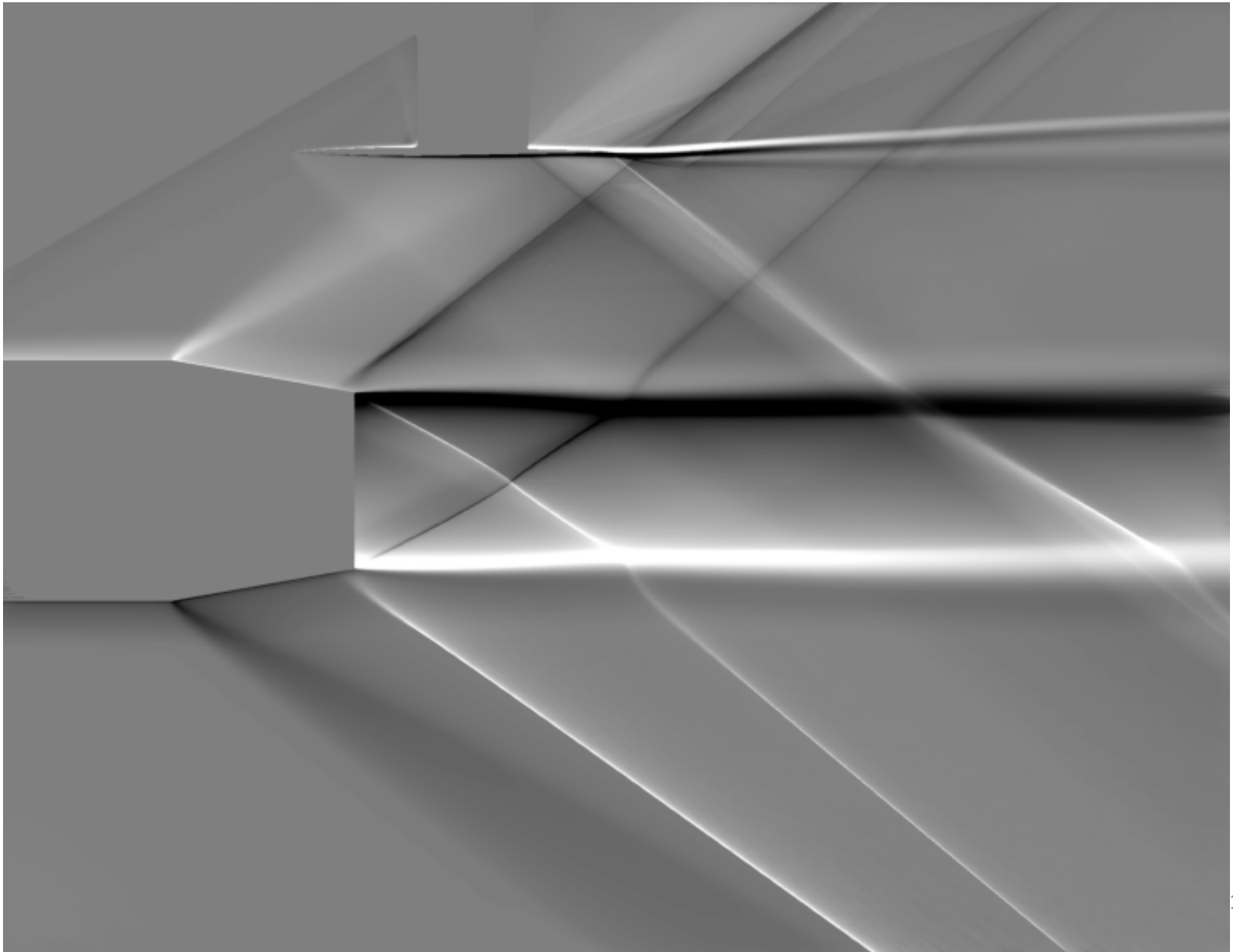
Biconvex Retroreflective Background Oriented Schlieren (AIAA 2017-43)



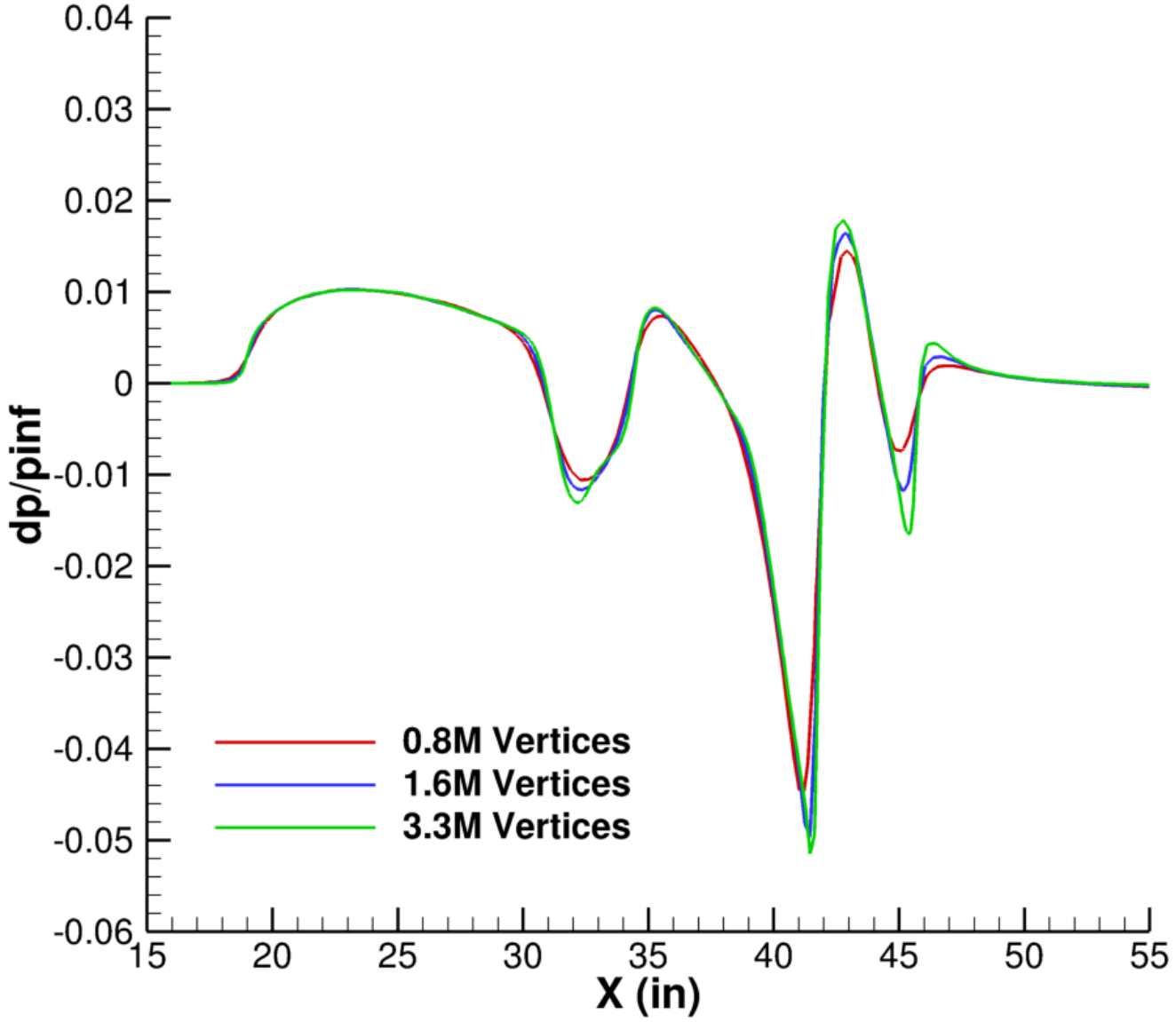
Biconvex RBOS (with Inset CFD)



