Validation of a High-Order Compact Code for Nonlinear Flows about Complex Geometric

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Validation of a High−Order Compact Code for Nonlinear Flows about Complex Geometries

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Computational Requirements for Nozzle Exhaust Flow and Noise Calculations

- The code must be capable of accurately calculating nonlinear flowfields.
- Very small amplitude waves must be accurately captured.
- Complex geometries must be accurately represented.
- The code must be written to take advantage of distributed computing environments.
- The code should be robust and capable of being applied to arbitrary geometries.

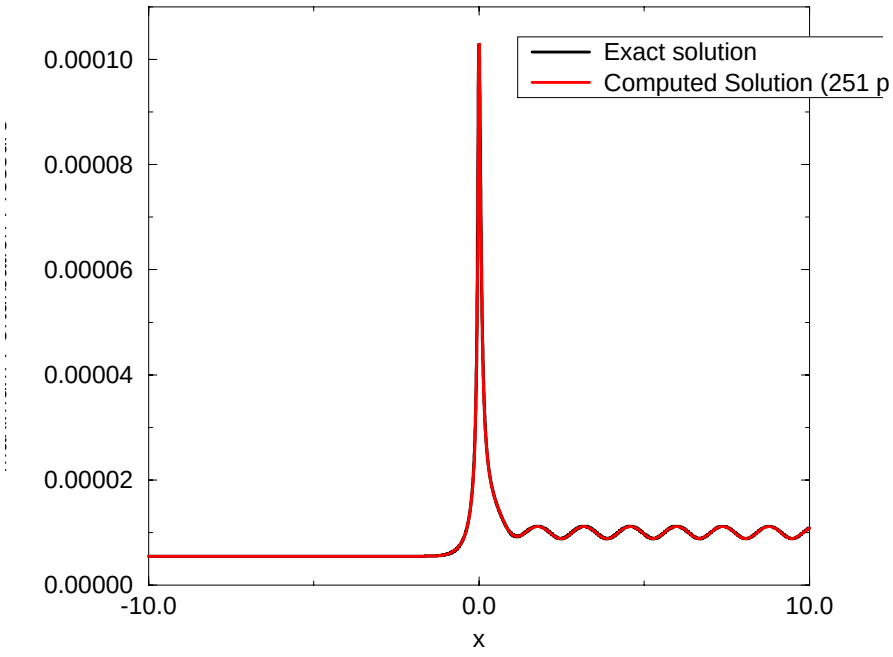
Current Numerical Method

- 4th order low−storage optimized Runge−Kutta time marching (LDDRK 5−6).
- Prefactored small−stencil 6th order compact spatial differencing.
- Explicit 10th order filtering applied at each stage.
- 3−D generalized curvilinear coordinates.
- Structured multi−block grids.
- MPI parallel for distributed computer clusters.
- Allows different equations in each block for more efficient use of resources.
- F90 used for memory management and improved data structures.
- Solves full nonlinear Euler, Navier−Stokes, LES (Smagorinsky), VLES (k−ε).

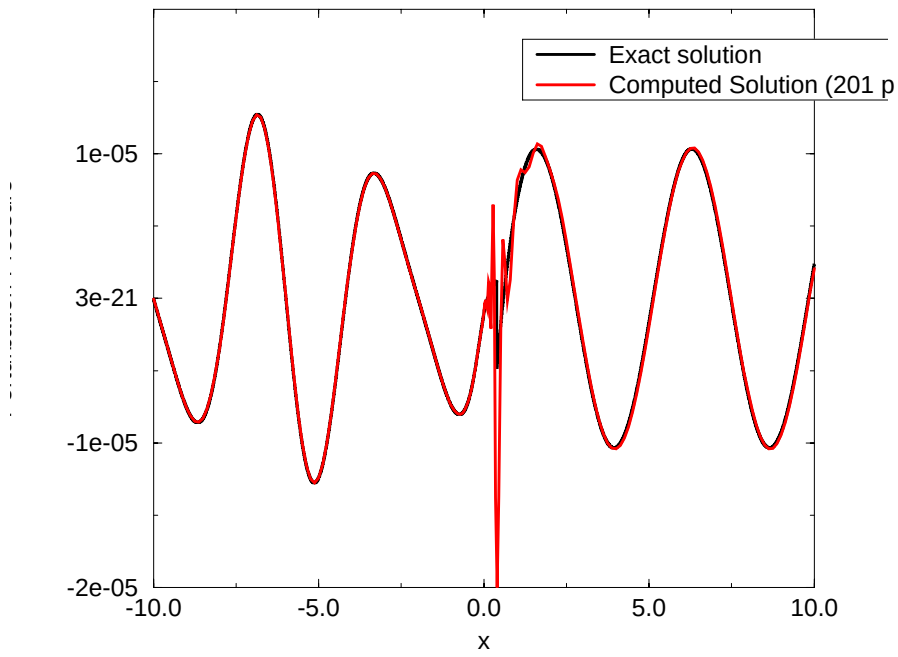
Validation of Prefactored Compact Scheme on CAA Benchmark Problems

