DLR TAU Results

AIAA DPW-4

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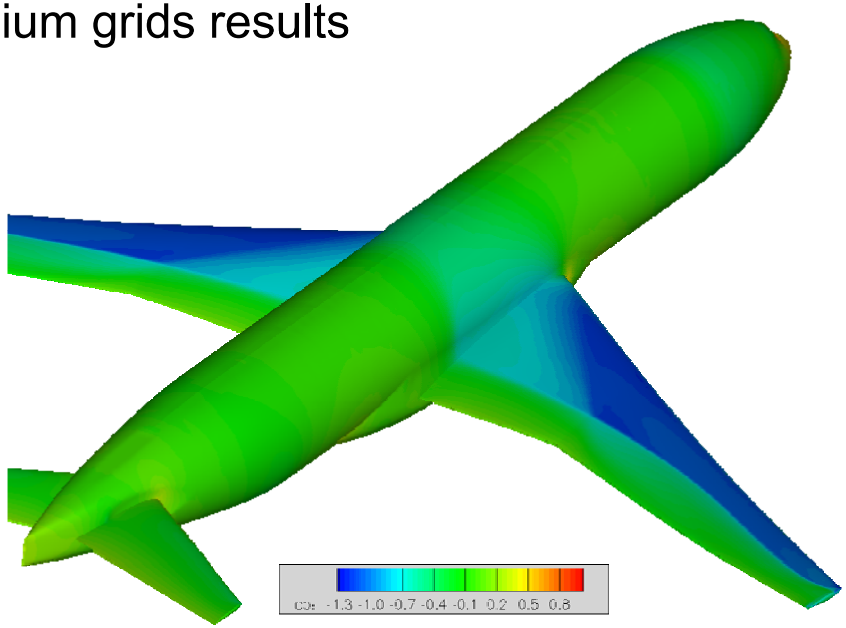
in der Helmholtz-Gemeinschaft

Content

- Objectives
- Grids
- TAU RANS Solver
- Case 1.1: Grid Refinement Study
- Case 1.2: Downwash Study
- Case 3: Reynolds Number Study
- Conclusions

Objectives
— DLR Objectives in DPW-4 —

- Test DLR-TAU with new Solar grid generation approach (hex-dominant in boundary layer):
  - Refinement studies using Solar grids
- Compare to standard TAU Centaur medium grids results (prism-dominant in boundary layer)
- Application of SA, Menter kω-SST, and RSM turbulence models
- i_h trim interpolation vs. HTP setting modification in CFD loop (mesh deformation)



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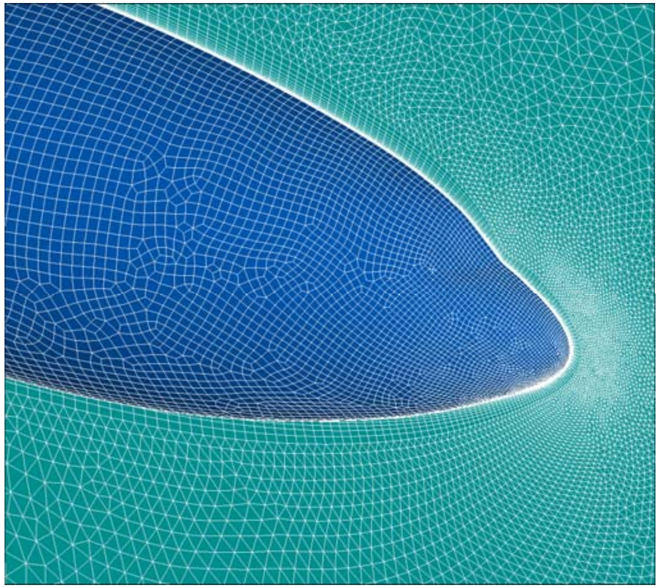
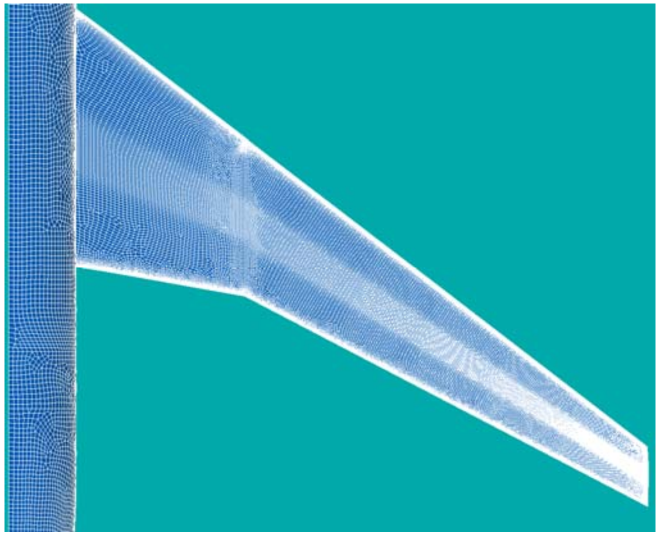
Grids
— Solar —

Solar grid generation system developed by ARA, BAE Systems, Airbus, QinetiQ:

- Anisotropic quad-dominant unstructured surface meshes
- Advancing layer near field mesher
- Buffer layer transitioning to triangulated near field shell
- Tetrahedral far field meshing
- Consistent grid family
- Here: grid refinement factor ≈1.42 used

	Coarse	Medium	Fine
Nodes	**4074967**	**11696804**	**34076798**
Hexa Layers	**30**	**42**	**60**



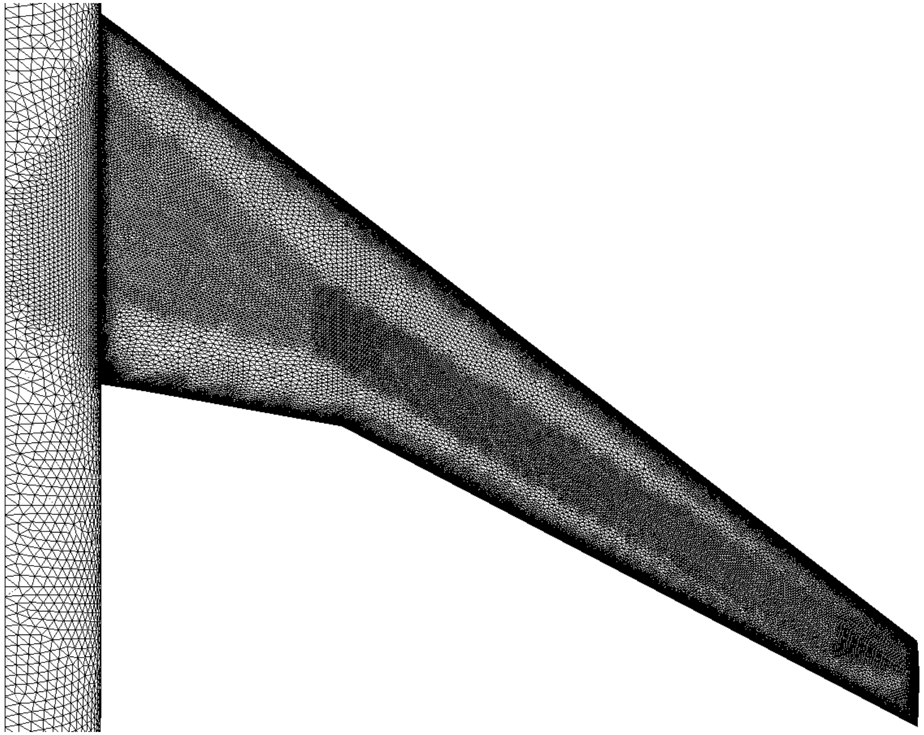


Grids
— Centaur 8.1 —

Centaur grid generation system developed by CentaurSoft:

- Triangulated surface meshes
- Prismatic elements for boundary layer resolution
- Tetrahedral far field meshing