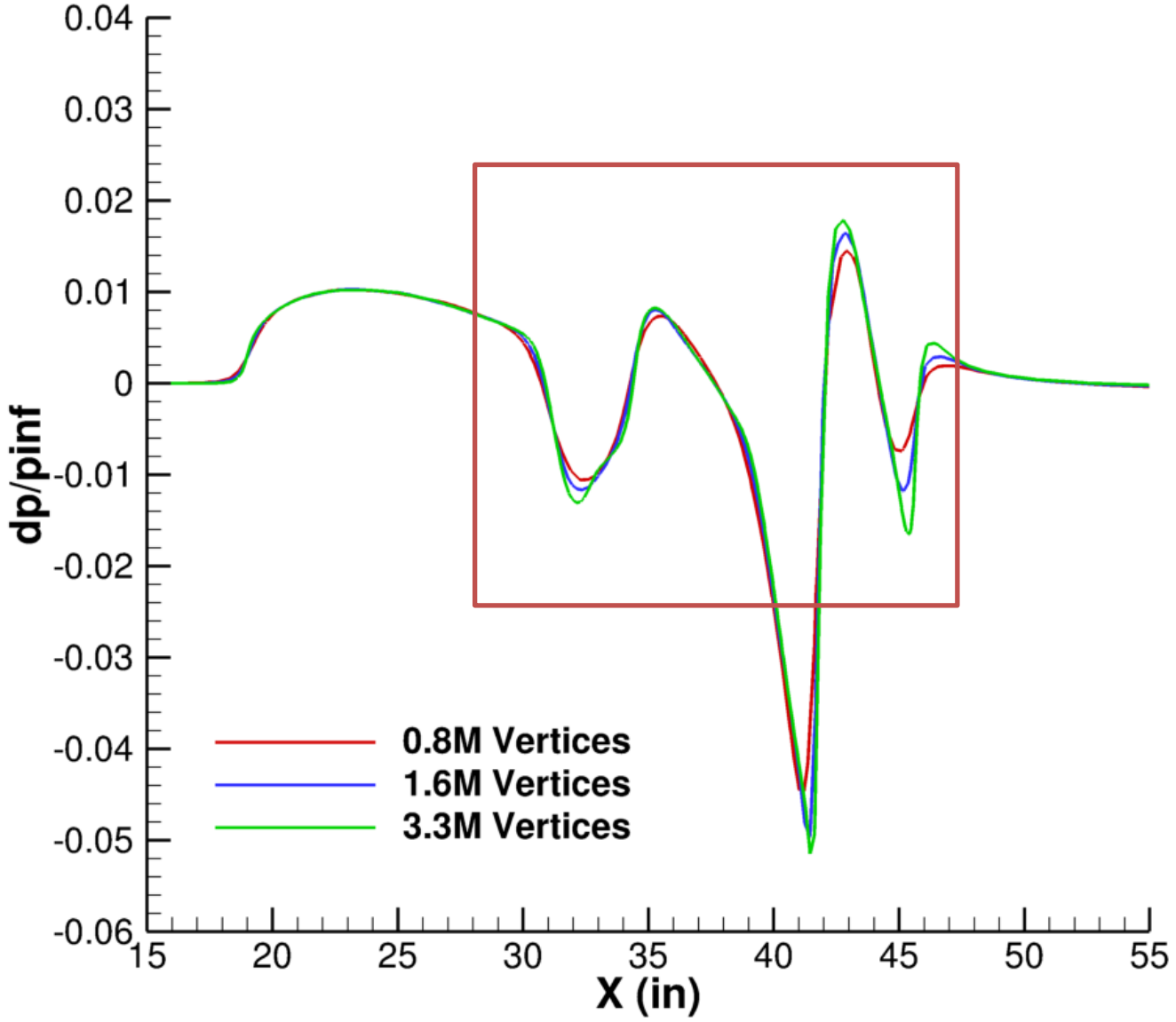
Biconvex Computational Schlieren



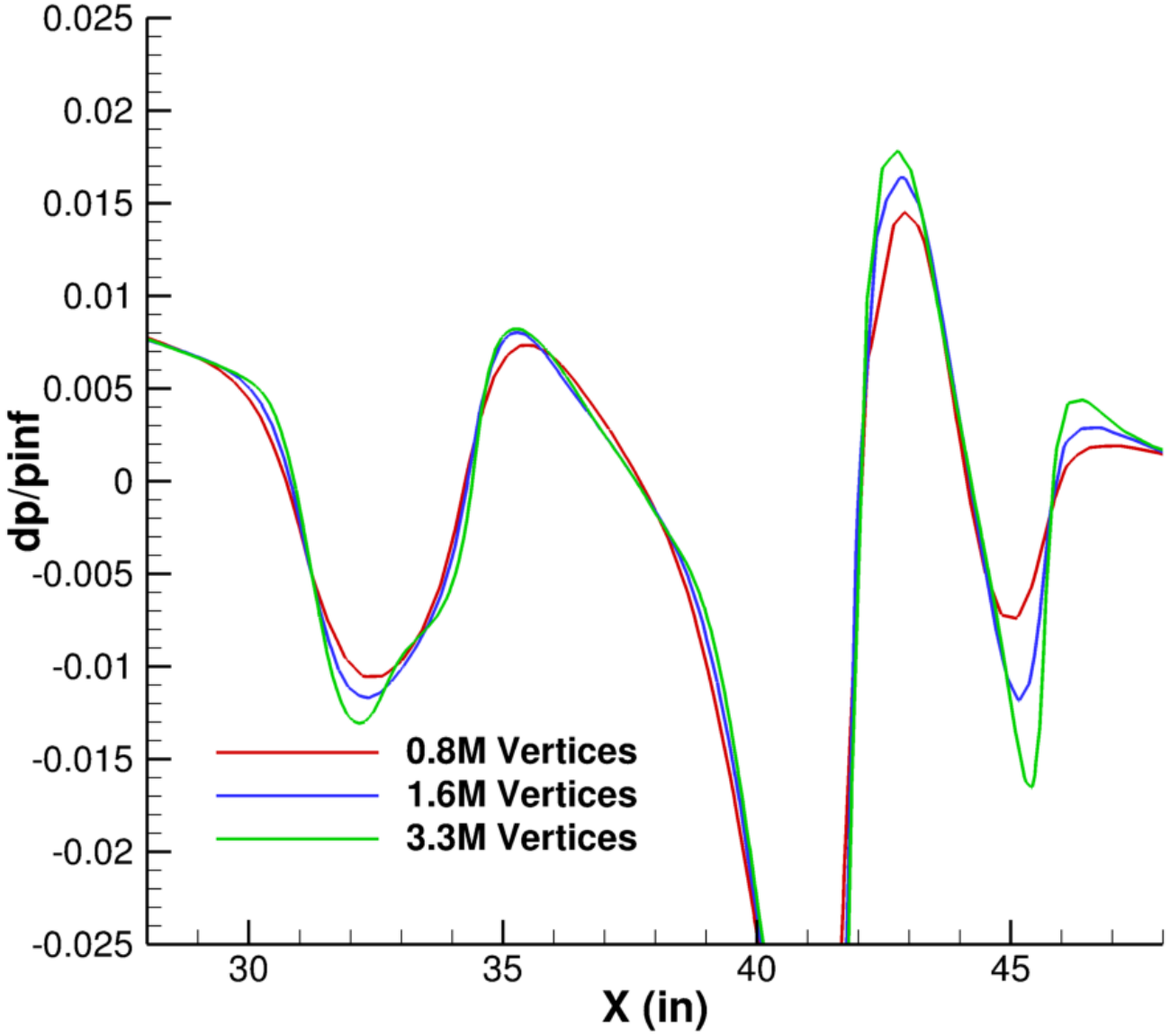
Biconvex FUN3D Workshop Grids



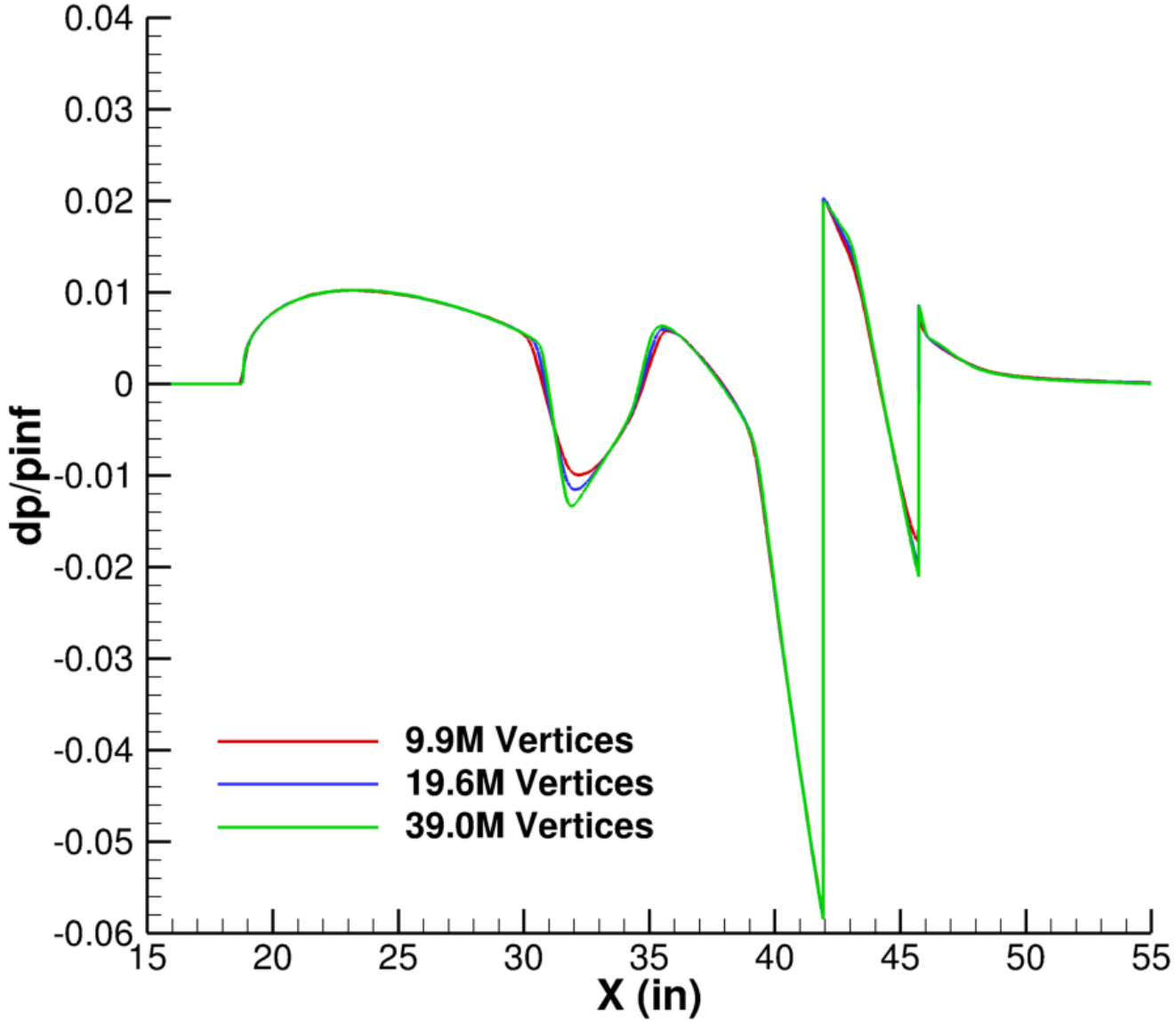
Biconvex FUN3D Workshop Grids



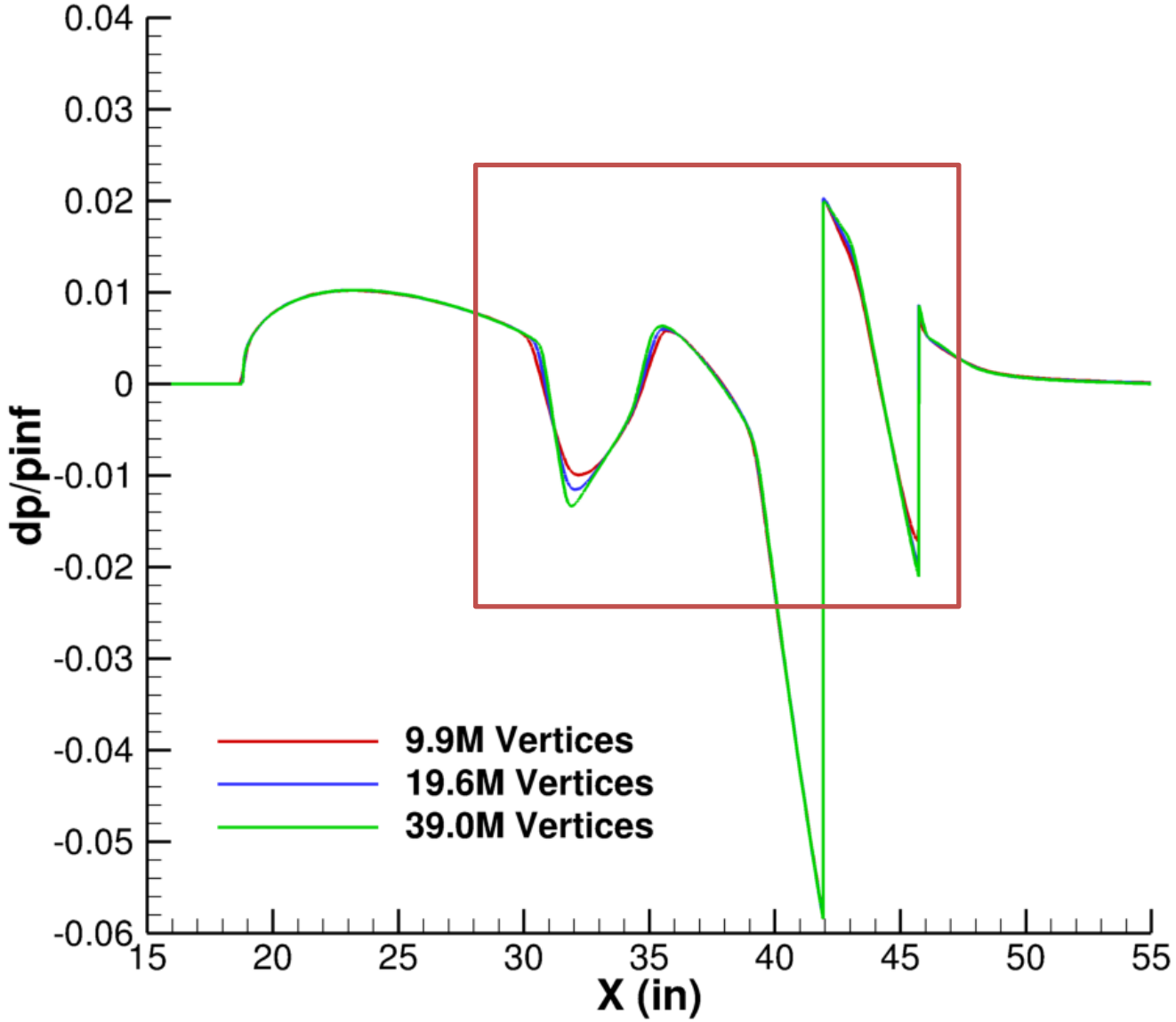
Biconvex FUN3D Workshop Grids



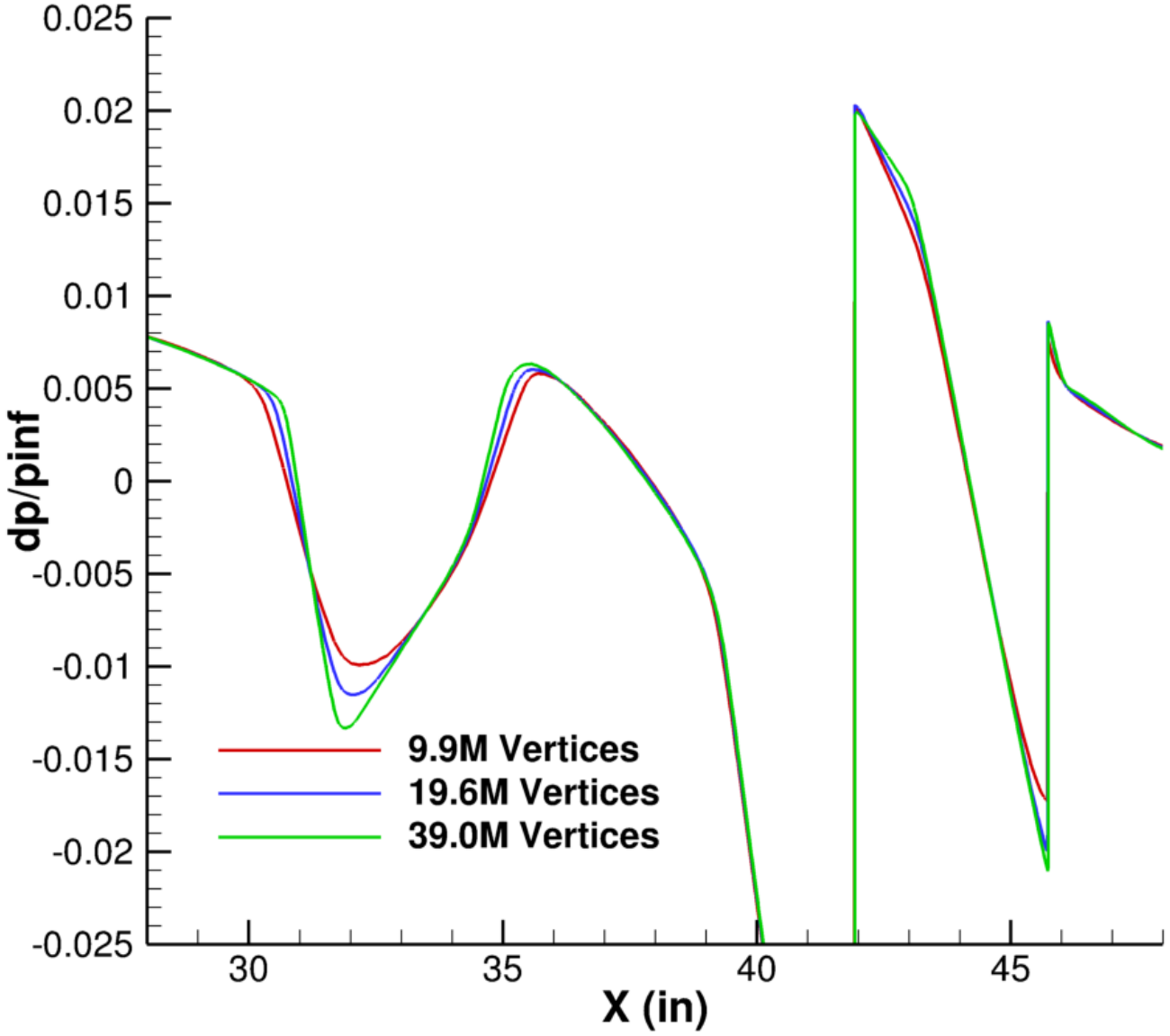
Biconvex FUN3D Adapted Grids



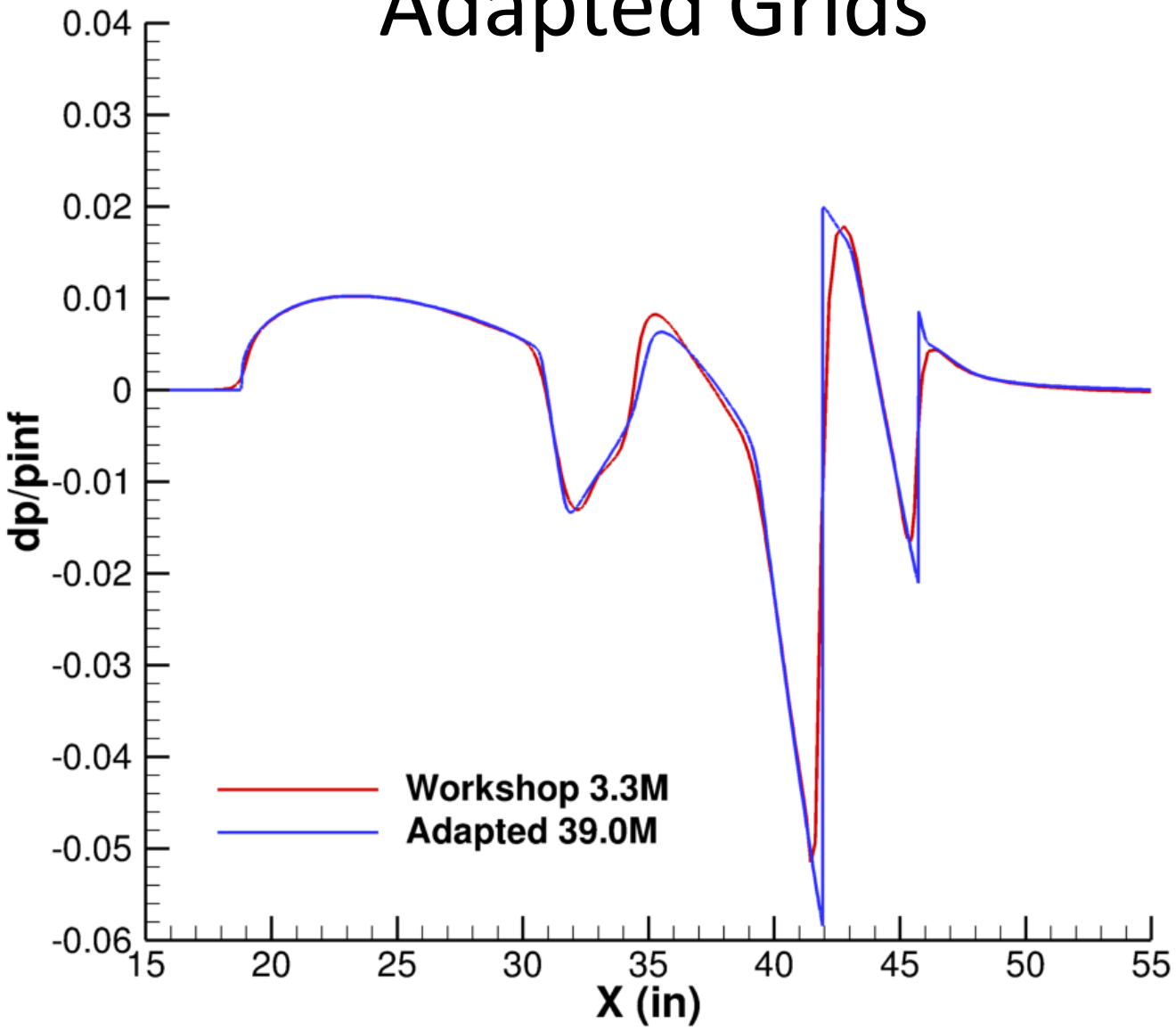
Biconvex FUN3D Adapted Grids



