1st AIAA CFD High Lift Prediction Workshop

High Lift Prediction using the Edge solver

by

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Contribution

- Calculations with Edge solver
  - Hybrid unstructured grids
- One family of grids computed
  - Provided by DLR, (Unst-Mixed-Nodecentered-B-v1)
- Mandatory Case1
  - Configuration 1, slat 30°, flap 25°
  - Grid convergence study, coarse-medium-fine grids, α=13° + α=28°
- Mandatory Case2
  - Configuration 1, slat 30°, flap 25°
  - Configuration 2, slat 30°, flap 20°
  - Polar for medium grids
- Optional Case3
  - Configuration 1, slat 30°, flap 25°
  - Brackets (flap + slat support) included
  - α=13° and α=28°

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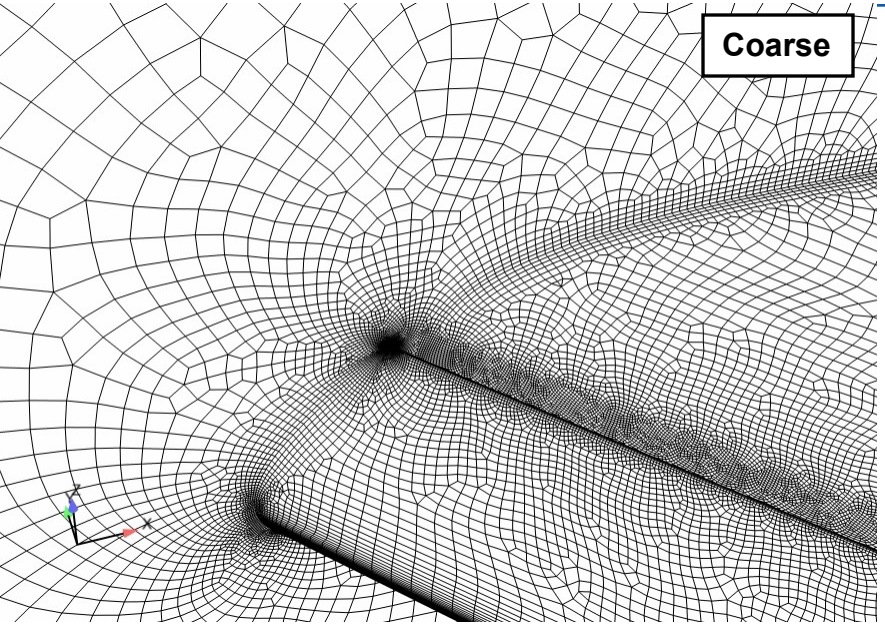
Selected grids

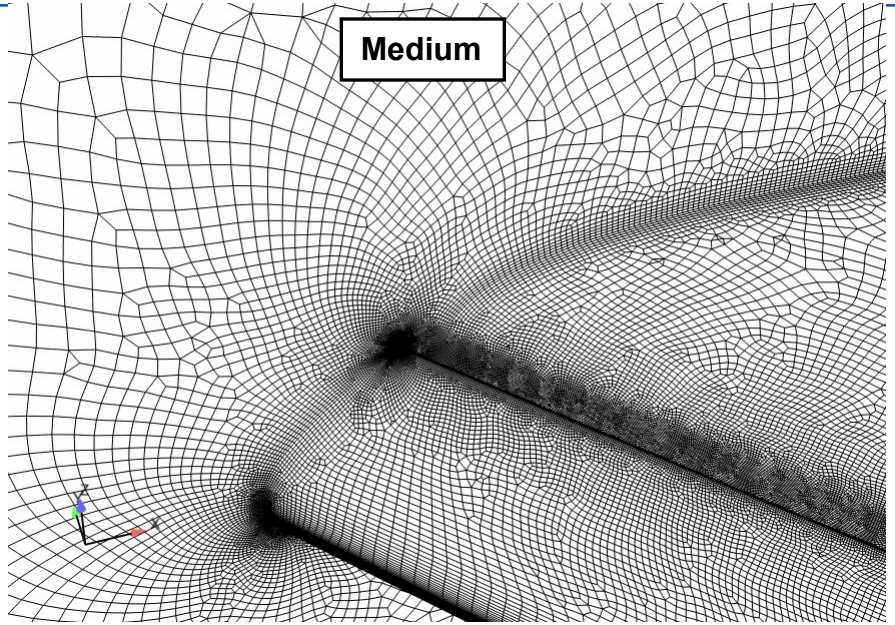
- DLR grids generated with SOLAR grid generator

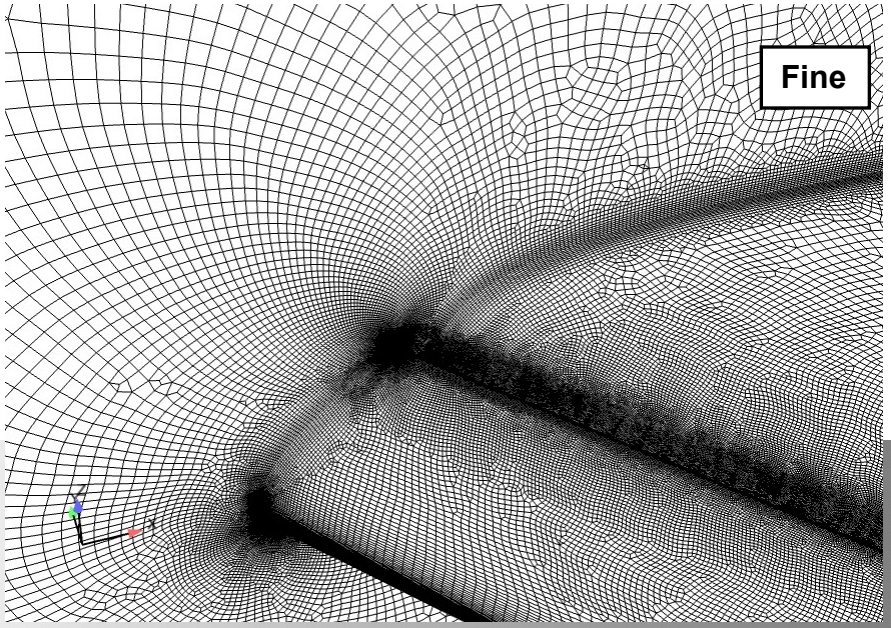
DLR grids, Config 1	Coarse	Medium	Fine
# nodes	12.3×10^6	37.0×10^6	110.7×10^6
# boundary nodes	328×10^3	683×10^3	1421×10^3
# hexahedral elements	11.2×10^6	34.1×10^6	103.3×10^6
# prisms	42×10^3	92×10^3	217×10^3
# tetrahedral elements	5.3×10^6	13.3×10^6	36.3×10^6

- Config 8 and Config 1 with bracket similar in size to medium grid

Grid pictures, slat-fuselage junction, Config 1







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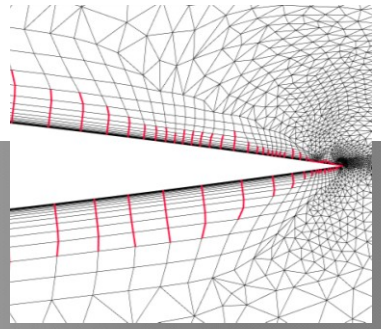
Computational information

- Edge in-house code for unstructured grids
- Finite volume, **node centered**, edge-based
- 3-4 level W-cycles, full multigrid
  - Semi coarsening, 1:4
- 3-stage Runge-Kutta scheme, CFL=1.25
- Central scheme with artificial dissipation for mean flow and turbulence
- All solutions started from free stream
- Full NS, compact discretization of normal derivatives
- Linux cluster used, up to 128 processors
  - Computing time ~ (128*) 24 hours for finest grids (~110 M nodes)
- Weak boundary conditions on all variables including no-slip velocity
  - AIAA 2009-3551
- Line-implicit time integration in regions with stretched grids
  - AIAA 2009-163



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Turbulence models

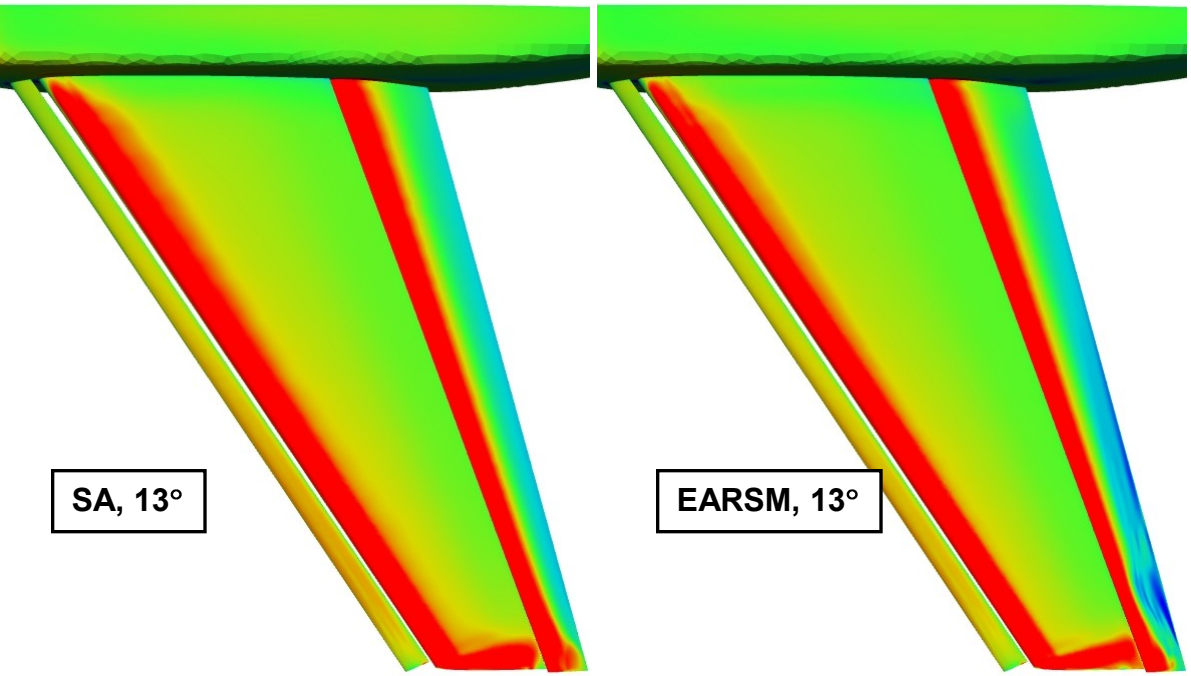
All grids:

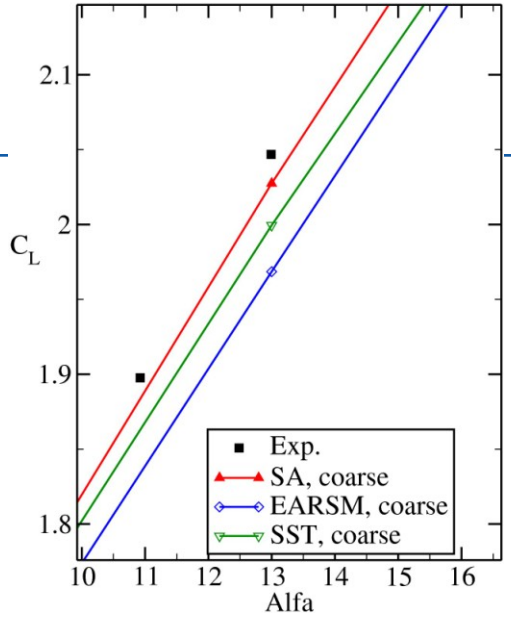
- Spalart-Allmaras model
  - AIAA Paper 92-0439

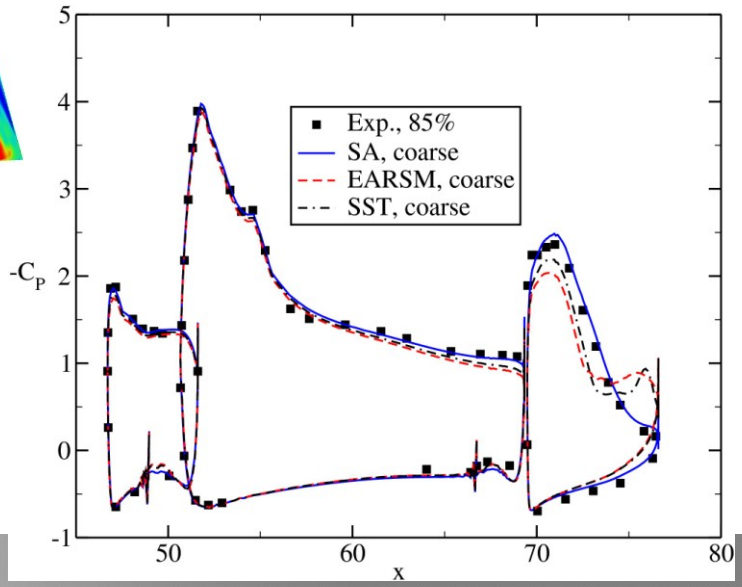
Additional investigation of turbulence models. Coarse grid, Config 1

- Hellsten k-ω EARSM for the turbulence
  - AIAA Journal, Vol. 43, 2005
- Menter k-ω SST
  - ASME Journal of Fluids Engineering , Vol. 119, 1997

Turbulence models, motivation







Initial calculations on coarse grid Config 1

- Lower lift with EARSM and SA at α = 13°
- Separation at outer part of flap
- Similar on medium grid