	Medium
Nodes	**13331301**
Prismatic Layers	**35**



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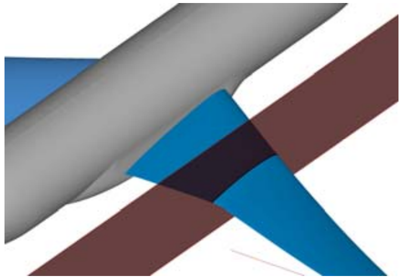
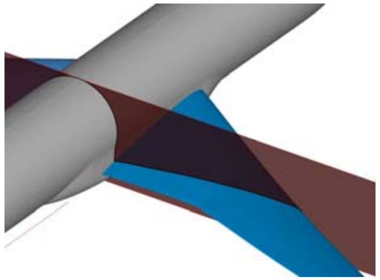
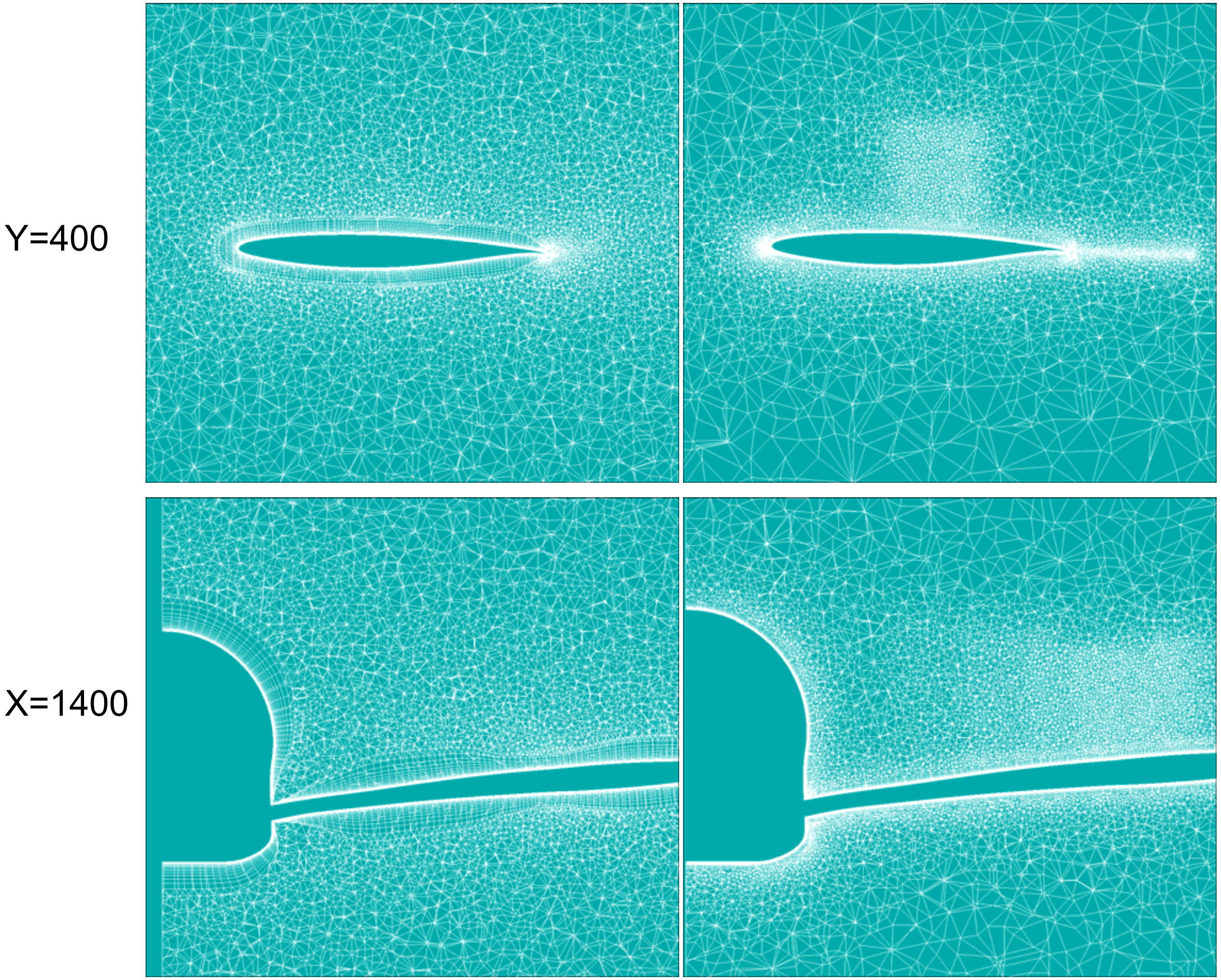
Grids
— Volume Grid —

- Medium grids
- Best practice for Centaur grids
- Limited experience with Solar grids







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TAU RANS Solver
— Overview —

- TAU solves Reynolds-averaged Navier-Stokes equations
- Finite Volume Method, node-centered, (cell-centered), dual grid technique
- Several discretization schemes, here:
  - 2^{nd} order central with Jameson-type dissipation
- Time integration: Runge-Kutta, Backward Euler
- Local time stepping, residual smoothing
- Multigrid
- Several turbulence models, here:
  - Spalart-Allmaras original (SA, SAO)
  - Menter kω-SST (kω-SST)
  - Speziale-Sakar-Gatski/Launder-Reece-Rodi, SSG/LRR-ω, (RSM)

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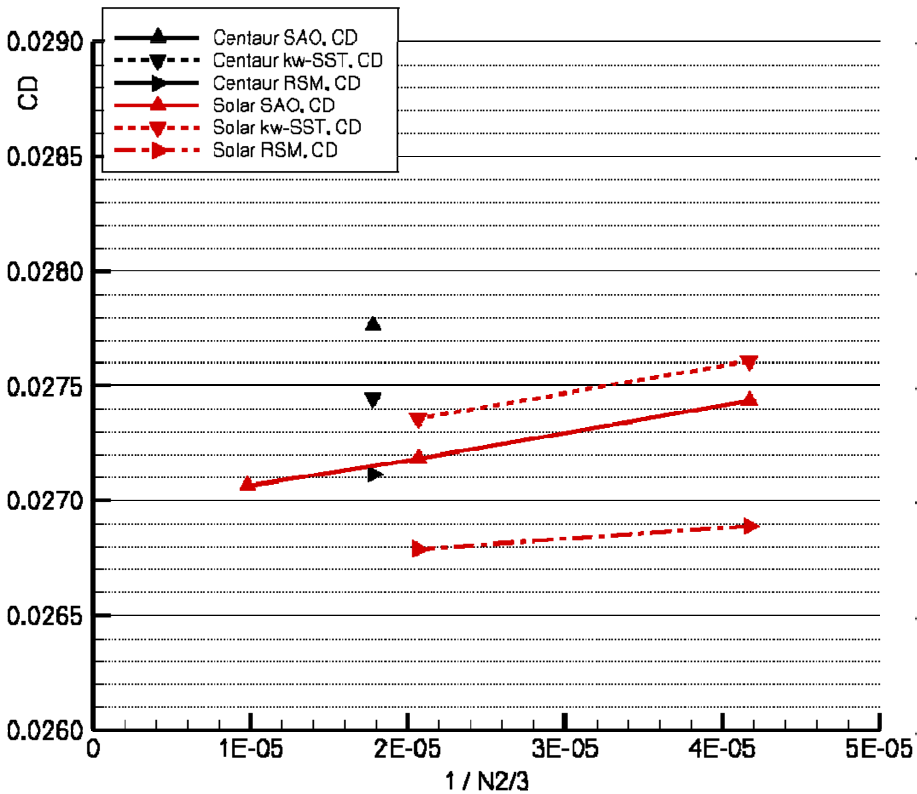
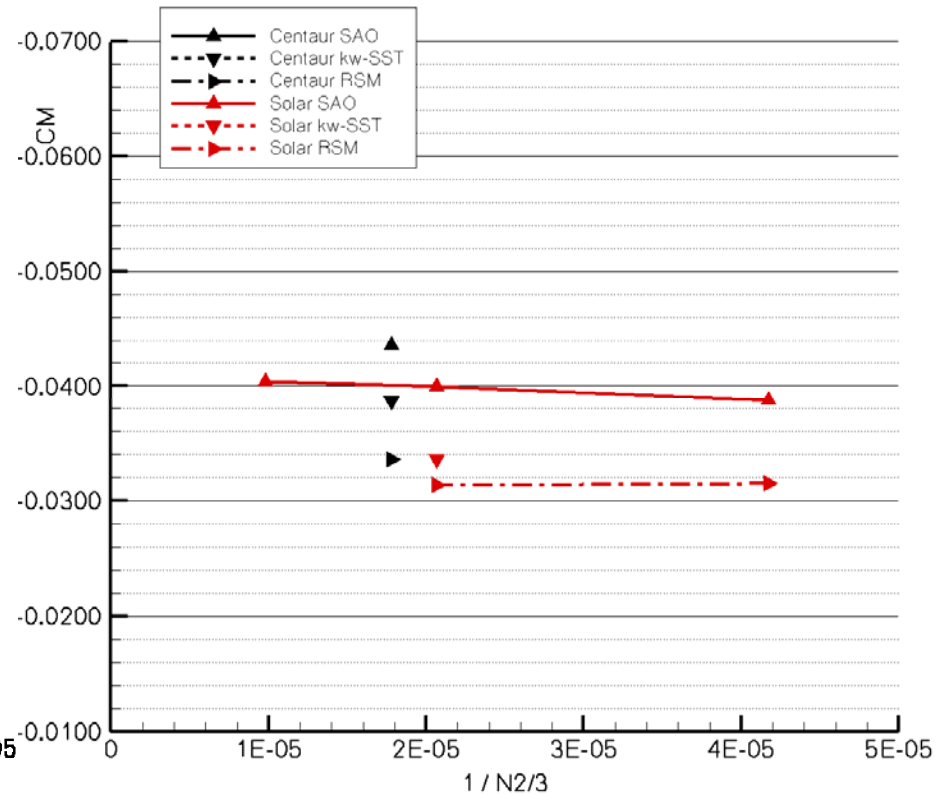
Case 1.1
— Grid Type/Size, Turbulence Model —





