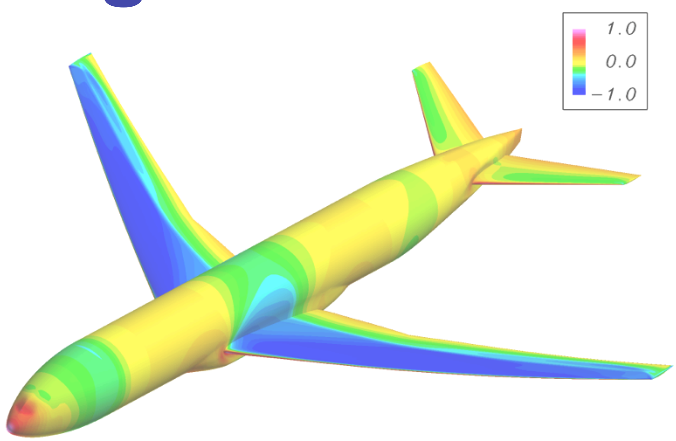
4th AIAA CFD Drag Prediction Workshop

Computational Results using UPACS & TAS



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Objective and Outline

- Evaluation of CFD codes used in APG/JAXA through DPW.
  - Multi-block structured mesh code, UPACS
  - Unstructured mesh code, TAS

- Outline of Presentation
  - Self-made computational grids
  - Codes
  - Case 1.1 Grid convergence study
  - Case 1.2 Downwash study
  - Case 2: Mach sweep
  - Case 3: Reynolds number study
- Points of discussion
  - Comparison of calculated aerodynamic force between two methods
  - Large flow separation at wing-body corner

Grid information

CRM WING/BODY/TAIL (i_H = 0)

Multi-Block Structured Grid (Gridgen)

	Cells	Surf. Faces	BL 1st-Cell Size [inch]	BL Growth Rate	TE Cells
Coarse	2.8M	127K	0.001478	1.31	14
Medium	9.0M	276K	0.000985	1.20	20
Fine	30.4M	620K	0.000657	1.13	30

Coarse & Fine grids ← Based on interpolation of Medium grid

Multi-grid "unfriendly"

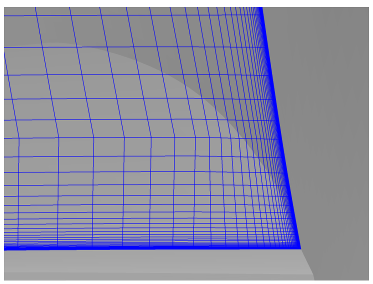
Hybrid unstructured Grid (MEGG3D)

	Nodes	Surf. Nodes	BL 1st-Cell Size [inch]	BL Growth Rate	TE Cells
Coarse	5.9M	213K	0.001478	1.31	1 - 4
Medium	13.5M	370K	0.000985	1.20	2 - 5
Fine	31.3M	589K	0.000657	1.13	3 - 7

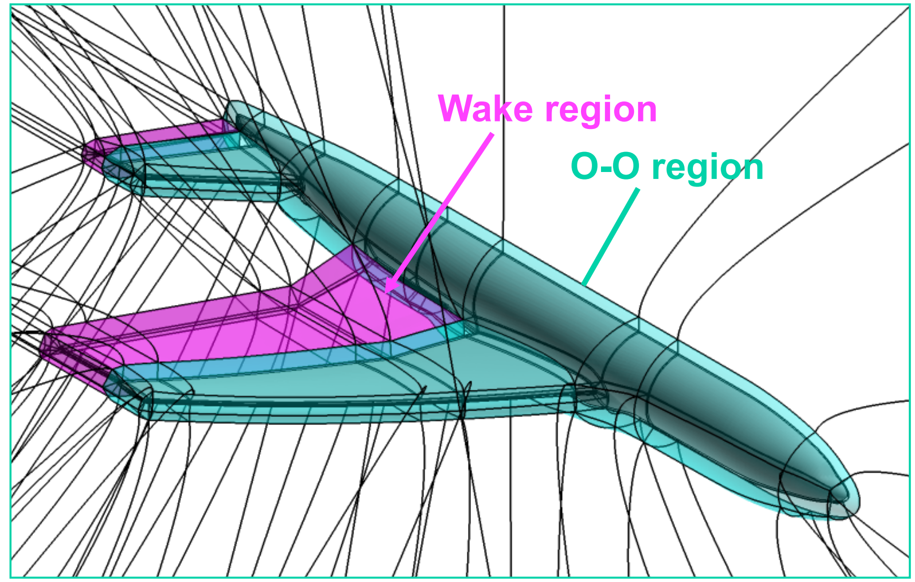
Different from the grid guideline

Point-matched multi-block structured grids

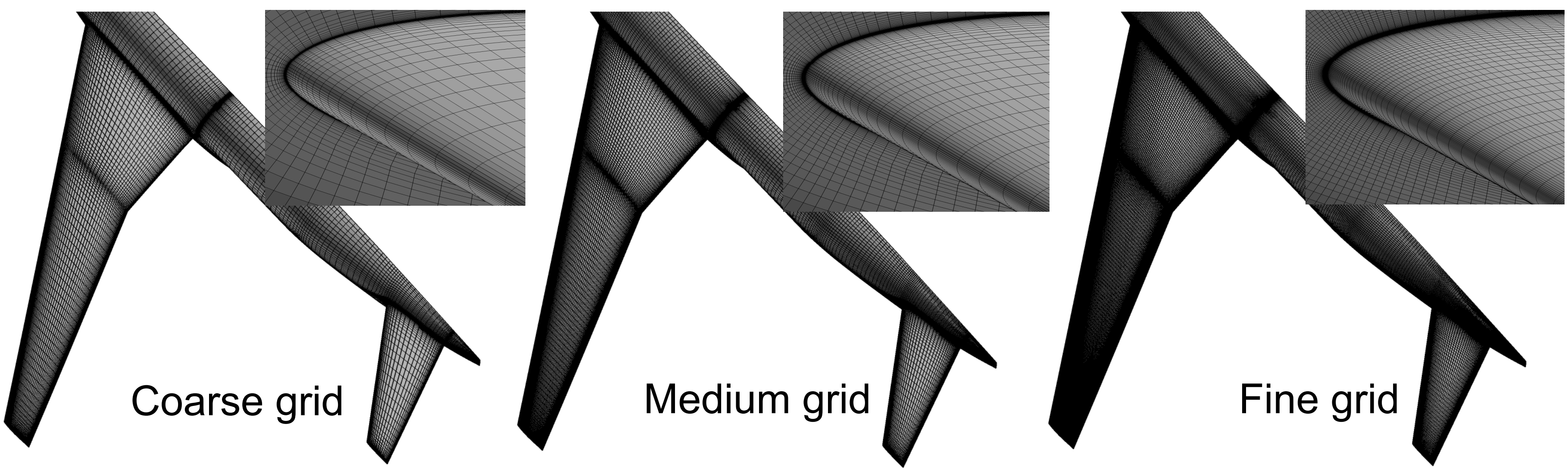
- Near the model surface:
  - O-O grid topology to guarantee better orthogonality within the boundary layer
- Outward:
  - C-O grid topology



Wing-body juncture corner

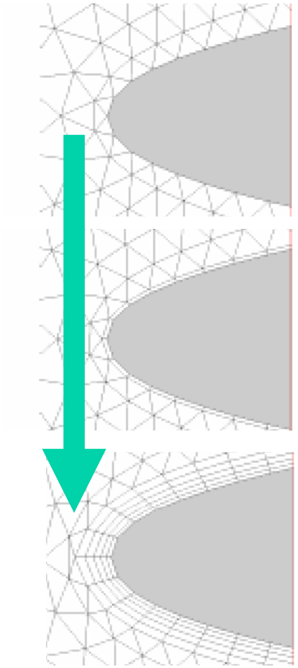


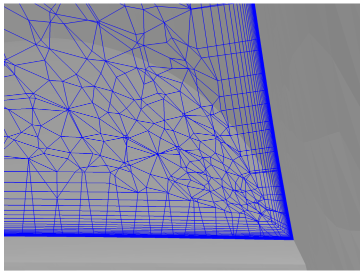
Block wire frame for NASA CRM



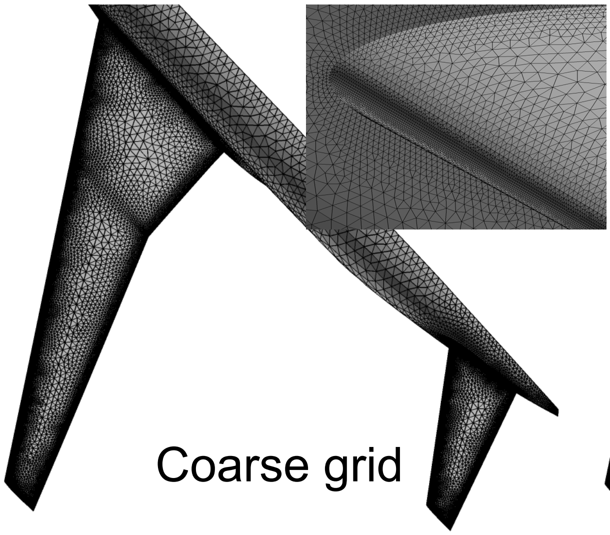
Mixed-element, hybrid-unstructured grids

- Surface grid (Triangles)
  - Direct advancing front method
  - Use of triangles that are not so stretched
- Volume grid (Tetrahedra, Prisms, Pyramids)
  - Delauney (tetra) → insertion of prismatic layer (prism)

