Investigation of an Overset Grid Flow Solver for Prediction of Subsonic Transport Cruise Performance

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Outline

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  - Wing pressures (case 1)
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  - Computers and users
  - Oscillatory results
- Factors affecting variation
- Graphical analysis
- Conclusions

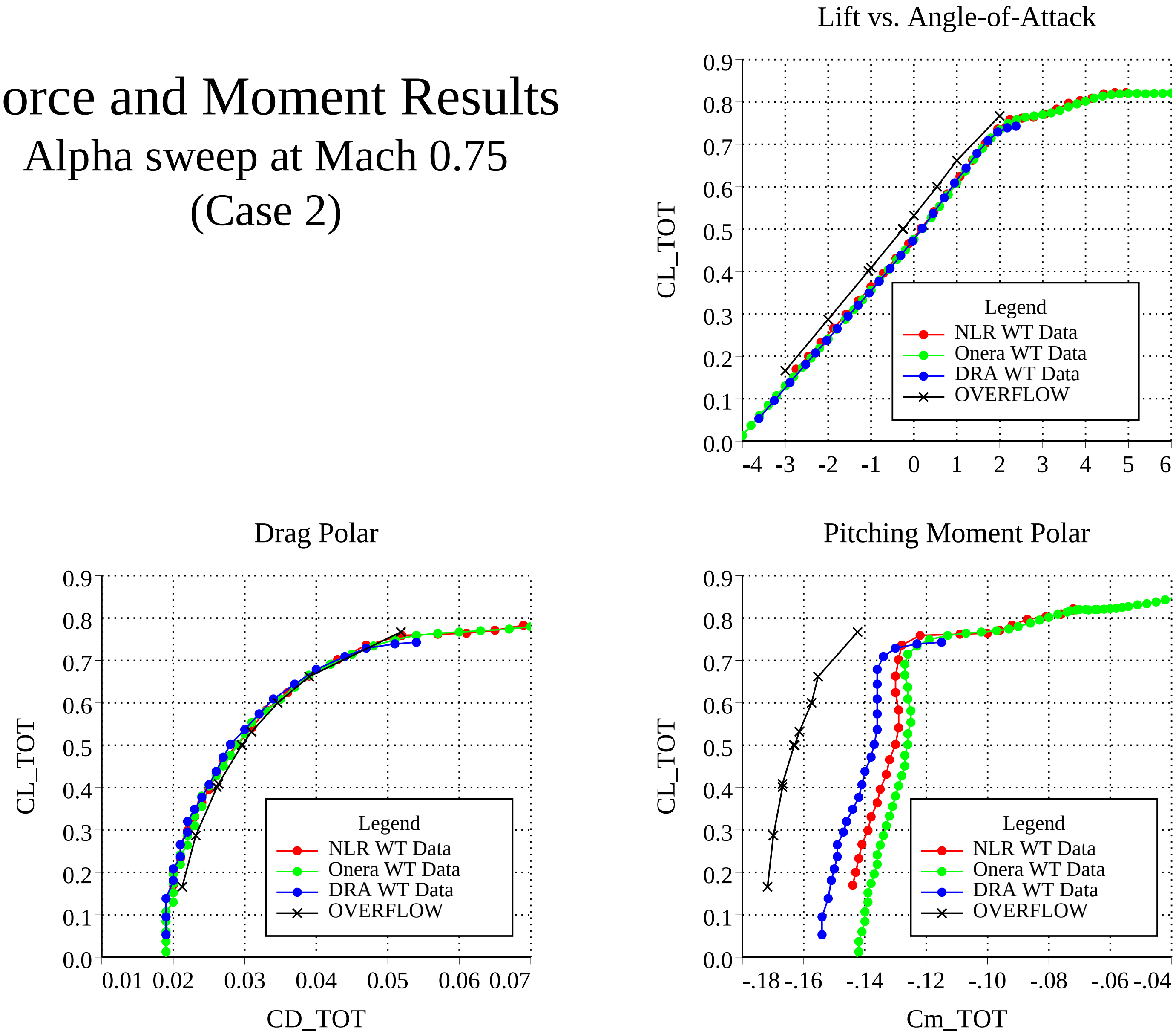
Introduction

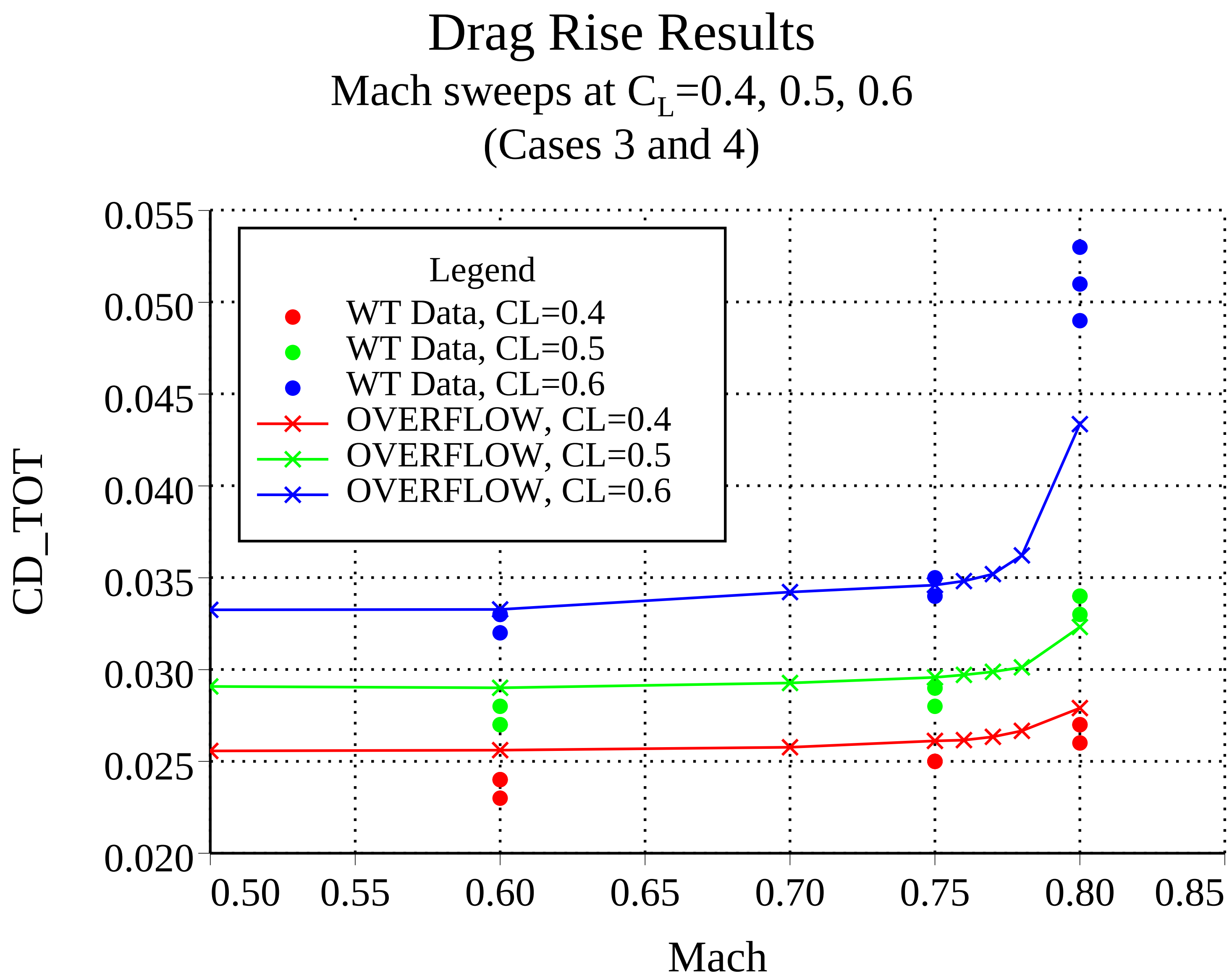
- OVERFLOW 1.8s flow solver
  - Central differencing with scalar dissipation
  - Spalart-Allmaras turbulence model
  - Three users
- Used standard overset grid system only
  - Single precision (32-bit REALs)

Force and Moment Results

Alpha sweep at Mach 0.75

(Case 2)