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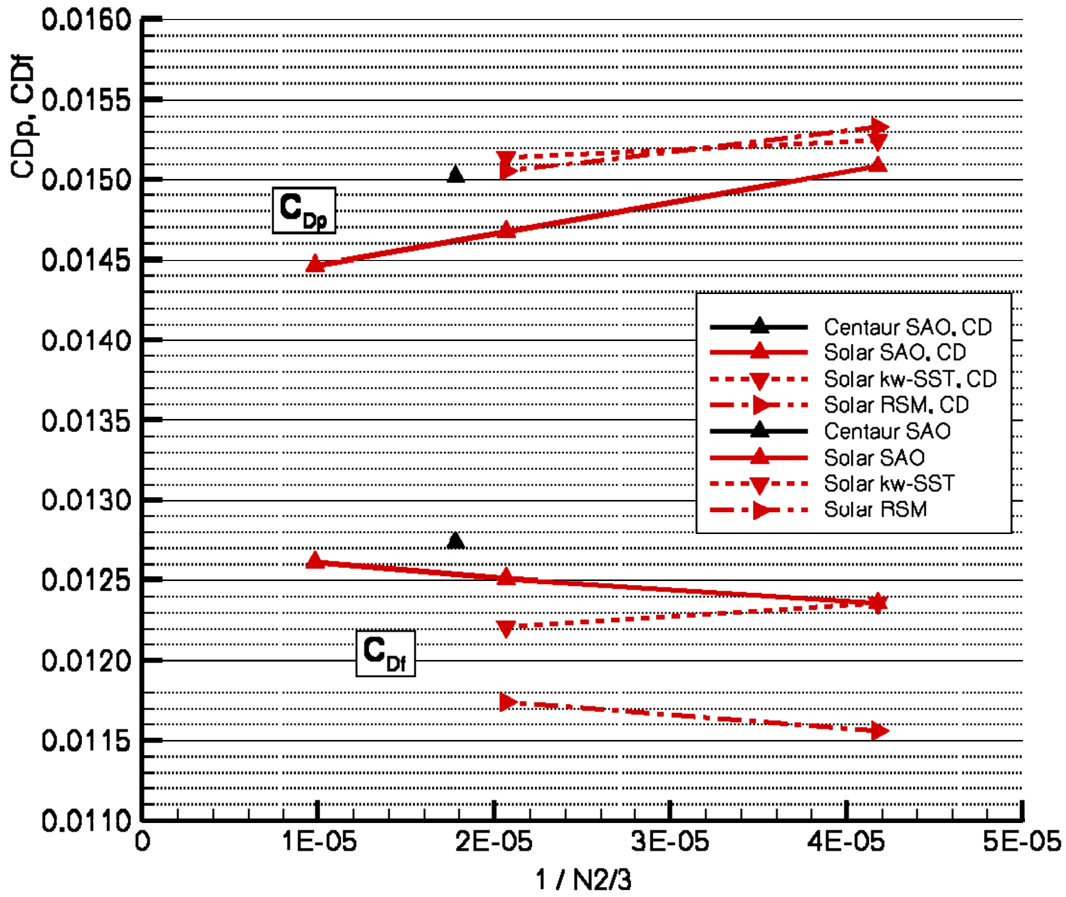
— Grid Type/Size, Turbulence Model —



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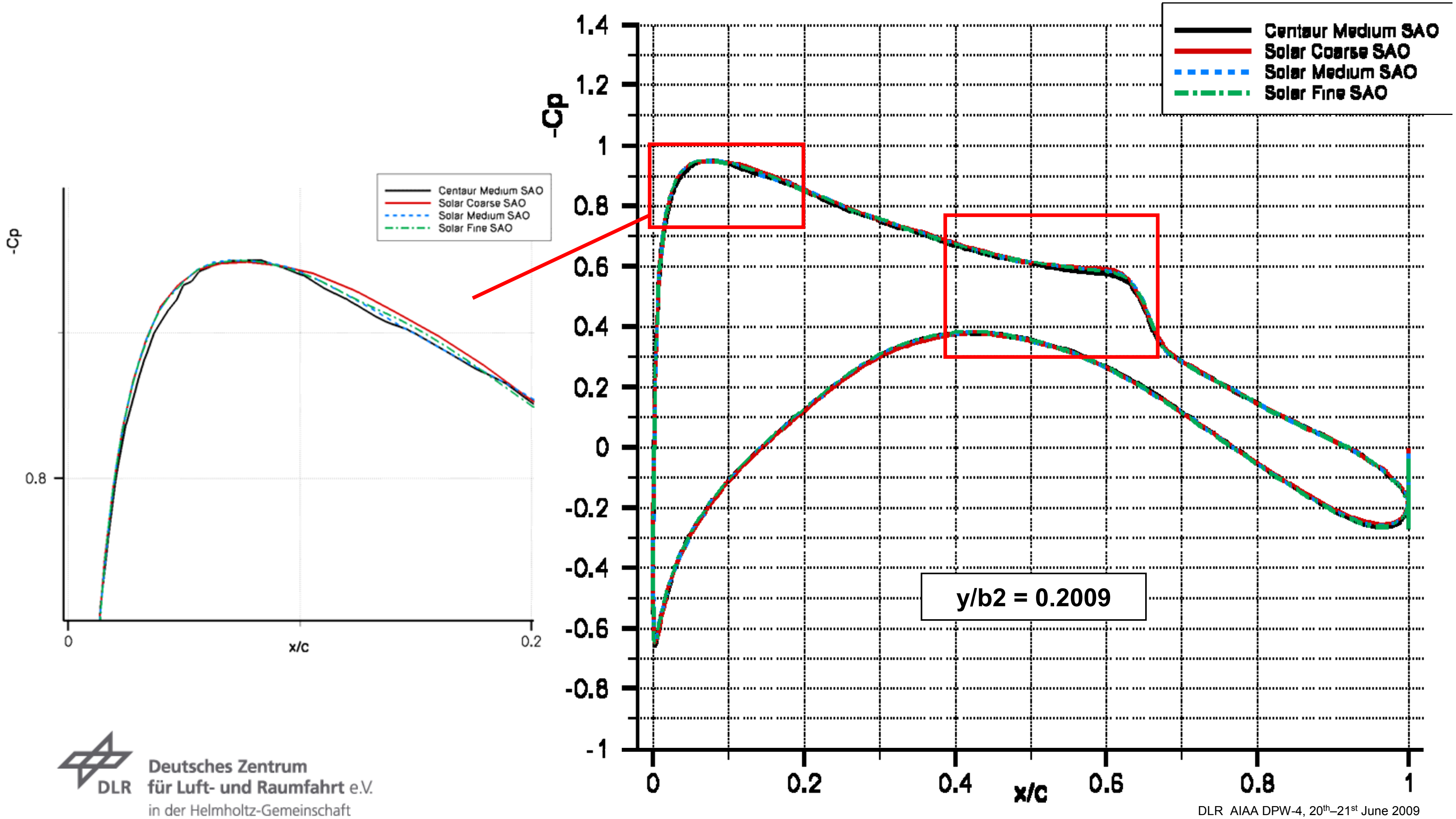
Case 1.1
— Grid Type/Size, SAO Model —