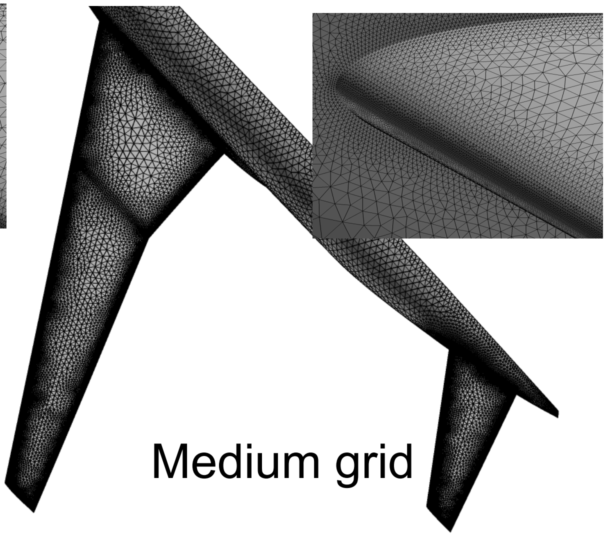




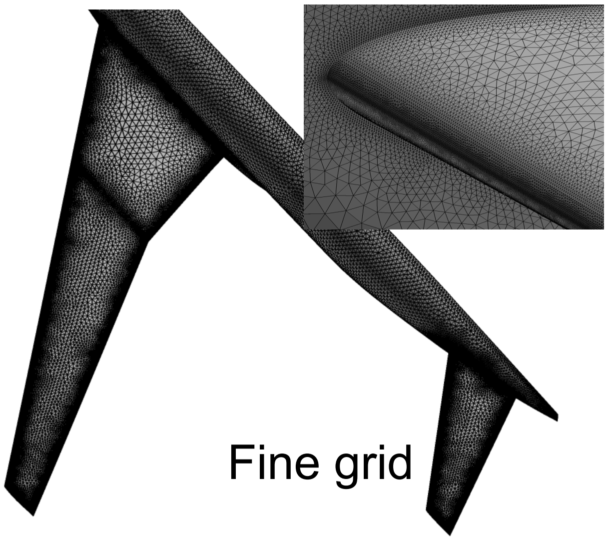
Wing-body juncture corner



Coarse grid

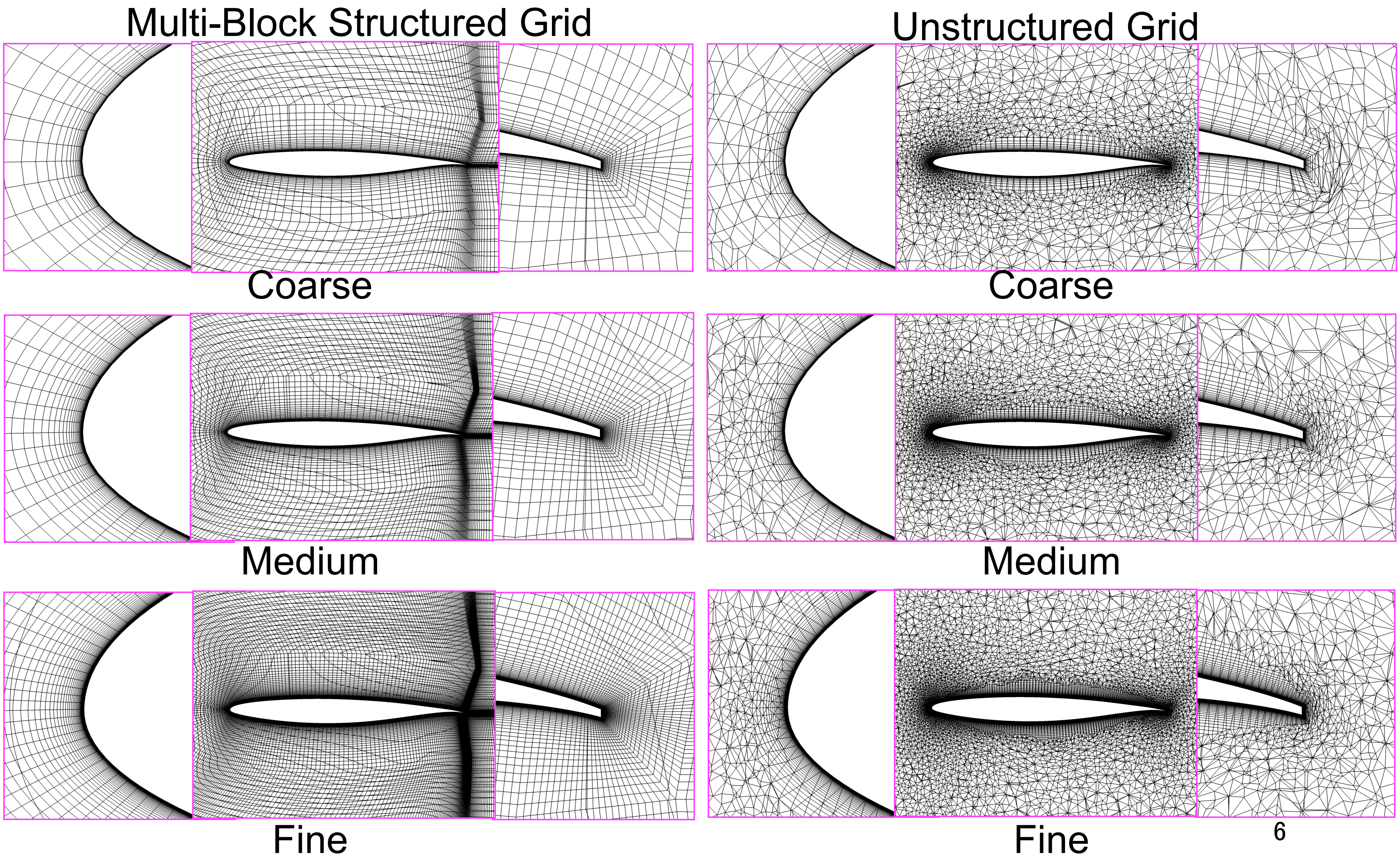


Medium grid



Fine grid

Comparison of cross-sectional view at kink location



Numerical methods: UPACS & TAS

	UPACS	TAS
Mesh type	Multi-block structured	Unstructured
Discretization	Cell-centered finite volume	Cell-vertex finite volume
Convection Flux	Roe 2nd-order with van Albada's Limitter	HLLEW 2nd-order with Venkatakrishnan's limitter
Time integration	Matrix-Free Gauss-Seidel	LU-Symmetric Gauss-Seidel
Turbulence model	Spalart-Allmaras model	Spalart-Allmaras model

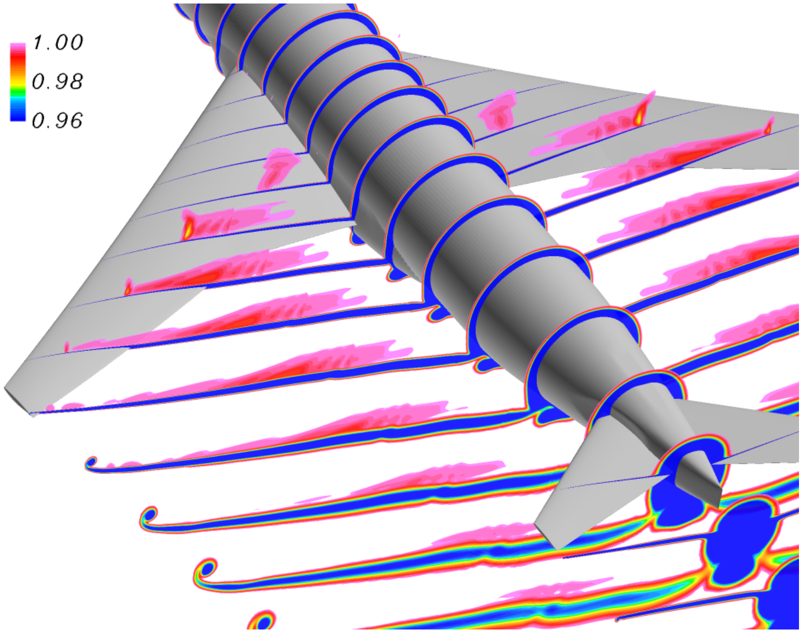
- Modification to the S-A model
  - without trip related terms
  - with a modification of production term: $S = \min(\sqrt{2\Omega^2}, \sqrt{2S^2})$
- Computer Platform: JSS - Fujitsu FX1 (SPARC64 VII 2.5GHz,3008cpu)
  - UPACS: # Processors: 32 (172cores)
  - TAS: # Processors: 43 (172cores)