⇒ Stay with SA

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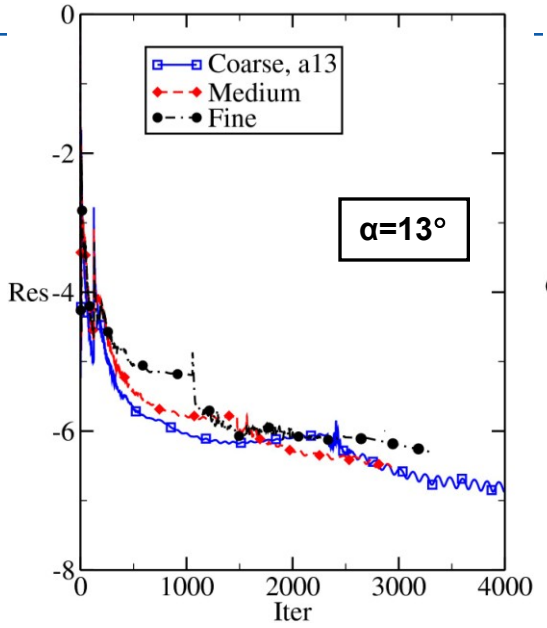
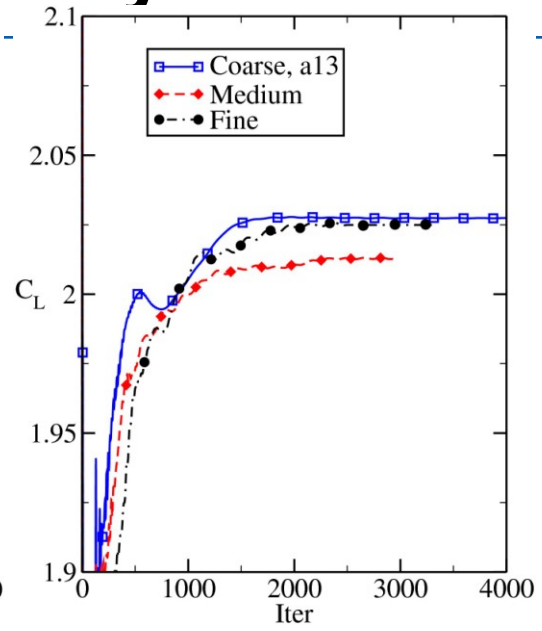
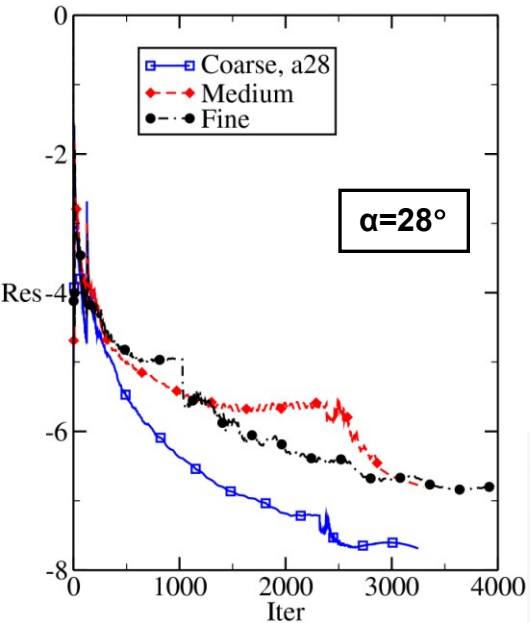
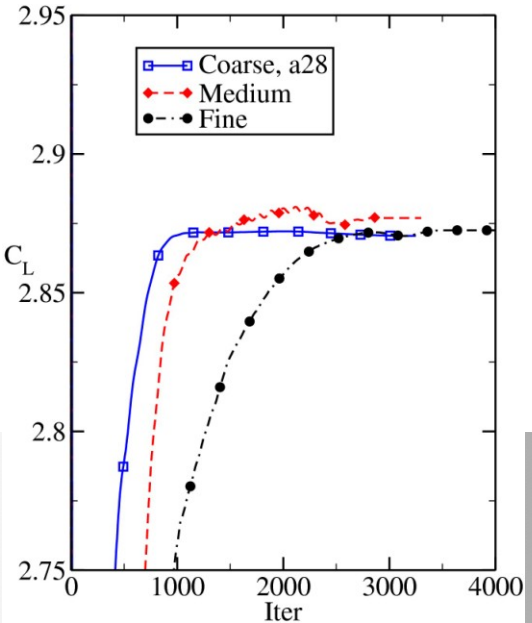
Steady state convergence



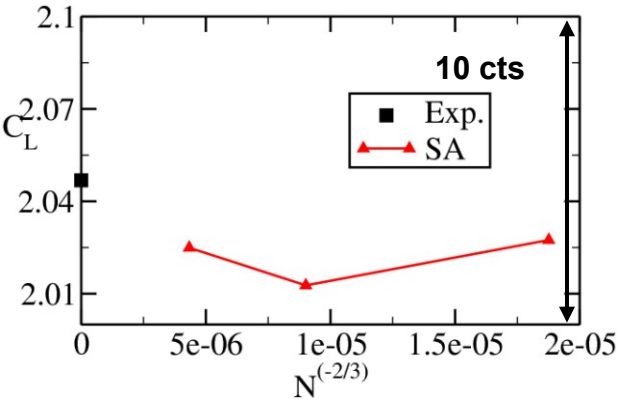


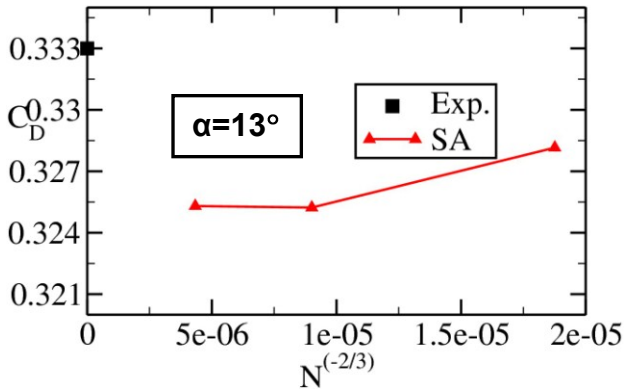


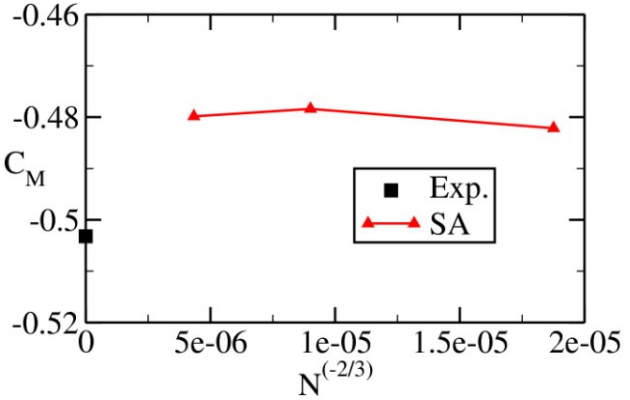


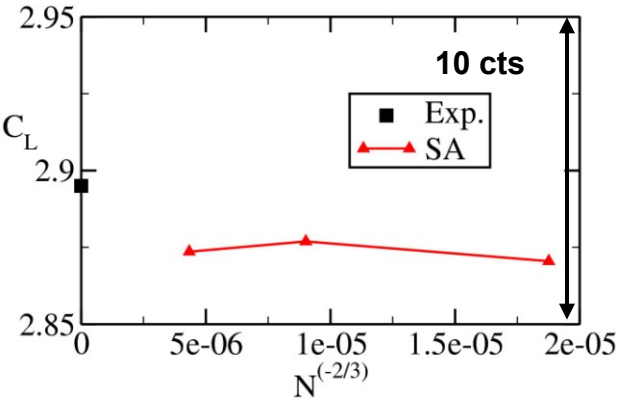
- Coarse-medium-fine grids
- 2500-3500 fine grid iterations

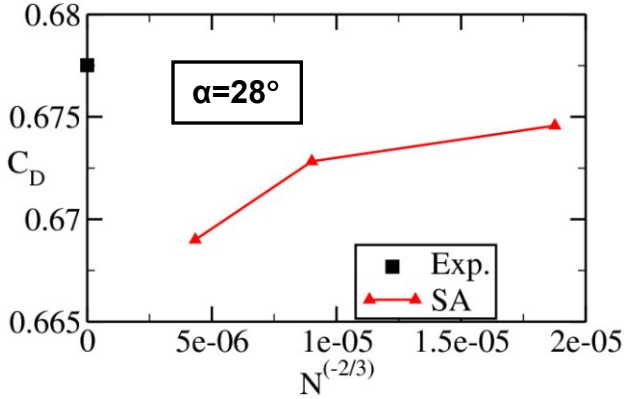
Grid convergence, Config 1

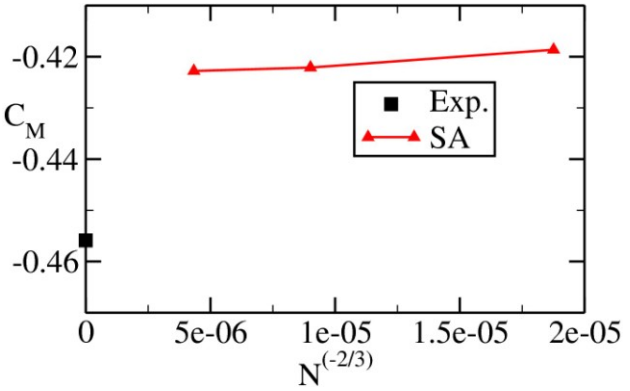












- Reasonable grid convergence
  - Not monotone but small differences between grids

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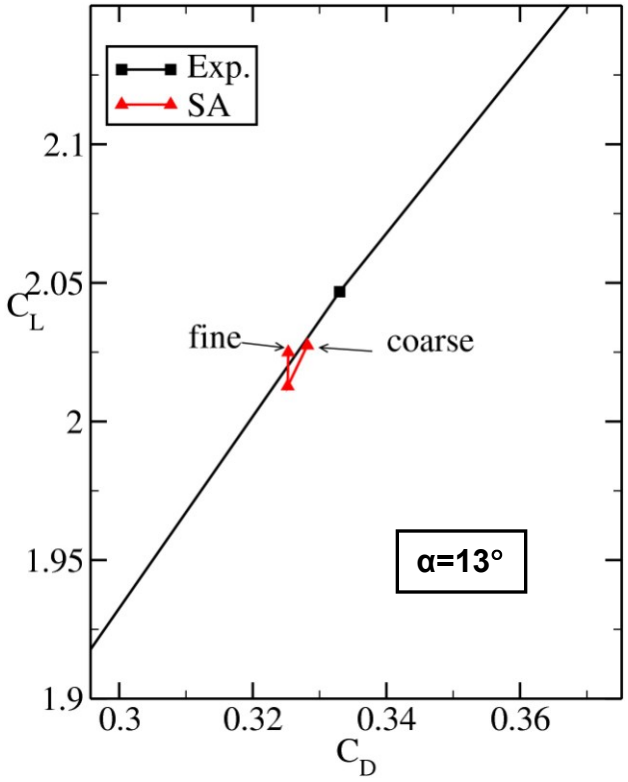
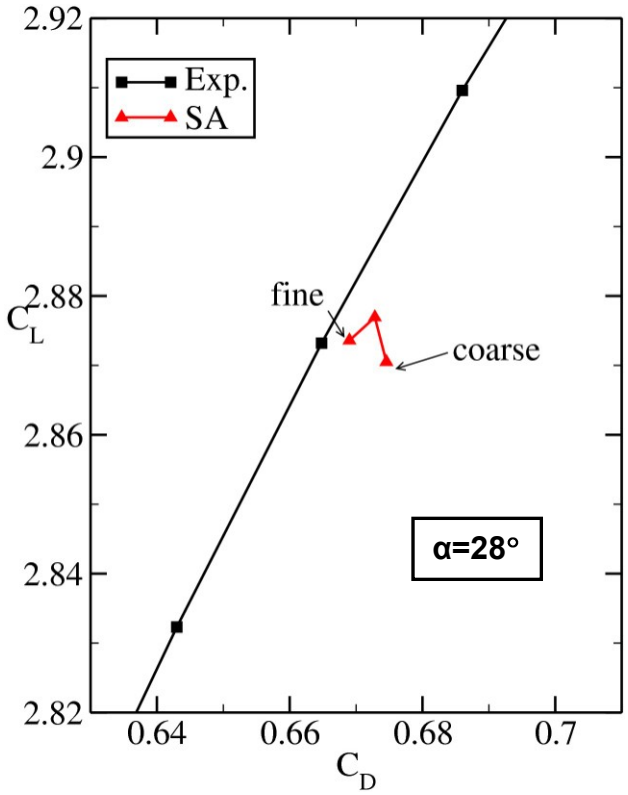
Grid convergence, Config 1