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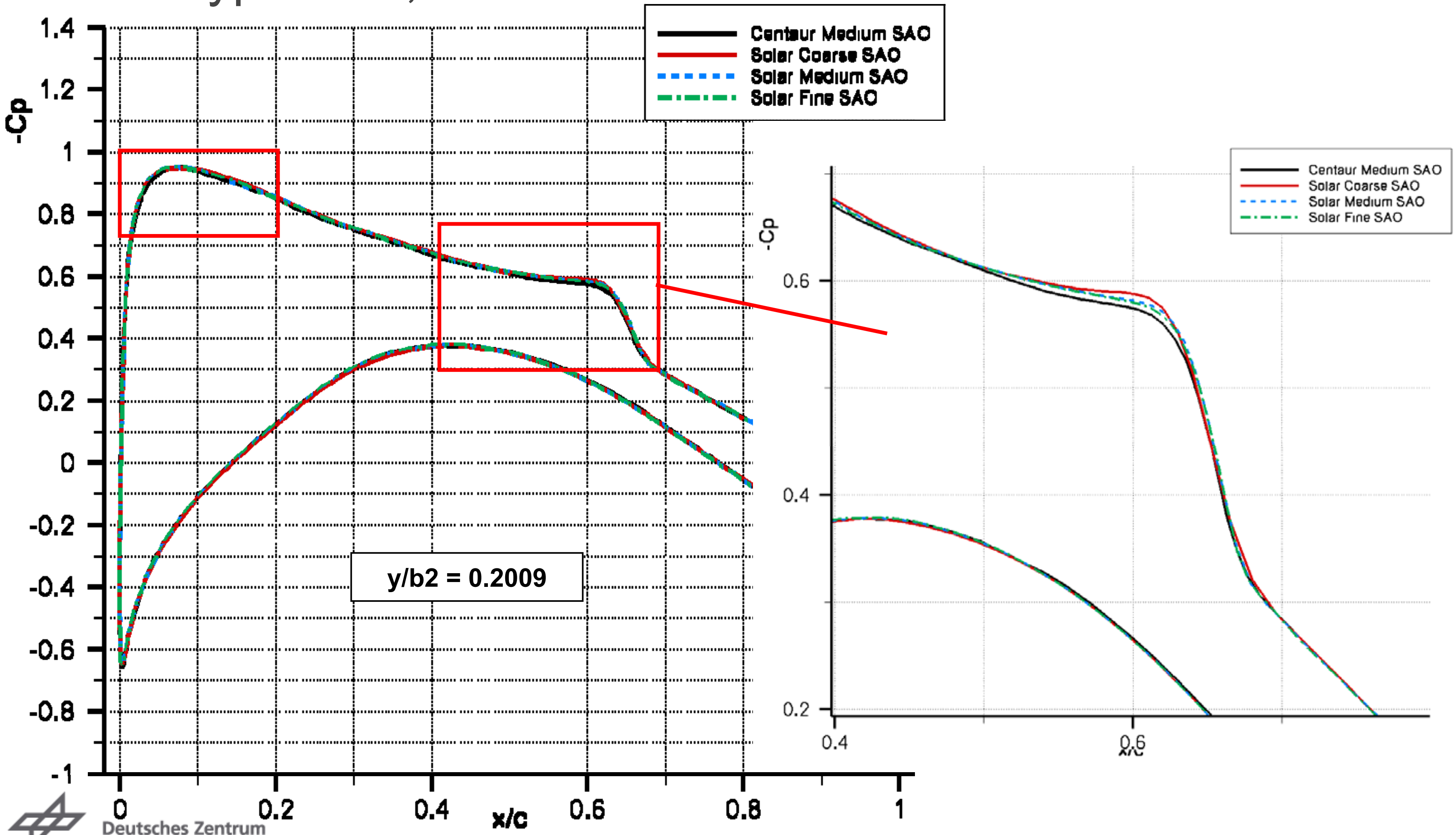
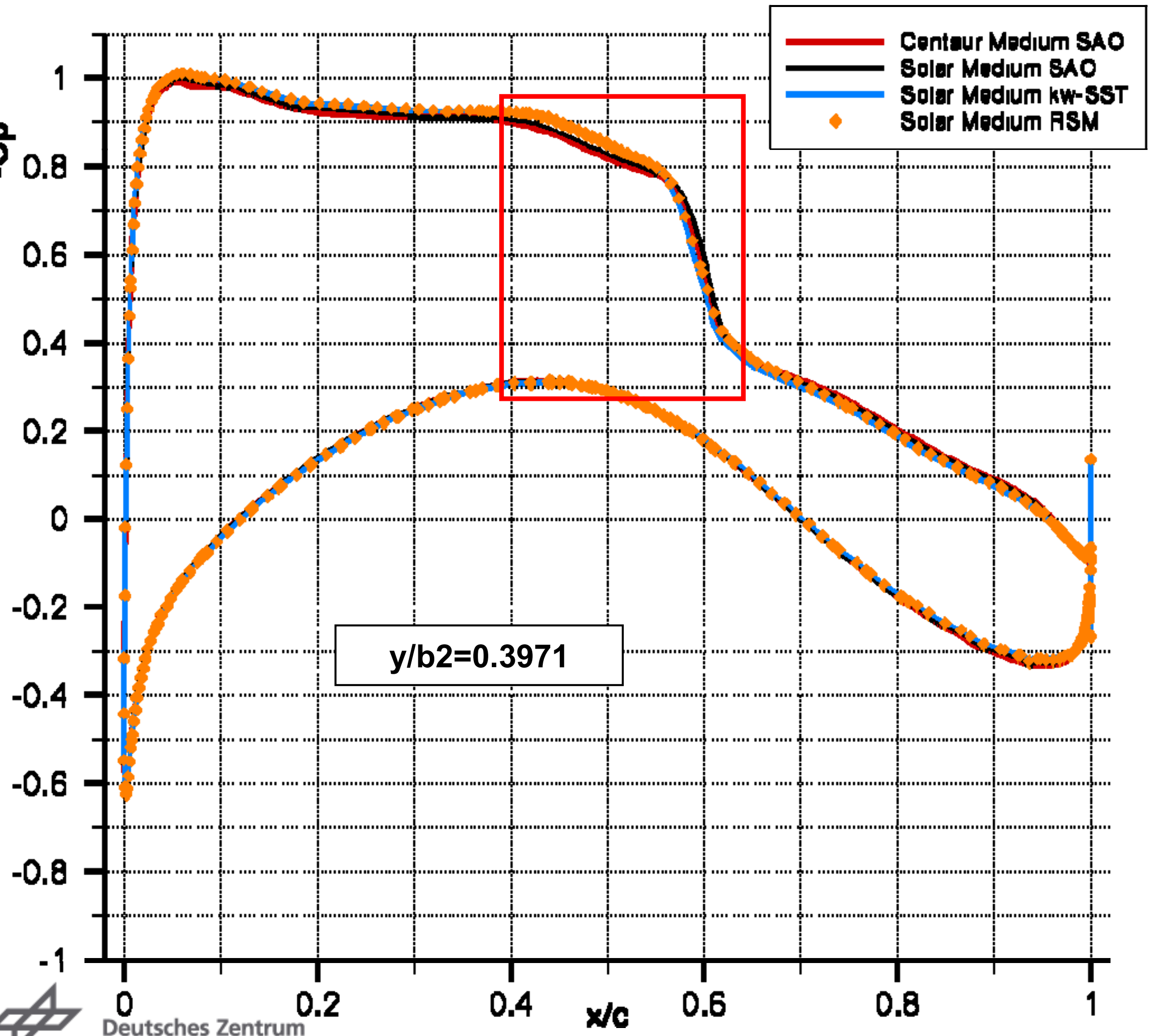