These problems showcase the ability of the scheme to accurately calculate the propagation of small disturbances through nonlinear mean flows on highly stretched grids.

Acoustic Wave Through Transonic Nozzle (Category 1, Problem 1, 3rd CAA Workshop)

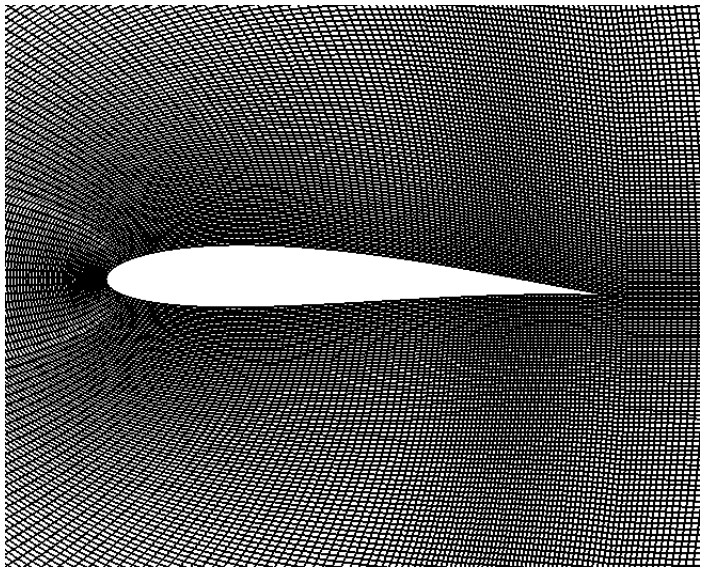


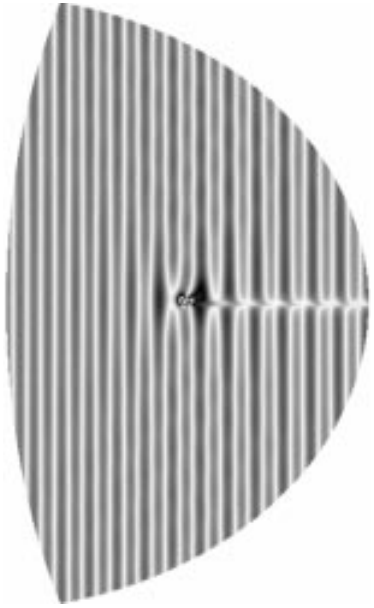
Acoustic Wave Through Shock (Category 1, Problem 2, 3rd CAA Workshop)



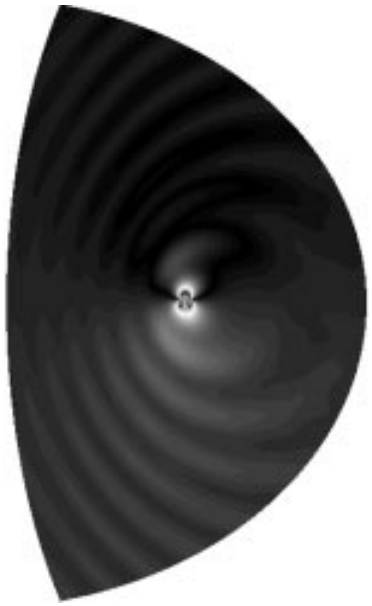
Curvilinear Grid Performance Test: Gust Response of a Joukowski Airfoil