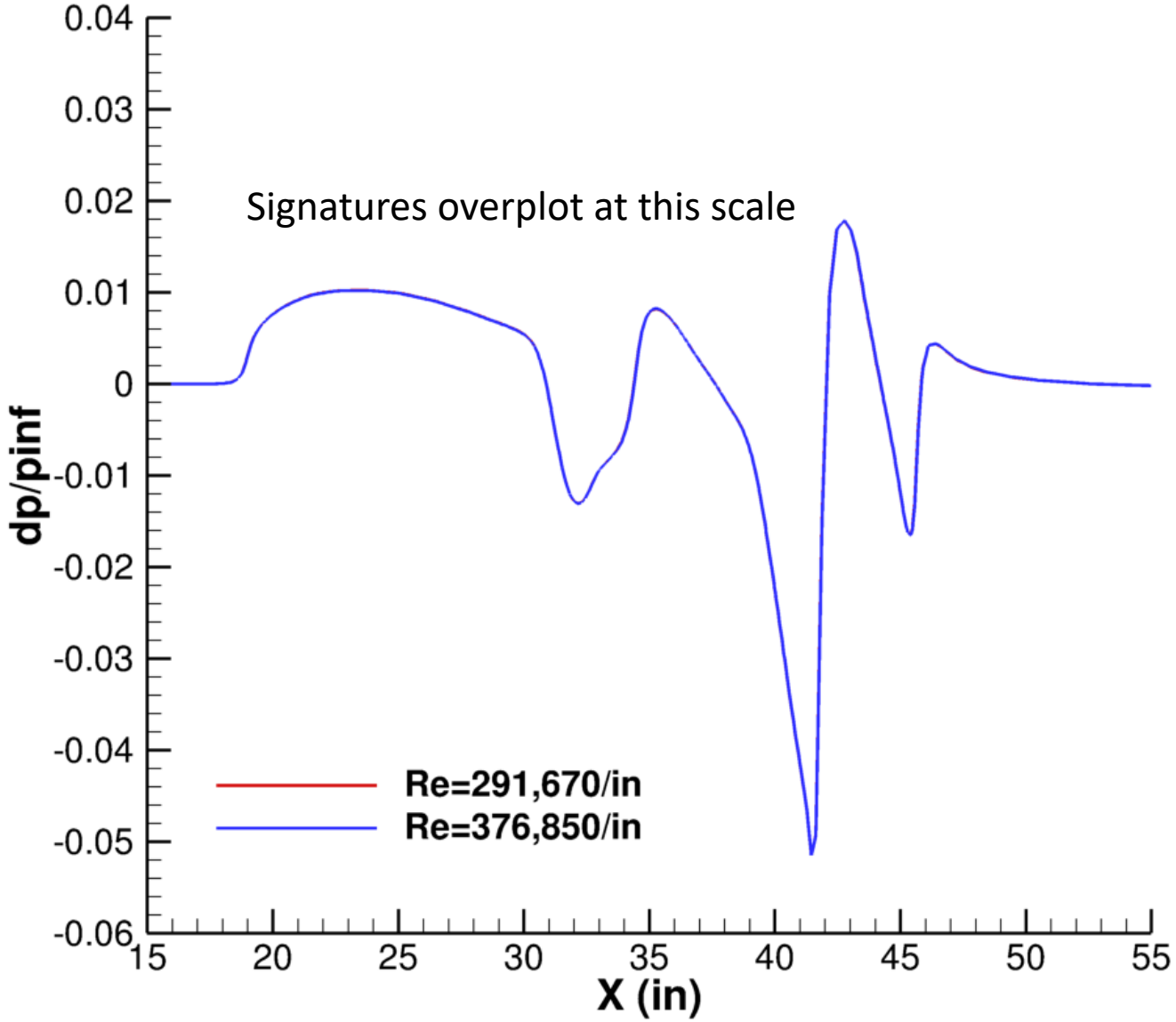
Biconvex FUN3D Adapted Grids



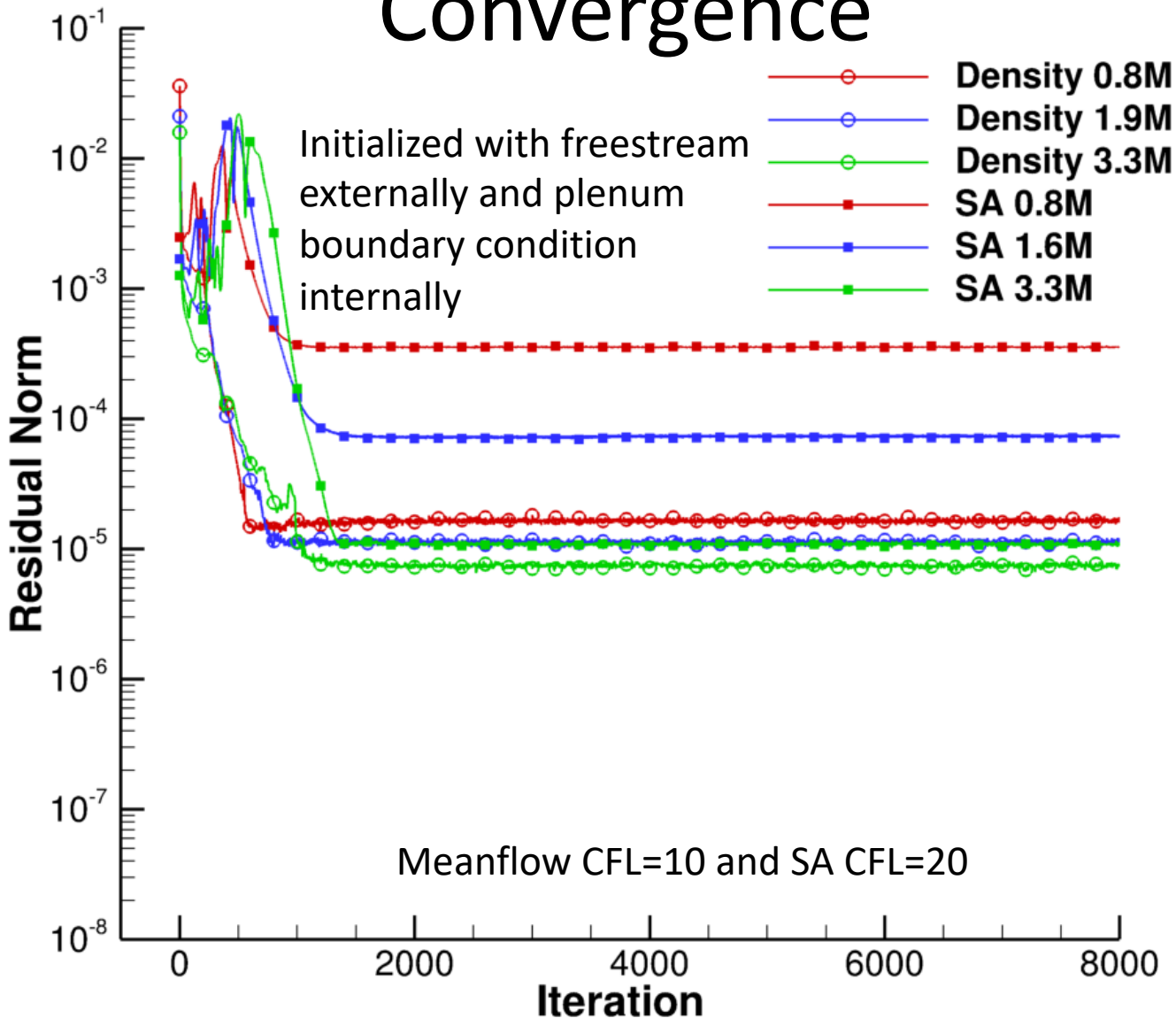
Biconvex FUN3D Workshop and Adapted Grids



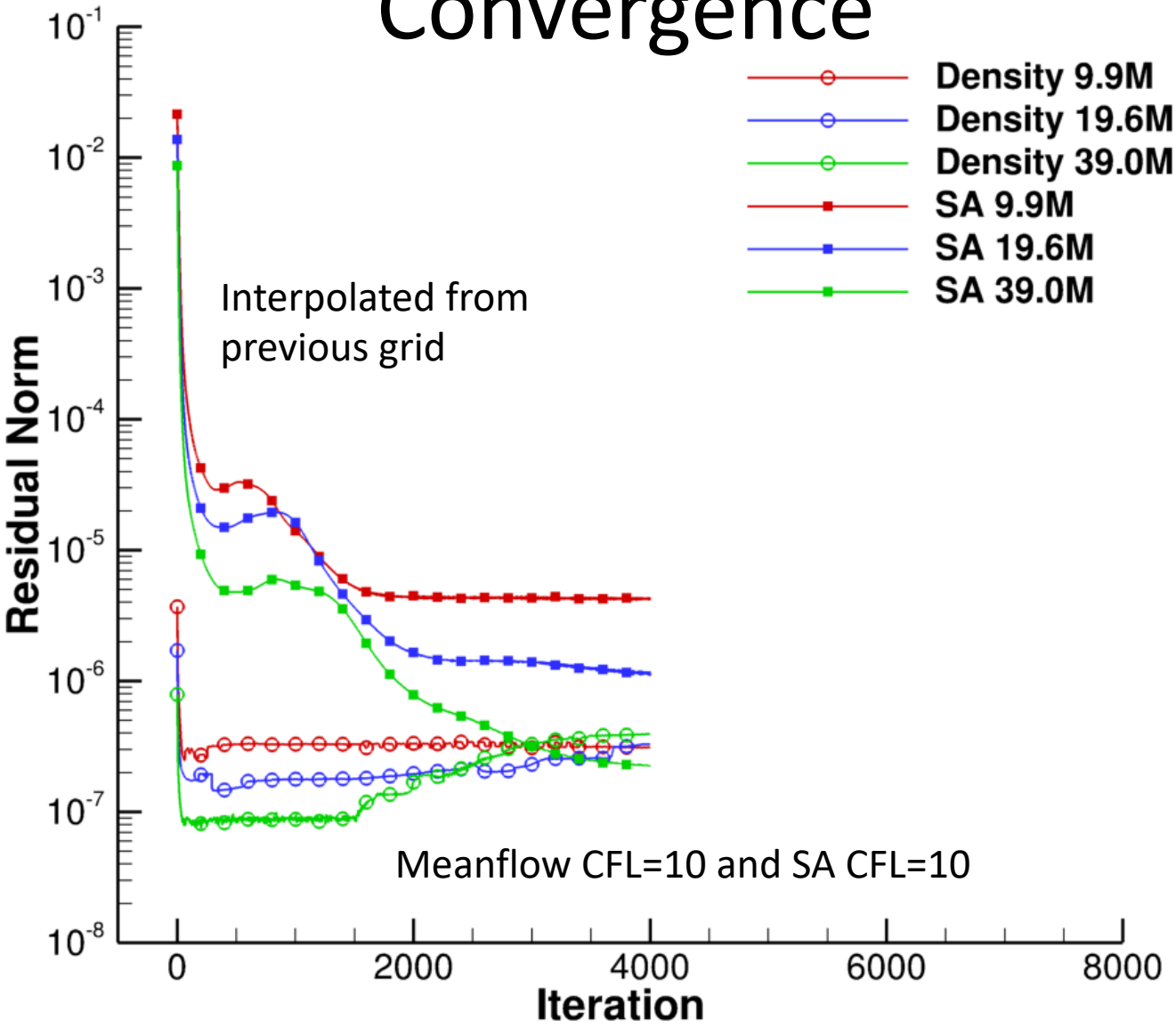
Biconvex FUN3D Reynolds Number



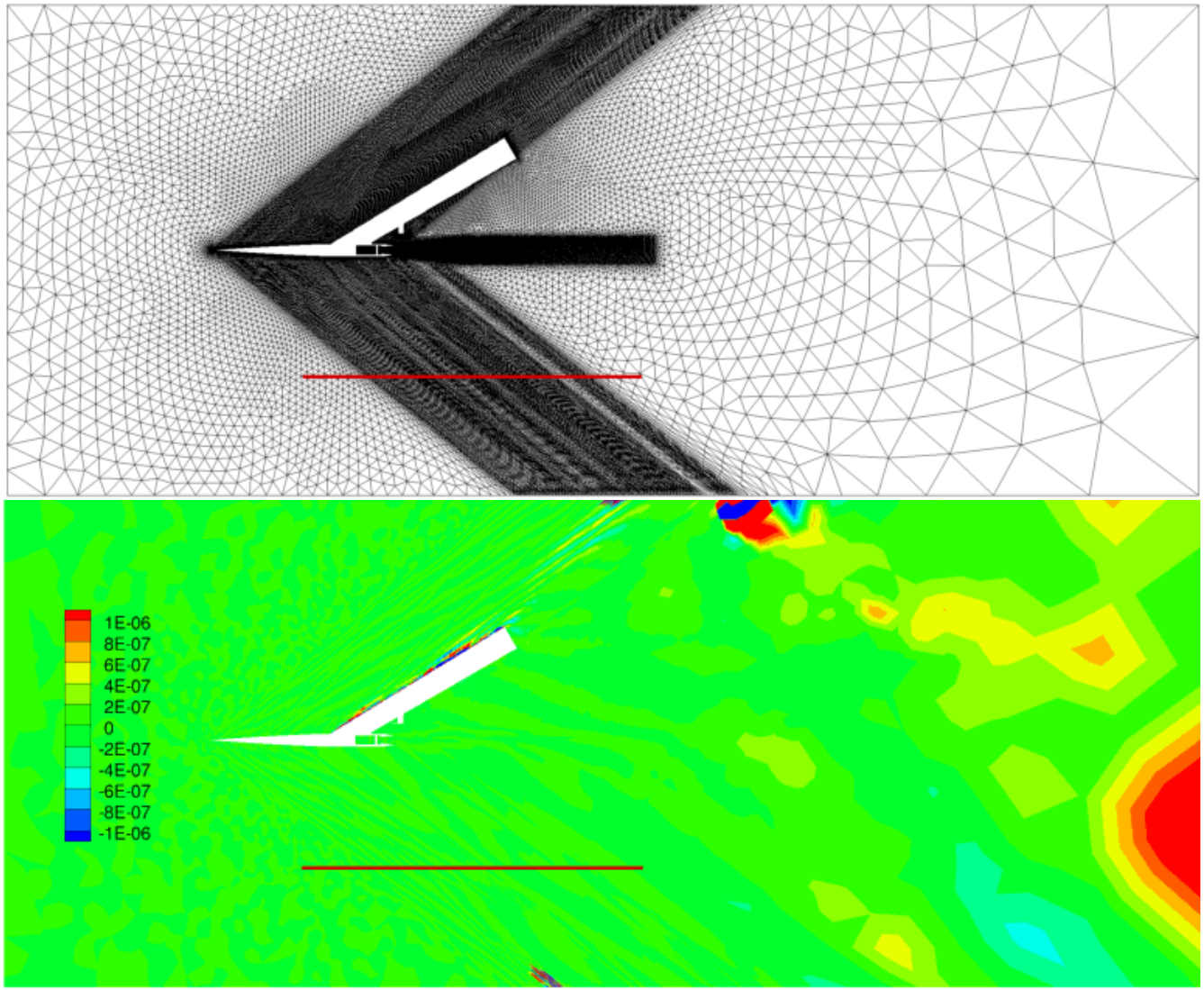
Biconvex FUN3D Workshop Iterative Convergence



Biconvex FUN3D Adapted Iterative Convergence



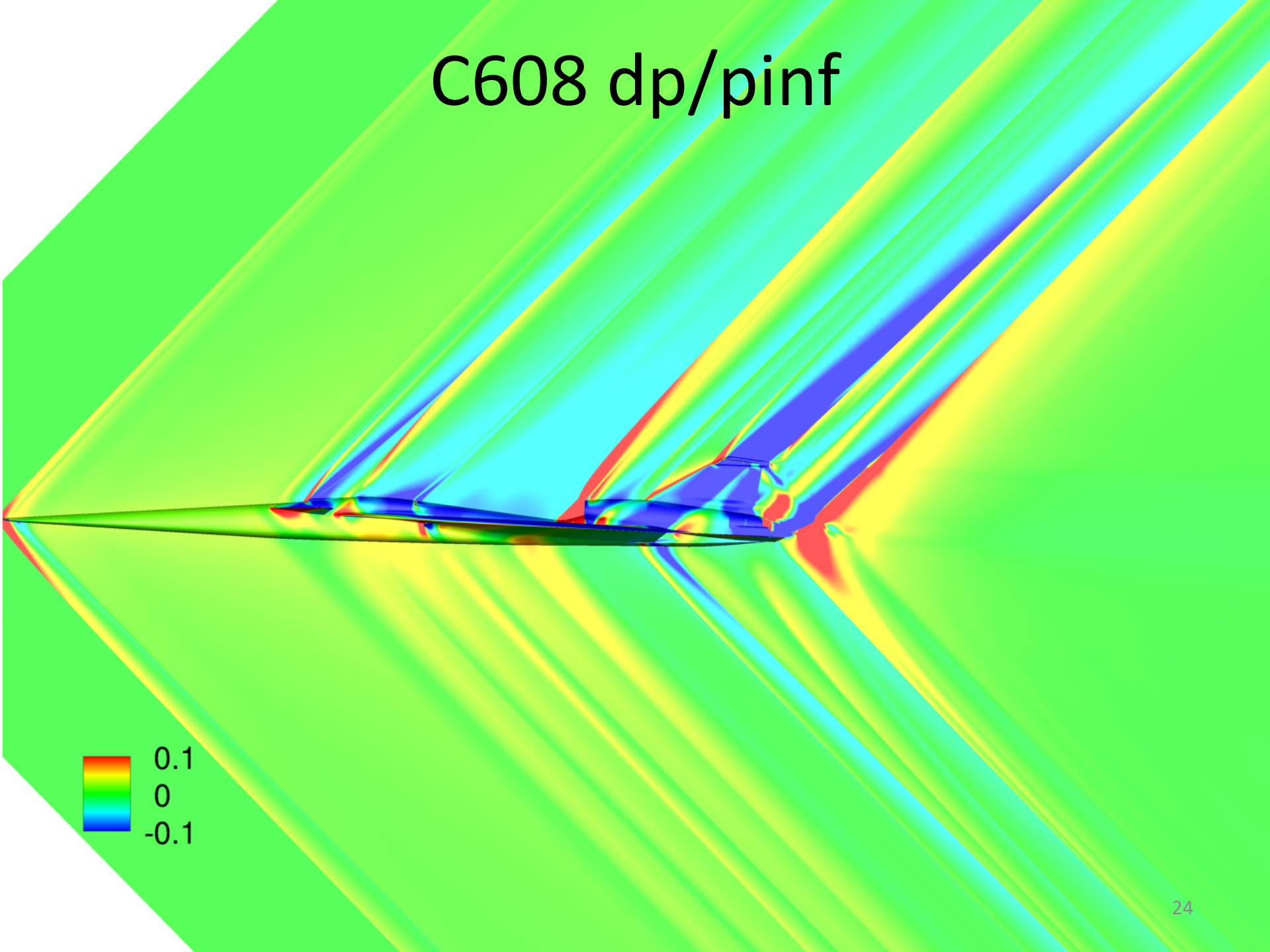
Biconvex FUN3D Workshop Continuity Residual