Wake resolution

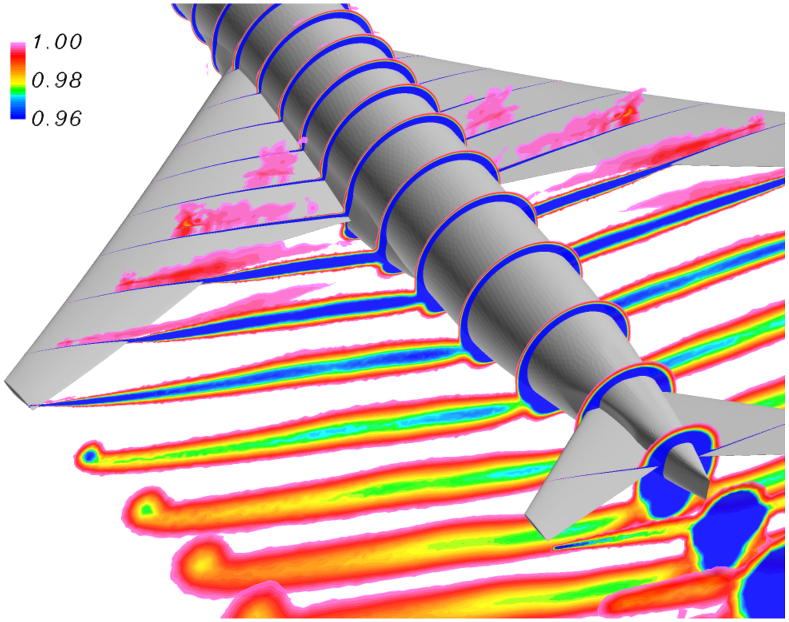
- Re=5M, CL=0.5, i_H=0, Fine grid

Total Pressure

UPACS

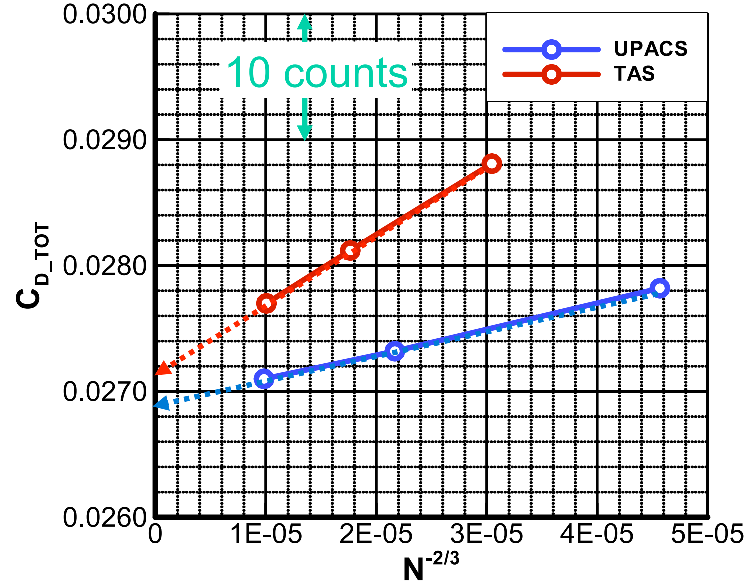


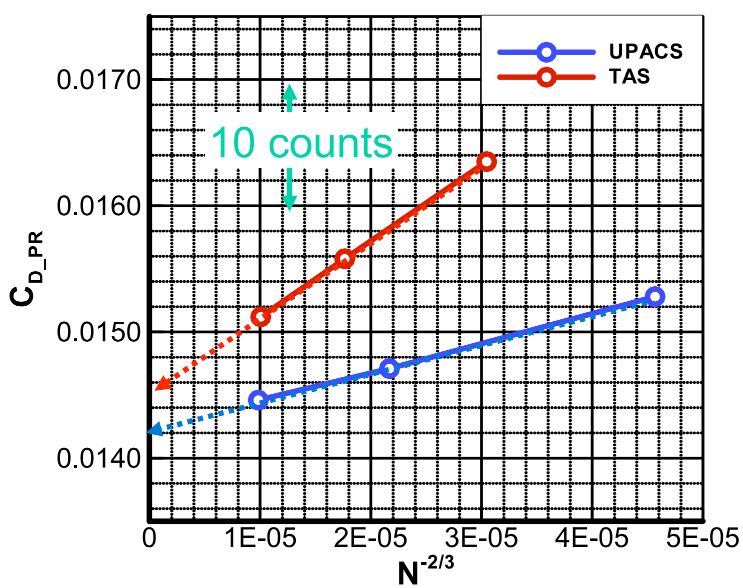
TAS

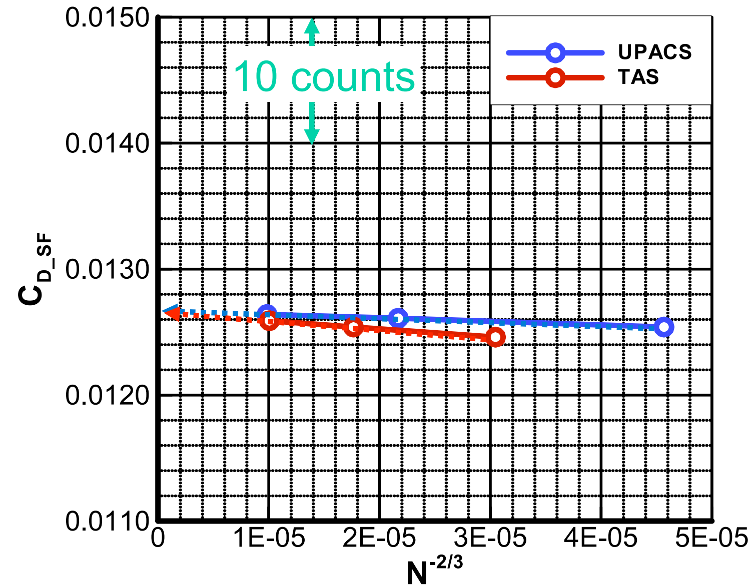


Case 1.1: Grid Convergence at Mach 0.85, C_L=0.5

- Both methods obtained good convergence.
- Unstructured method shows higher C_{D_PR} and more variation with grid size.
- C_{D_SF} varies about 1 count.
- 2 to 3 counts difference at converged value?

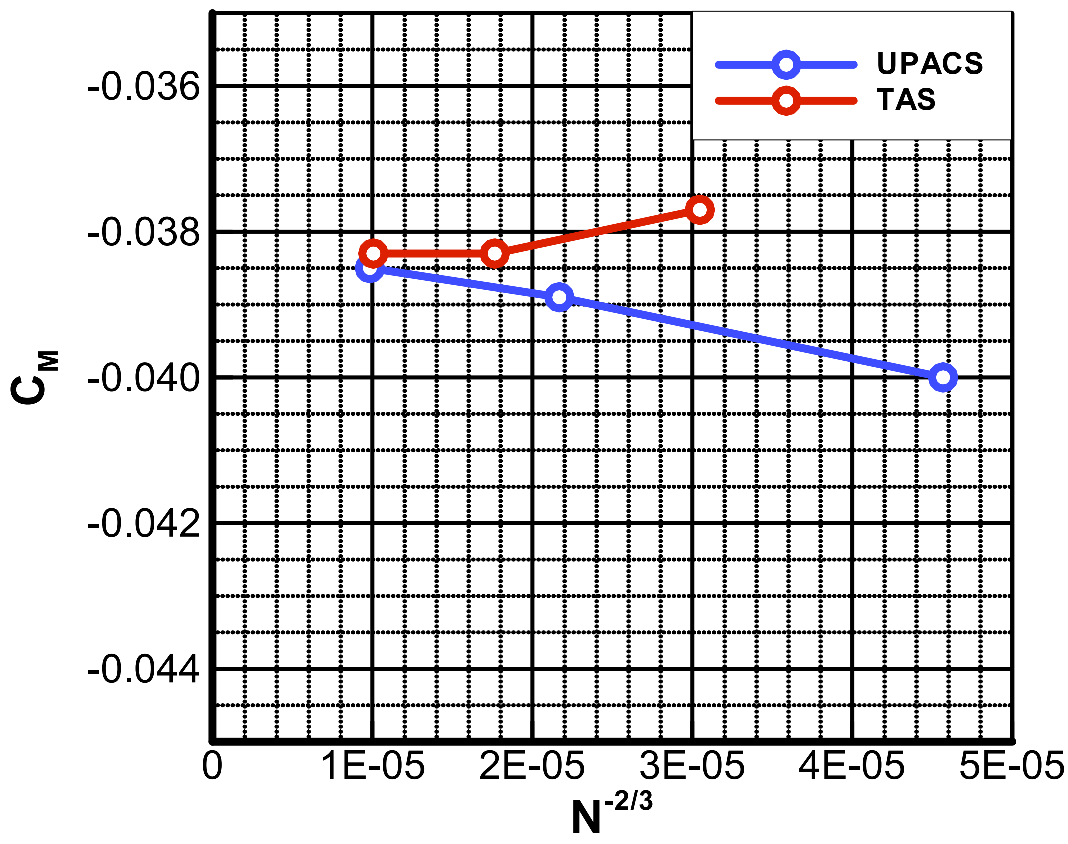






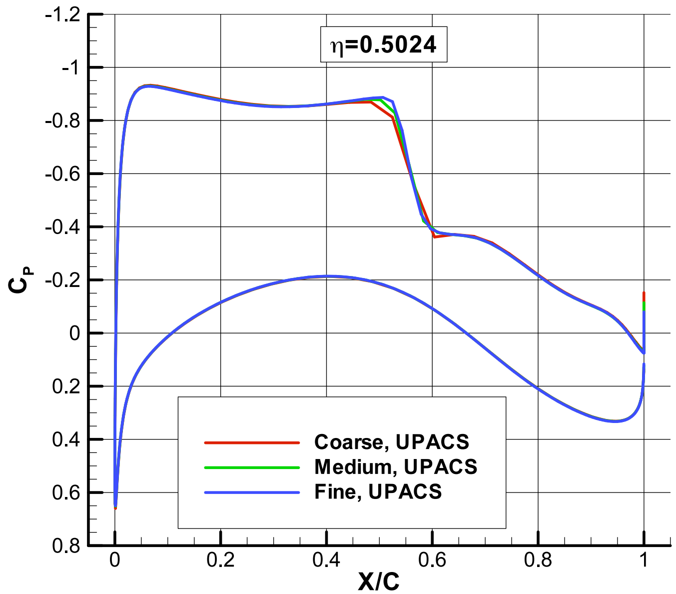
Case 1.1: Grid Convergence at Mach 0.85, C_L=0.5