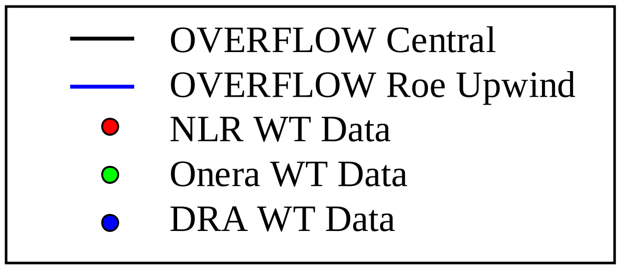


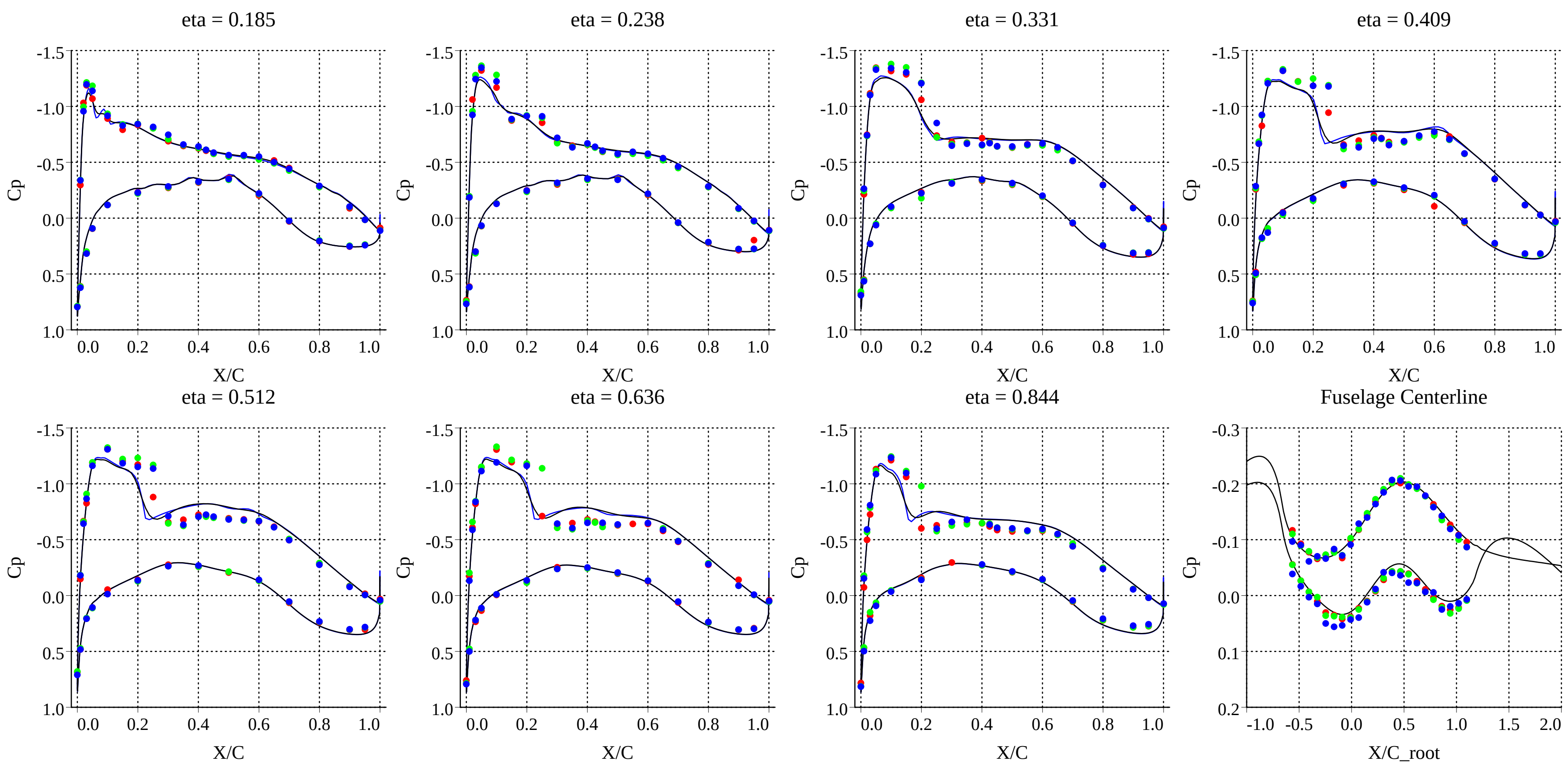
Drag Rise Results
Mach sweeps at CL=0.4, 0.5, 0.6
(Cases 3 and 4)
Legend
WT Data, CL=0.4
WT Data, CL=0.5
WT Data, CL=0.6
OVERFLOW, CL=0.4
OVERFLOW, CL=0.5
OVERFLOW, CL=0.6
CD_TOT
0.055
0.050
0.045
0.040
0.035
0.030
0.025
0.020
0.50
0.55
0.60
0.65
0.70
0.75
0.80
0.85
Mach