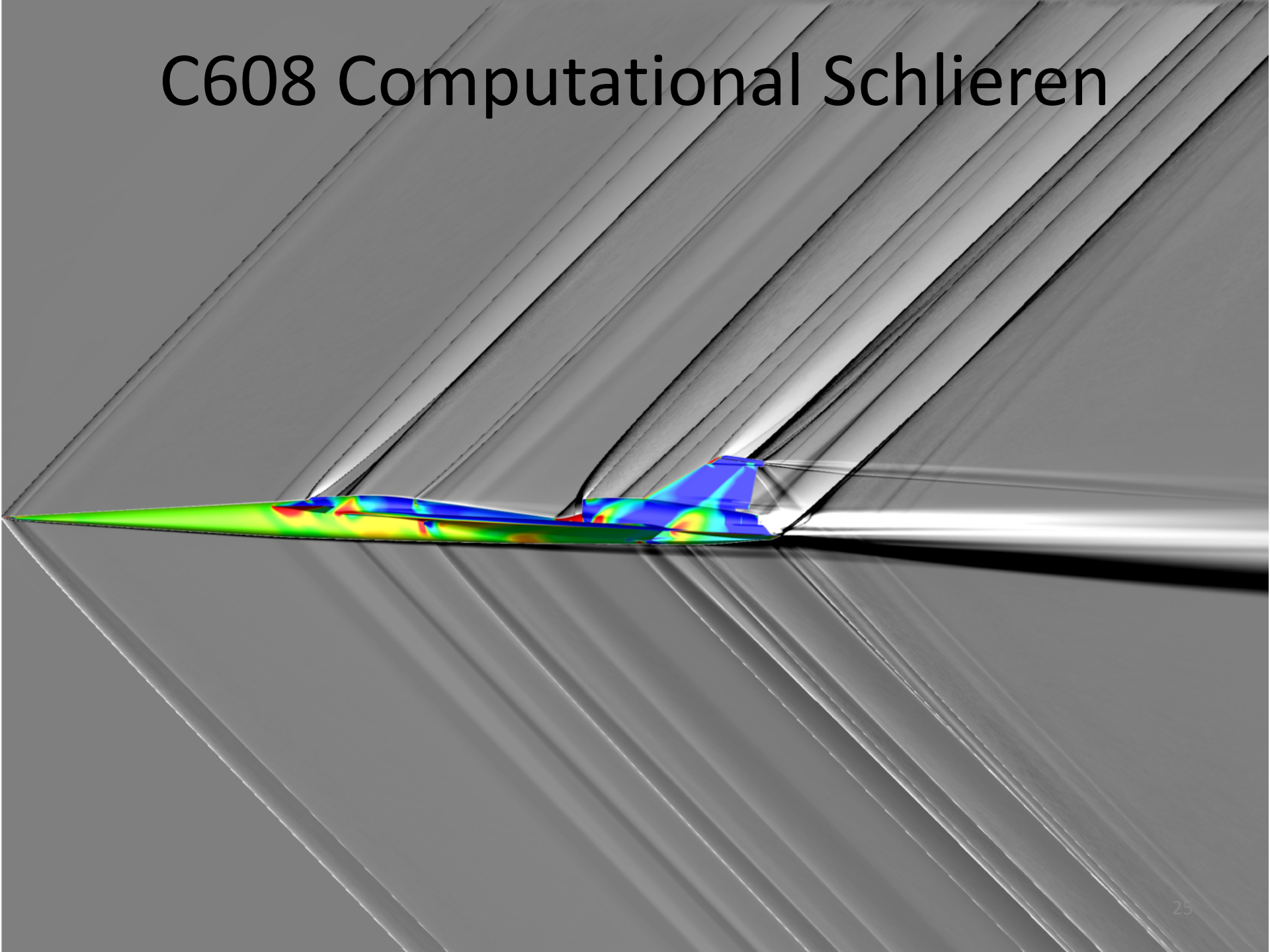
C608 Cases

- Workshop-provided mixed-element grids
  - Meanflow nonlinear divergence on tetrahedral grids
- Tetrahedral grids adapted to control Mach number interpolation error
  - Reduced sensitivity observed in Flux function and limiter study (not shown)
- Environmental Control System (ECS) and engine inlet alternate boundary conditions sensitivity
  - Specified Mach more robust (adapted grids)