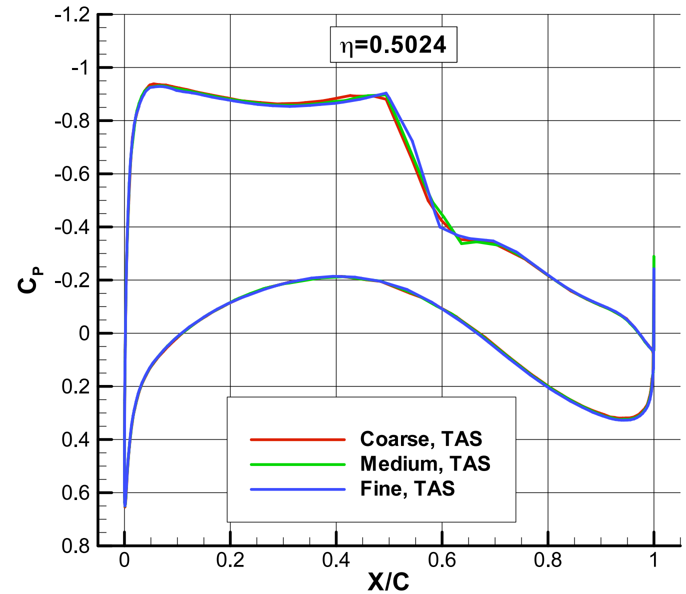
- Pitching Moment

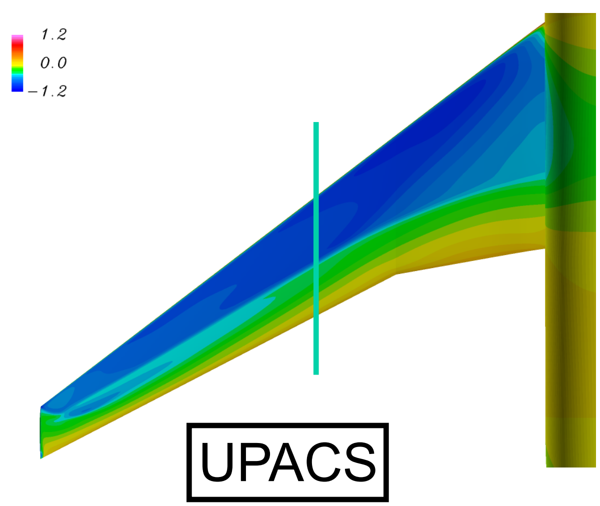


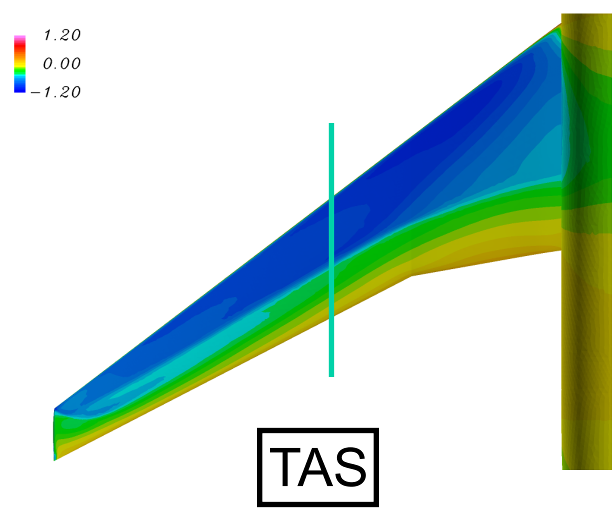
Case 1.1: Grid Convergence at Mach 0.85, C_L=0.5

- Wing C_P at η=0.5



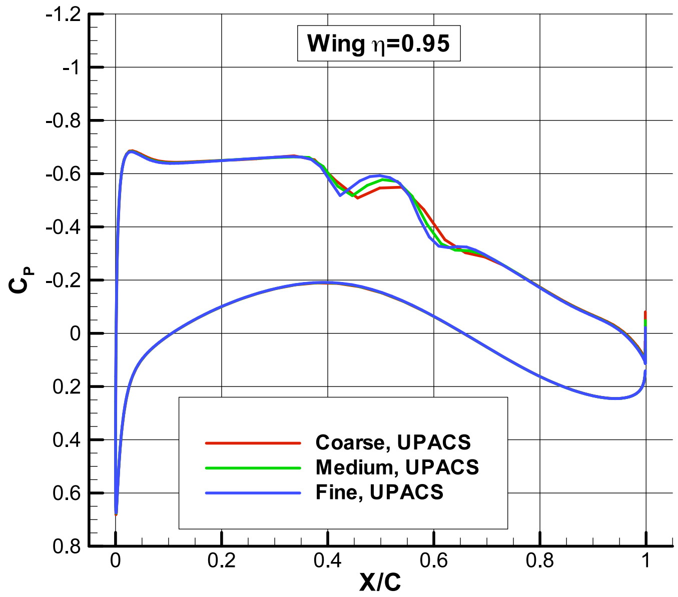


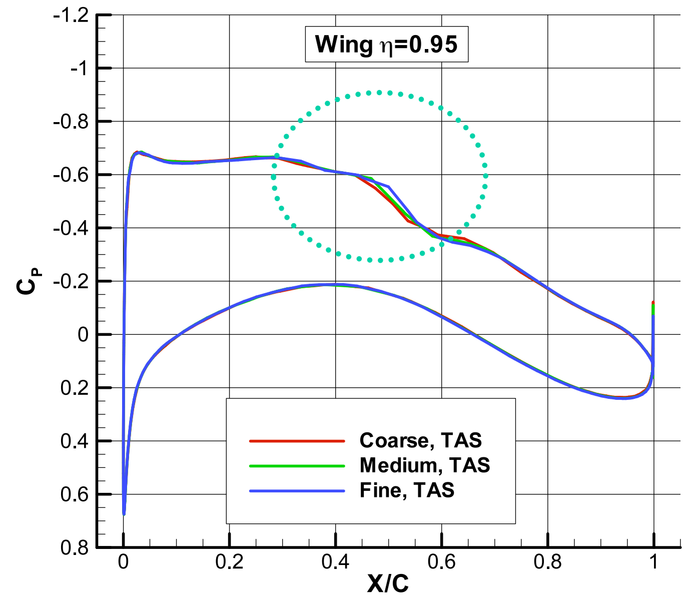


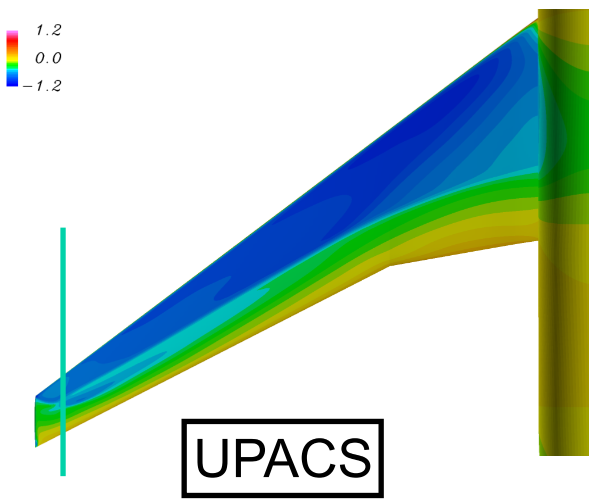


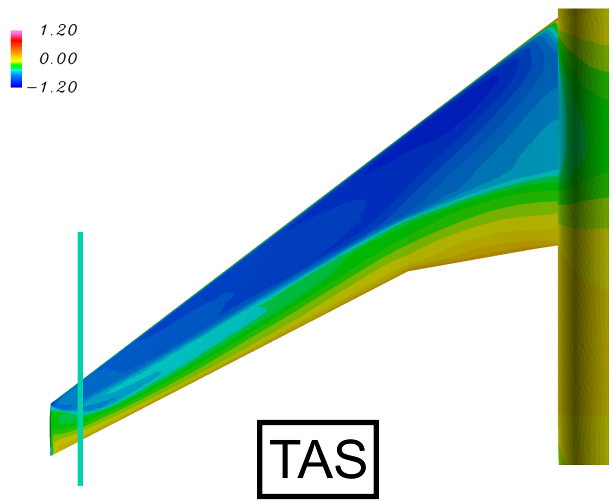
Case 1.1: Grid Convergence at Mach 0.85, C_L=0.5