Closeup of Cambered Airfoil Grid





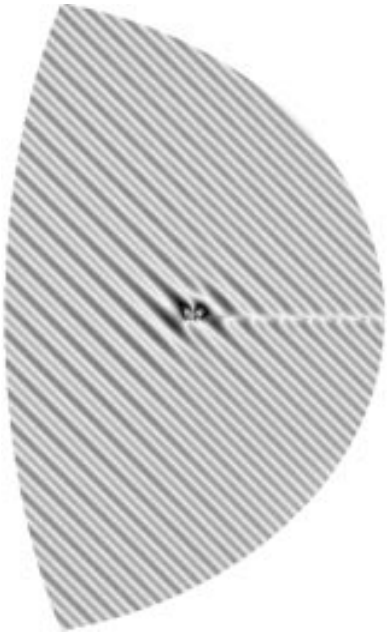
k = 1.0
1D gust



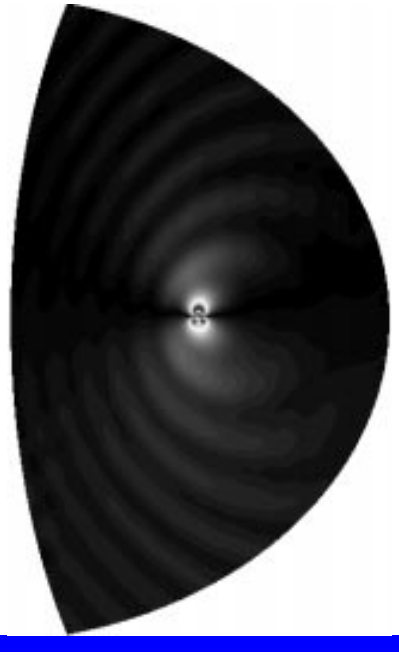
V velocity

Perturbation Pressure

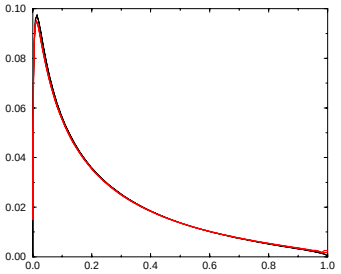
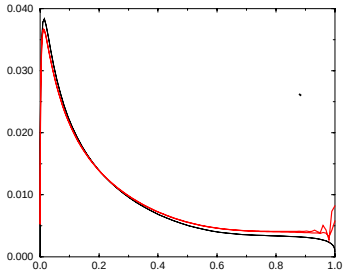
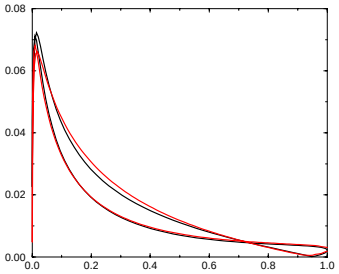
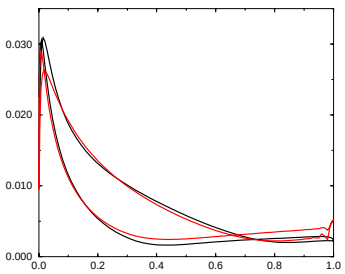
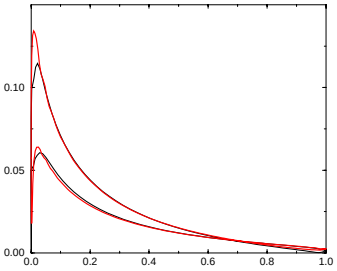
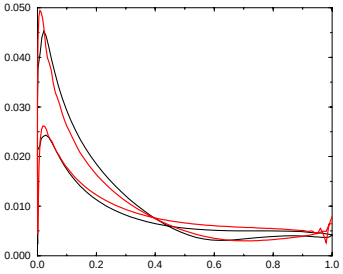
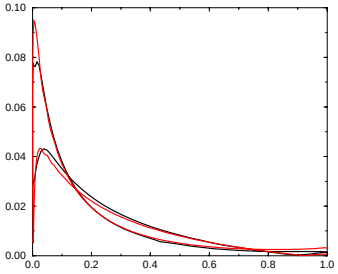
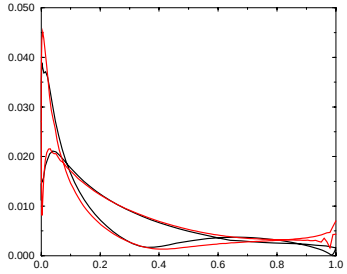
In this benchmark CAA problem, the effects of wall geometry, gust geometry, curvilinear grids, and farfield boundary conditions are tested.