Pressure Coefficient

Mach 0.75, C_L=0.5

(Case 1)

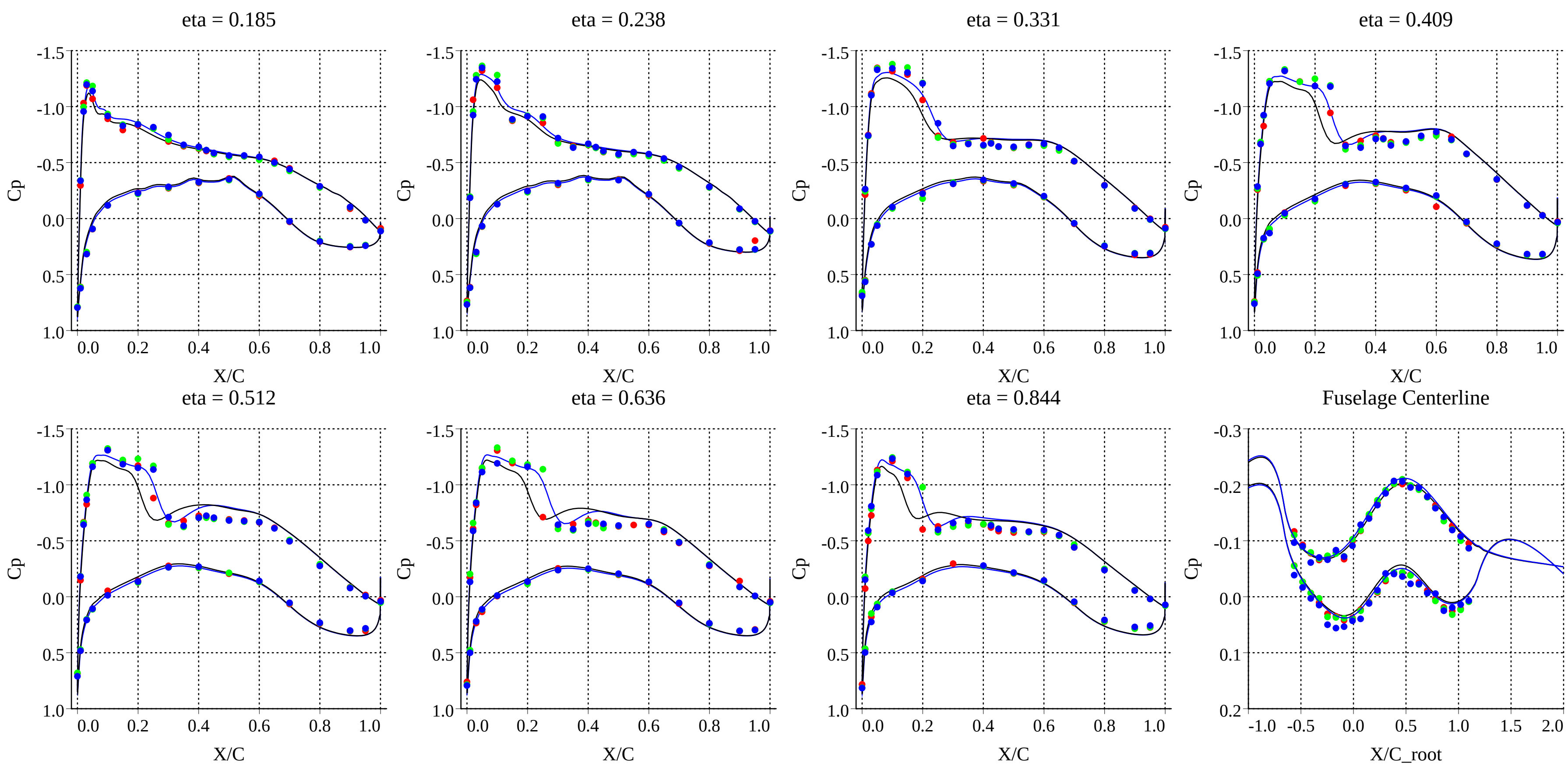




Pressure Coefficient

Mach 0.75

C_L vs. α Match



Results Summary

A statistical analysis of a collection of CFD results is more significant than comparison of one set of results with wind tunnel data.