- Wing C_P at η=0.95



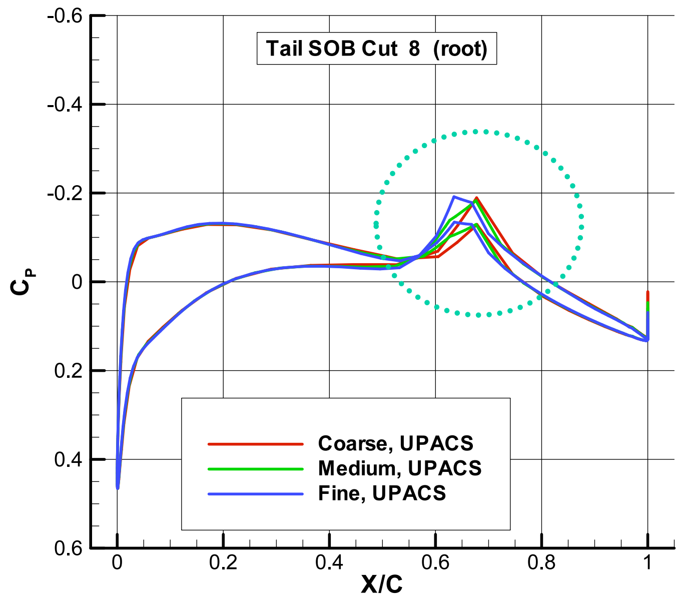


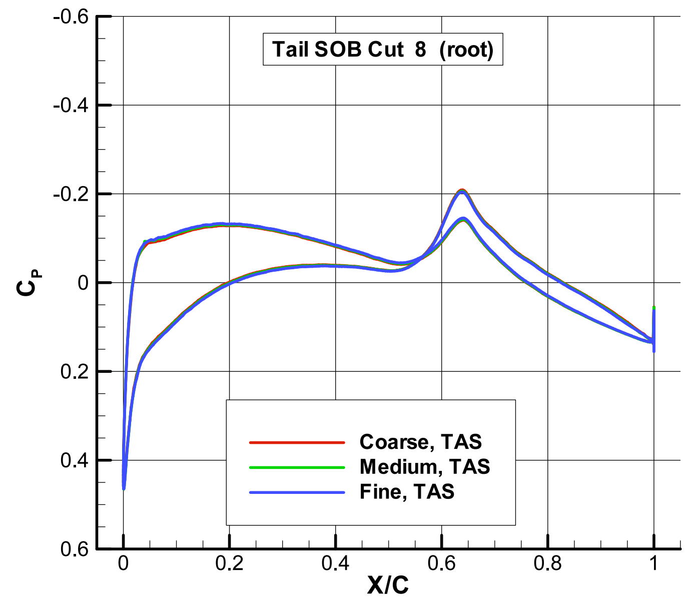


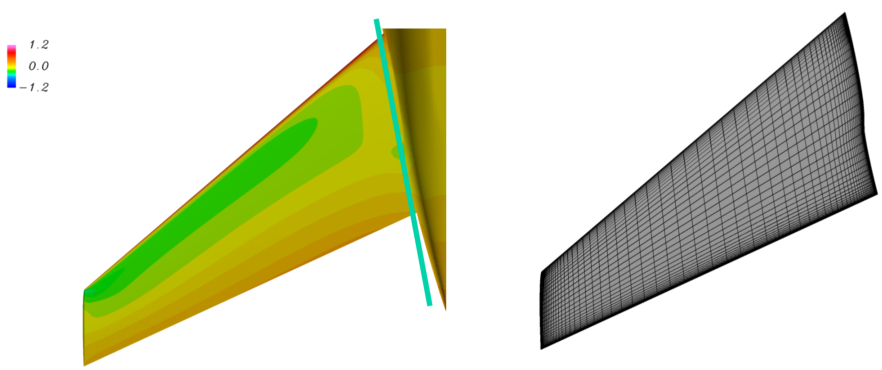


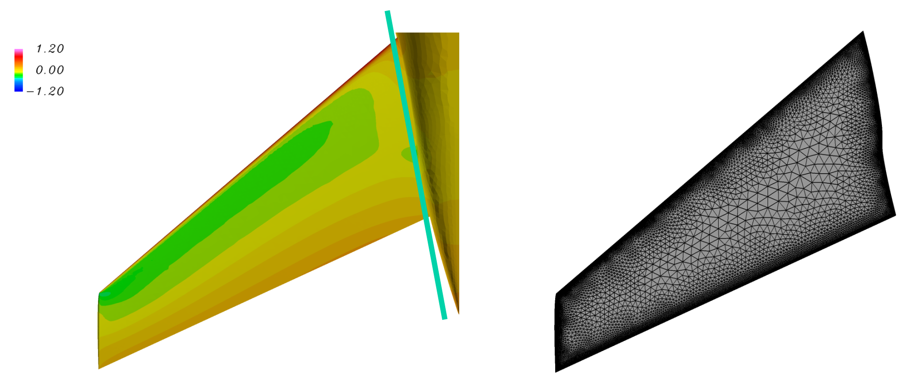
Case 1.1: Grid Convergence at Mach 0.85, C_L=0.5

- Tail Cp near root







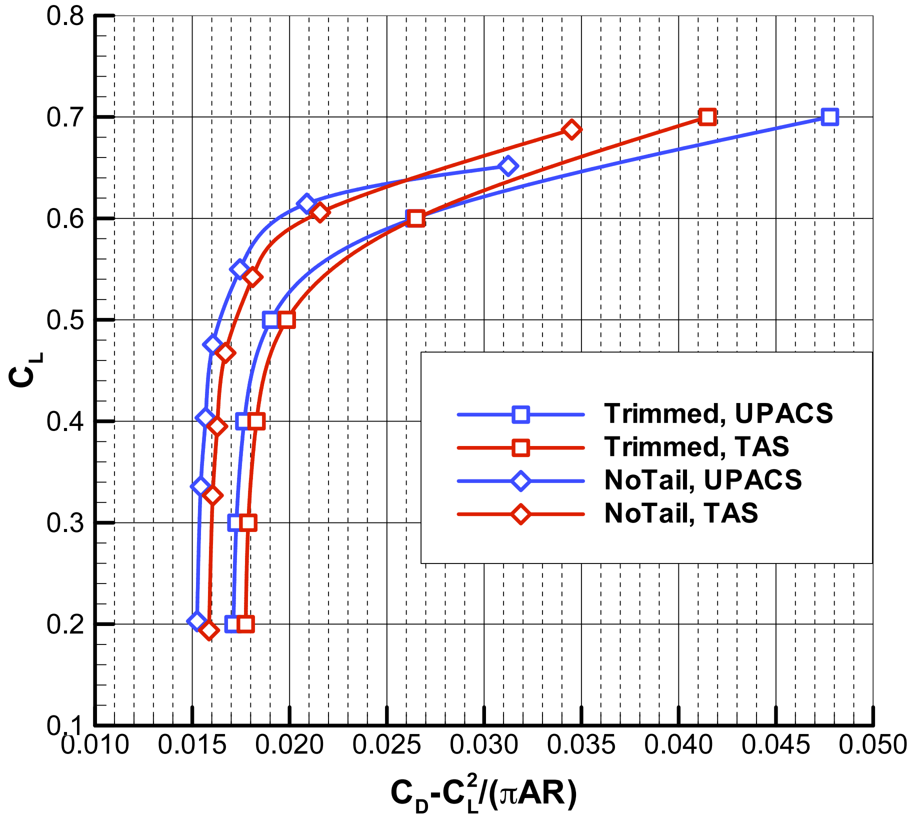


UPACS

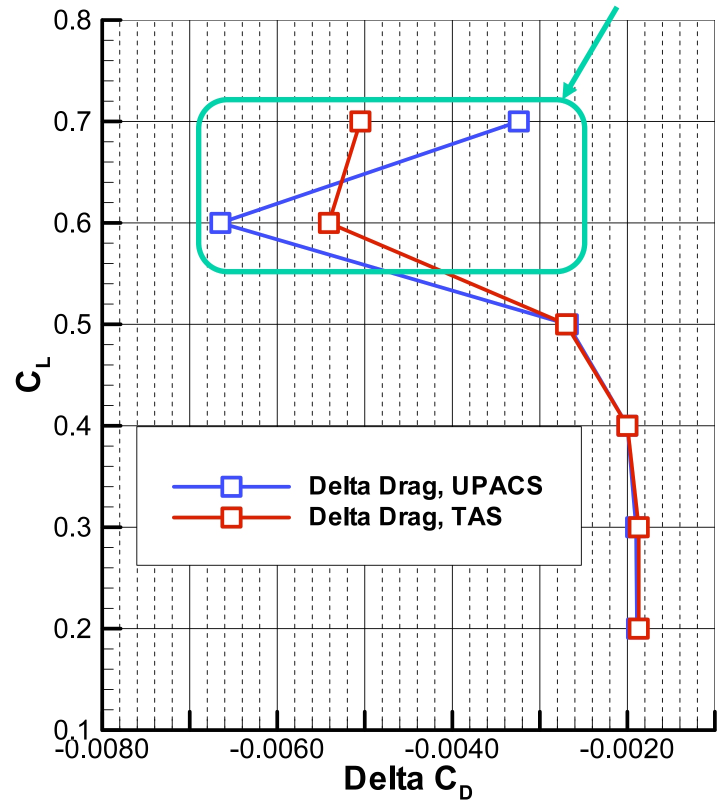
TAS

Case 1.2: Trimmed Drag at Mach=0.85

- Difference in drag polar is consistent for CL< 0.6.
- Delta drag varies from 19 counts to 67 counts with alpha.
- Delta drag by two methods agree well up to CL=0.5.