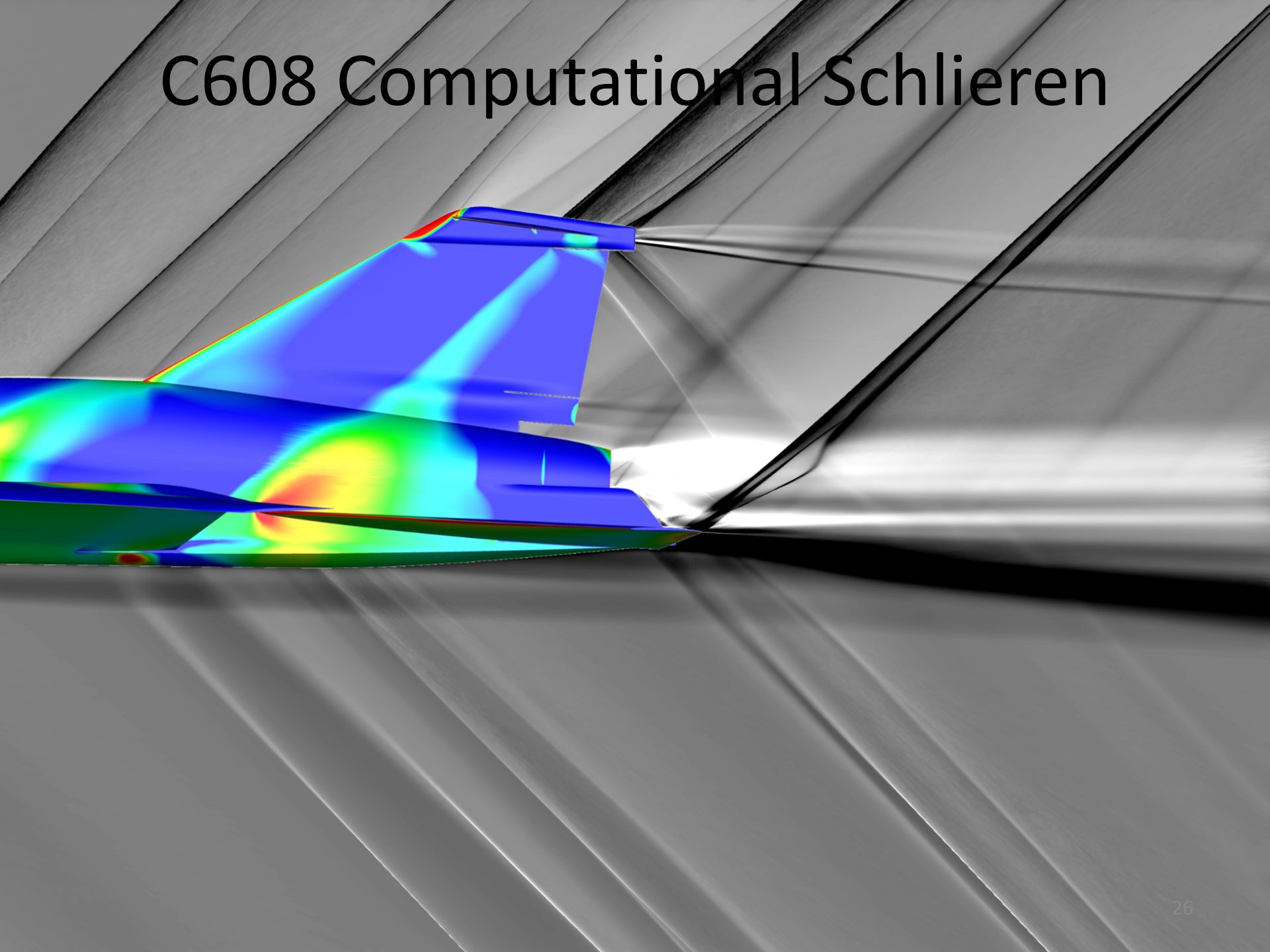
C608 dp/pinf



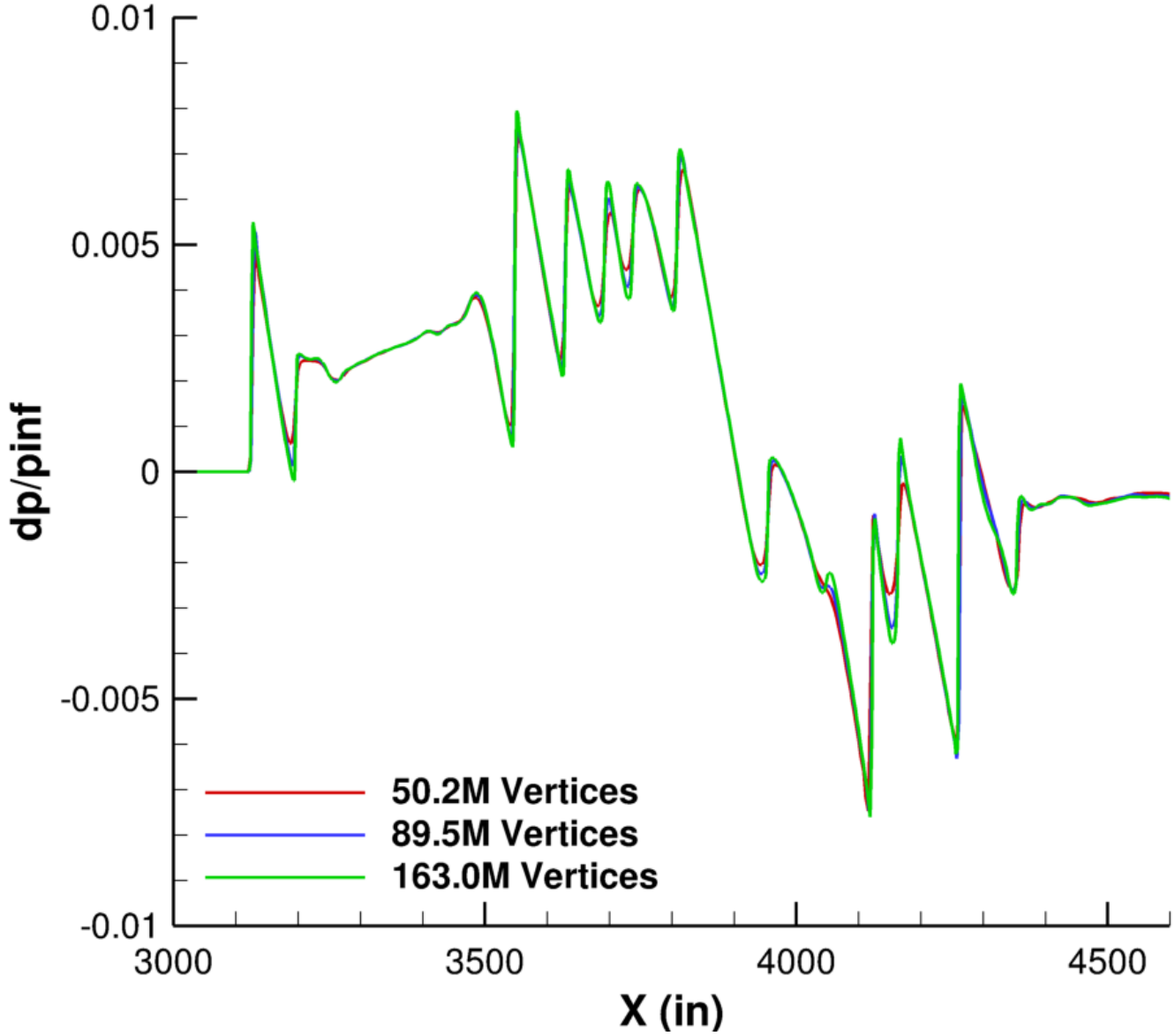
C608 Computational Schlieren



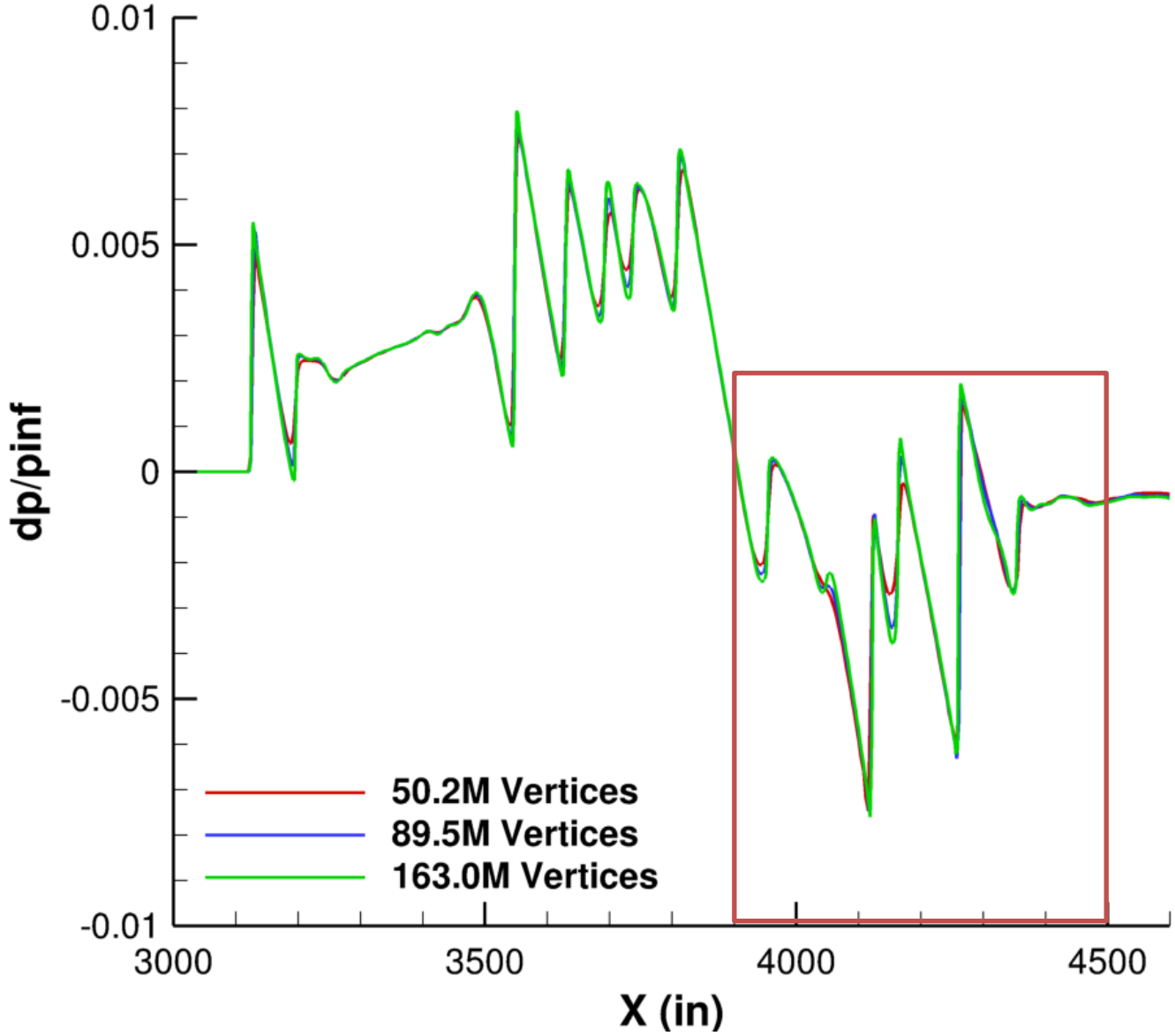
C608 Computational Schlieren



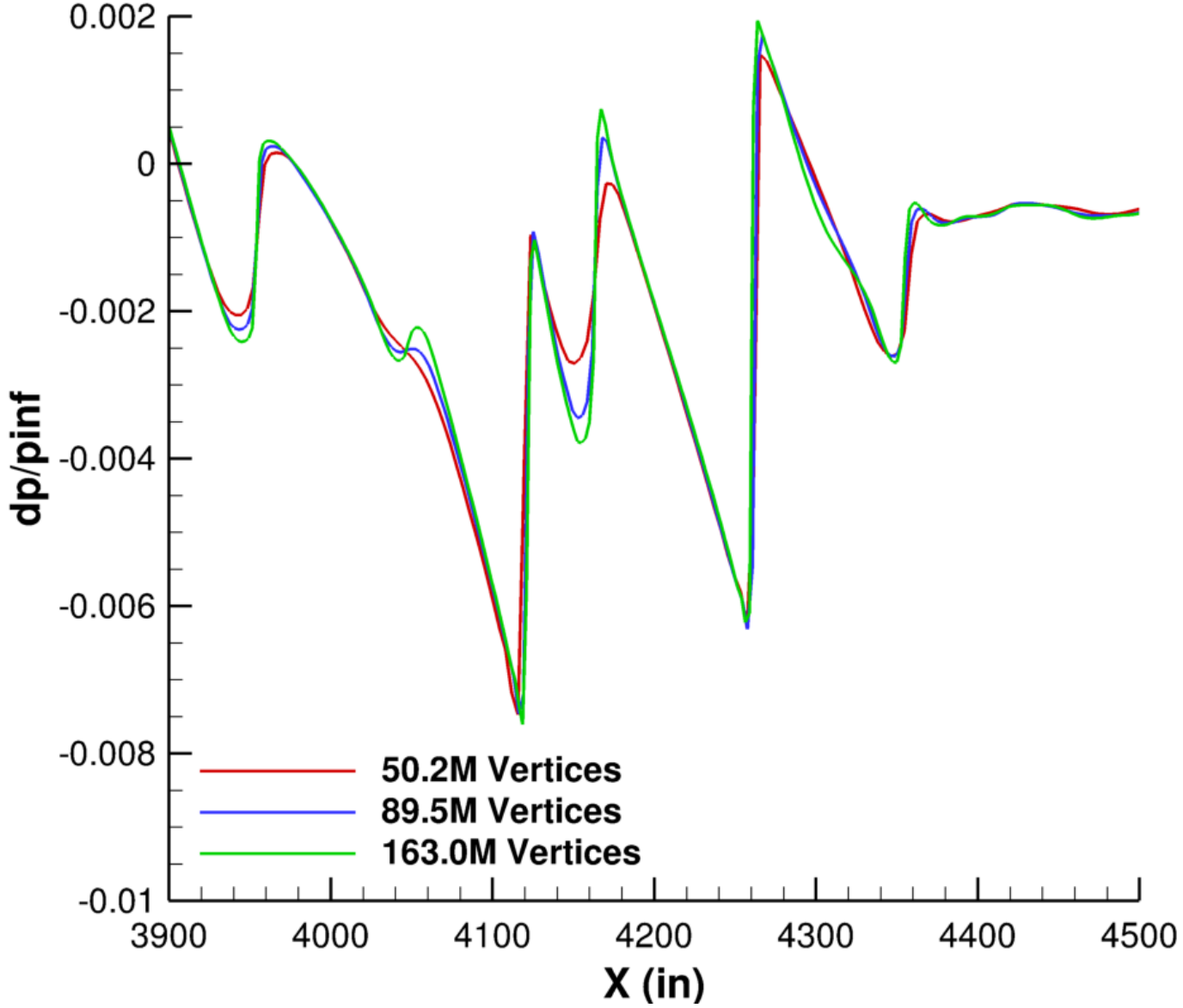
C608 FUN3D Workshop Grids



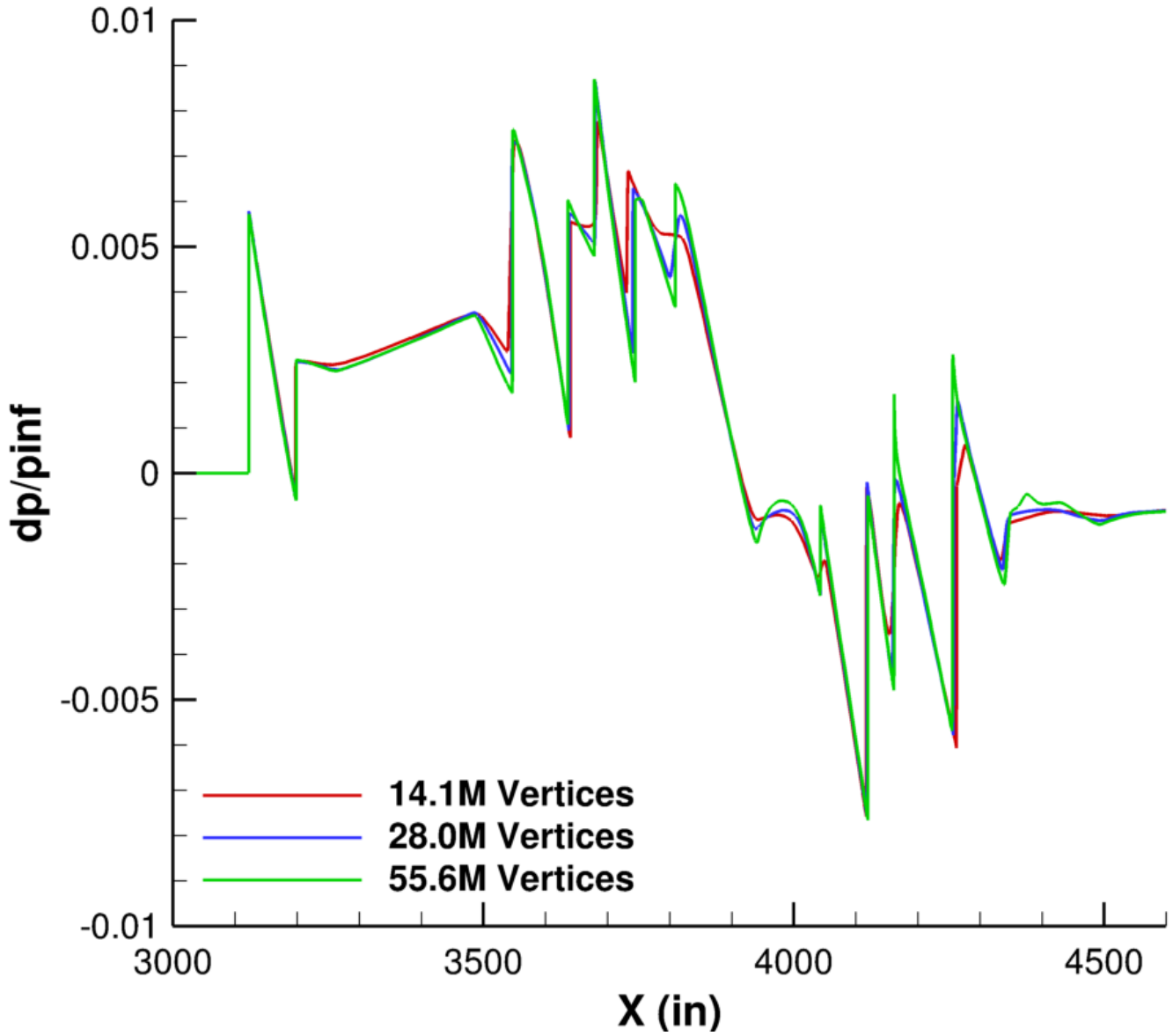
C608 FUN3D Workshop Grids