With that in mind, we observe:

- Lift is higher than WT for a given angle-of-attack
  - Has been true for many configurations
  - Drag is high too; polar is "about right"
- CFD drag rise is qualitatively in agreement with WT
  - Drag is higher than WT at lower CL, Mach
  - Drag is lower than WT at higher CL, Mach
- Matching angle-of-attack does better for comparing surface pressures than matching lift

Flow Solver Operation – Computers and Users

- Case 1 run by three different users independently
  - Method parameters were fixed
  - Time step suggested
  - Free to choose convergence criteria, angle-of-attack for C_L match
  - Results were almost identical:

User	ALPHA	CL_TOT	CD_TOT	CM_TOT
1	-0.257	0.500	0.02959	-0.1632
2	-0.258	0.500	0.02958	-0.1631
3	-0.254	0.500	0.02960	-0.1629

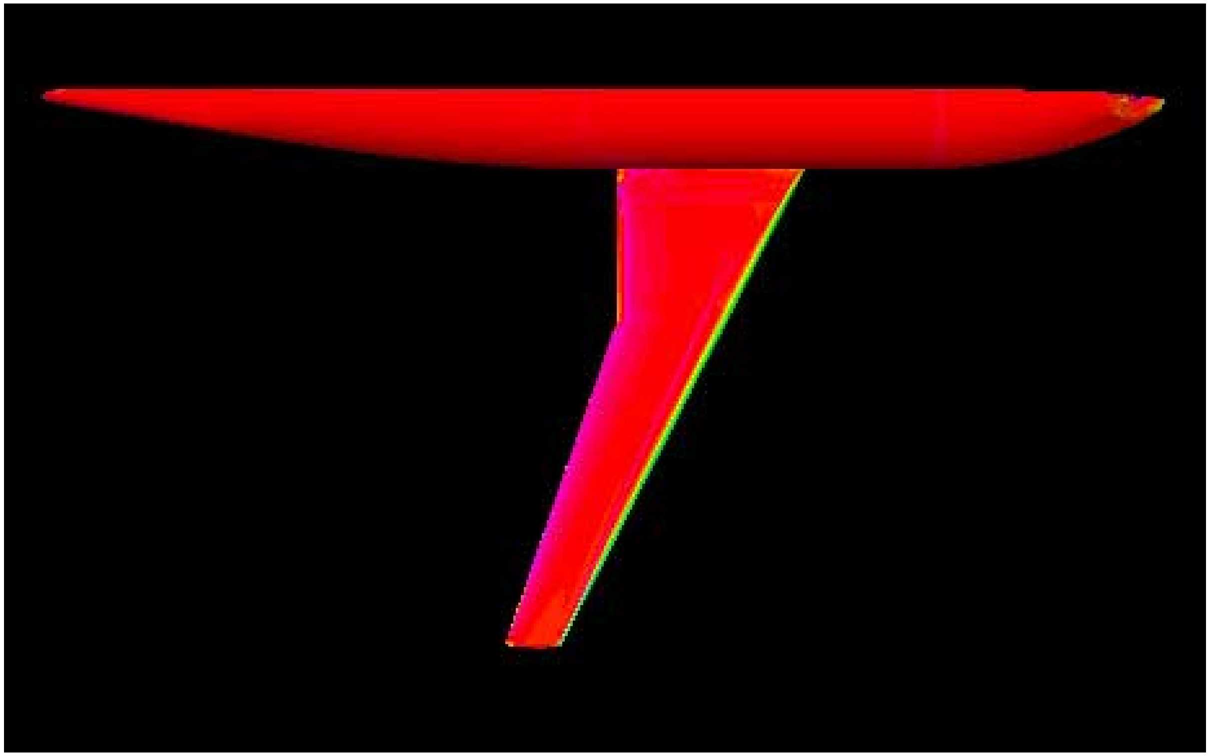
- Three different computer systems used
  - SGI Origin 2000 (2-8 processors), shared memory parallelization
  - Compaq XP-1000 Alphas (1-6 machines), PVM parallelization
  - SGI Octane (1-2 processors)
- All runs used 32-bit REALs, adequate for wind tunnel grid spacing

Flow Solver Operation – Spalart-Allmaras Model

- Run "fully turbulent" using default form of SA model in OVERFLOW
  - Low freestream μ_t
  - Unpublished version of model with f_{v3} term
    - Can have some laminar run, depending on Reynolds number
    - Turbulence index indicates this is a small region