Case 1.1
— Turbulence Model —



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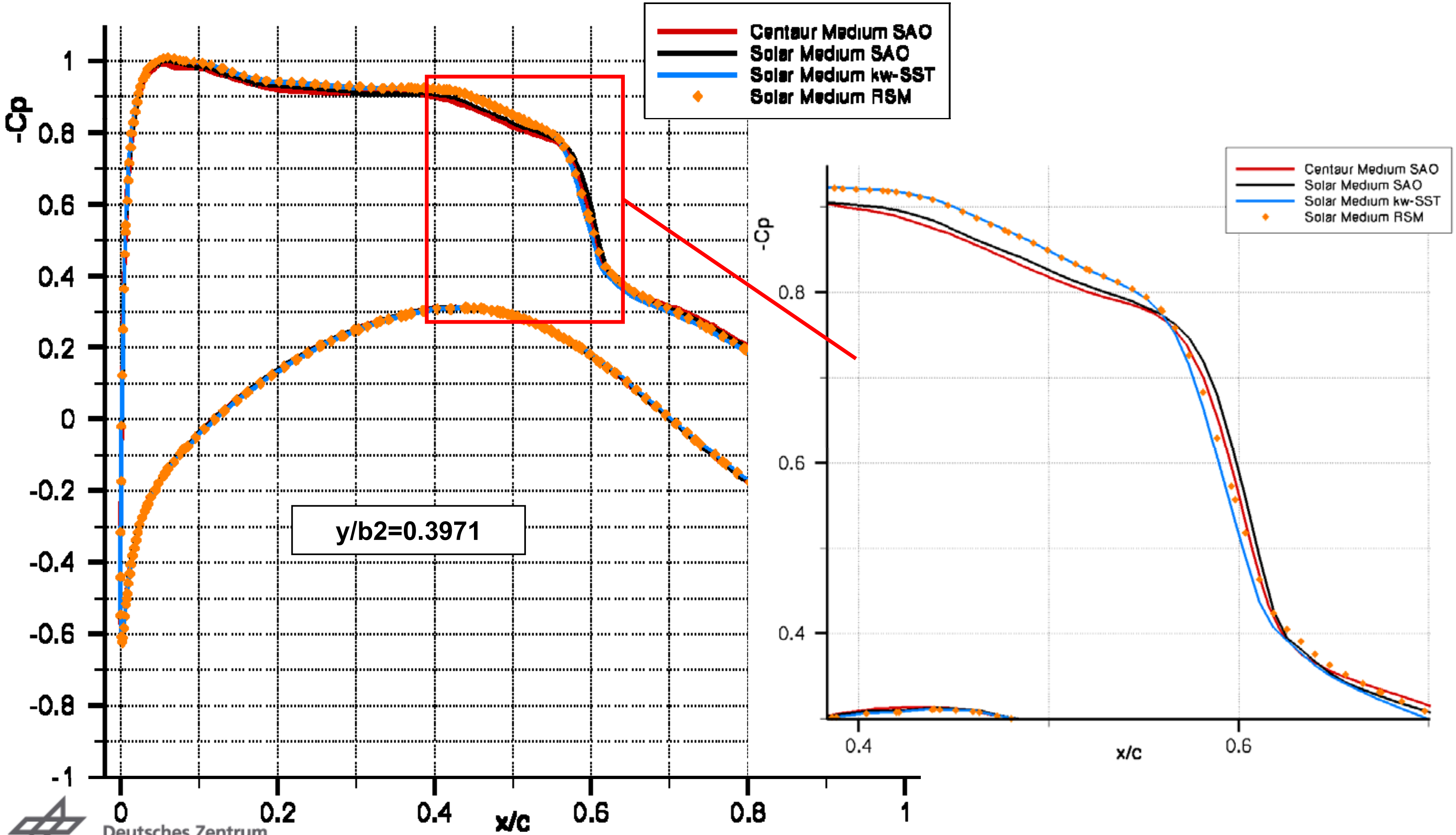