k = 1.0
2D gust



Airfoil Surface RMS Pressure Disturbance for Joukowski Airfoil in a Vortical Gust

	1−D Gust, k = 0.1	1−D Gust, k = 1.0	2−D Gust, k = 0.1	2−D Gust, k = 1.0
Symmetric Airfoil				
Cambered Airfoil				

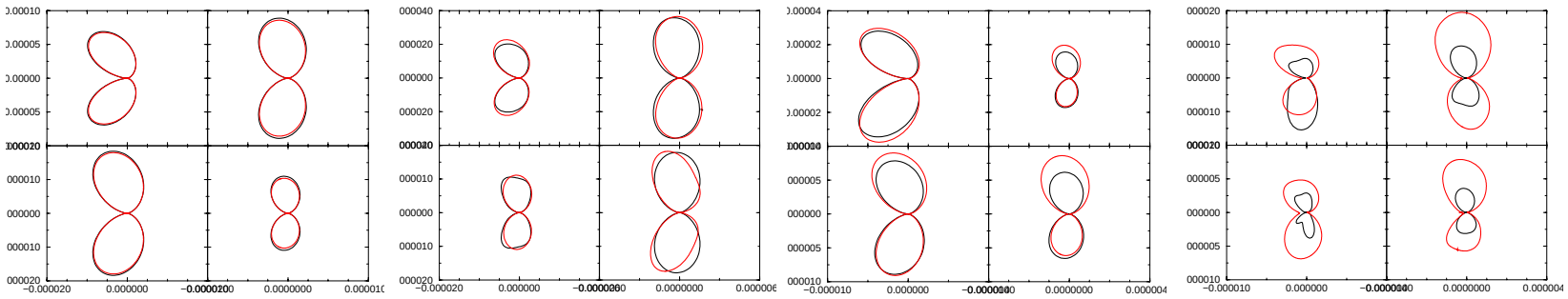
GUST3D Results

Computed Results

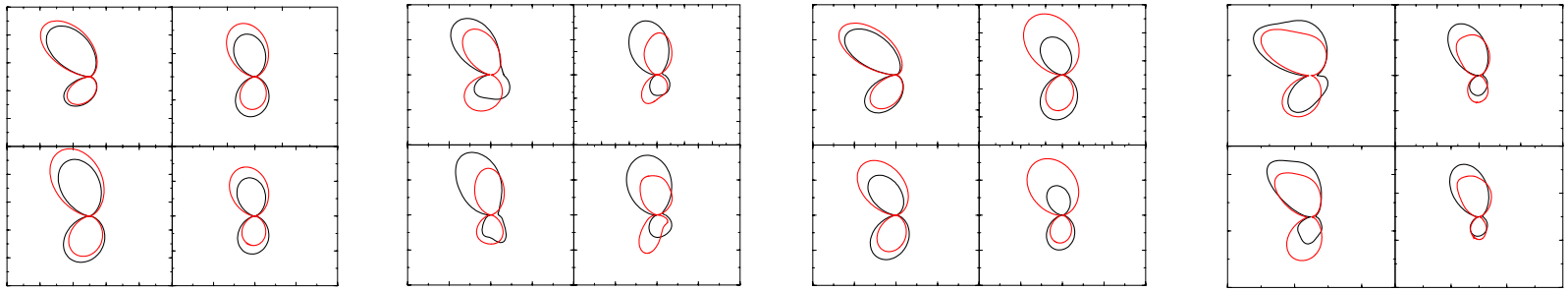
Far Field Noise Radiation Results for Joukowski Airfoil in a Vortical Gust