C608 FUN3D Workshop Grids



C608 FUN3D Adapted Grids



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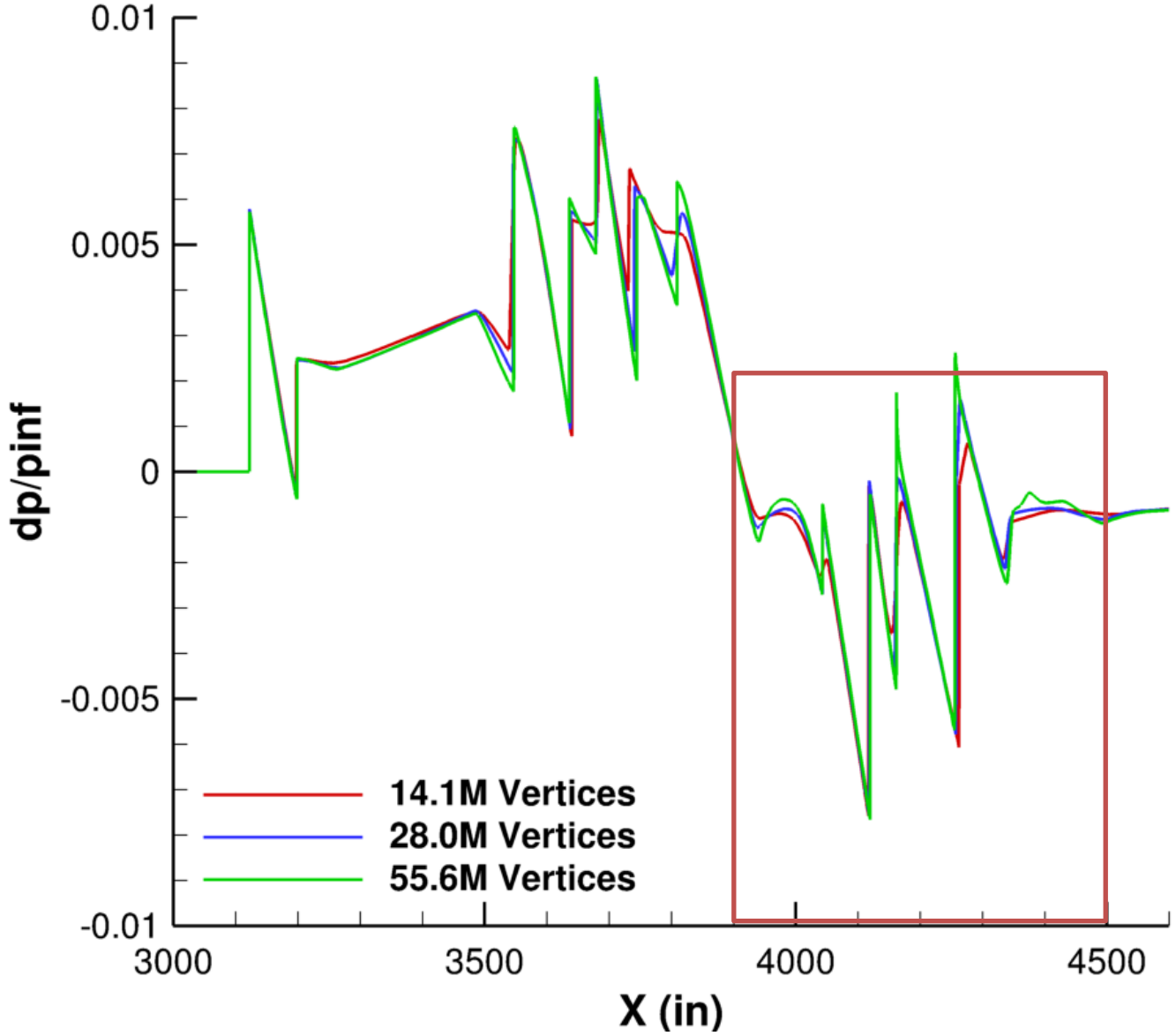

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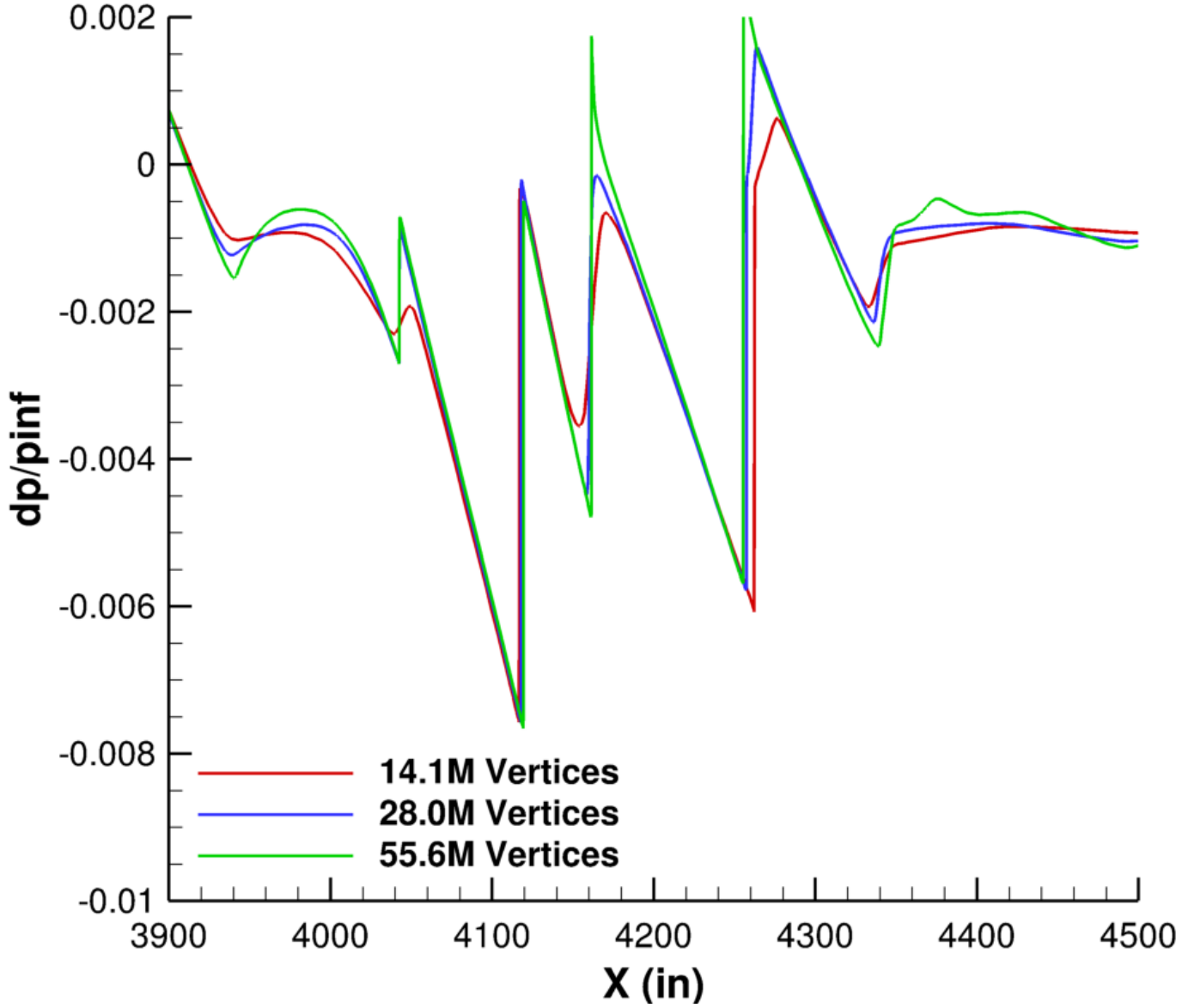
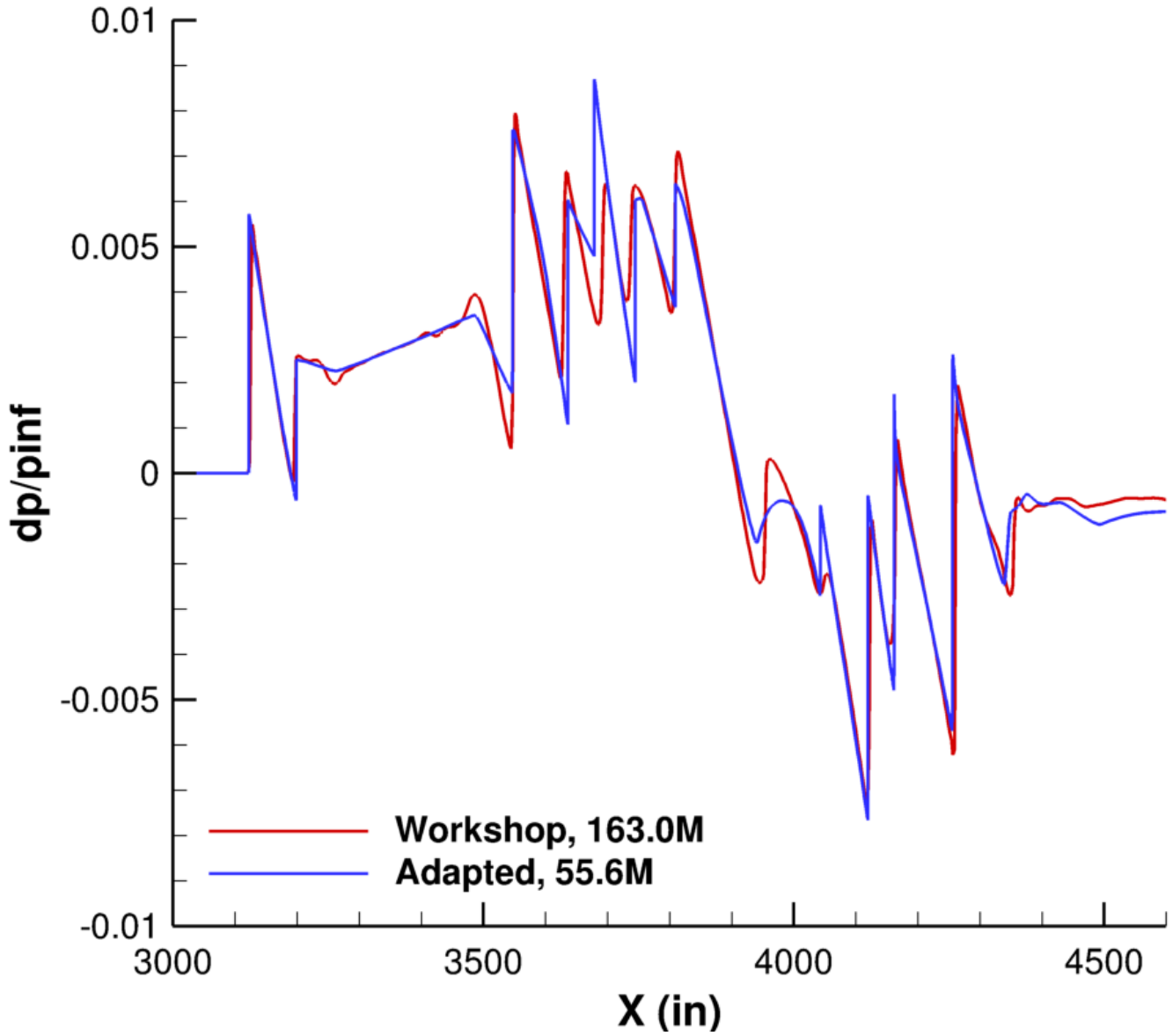
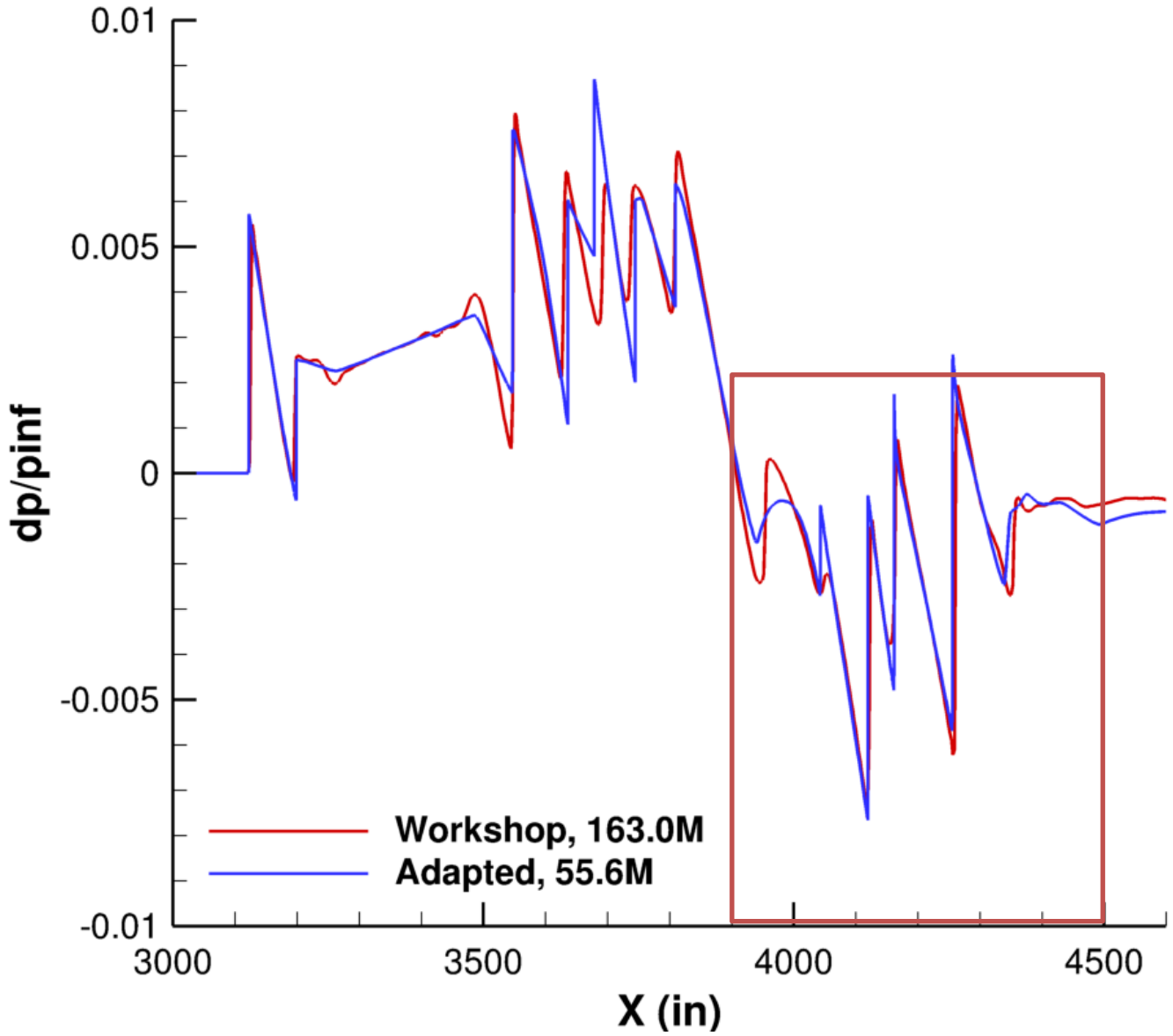