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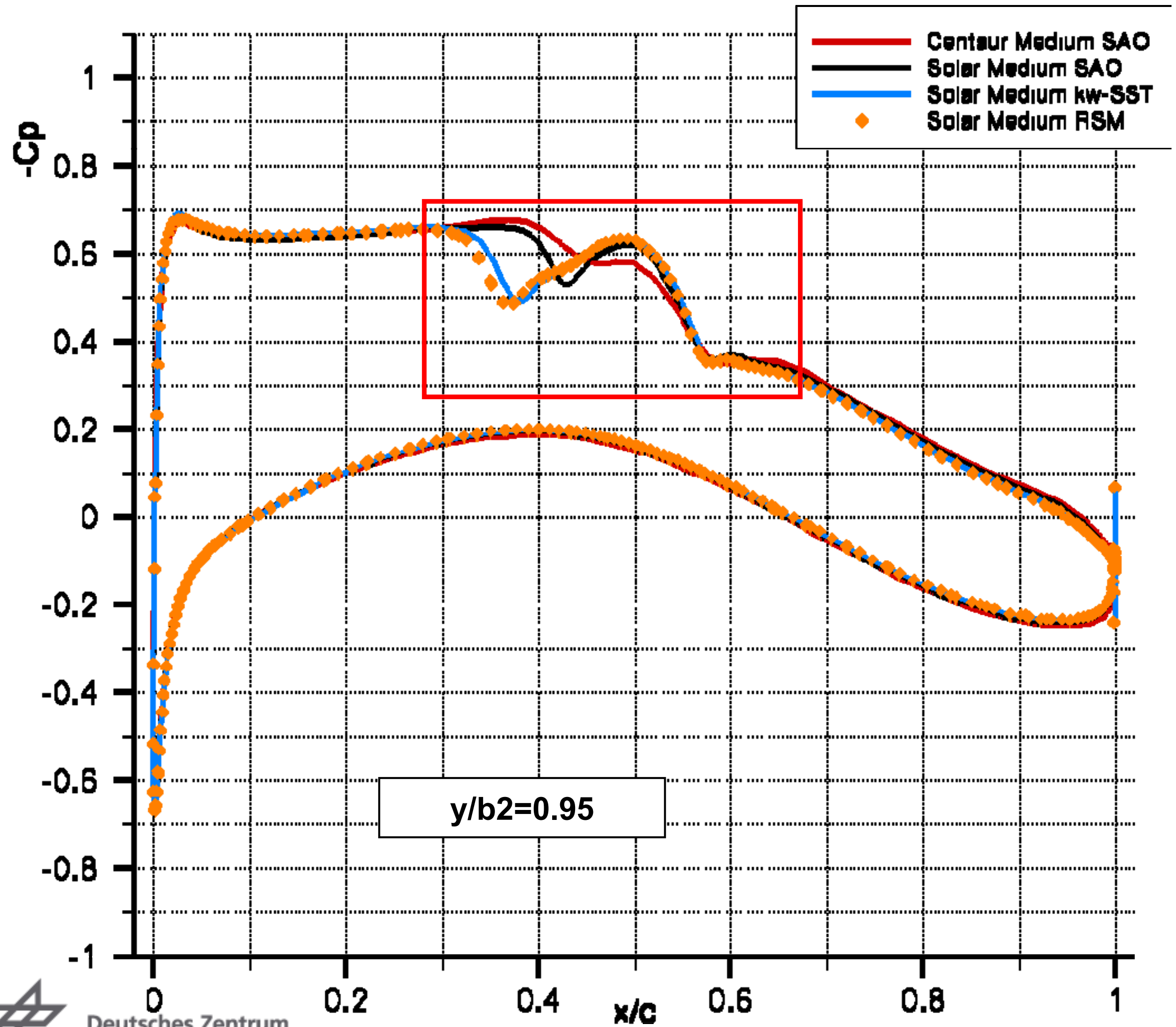
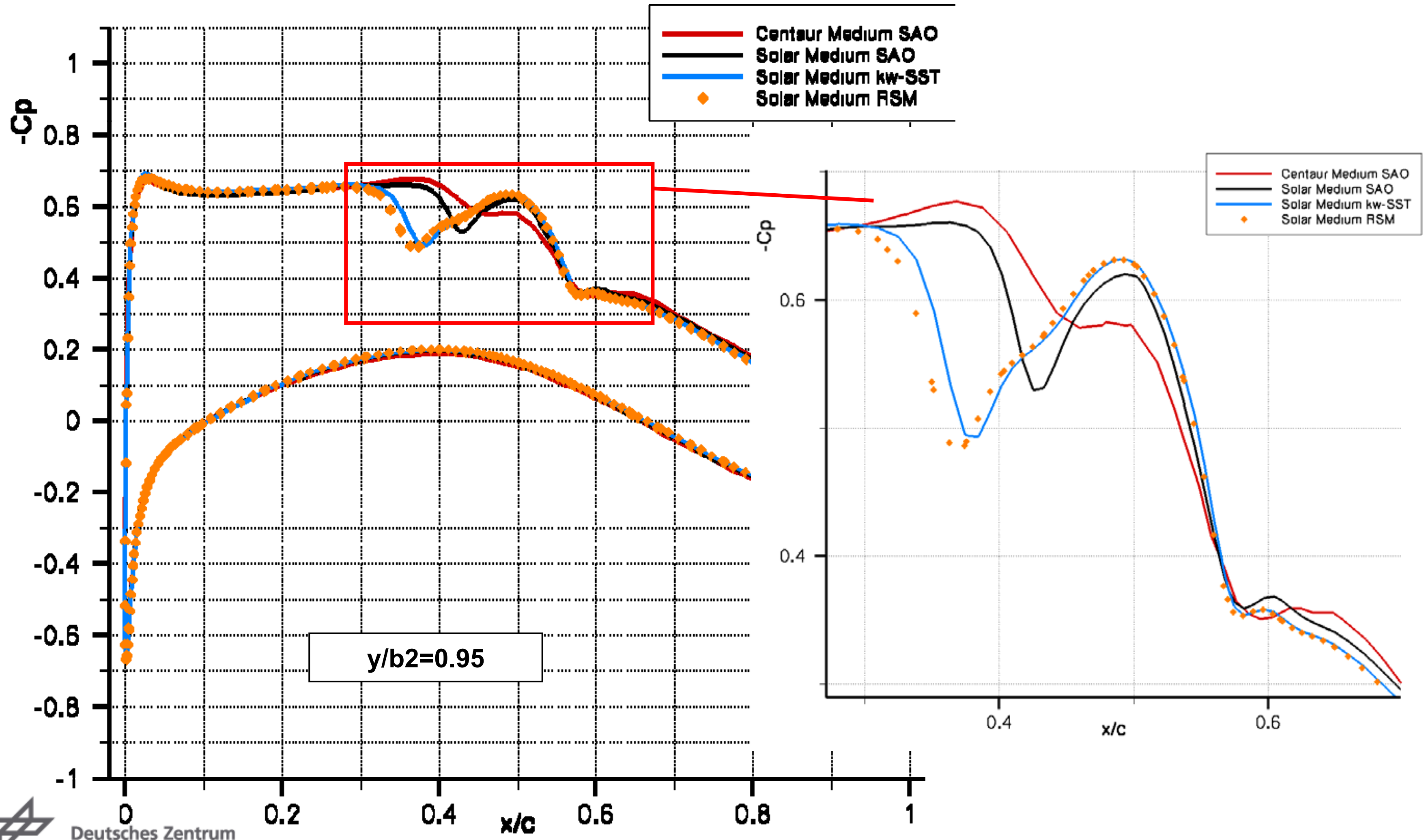
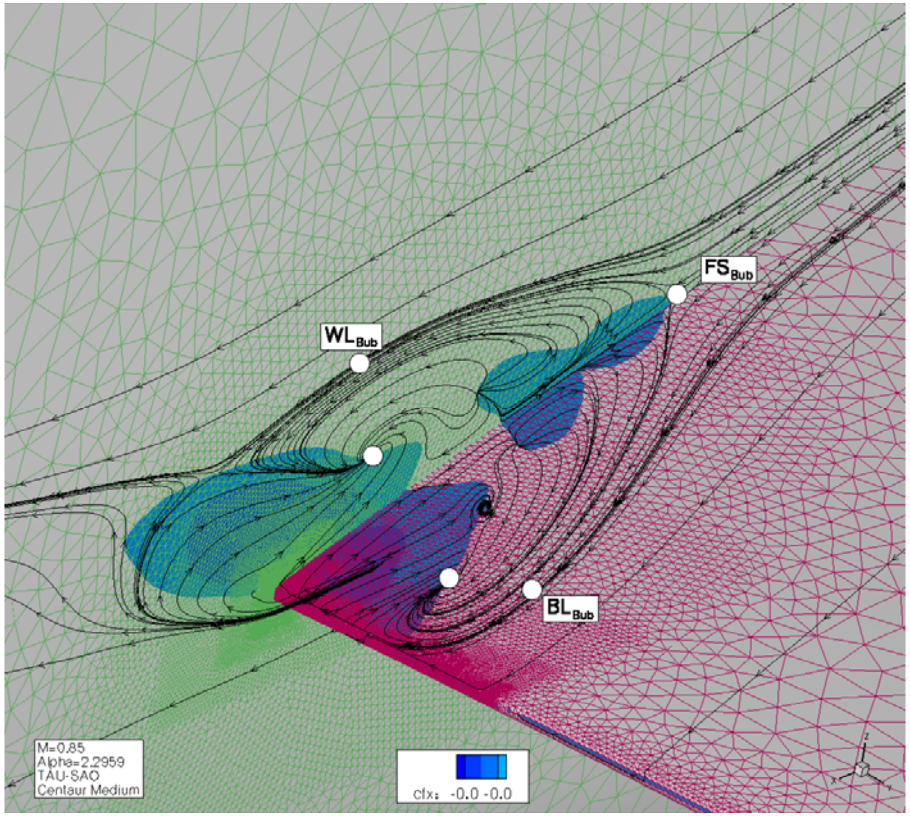