1−D Gust, k = 0.1 | **1−D Gust, k = 1.0** | **2−D Gust, k = 0.1** | **2−D Gust, k = 1.0**

Symmetric Airfoil



Cambered Airfoil



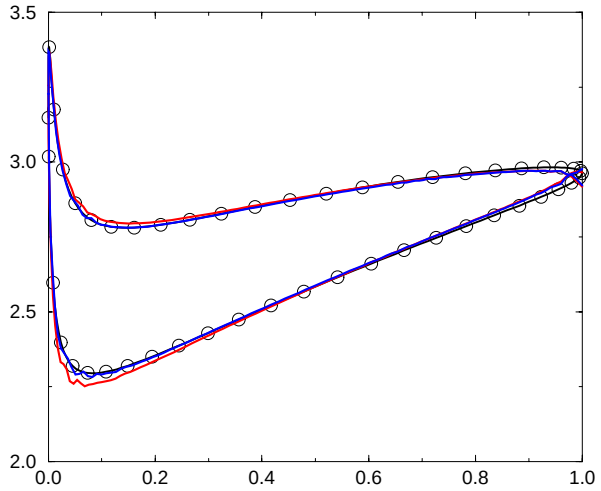
R = 1	**R = 3**
R = 2	**R = 4**

GUST3D Results

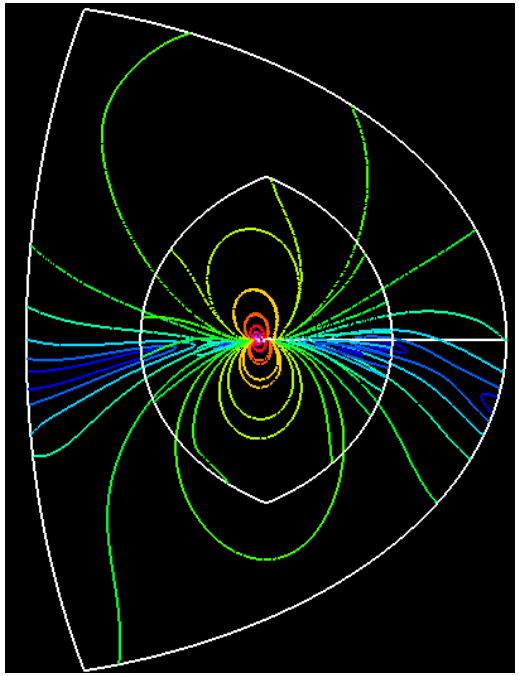
Computed Results

Boundary Distance Study for Joukowski Airfoil Problem (Cambered, k=0.1, 2D gust)

Mean Pressure on Airfoil



Log Pressure Perturbation Contours

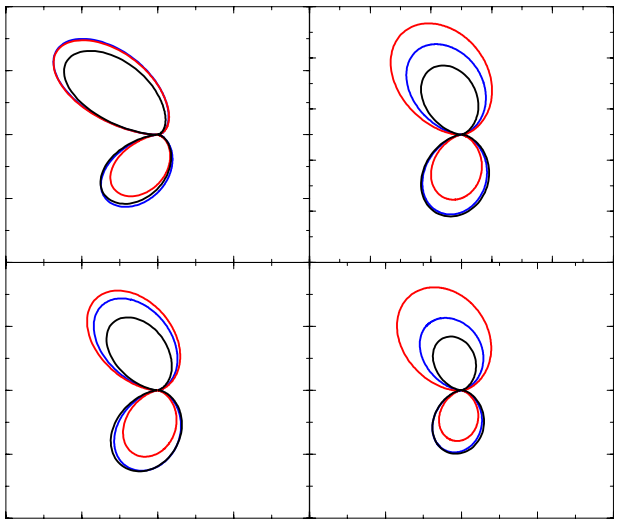


GUST3D Results

Computed Results (Coarse Grid = 433 x 125 = 54,125 points)