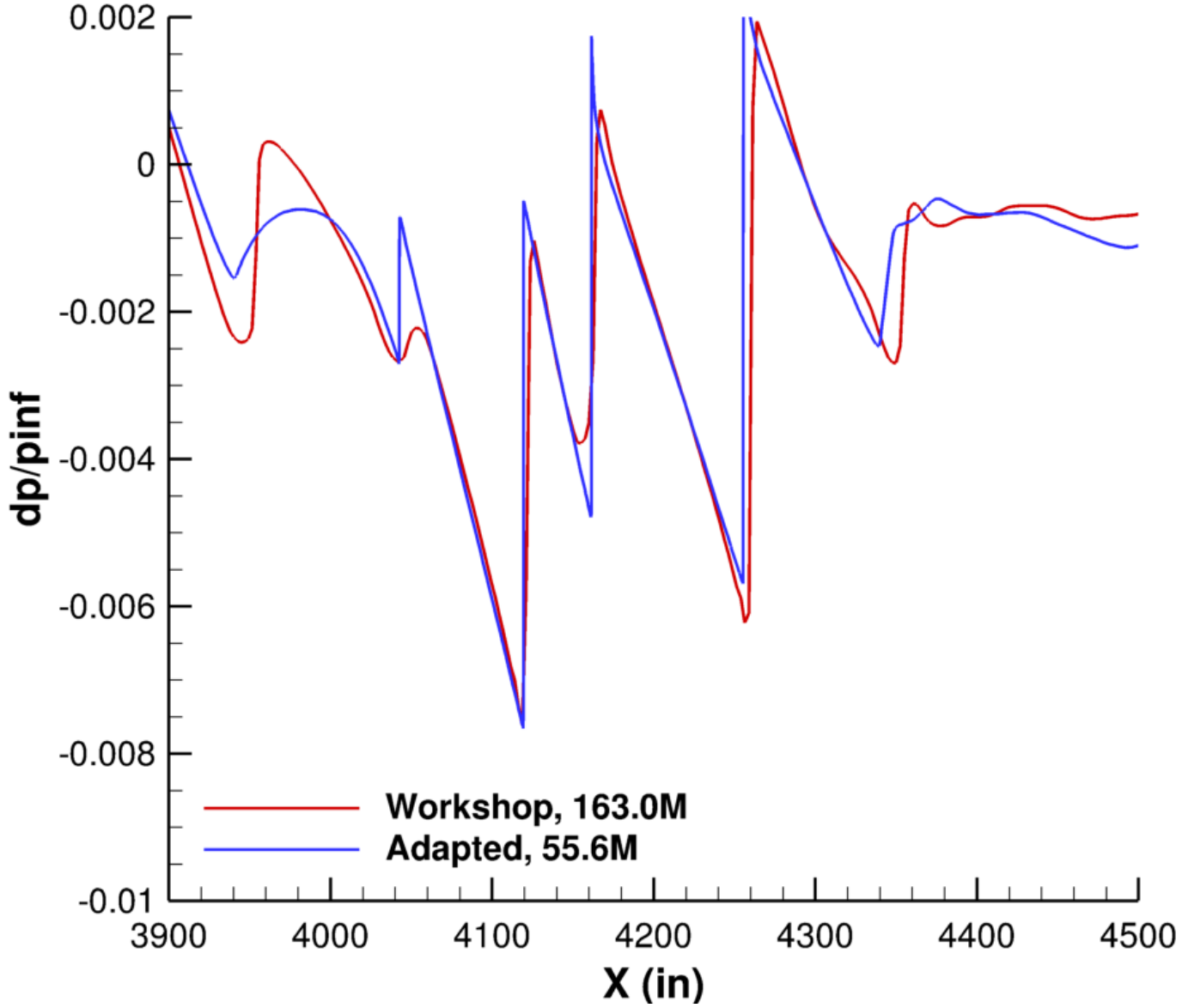
C608 FUN3D Adapted Grids



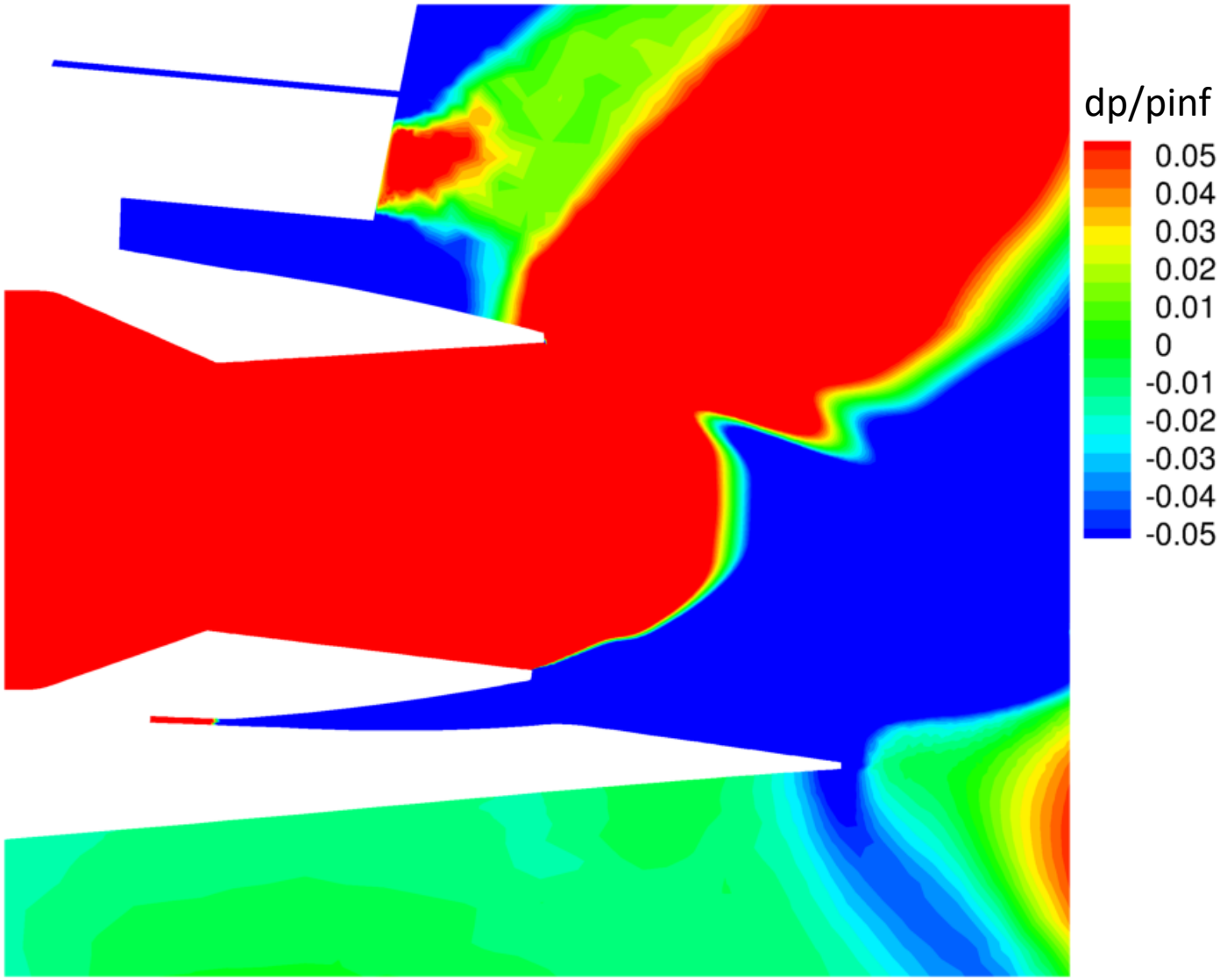
C608 FUN3D Adapted Grids



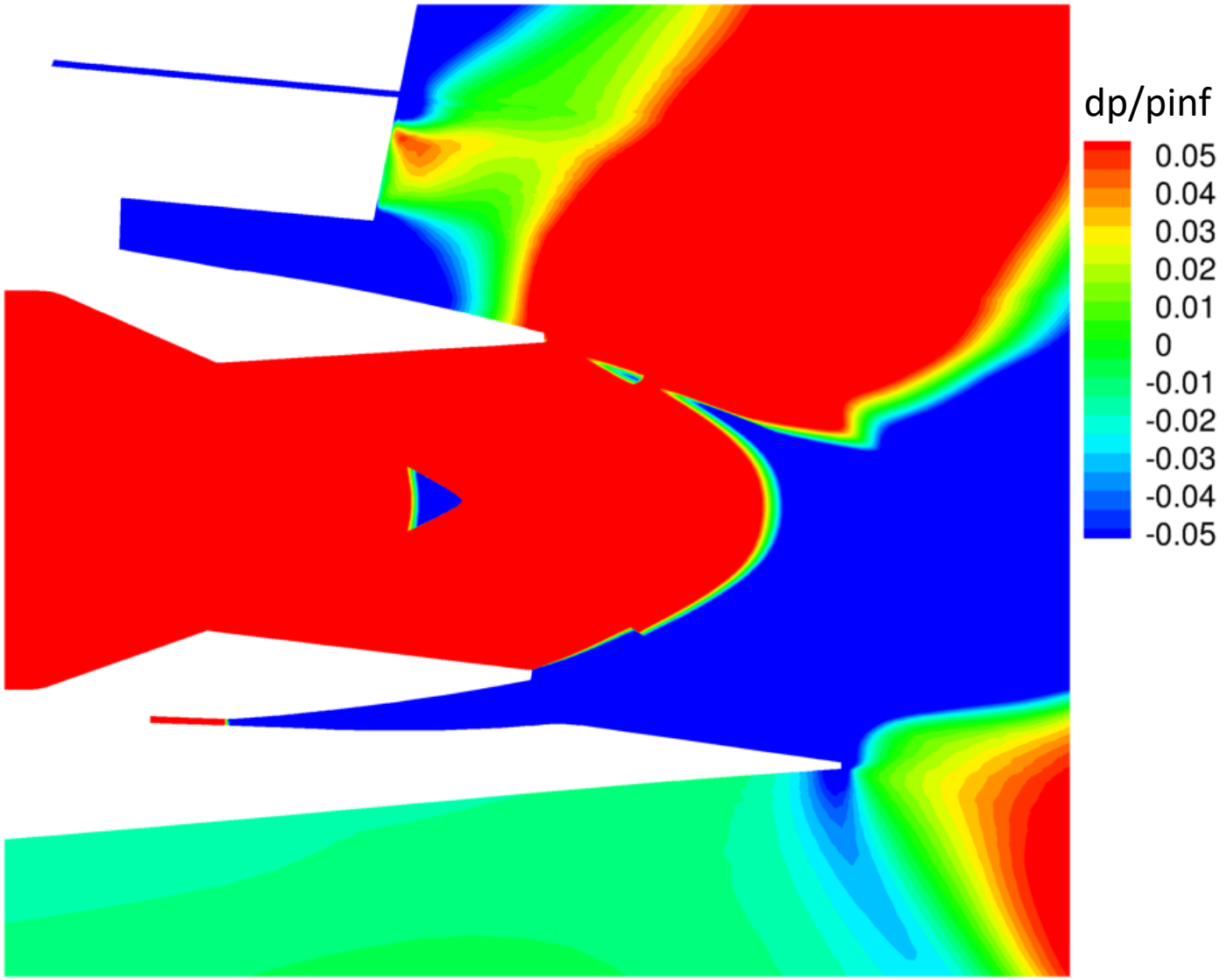
C608 FUN3D Adapted Grids



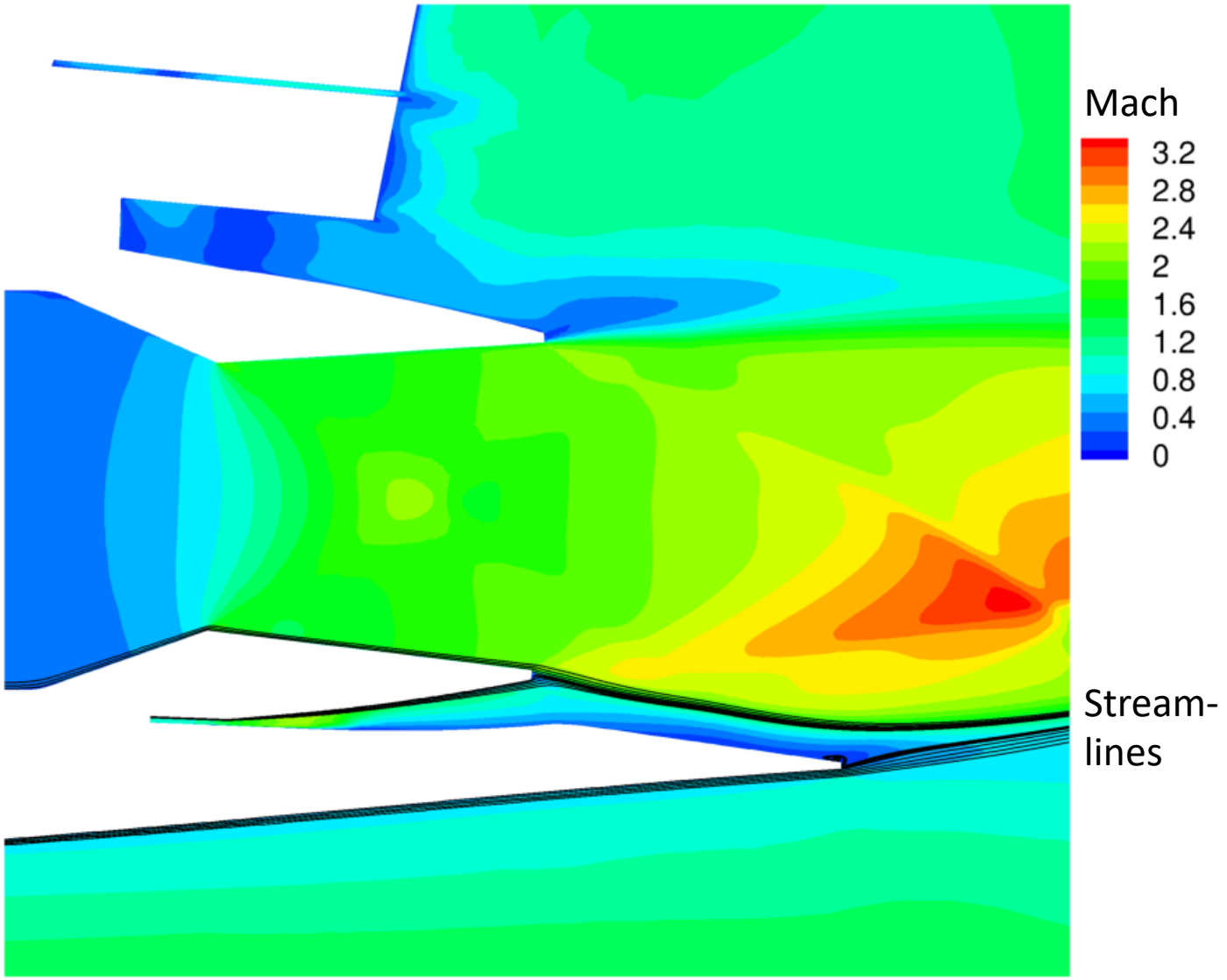
Workshop Grid (89.5M)



Adapted Grid (55.6M)



Workshop Grid (89.5M)



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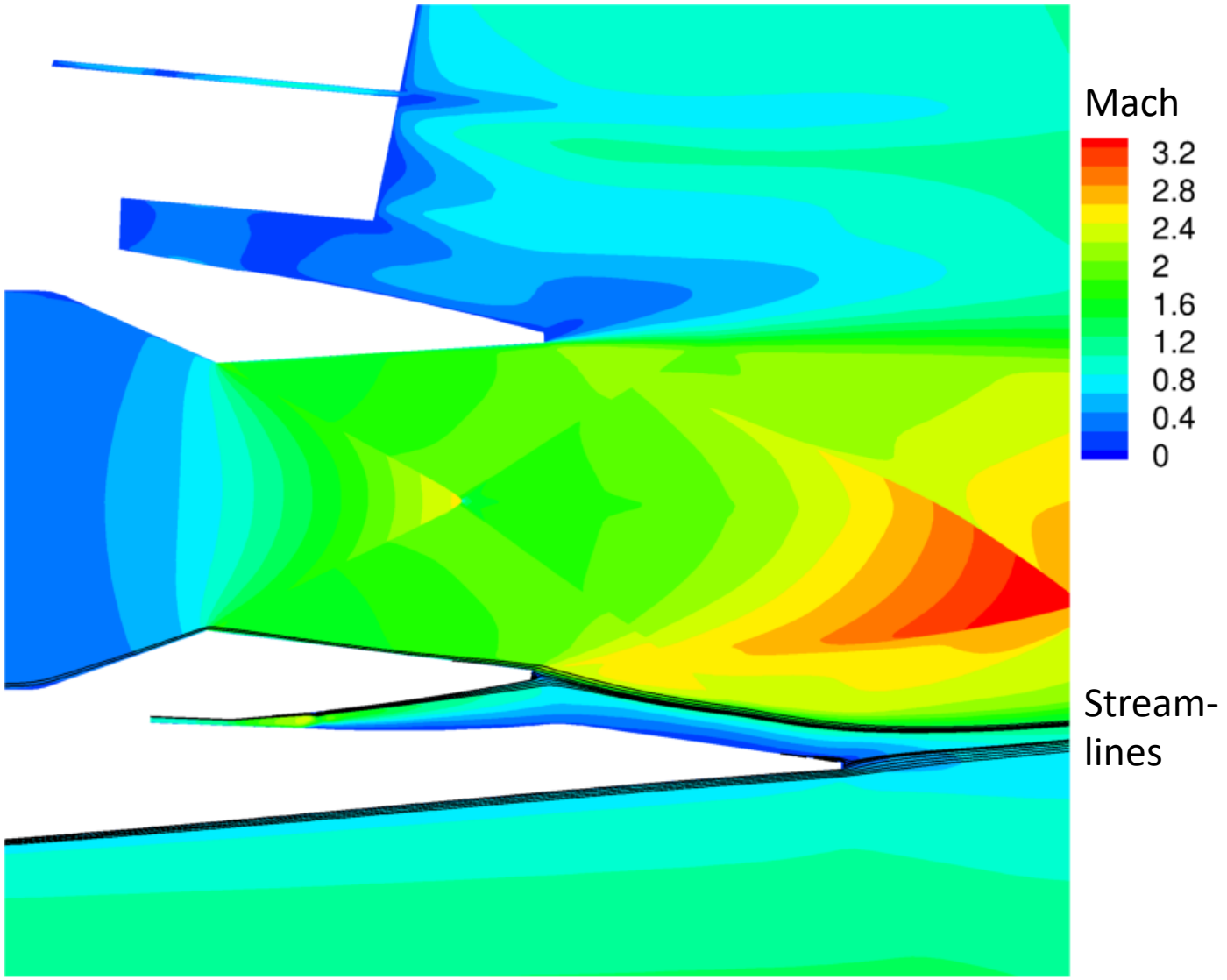

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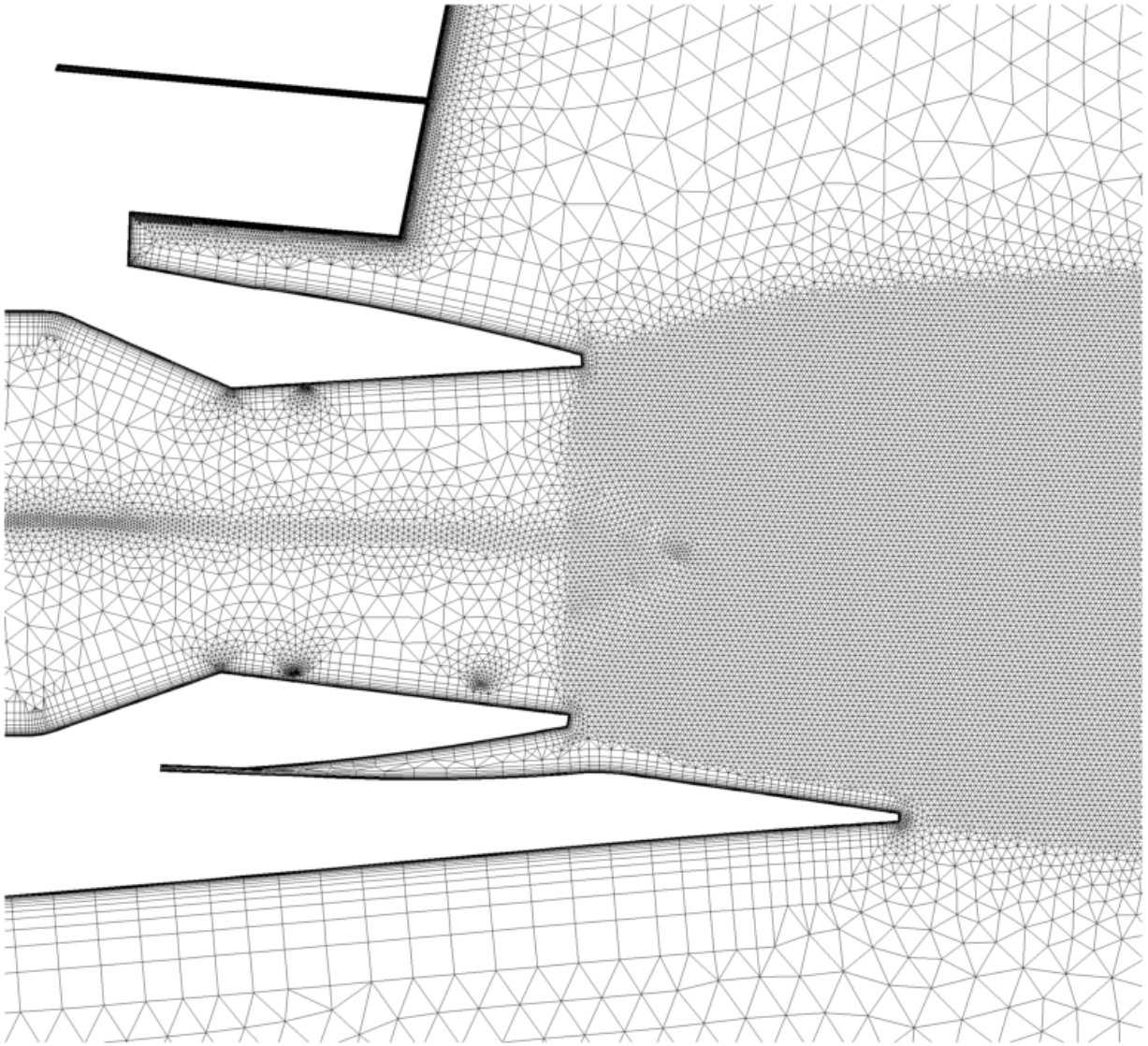

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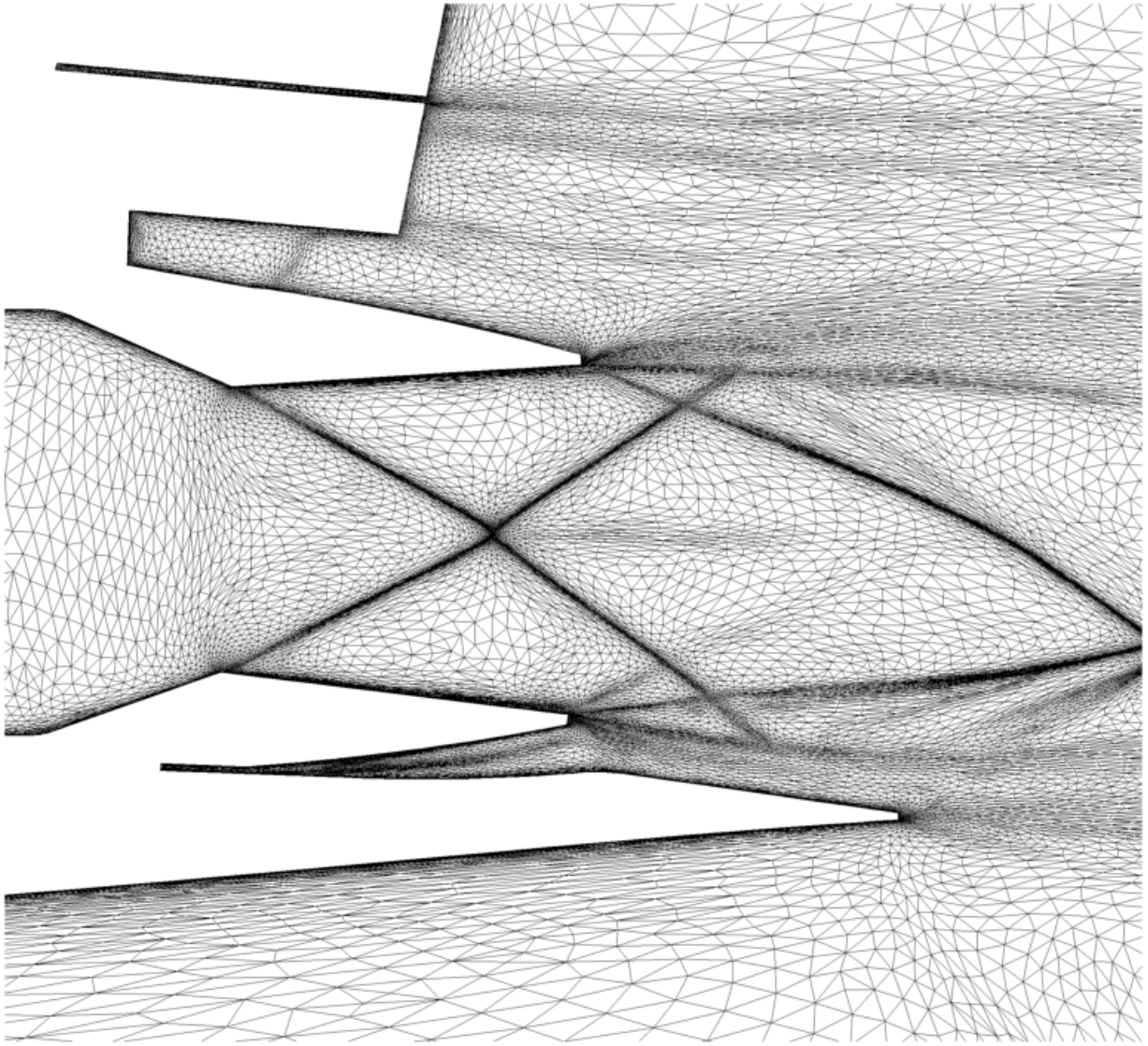
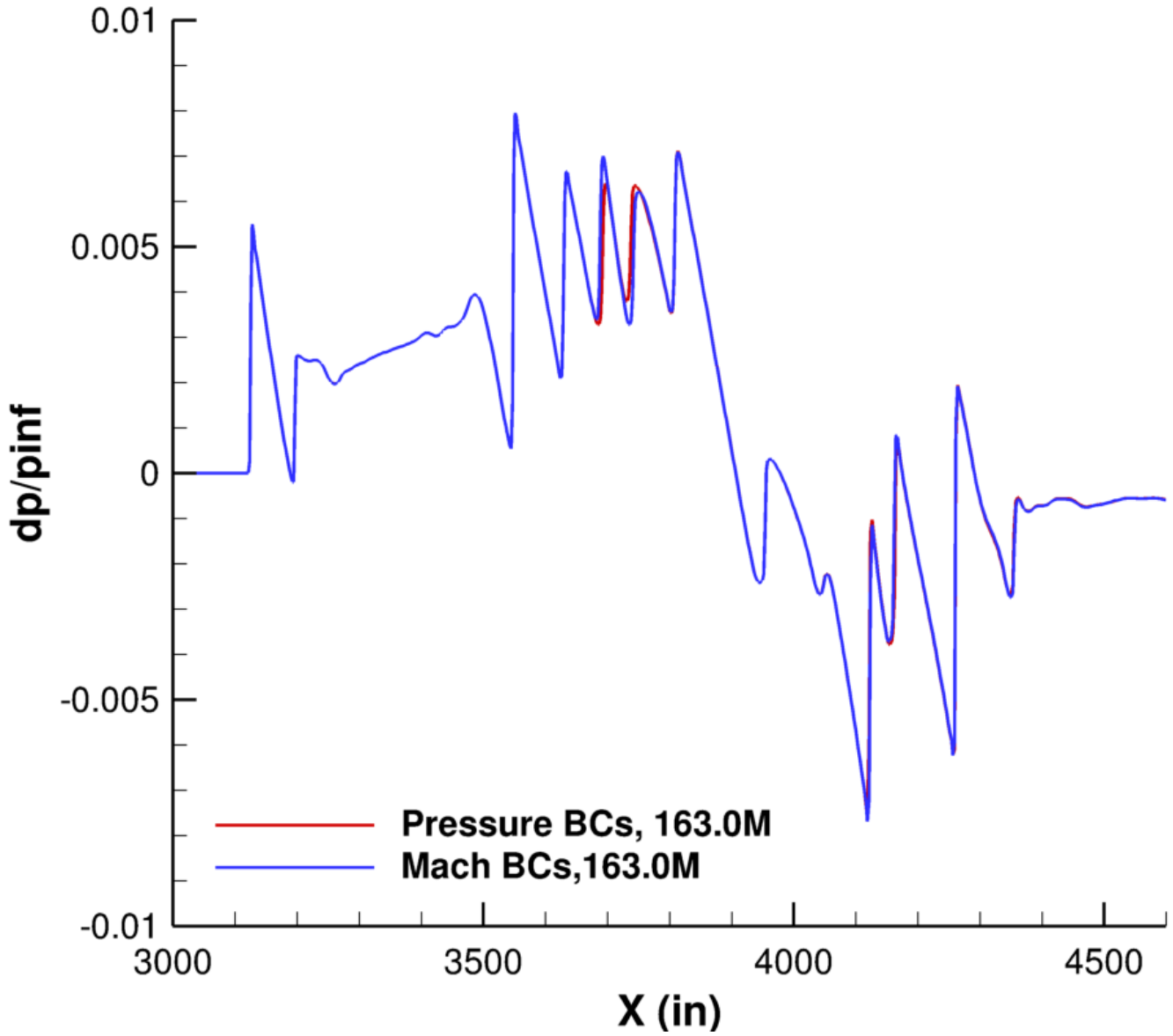
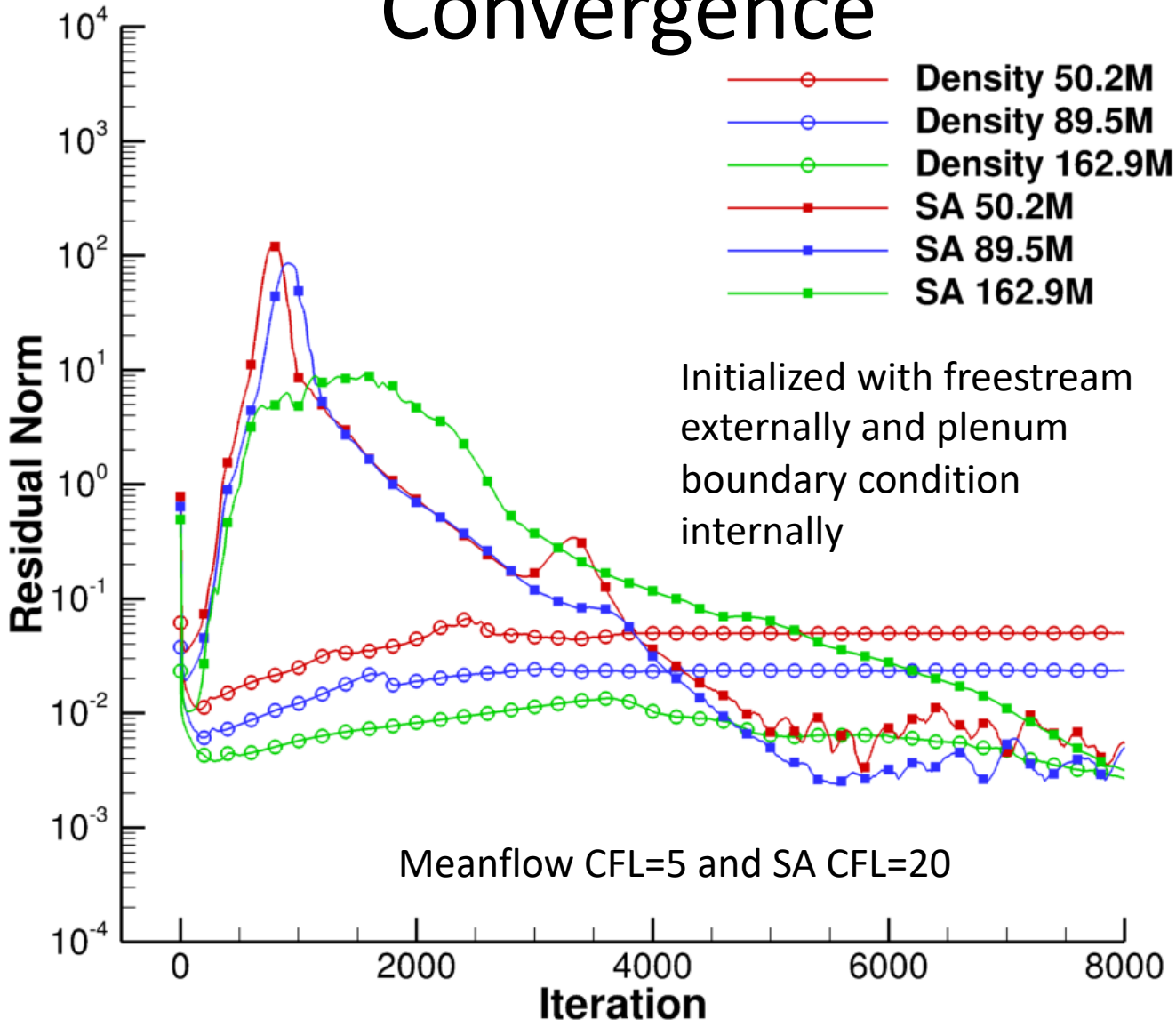