- Reasonable grid convergence

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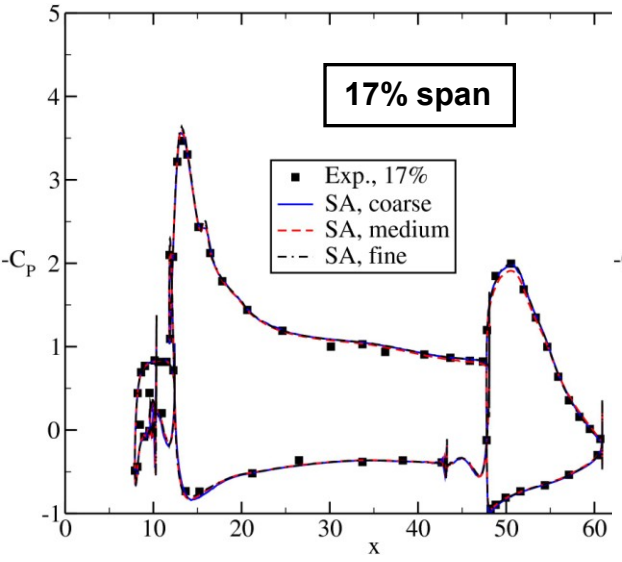
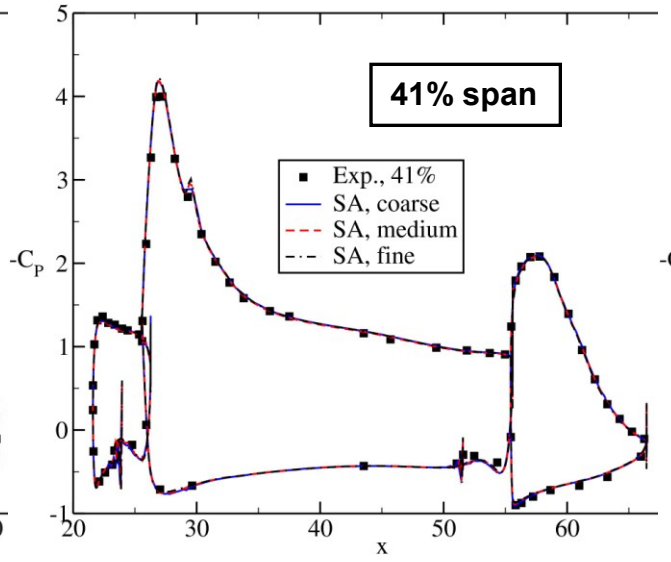
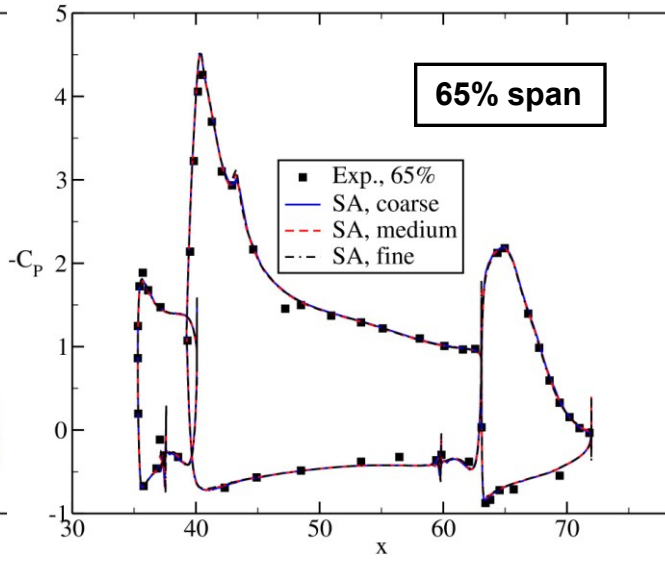
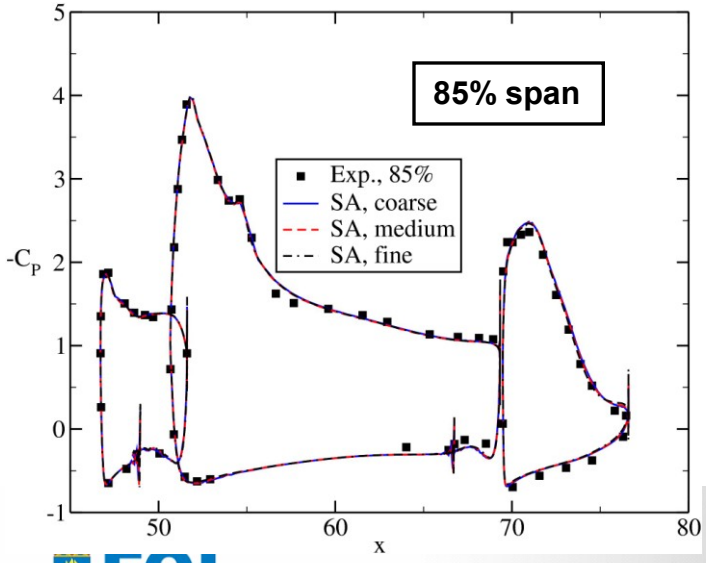
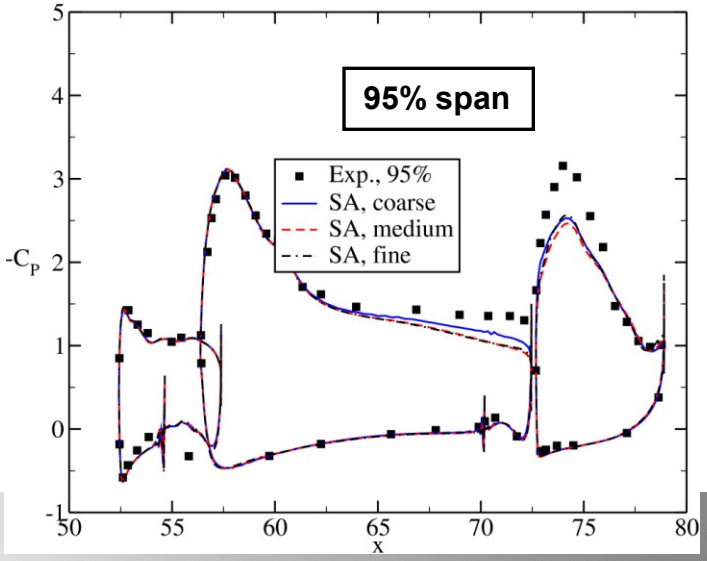
Grid convergence, Config 1, C_P, α = 13°

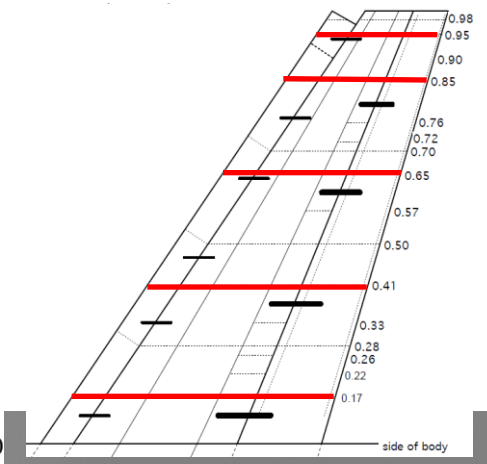












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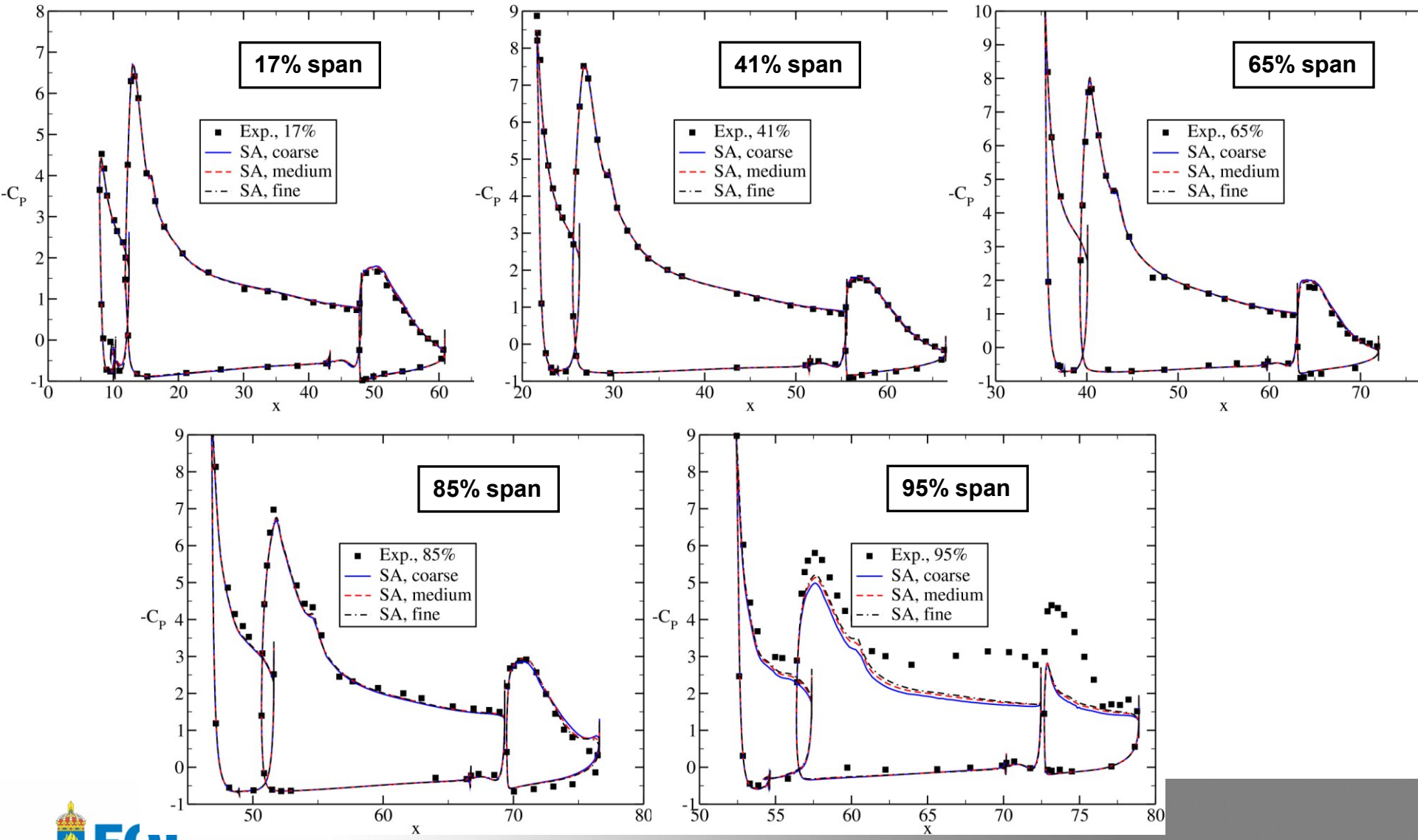
Grid convergence, Config 1, C_P, α = 28°