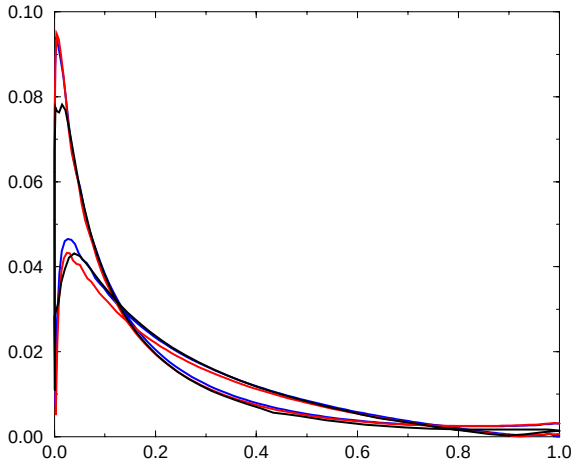
Computed Results (Large Grid = 605 x 240 = 145,200 points)

Pressure Perturbation in Far Field

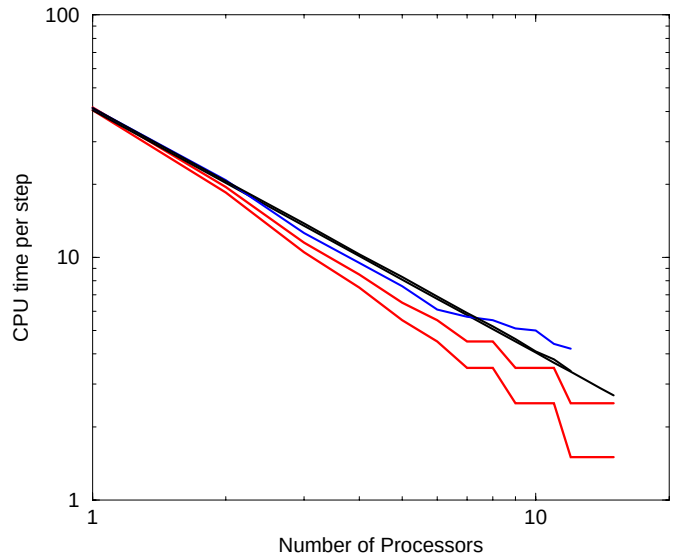


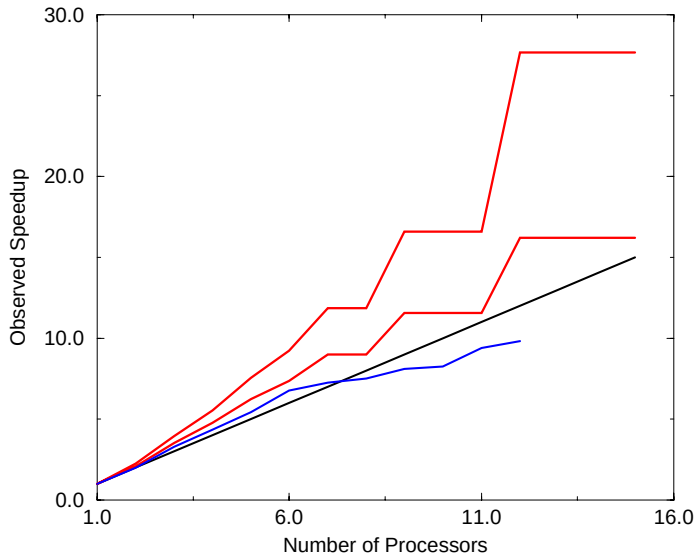
R = 1	R = 3
R = 2	R = 4

RMS Pressure Perturbation on Airfoil



Performance of ICOMP Parallel Macintosh Cluster





Best Expected Performance
ICOMP Mac G4 Cluster (2 G4/400 + 13 G4/450 DP)
ICOMP SGI Octane Cluster (6 R12000 + 6 R10000)

- The two red lines show best and worst performance of Mac cluster on the F90 MPI prefactored compact code.
- With 15 processors, the program is 17 times faster!

R. Hixon References

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