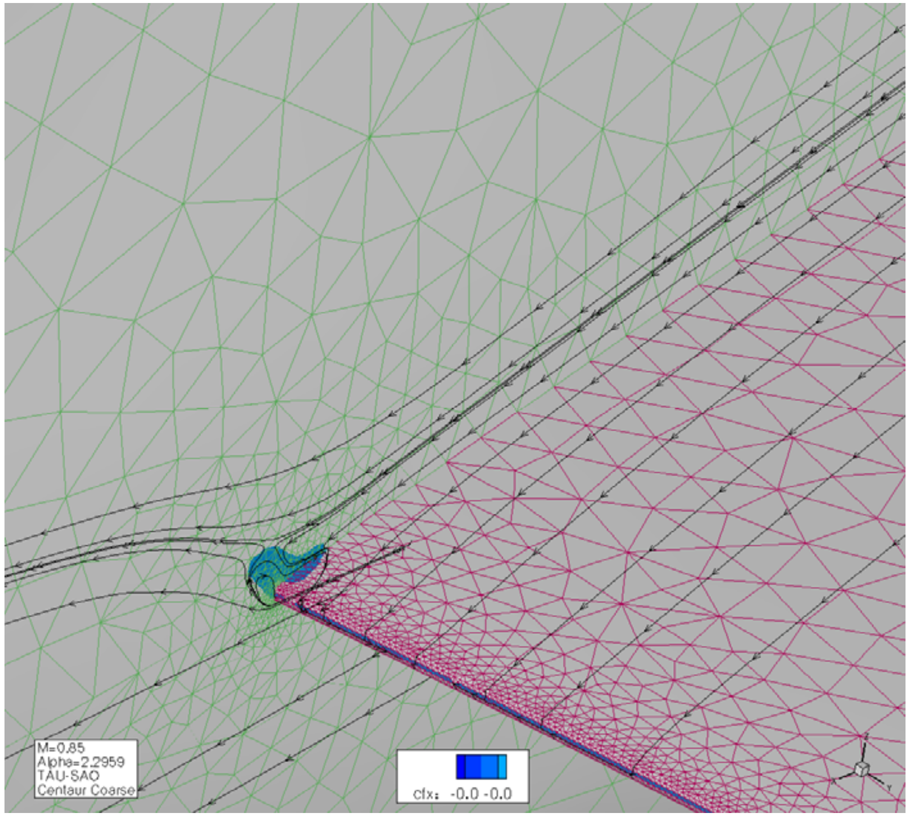
Case 1.1
— Turbulence Model —



Case 1.1
— Grid Size —

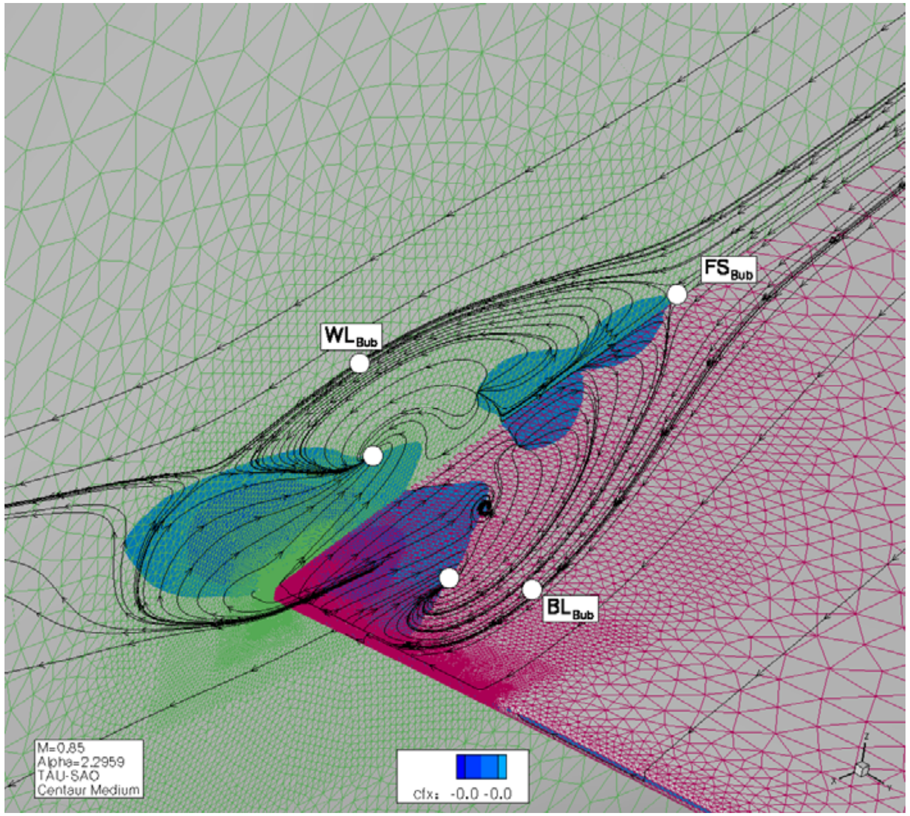


SAO, Centaur grid, medium

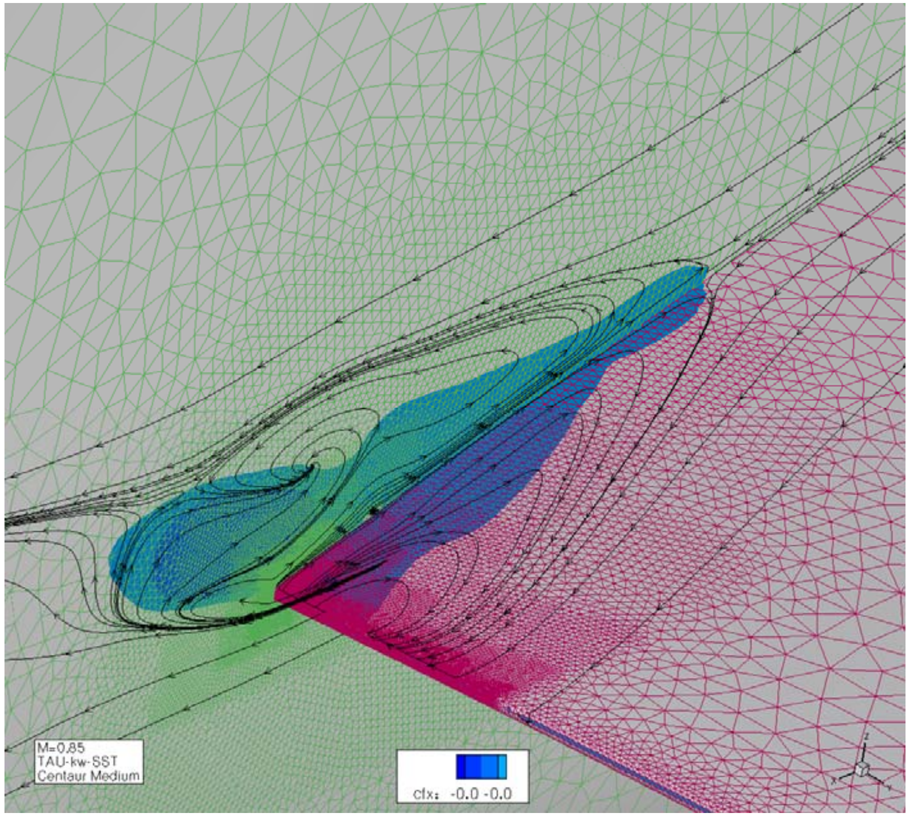


SAO, Centaur grid, coarse

Case 1.1
— Turbulence Model —



SAO, Centaur grid, medium



Menter kω-SST, Centaur grid, medium

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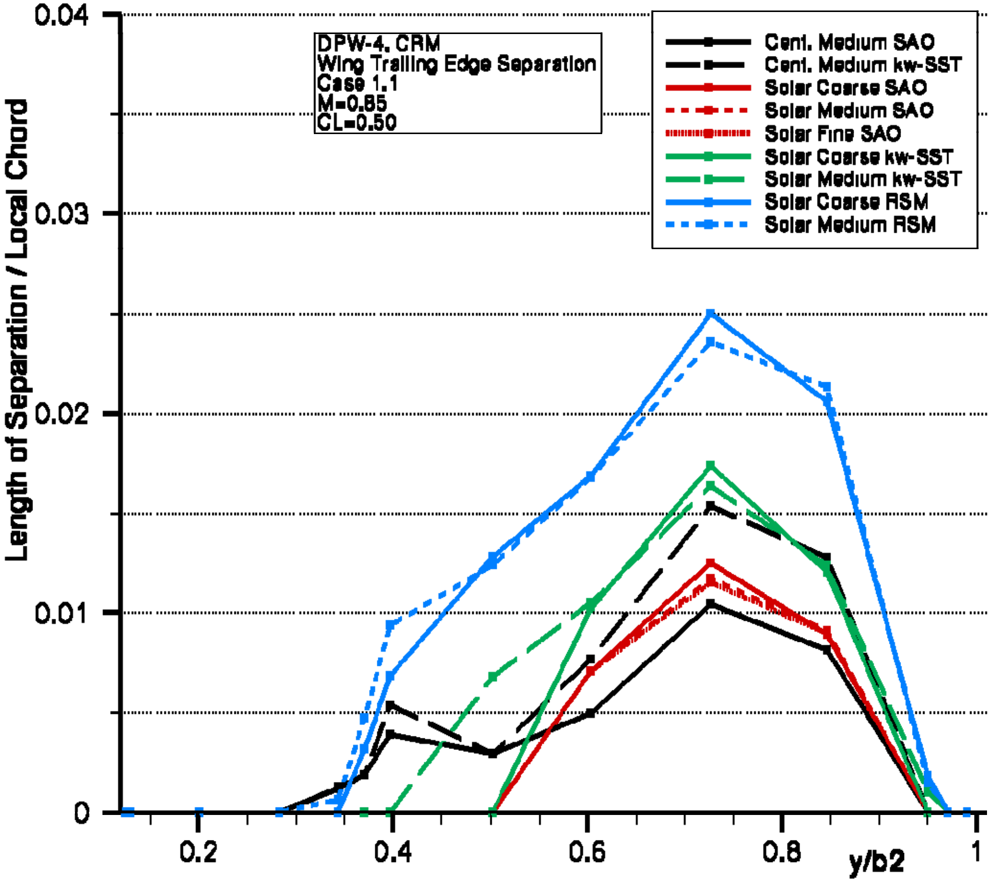