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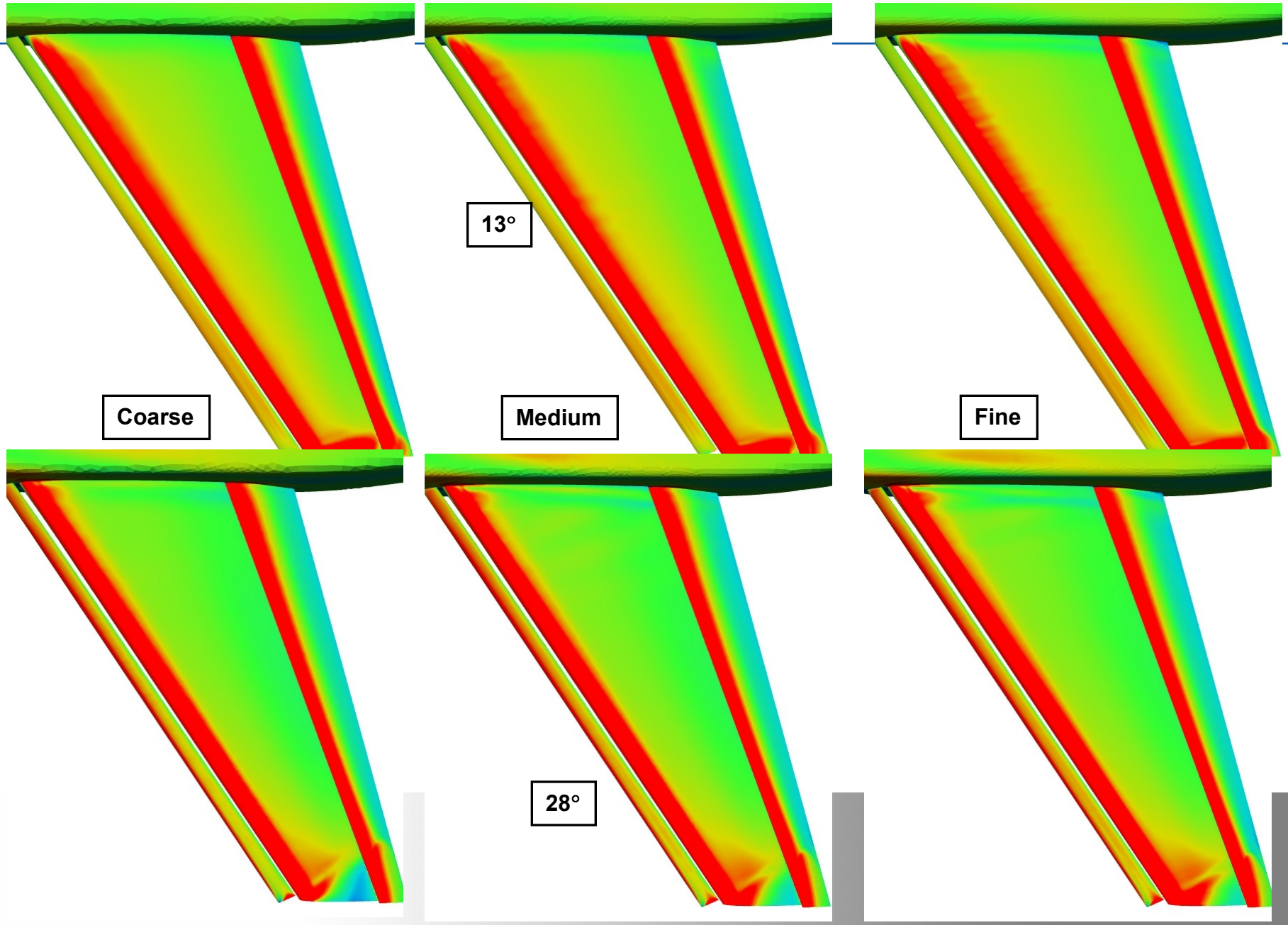
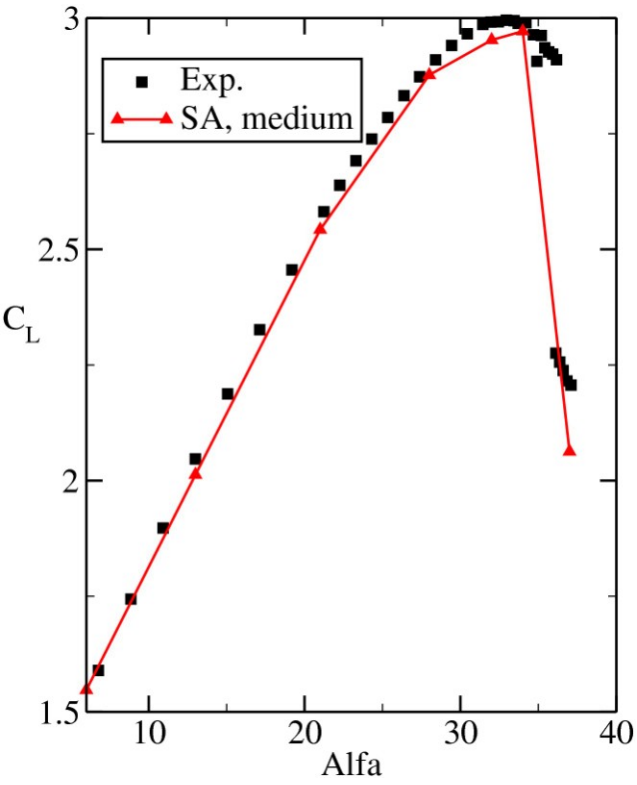
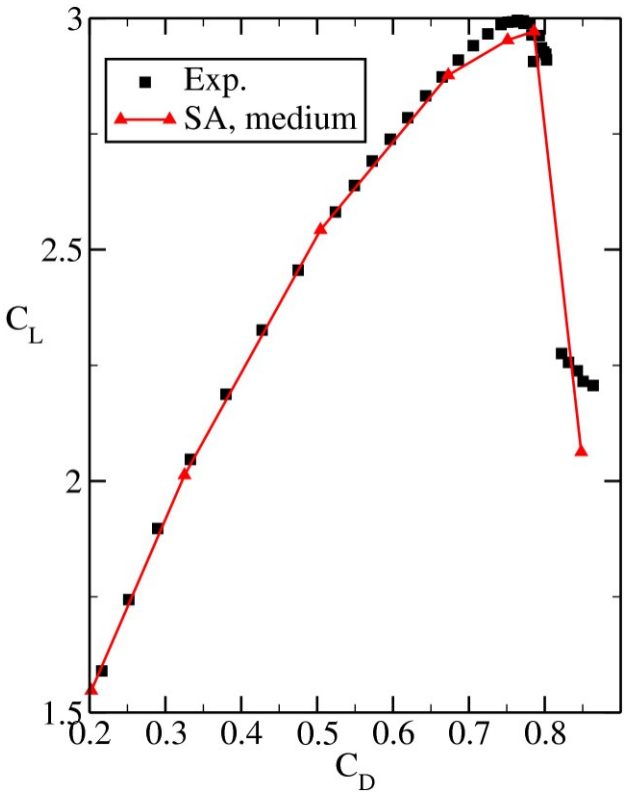
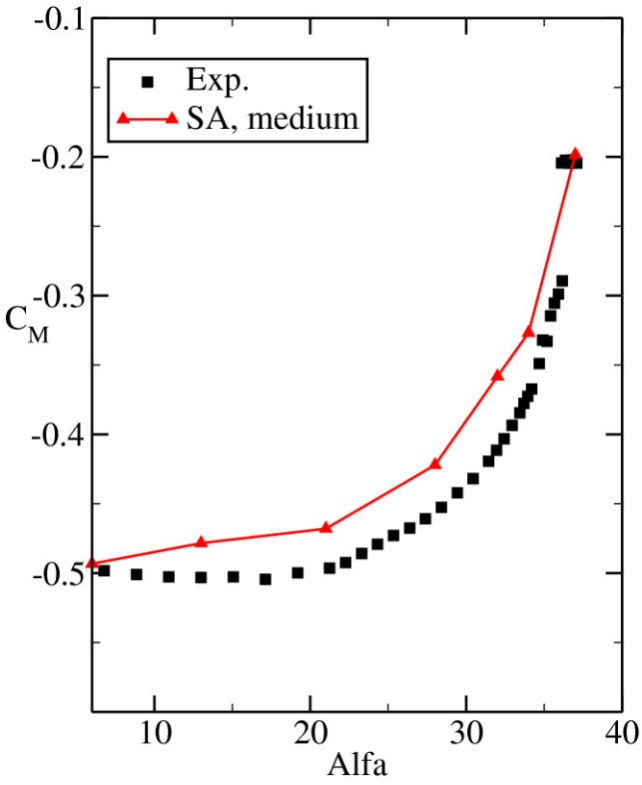
Grid convergence, Config 1, C_f, α = 13 + 28°



Polar calculations, Config 1







- Good agreement

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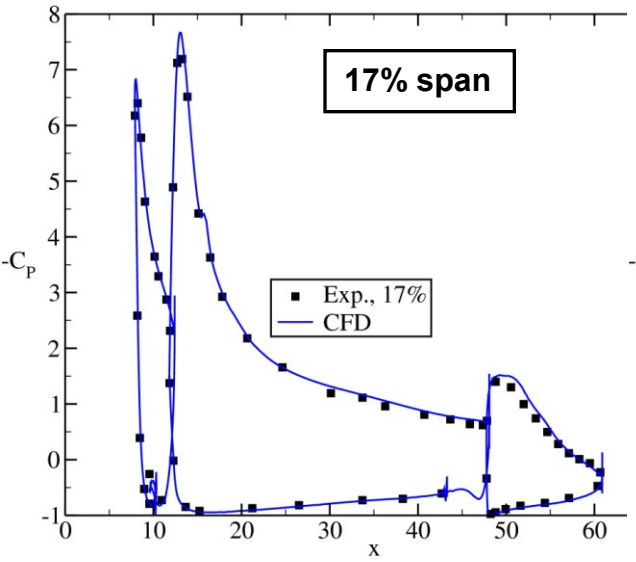
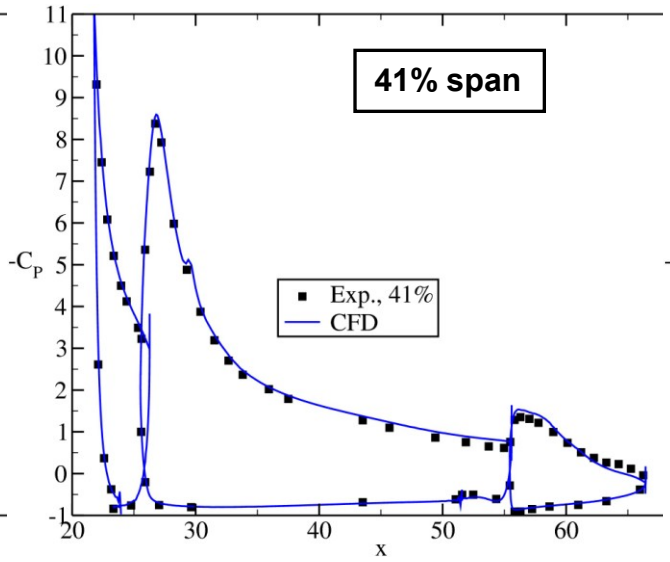
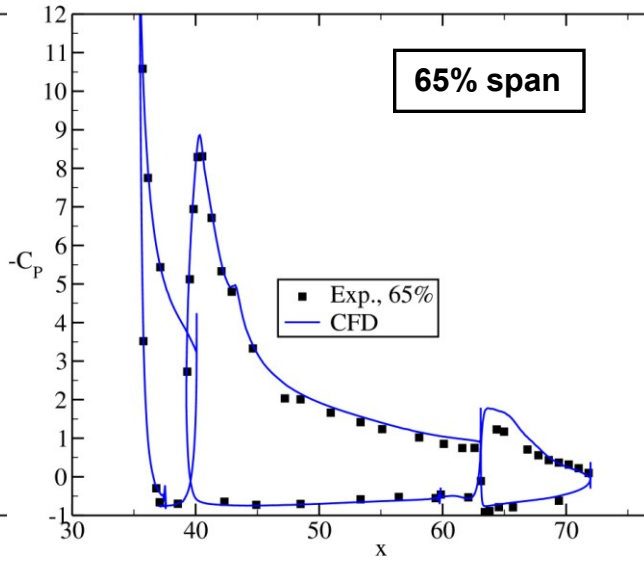
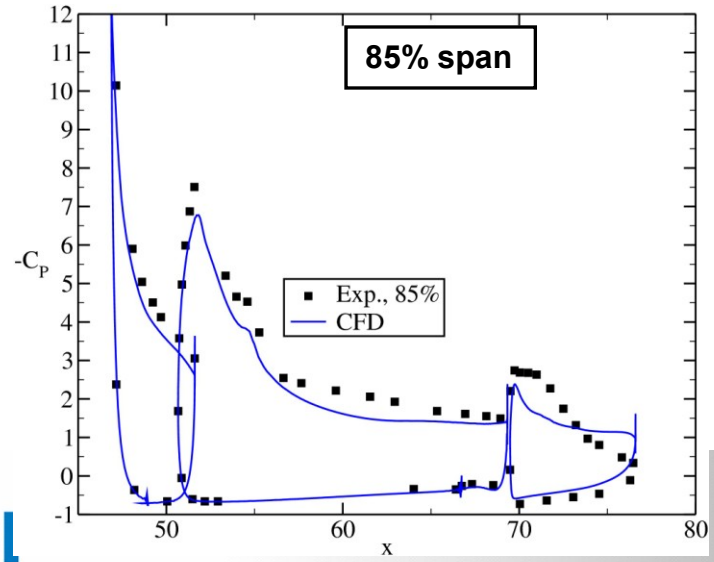
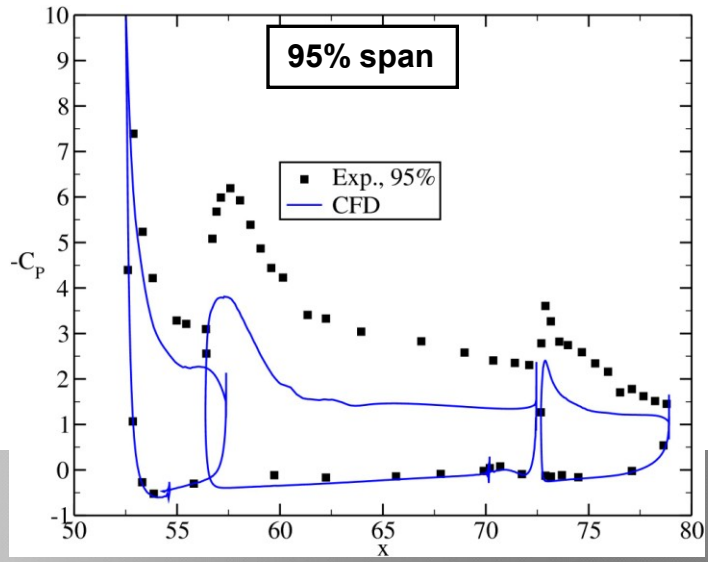
Config 1, C_P, α = 34°