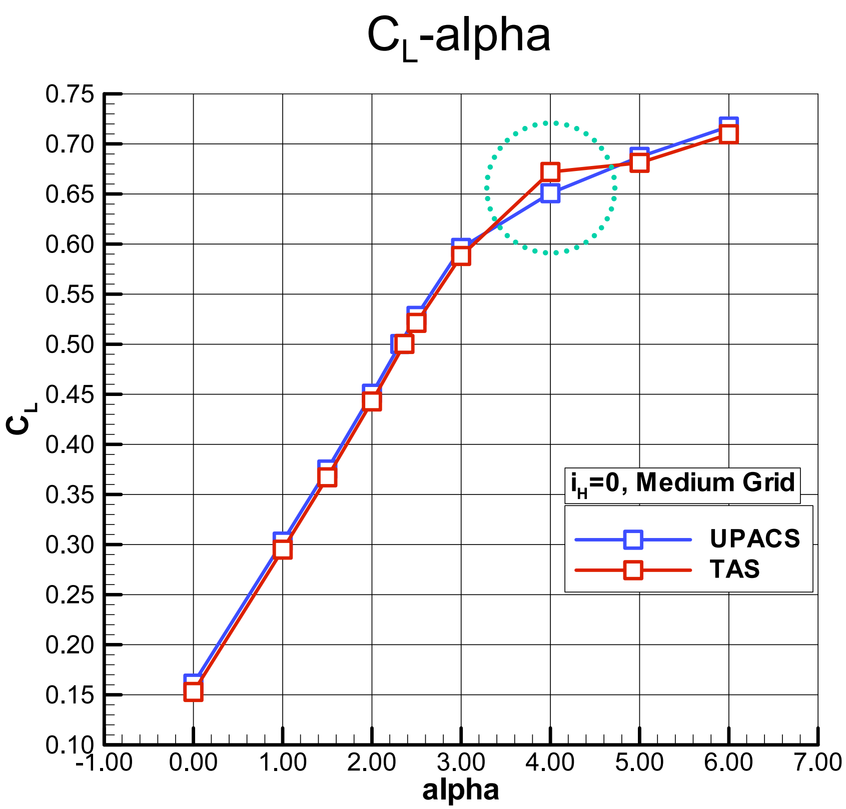


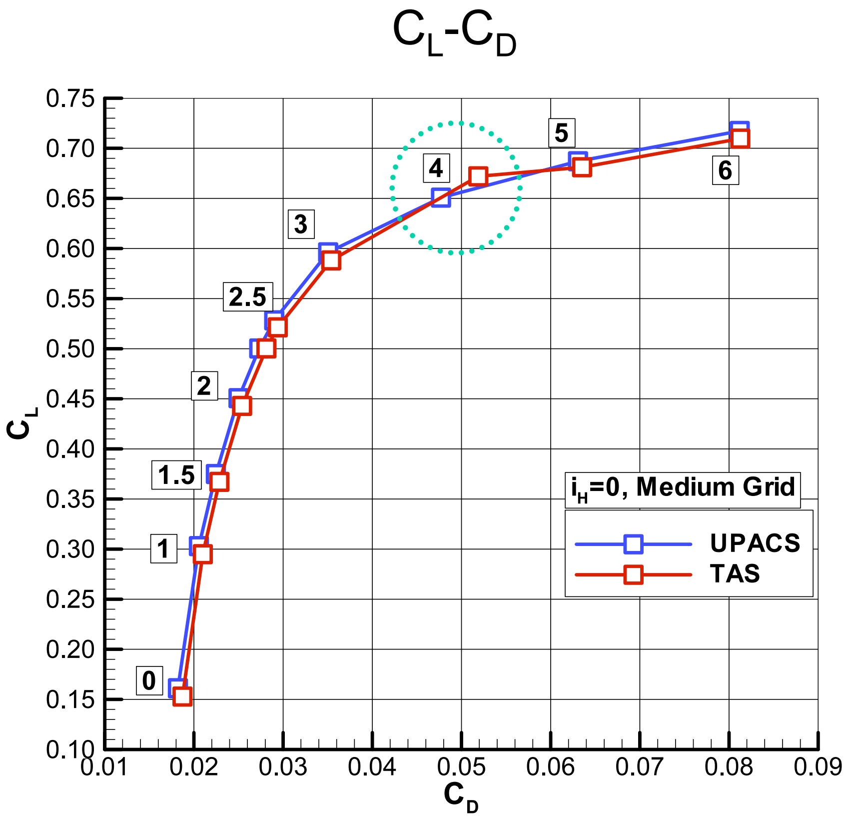
Precise interpolation is necessary



C_L and C_D

- i_H=0, Re=5M, Medium grid

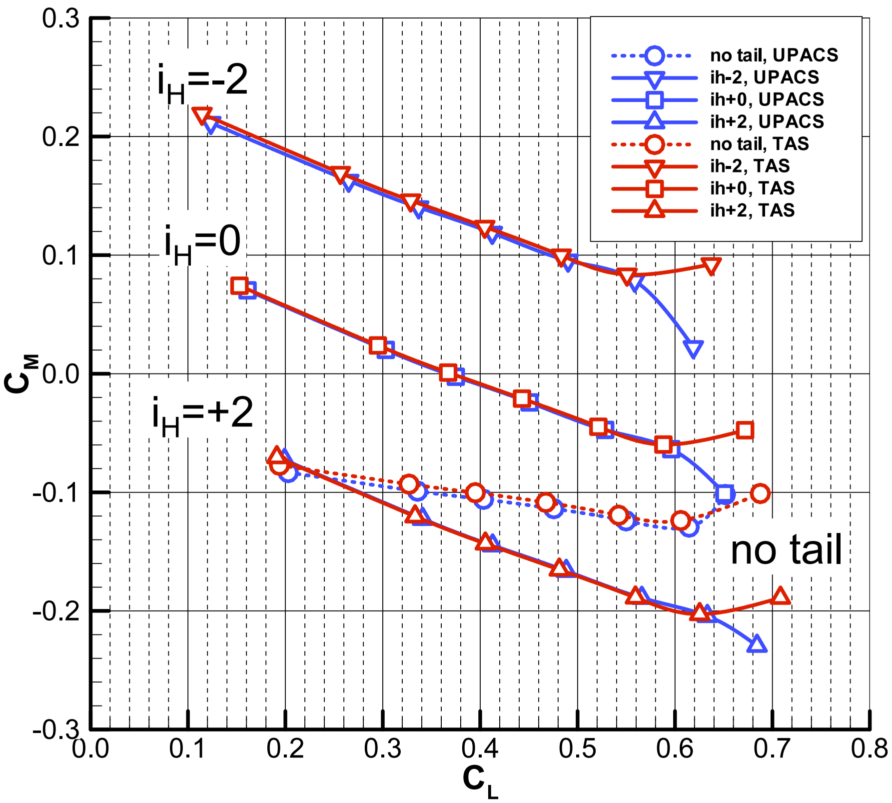




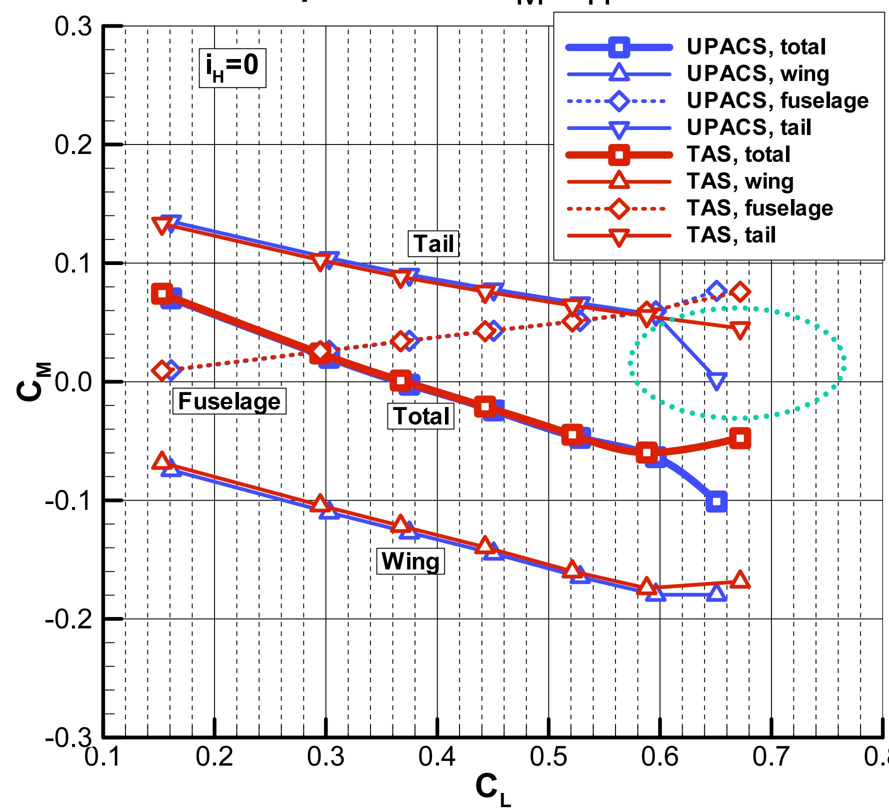
Effect of i_H on Pitching Moment

- Re=5M, Mach=0.85, Medium grid
- Very good agreement in the range alpha < 4deg
- Tail C_M by UPACS shows sudden change at alpha=4deg