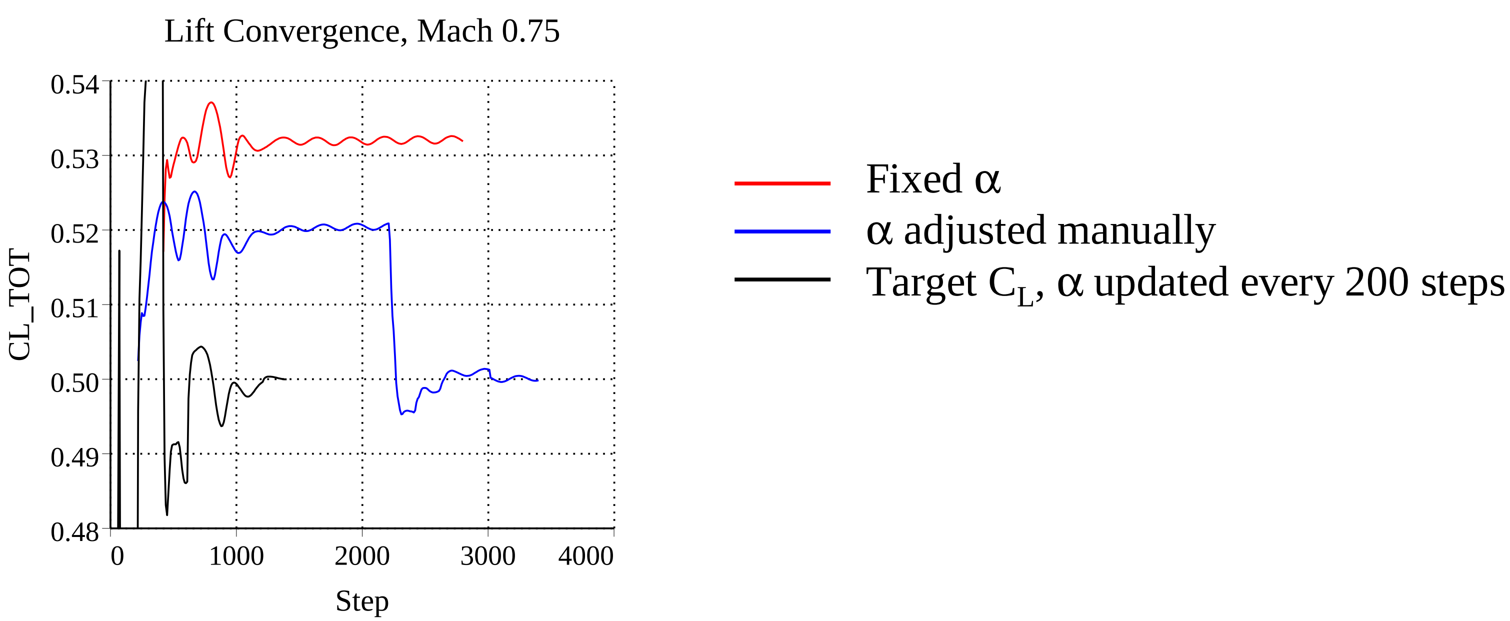
Turbulence index function indicating laminar region near leading edge

(Mach 0.75, C_L=0.5 case)