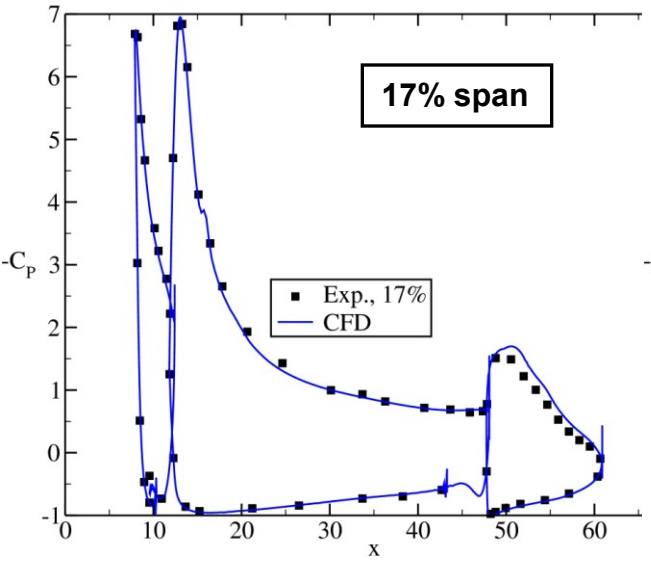


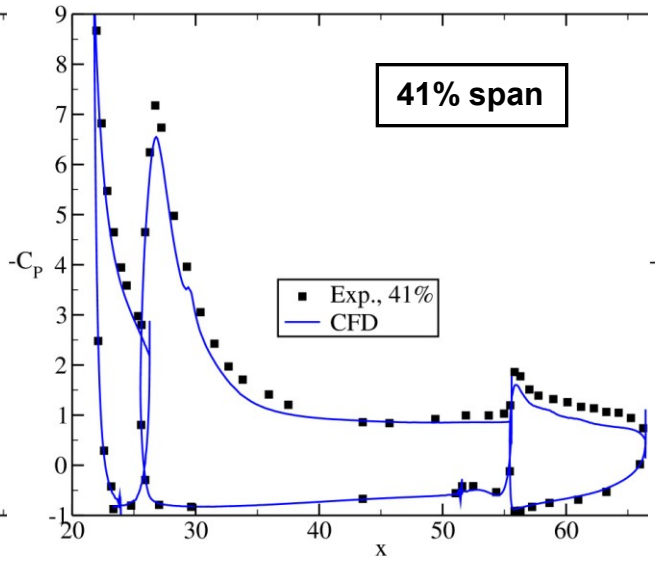


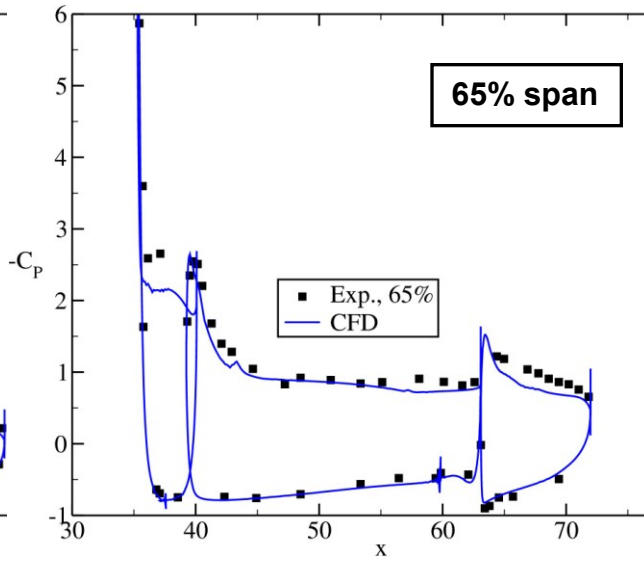


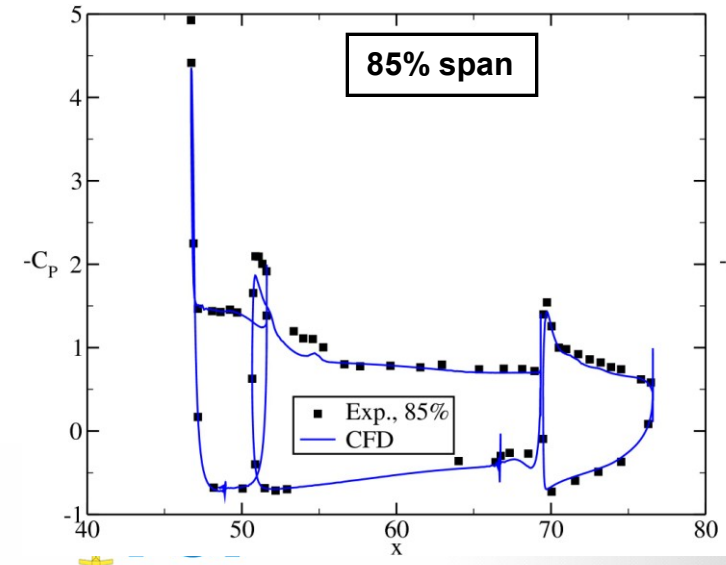


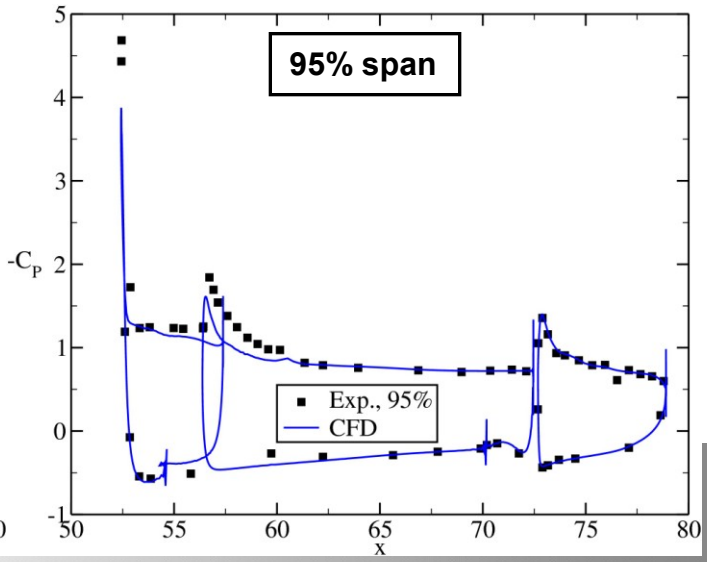
Config 1, C_P, α = 37°

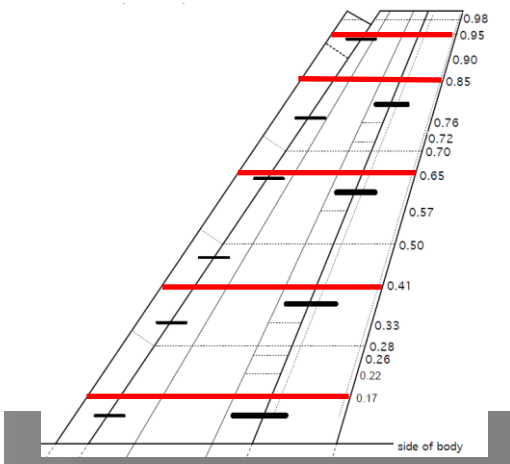




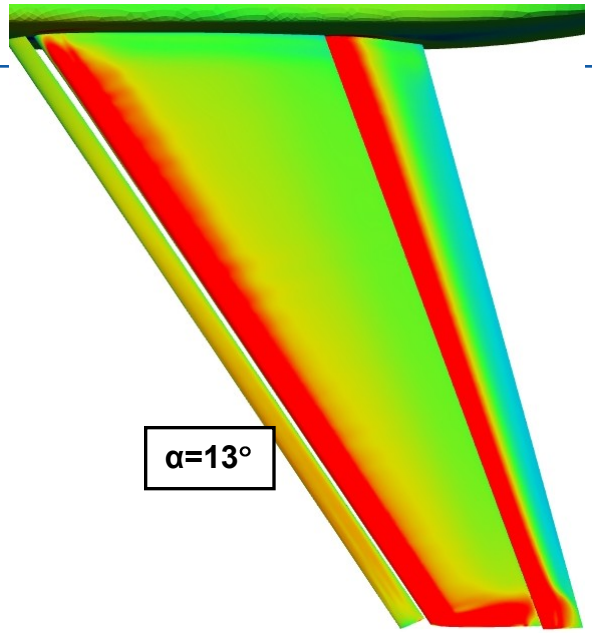


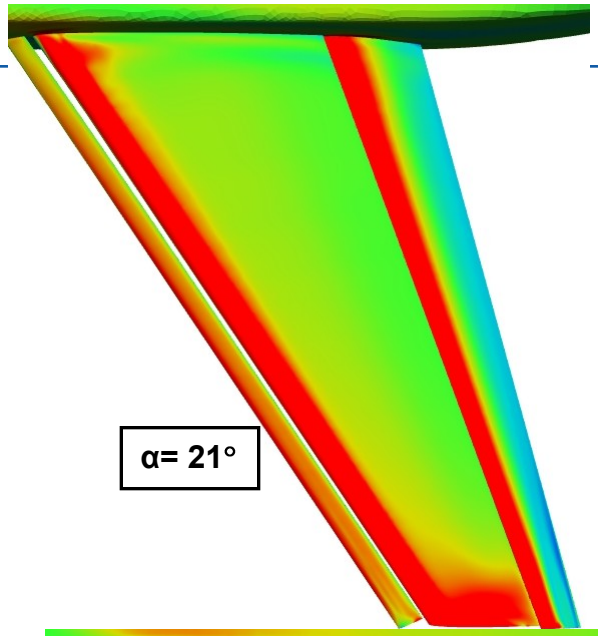


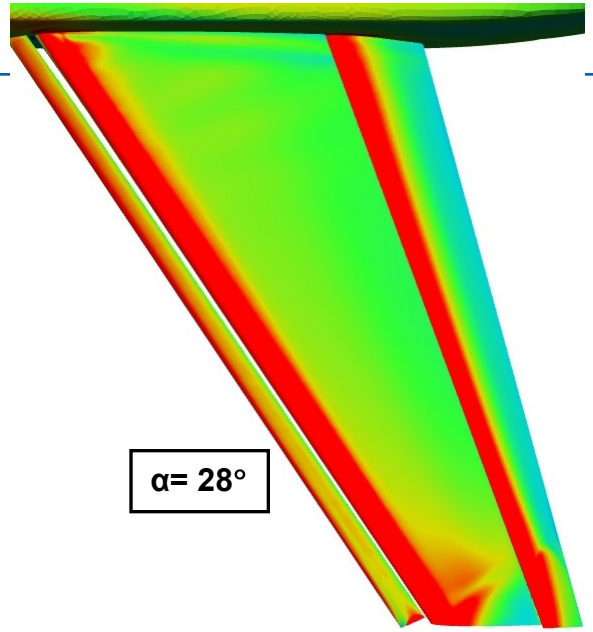


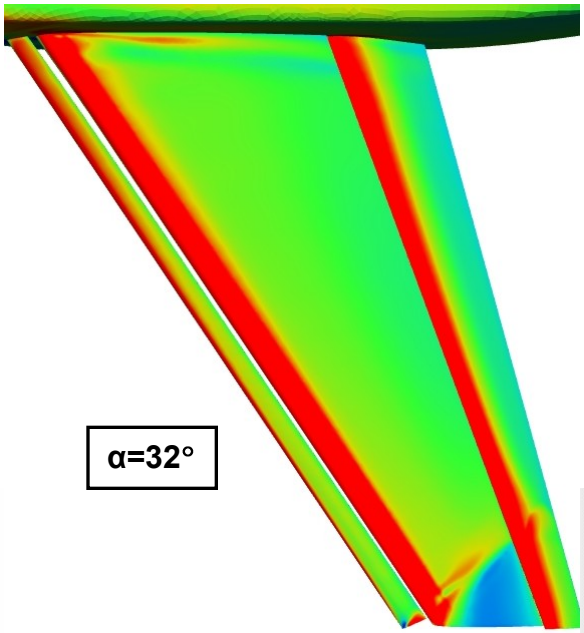


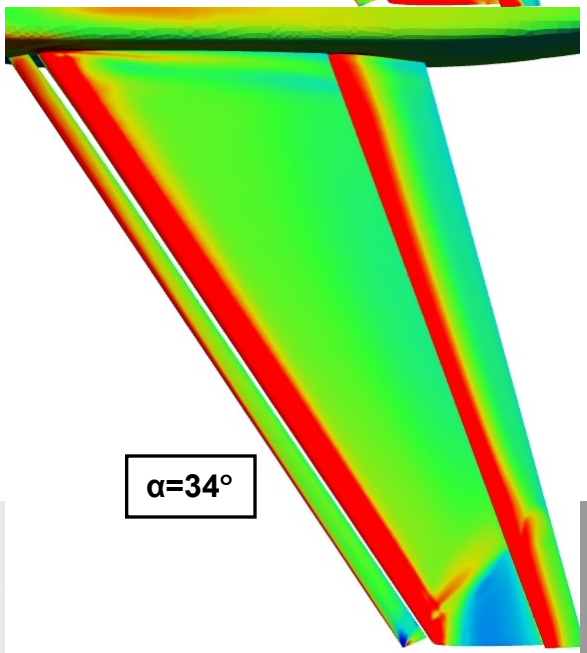
Config 1, C_f, polar

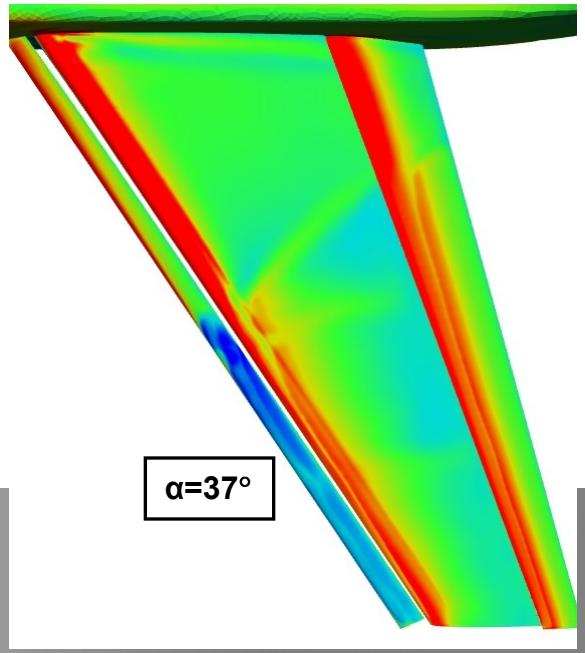




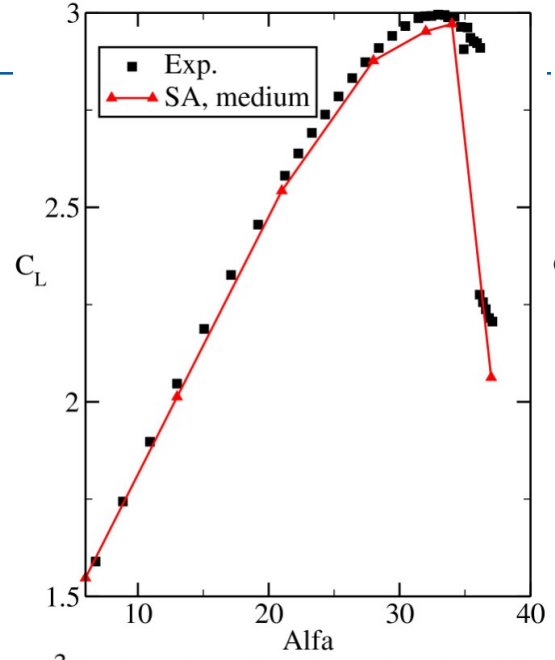


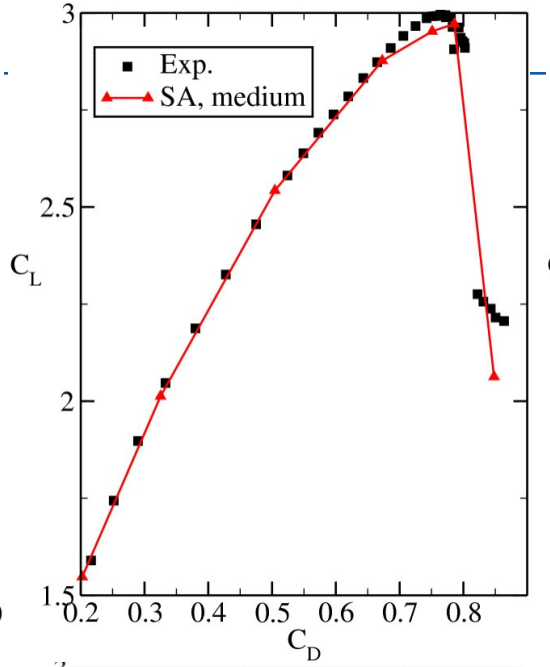