Total C_M change with i_H

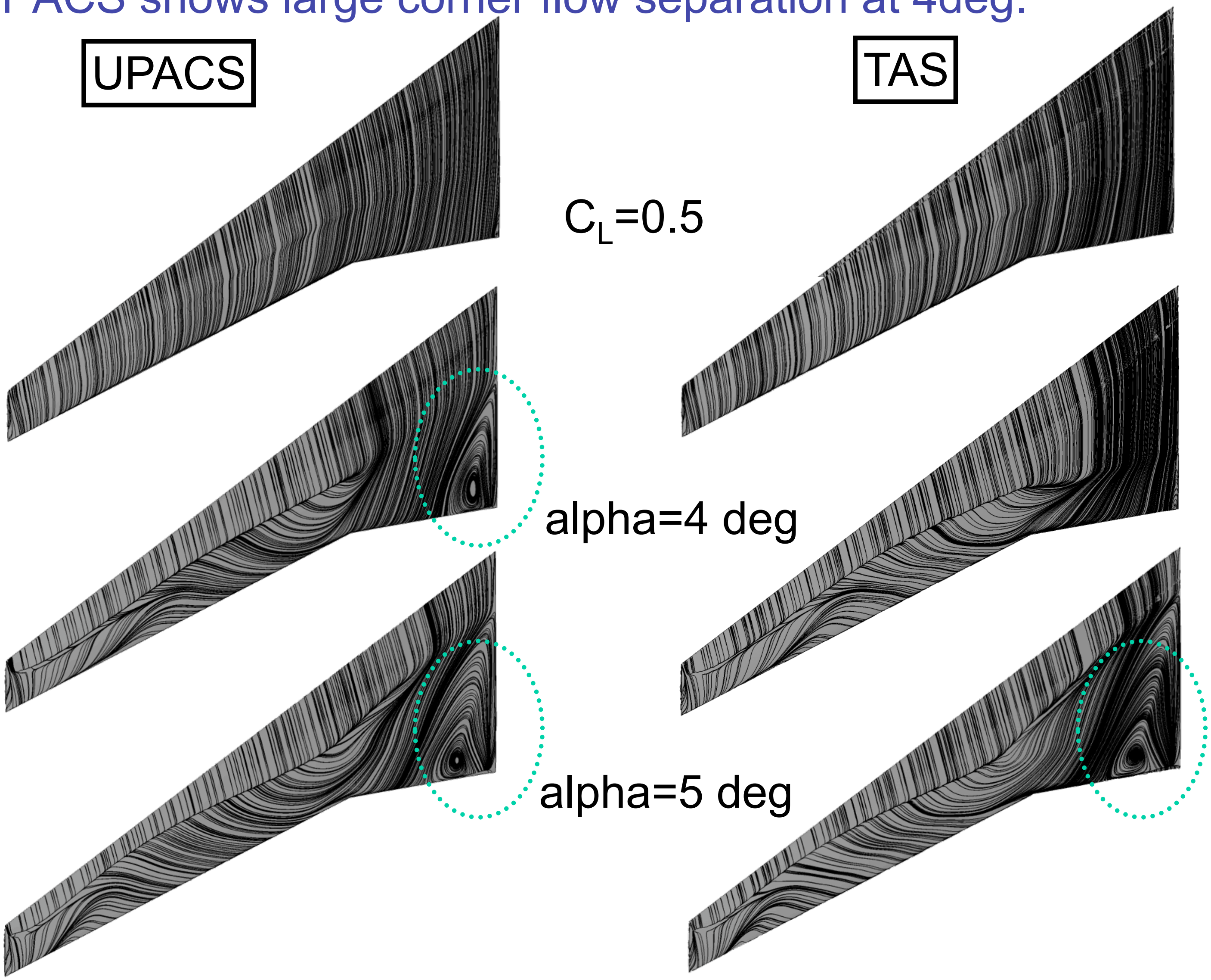


Component C_M, i_H=0



Oilflow on wing upper surface

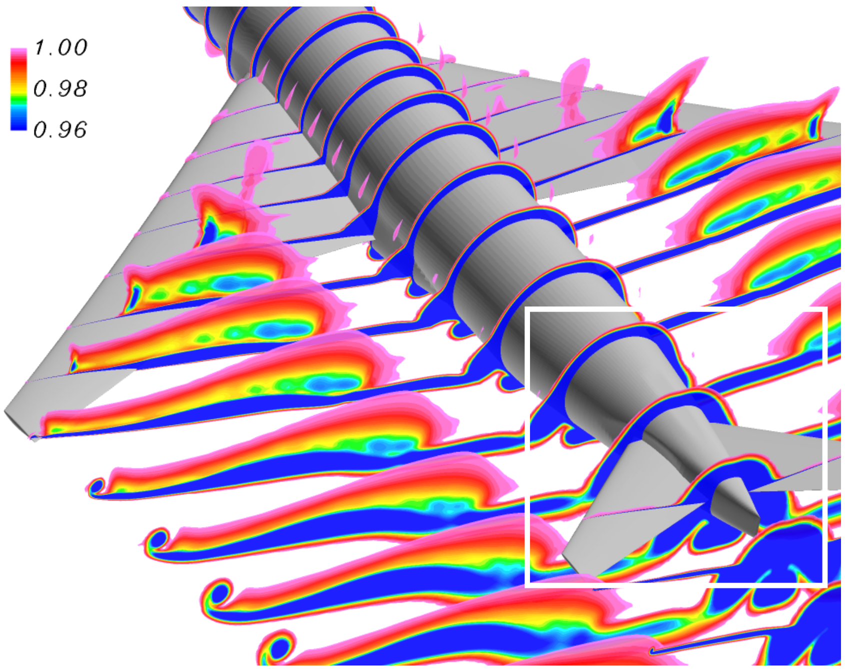
- UPACS shows large corner flow separation at 4deg.



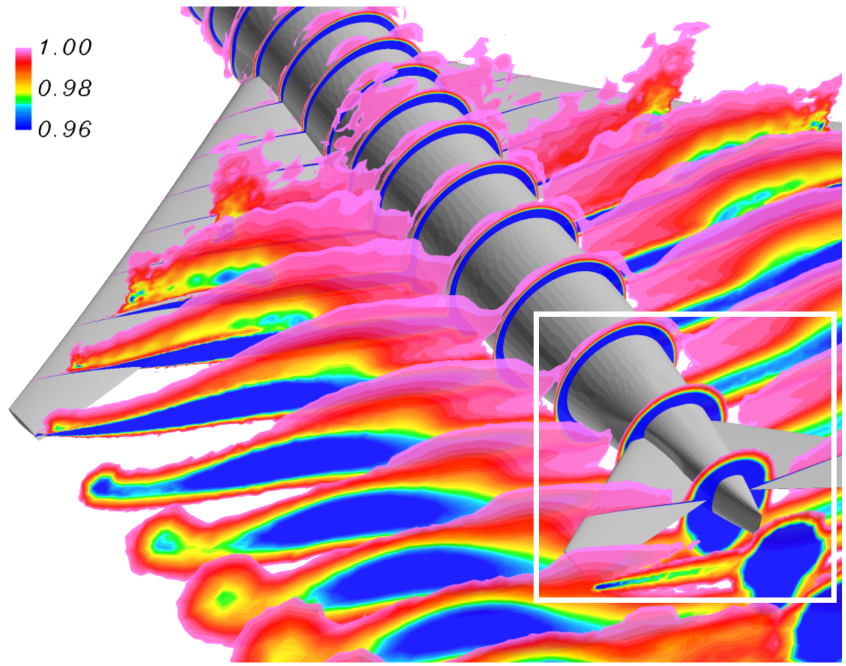
Influence of the corner separation on tail