Flow Solver Operation – Oscillatory Solutions

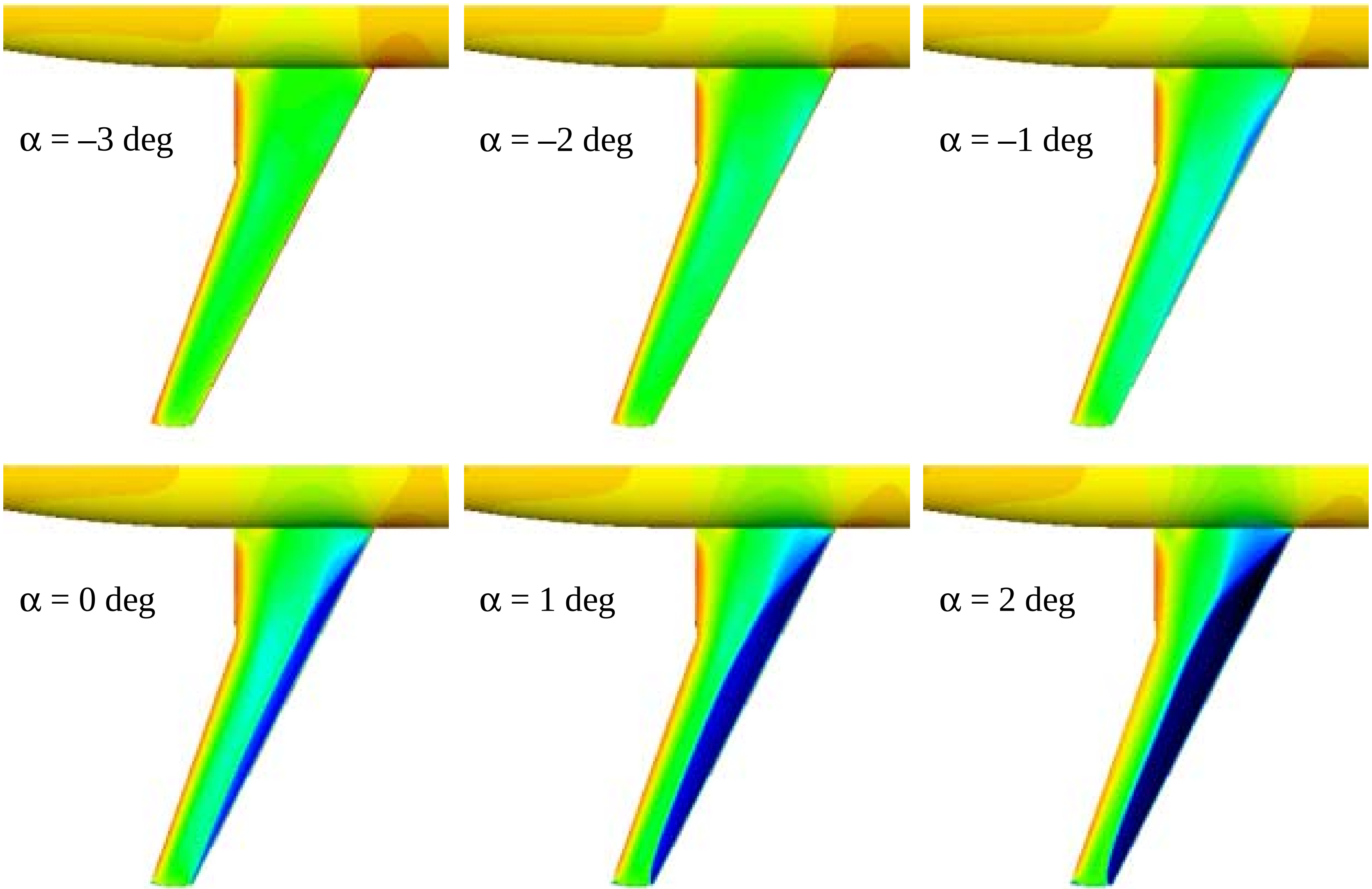
- Almost all cases were oscillatory
  - Variation in C_L was roughly ±0.001, and varied with case
    - Average aerodynamic coefficients used
  - α was adjusted manually to match C_L by two users
  - "Target C_L" capability was used by third user
  - No attempt was made to run in time-accurate mode