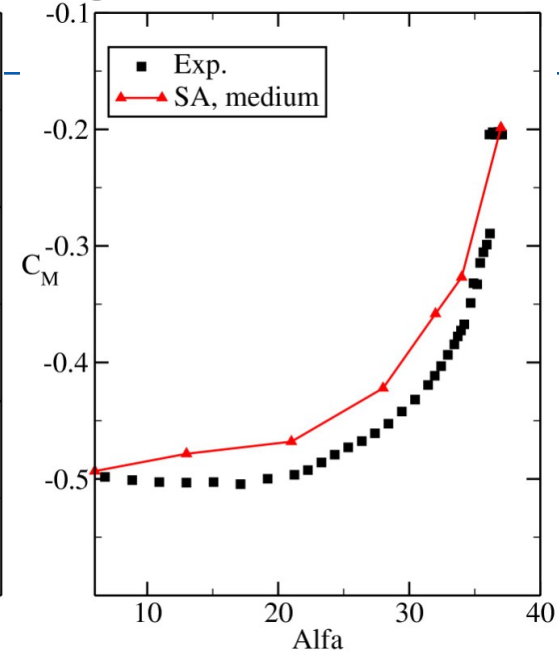


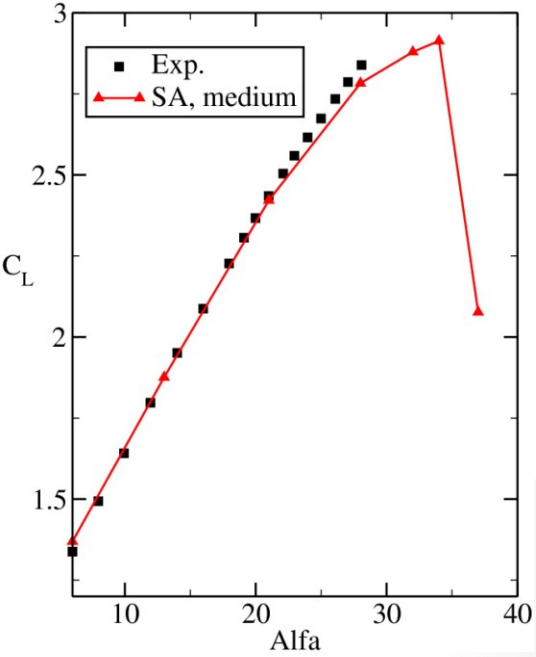


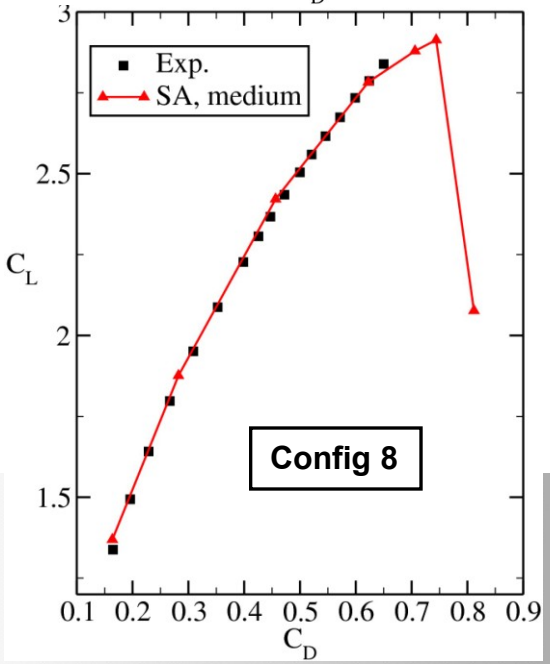
Flap deflection studies, Config 1+ 8

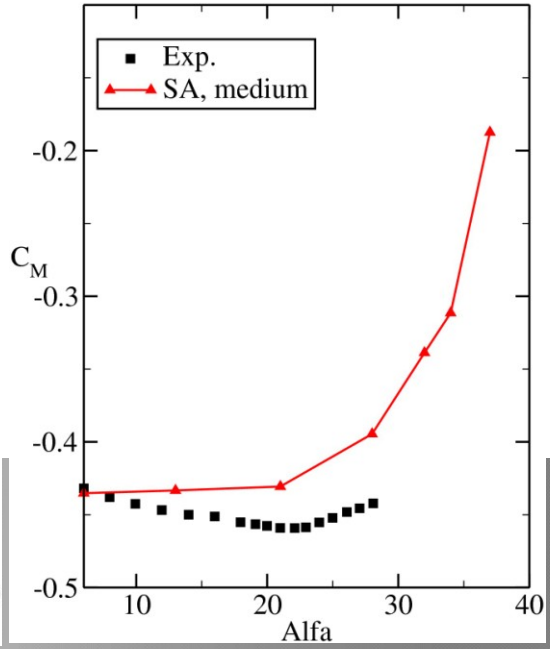




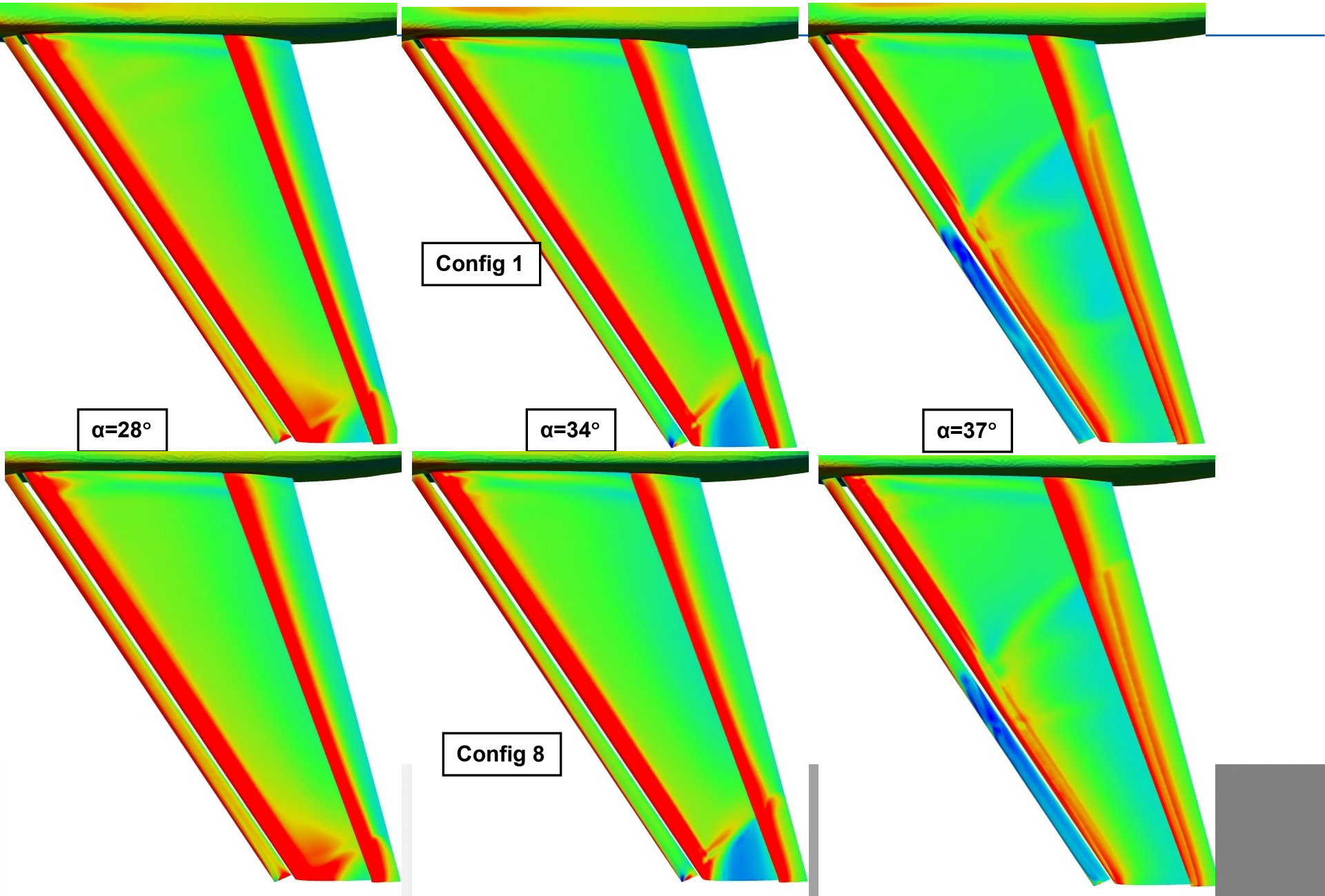




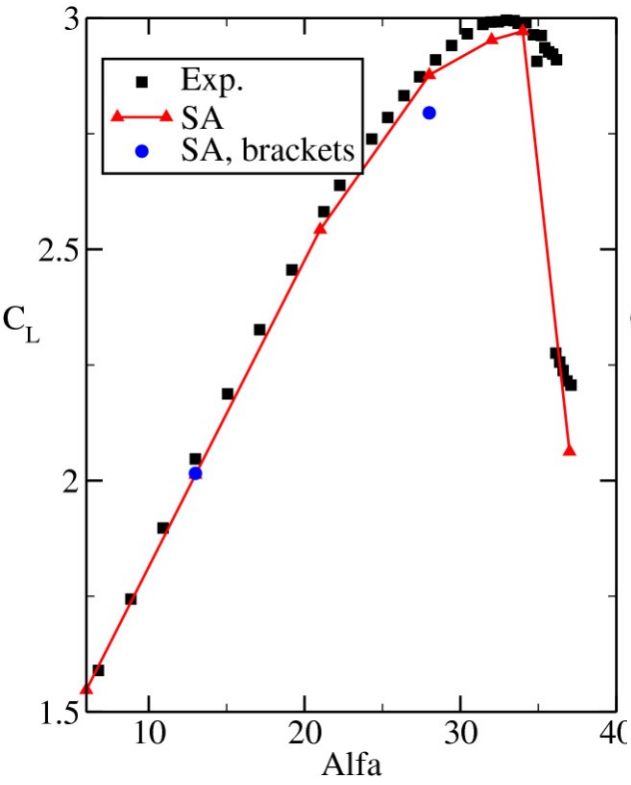


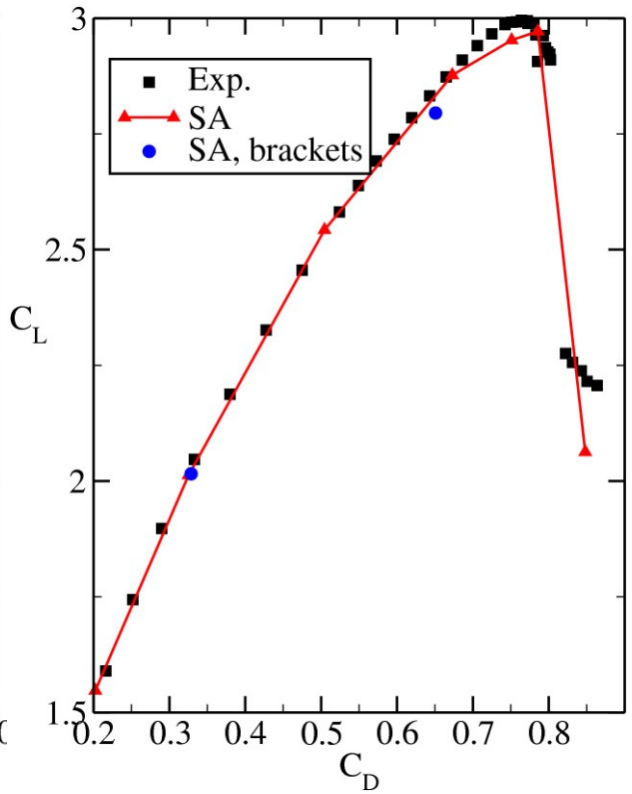


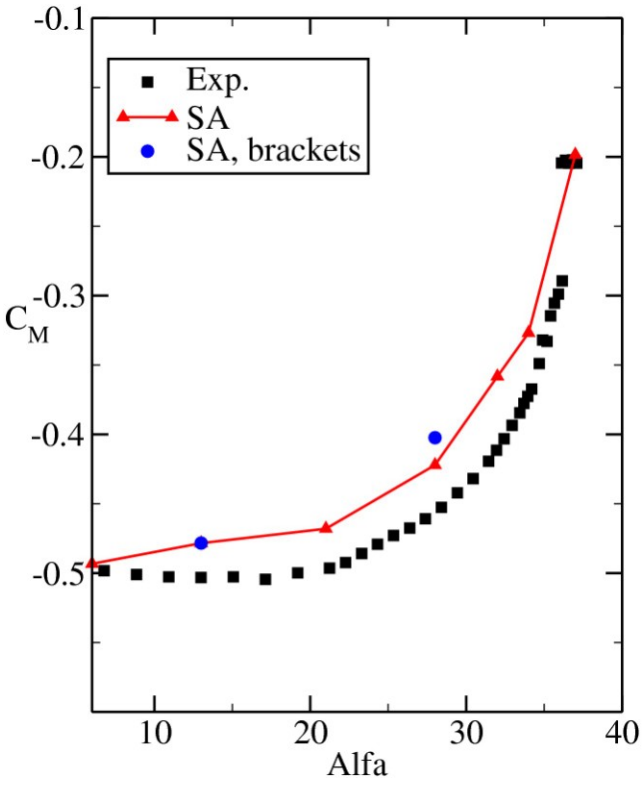
Config 1 + 8, C_f, polar



Optional Case 3, Config 1 with slat/flap support



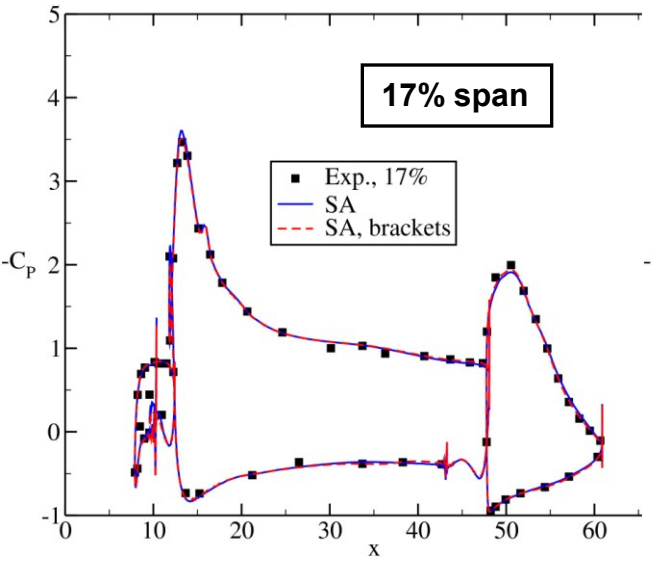


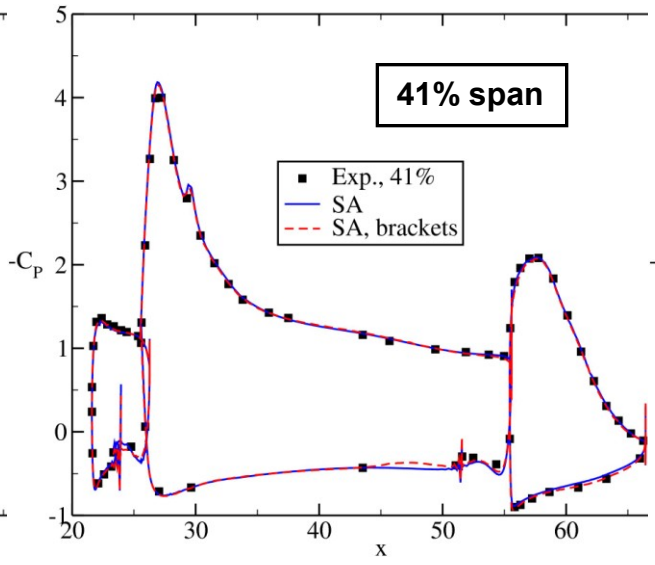


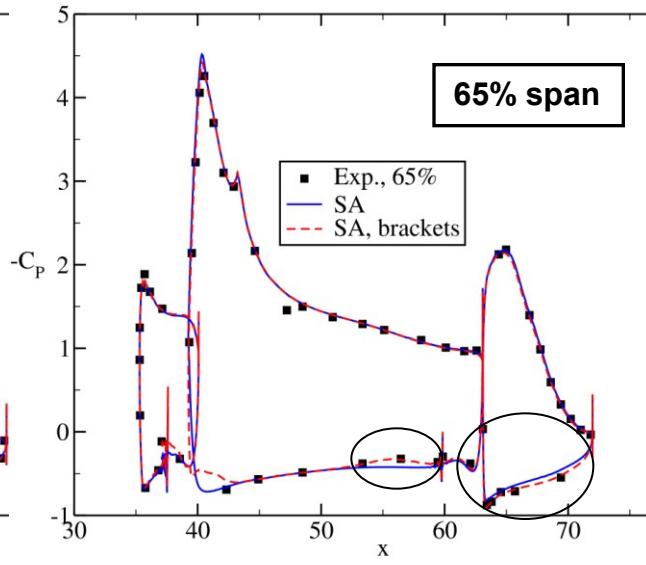
- Influence at higher incidences
- Not in the right direction