Total Pressure, alpha=4deg

UPACS

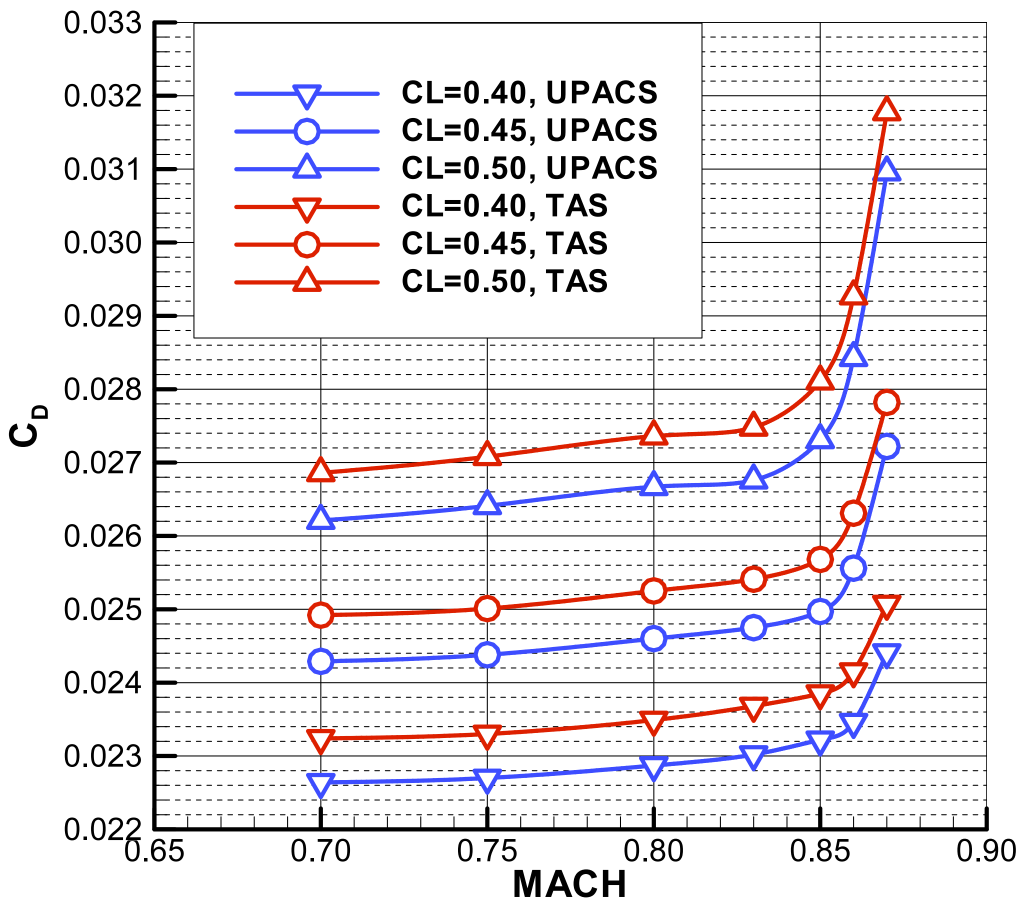


TAS

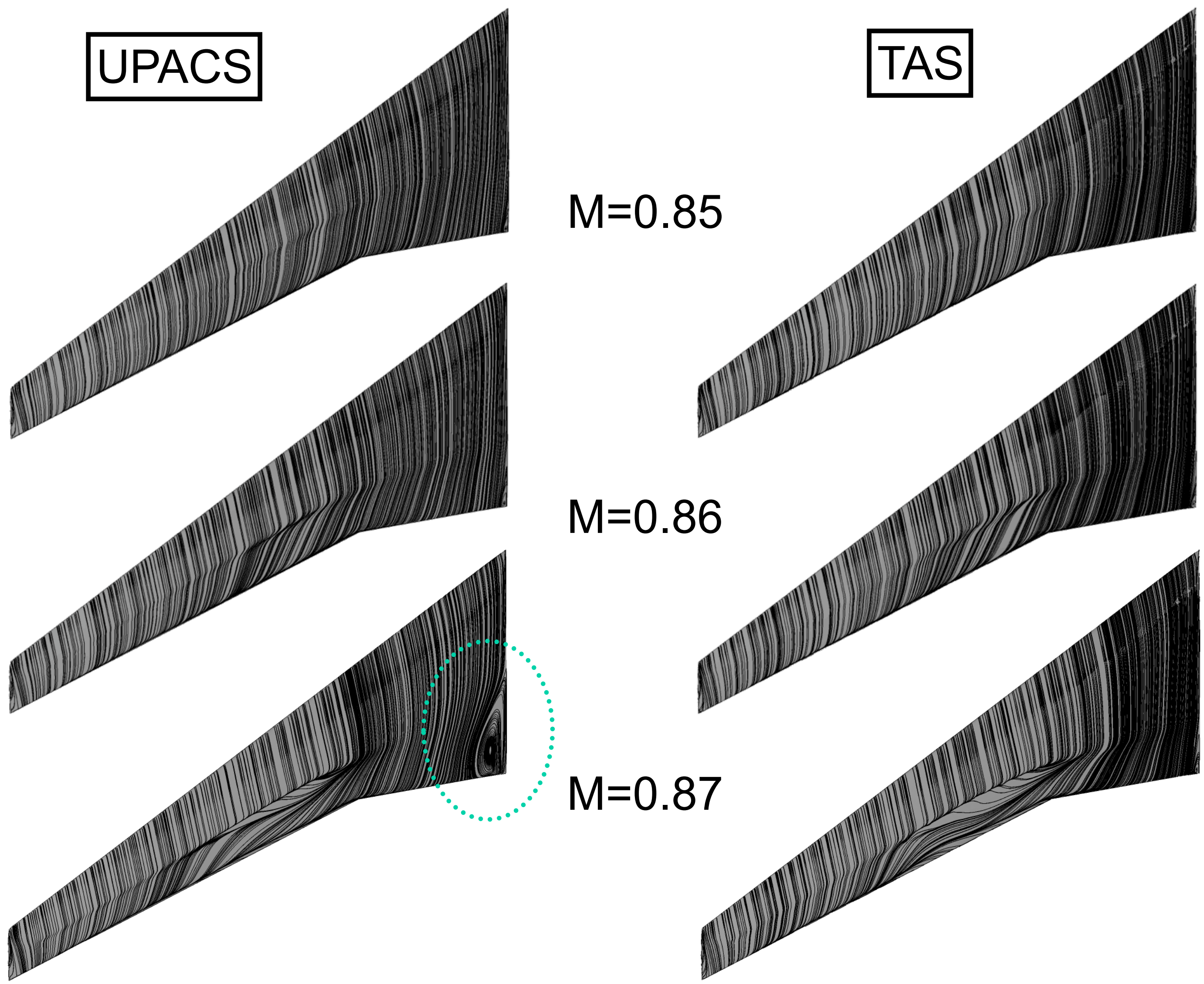


Case 2: Mach sweep

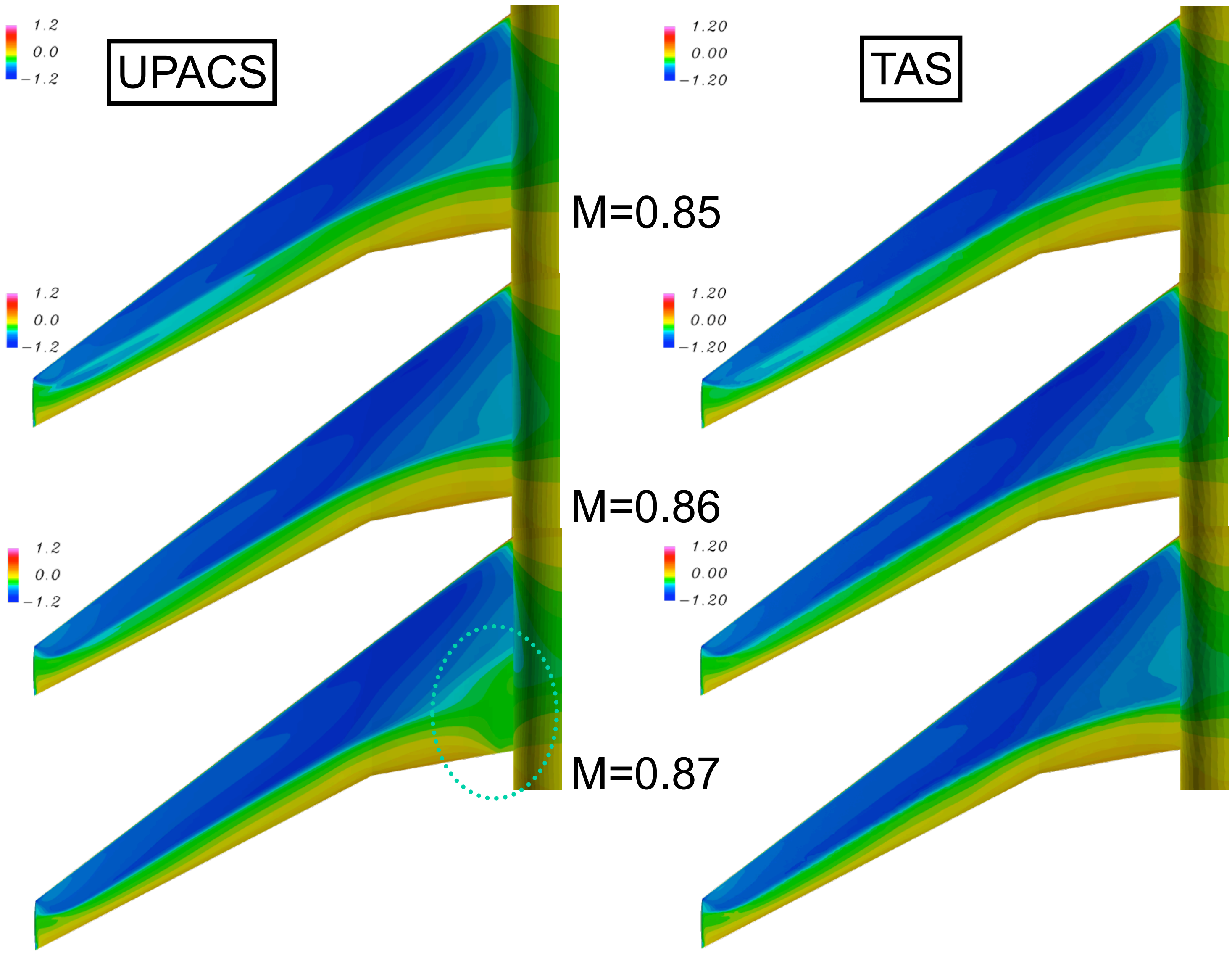
- M < 0.85: Obtained by interpolation of fixed alpha computations
- M > 0.85: specified C_L solutions when error (>0.5 cnts) is estimated
- Both method show the same characteristics of drag divergence
- Consistent difference through the Mach number range



Oilflow on Wing Upper Surface

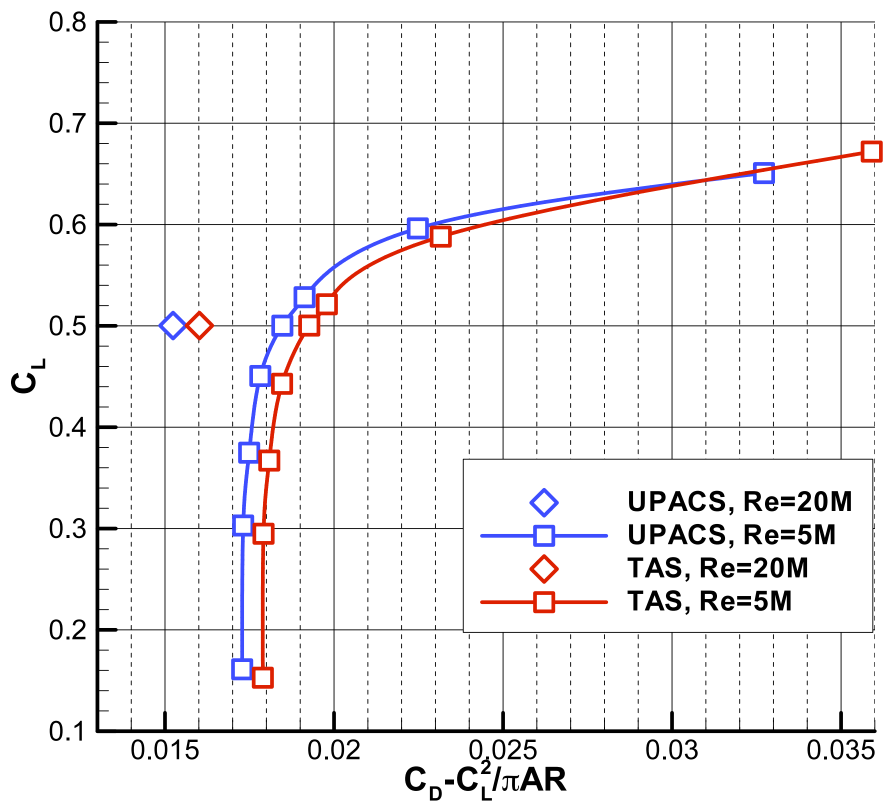


Cp on wing upper surface



Case 3: Reynolds number study

	Re=5M			Re=20M			Diff.		
	C_D	C_{D_PR}	C_{D_SF}	C_D	C_{D_PR}	C_{D_SF}	C_D	C_{D_PR}	C_{D_SF}
UPACS	0.0273	0.0147	0.0126	0.0241	0.0136	0.0105	0.0032	0.0011	0.0021
TAS	0.0281	0.0156	0.0125	0.0249	0.0144	0.0105	0.0033	0.0012	0.0021
Diff.	-0.0008	-0.0009	0.0001	-0.0008	-0.0008	0.0000	-0.0001	-0.0001	0.0000



Summary

- Case1 (1) Grid convergence
  - Both methods show good grid convergence.
    - 2 to 3 counts difference in the converged value?
  - Unstructured method has 8 counts higher drag than structured method with Medium grid.
  - This difference is consistent throughout the following studies except the case large flow separation is existing at wing root.
  - Variation of skin friction drag is very small.
- Case 1 (2) Downwash study
  - Lower than alpha=4deg. or C_L=0.6, difference of trimmed drag between two methods is very small.
  - Structured method shows large flow separation at alpha=4 deg. This changes the pitching moment of tail.
  - Beyond 4 deg., Unstructured method also shows the same characteristics
- Case 2 Mach sweep study
  - Both method show the same characteristics of drag divergence.
  - Start divergence around Mach=0.85 for C_L=0.5.
  - Structured method shows large flow separation at wing root at M=0.87, C_L=0.5.
- Case 3
  - Delta C_{D_PR}=11 counts, Delta C_{D_SF}=21 counts with both methods.

Questions?