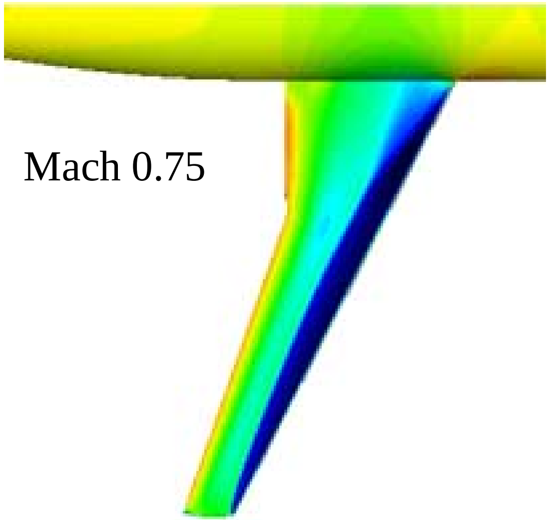
Factors Affecting Variation

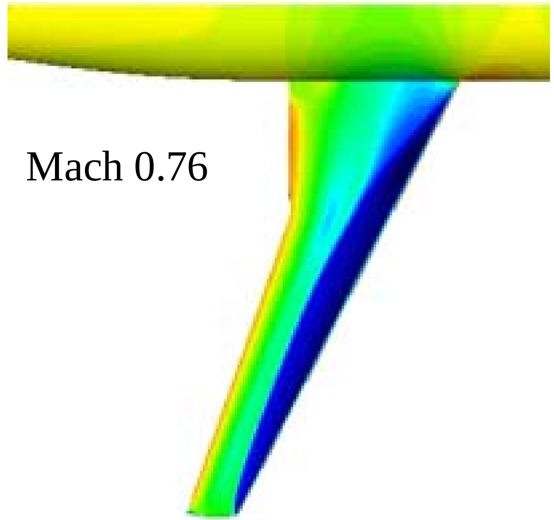
- Grid issues
  - Supplied overset grid system avoids axis at nose
  - Viscous grid stretching ratio is 1.25
    - Maximum stretching ratio of 1.2 is recommended for accurate drag prediction
    - Several cells of constant spacing at the wall is best
  - Effect of large blunt trailing edge gridding is still a question
- Grid convergence
  - Medium grid level (from grid sequencing) does not converge, but preliminary $\Delta C_L = -0.015$, $\Delta C_D = 0.0058$ (large!), $\Delta C_m = 0.003$
- Solver options
  - Results using Roe upwind instead of central differencing show only 3 counts difference in C_D for Case 1
- Turbulence model
  - Variation not tested in OVERFLOW
  - Representative information from CFL3D runs
- Users
  - Multiple users obtained essentially identical answers

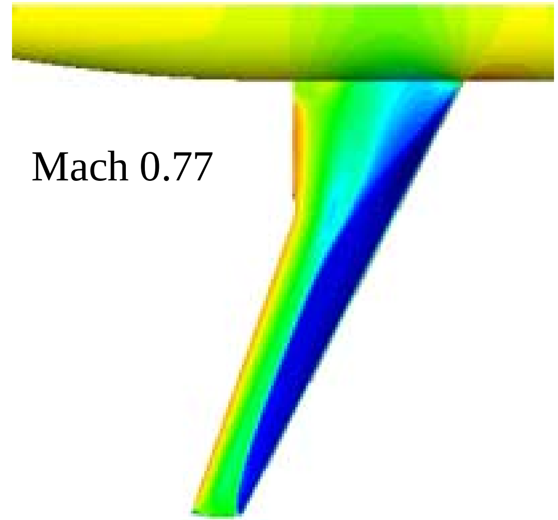
Surface Pressure for Angle-of-Attack Sweep, Mach 0.75

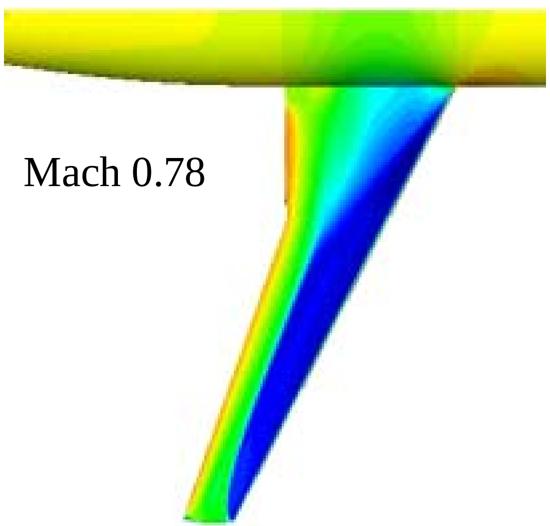


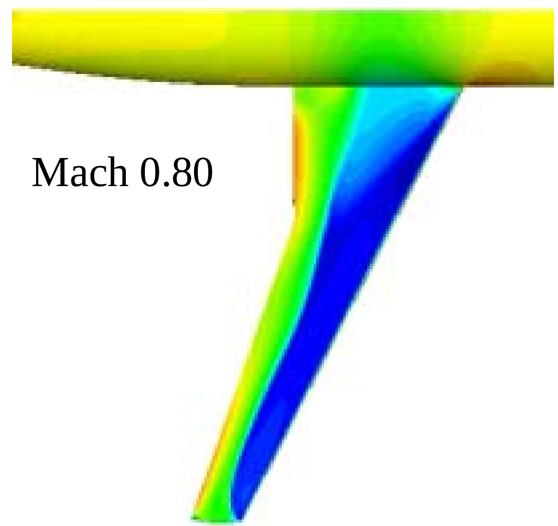
Surface Pressure for Mach Sweep, C_L=0.6











Conclusions

- Basic drag prediction capability has been quantified
  – Drag rise data needs more analysis
  – Must identify source of characteristic angle-of-attack offset
  – Thorough investigation of grid convergence is needed

- Careful analysis of experimental uncertainties is needed

- Next round: characterize off-design, distributed aero loads?