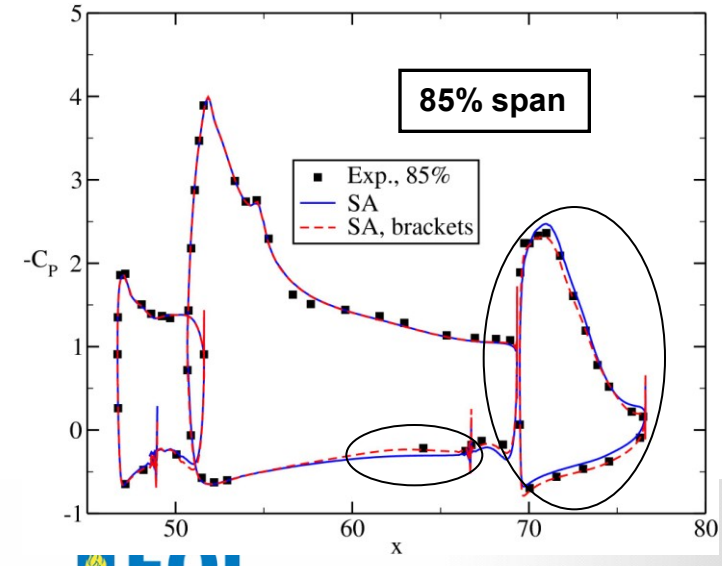
FOI

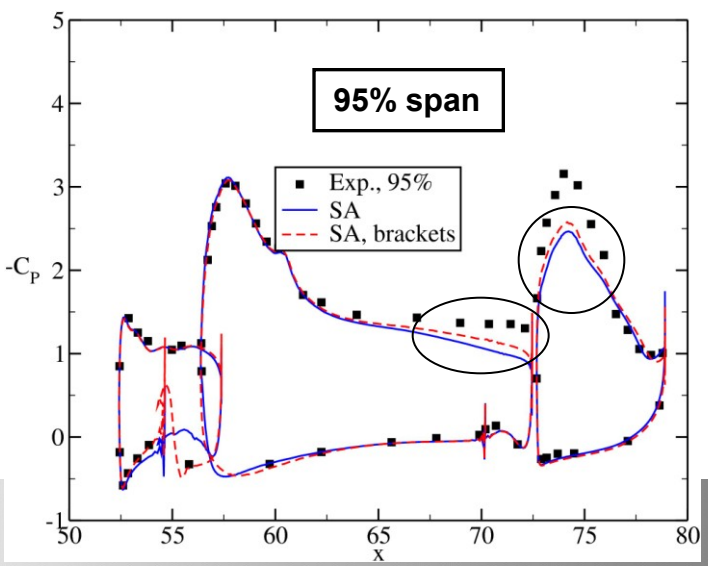
Config 1 + bracket, C_P, α = 13°

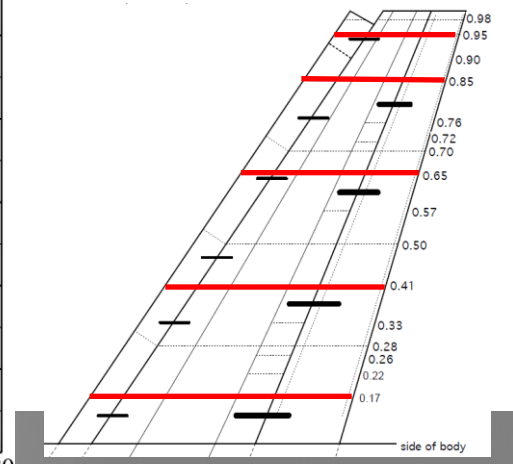




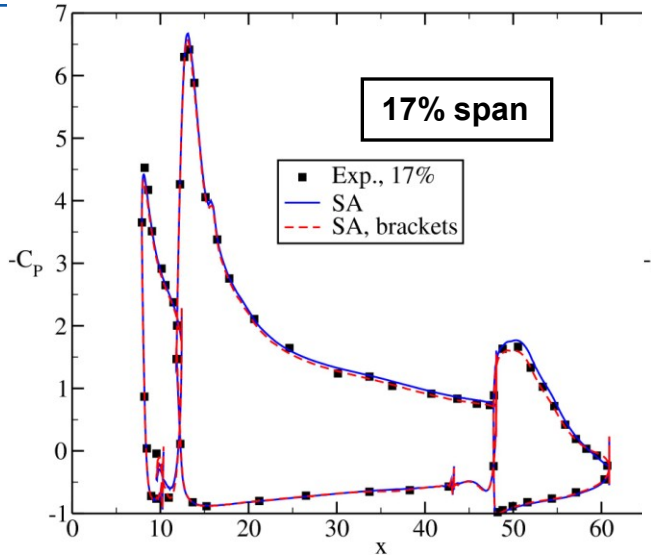


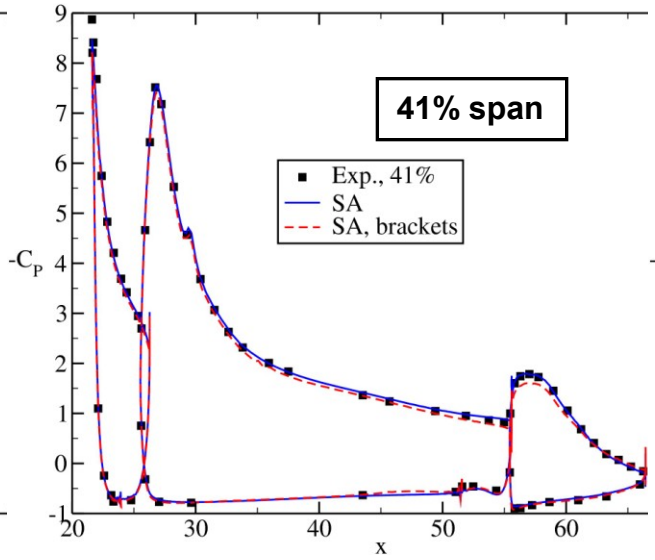


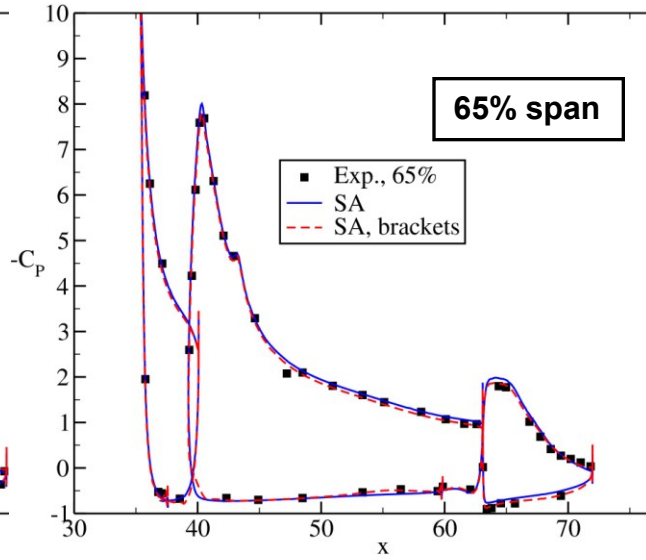


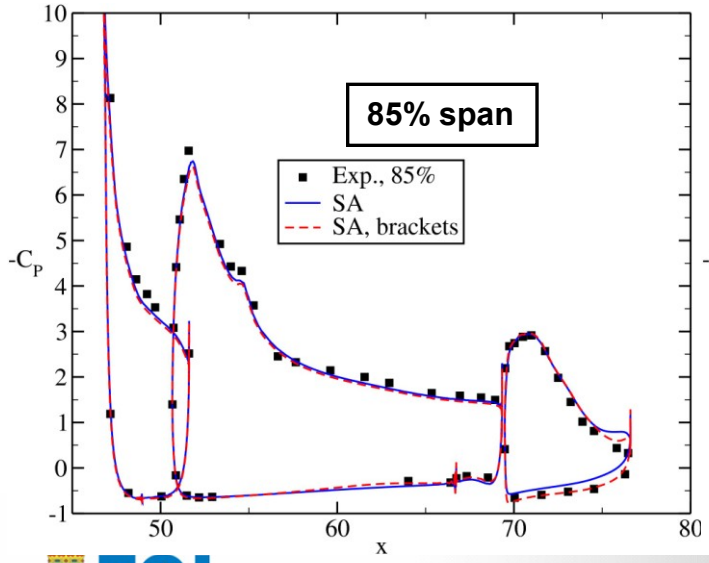


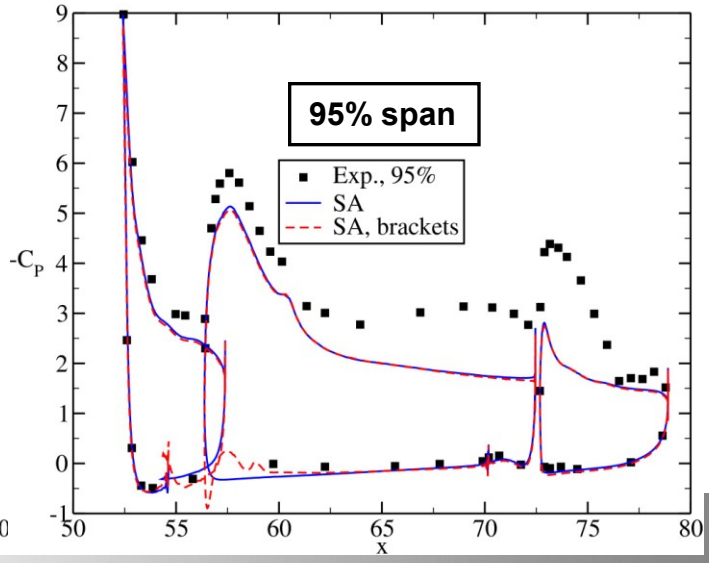
Config 1 + bracket, C_P, α = 28°

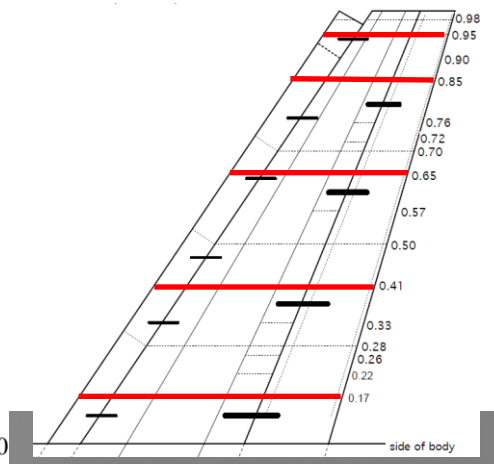






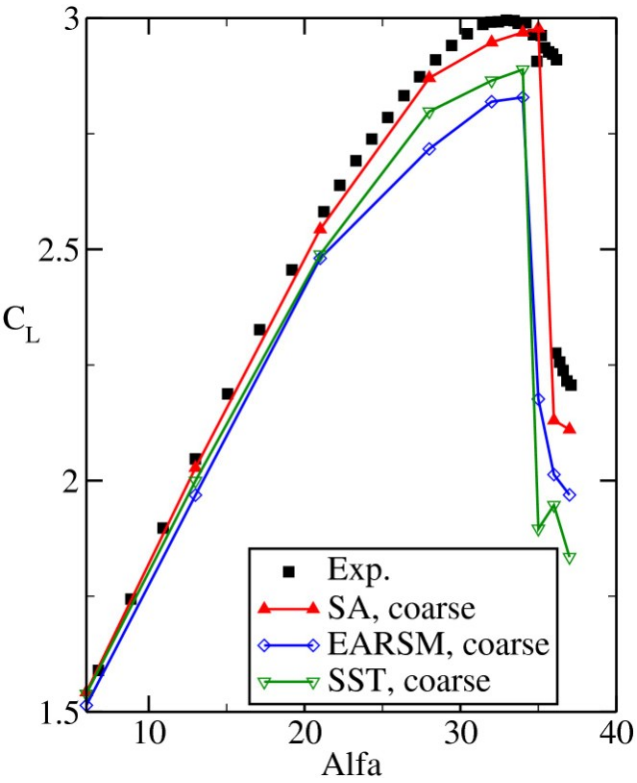


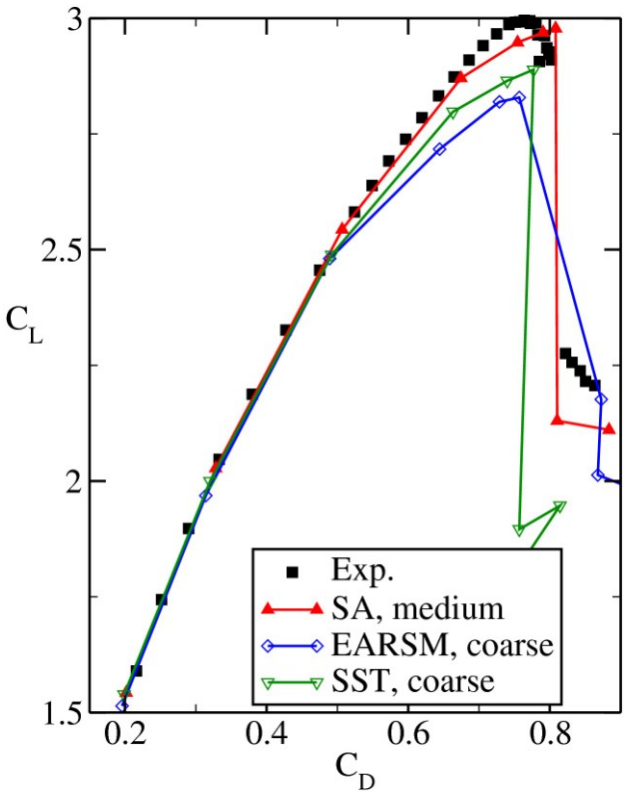


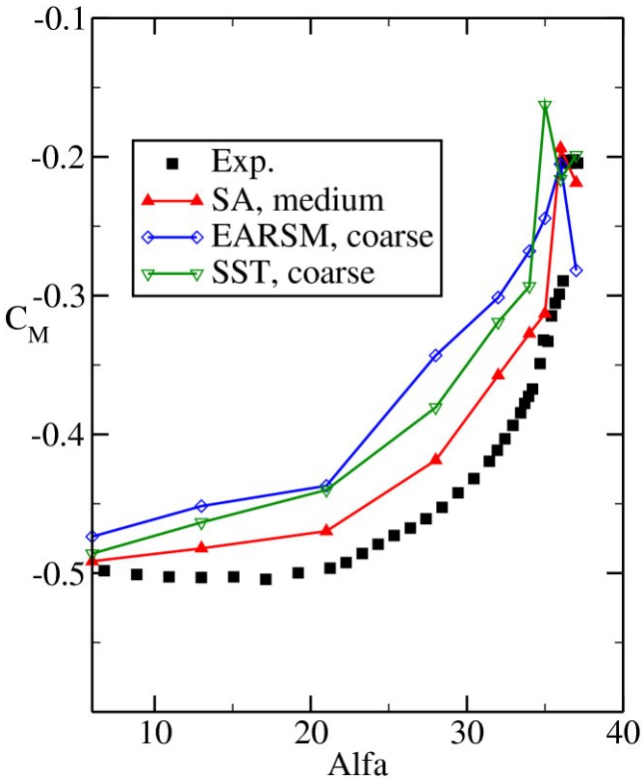


FOI

Turb. model influence, Config 1, coarse grid



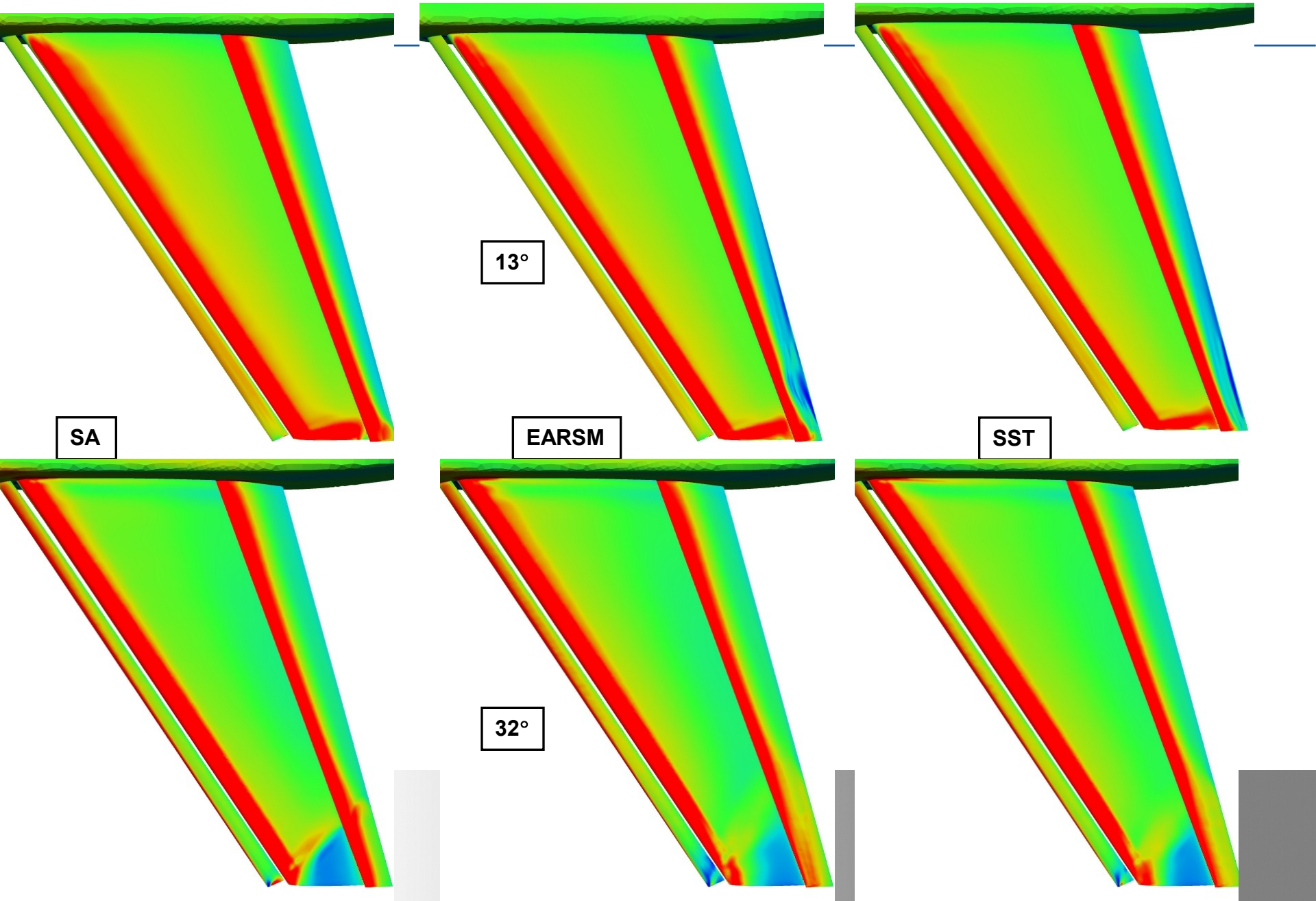




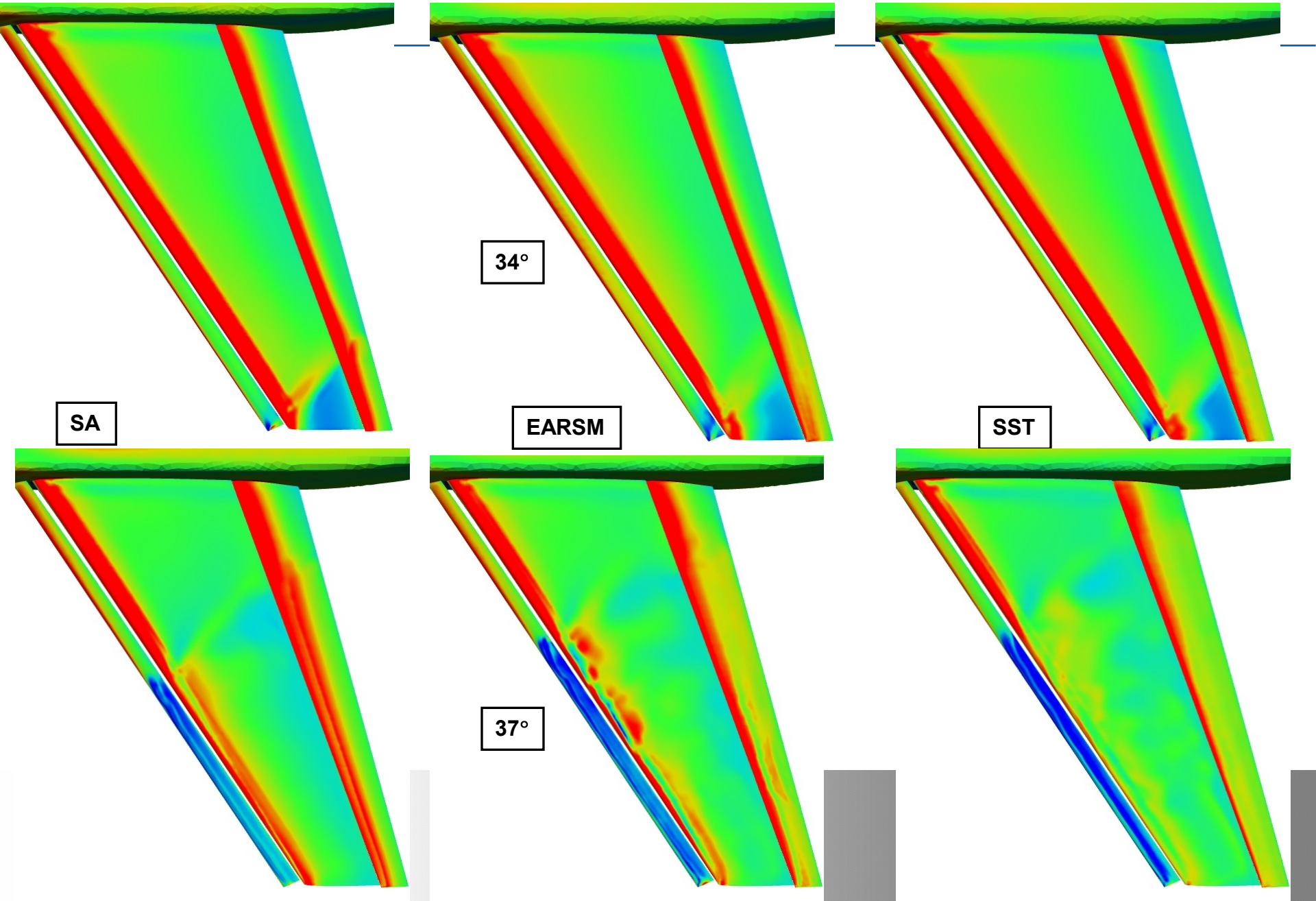
- Added angles 35°, 36°
- Models: SA, EARSM, SST
- Lower lift with EARSM, SST
- Earlier lift break down with EARSM, SST

FOI

Turb. model influence, Config 1, C_f



Turb. model influence, Config 1, C_f



Lessons learned

- High quality SOLAR grids
  - Good steady-state convergence
  - Good grid convergence, small differences between solutions
- SA model produces better experimental agreement
  - Good Cp agreement, some deviation at outer span
  - Lower lift and earlier lift break down with EARSM and SST, flow separation is exaggerated
- Similar results for the two flap deflections
- Influence from brackets at higher incidences
- Many open questions
  - Turbulence modeling, laminar/turbulent transition, …
  - Insufficient steady state convergence ?
  - Similar predictions between FOI and DLR results, but differences at tip region (?)
  - …

FOI