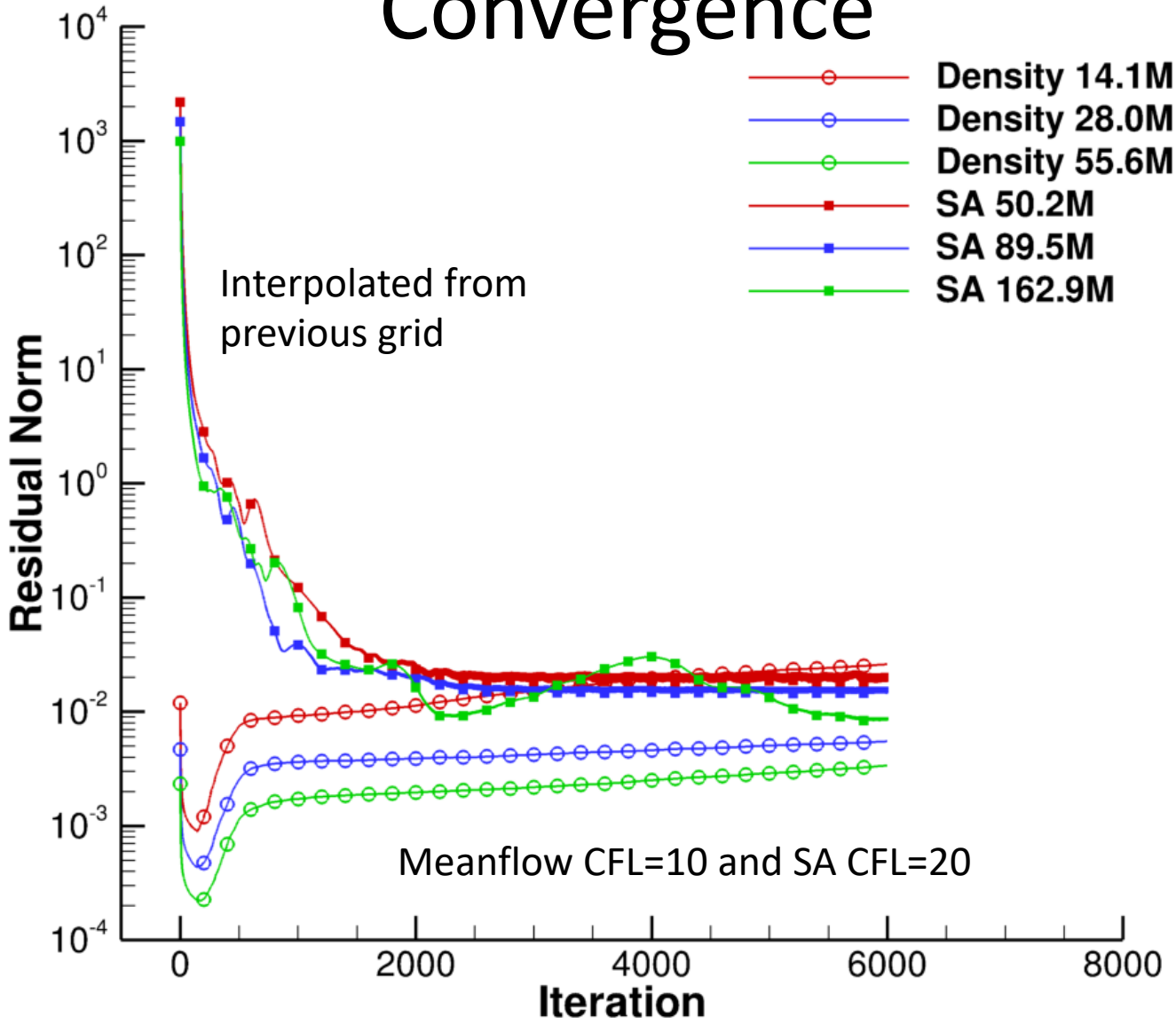
C608 FUN3D Workshop Grid BCs



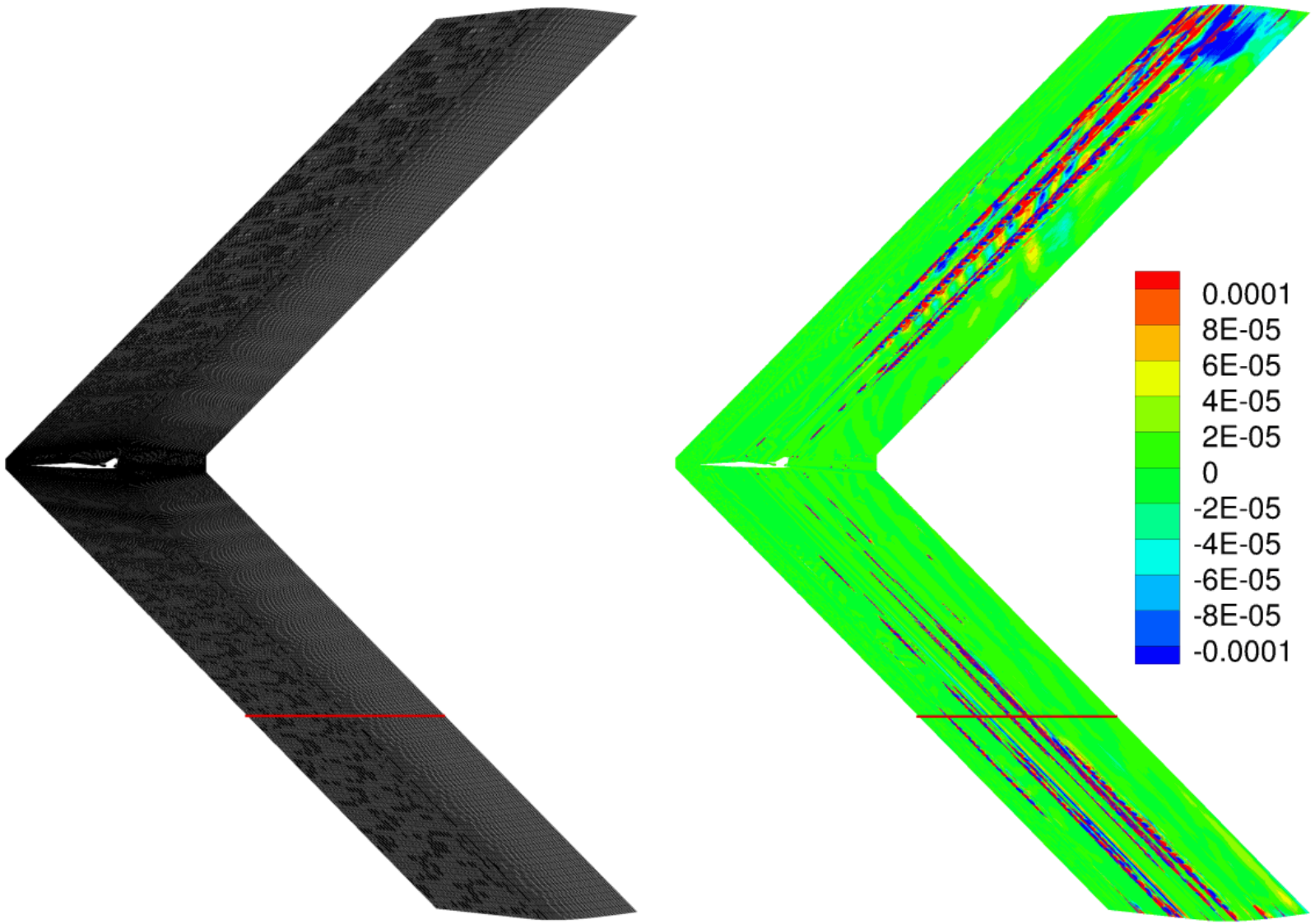
C608 FUN3D Workshop Iterative Convergence



C608 FUN3D Adapted Iterative Convergence



C608 FUN3D Workshop Continuity Residual



Summary

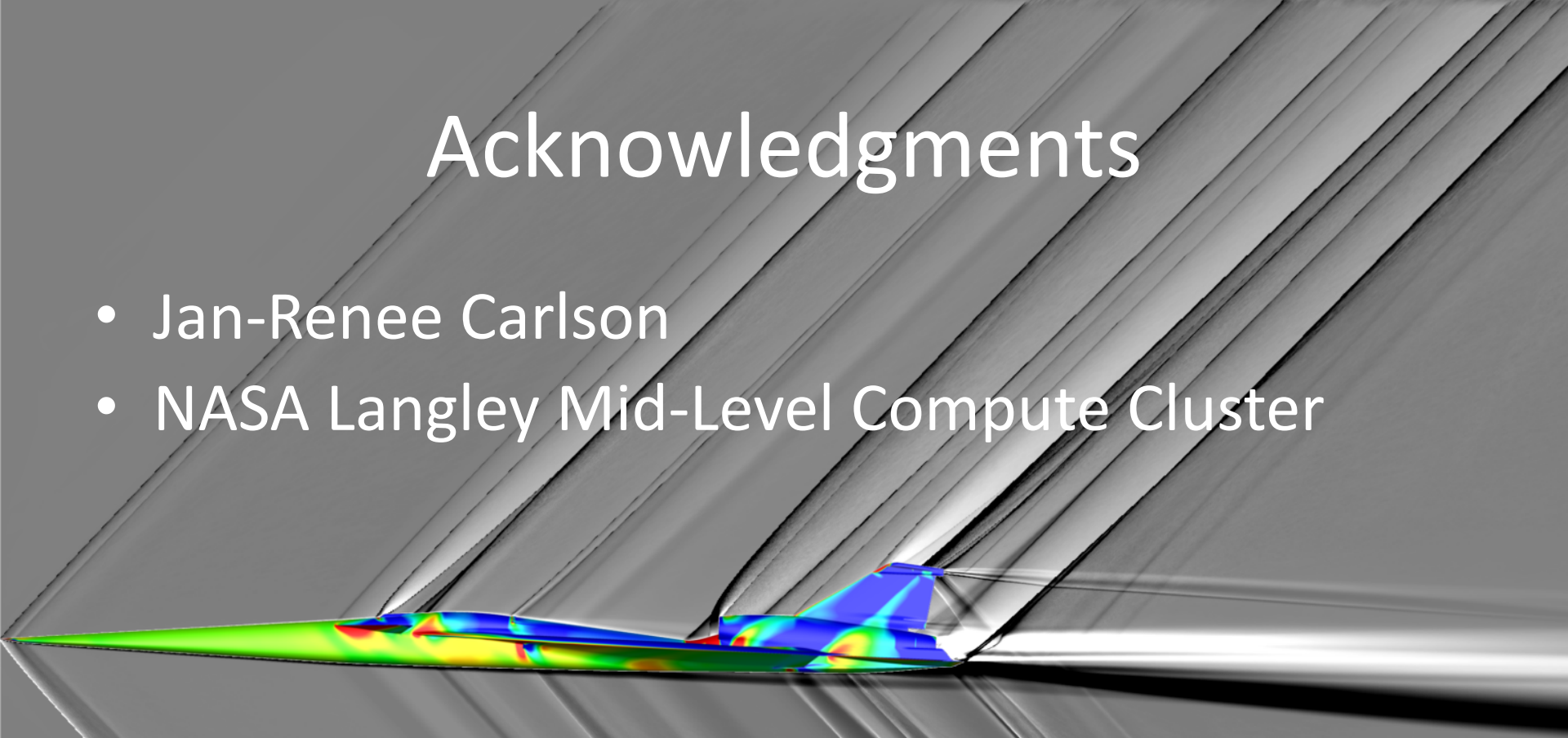
- Automated grid adaptation applied to control Mach number interpolation error
- Biconvex showed grid sensitivity at the sting-body juncture in the fixed and adapted grids
- Biconvex grid sensitivity reduced with grid adaptation for shock generator and plume
- Computational schlieren is available to compare to Retroreflective Background-Oriented Schlieren

Summary

- Differences between fixed grid and adapted grid C608 aft-deck lip shock driven by nozzle and bypass flows

Acknowledgments

- Jan-Renee Carlson
- NASA Langley Mid-Level Compute Cluster



- Commercial Supersonics Technology Project
- This work was partially supported by the Transformational Tools and Technologies (TTT) Project of the NASA Transformative Aeronautics Concepts Program (TACP)