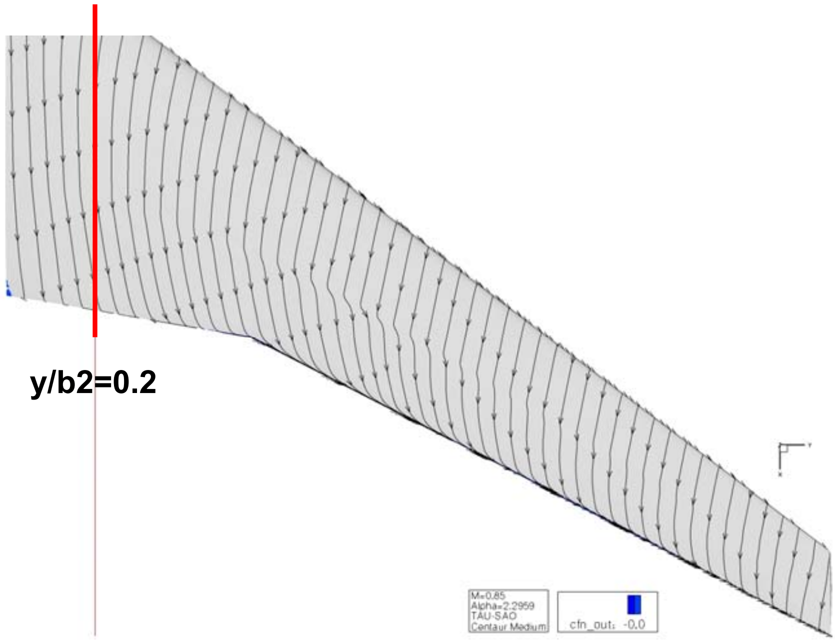

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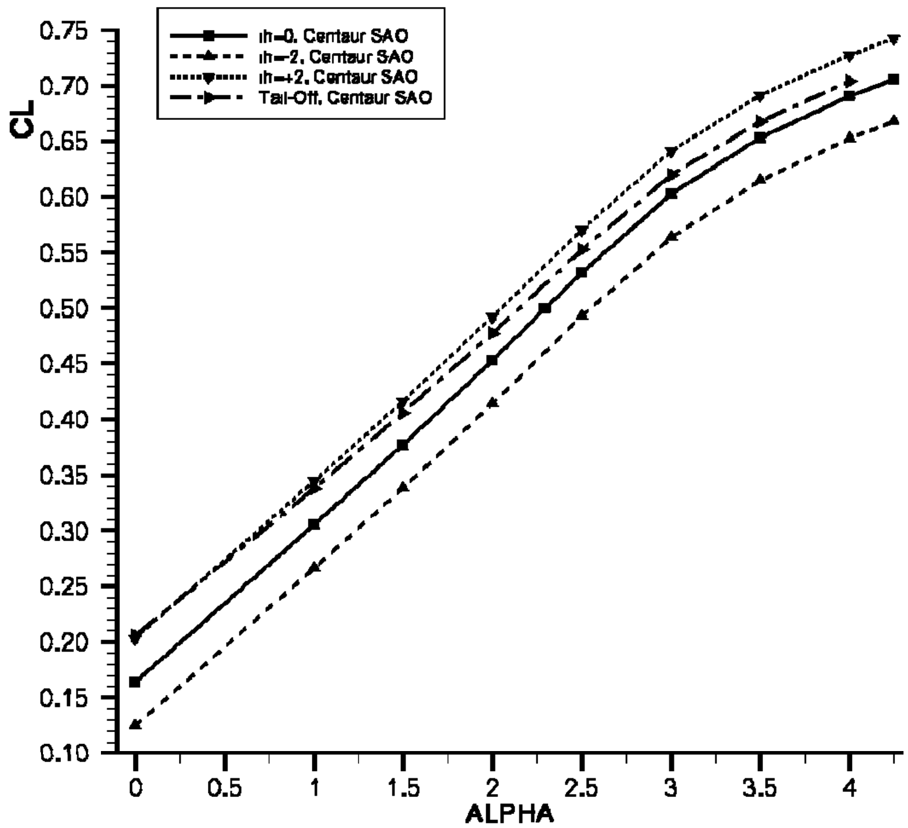
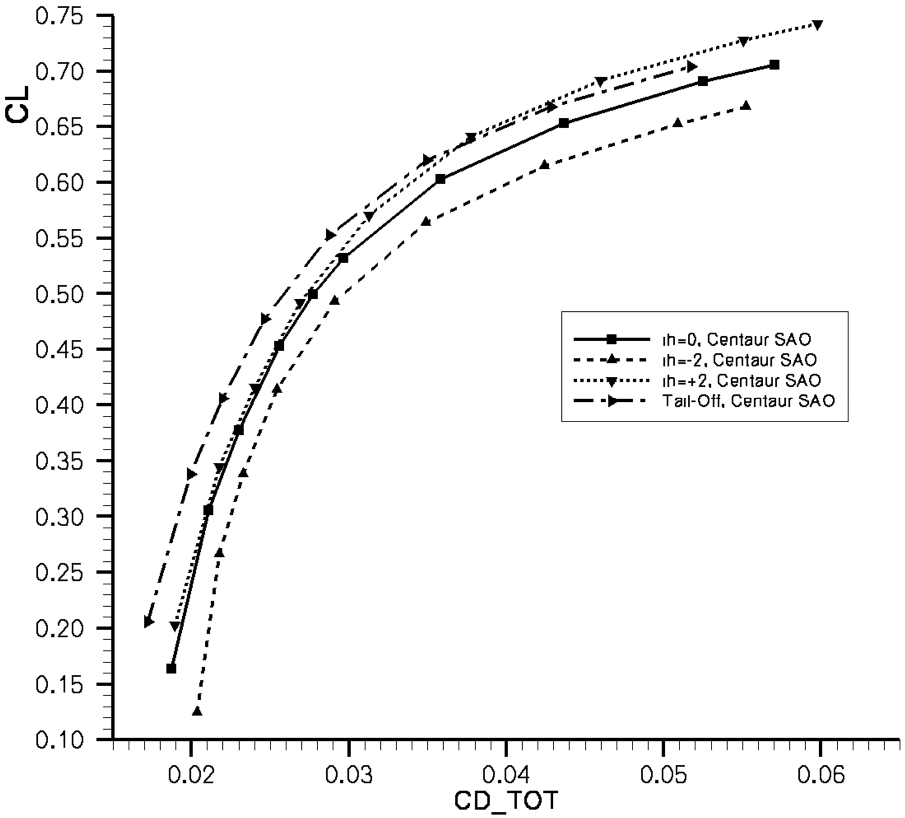
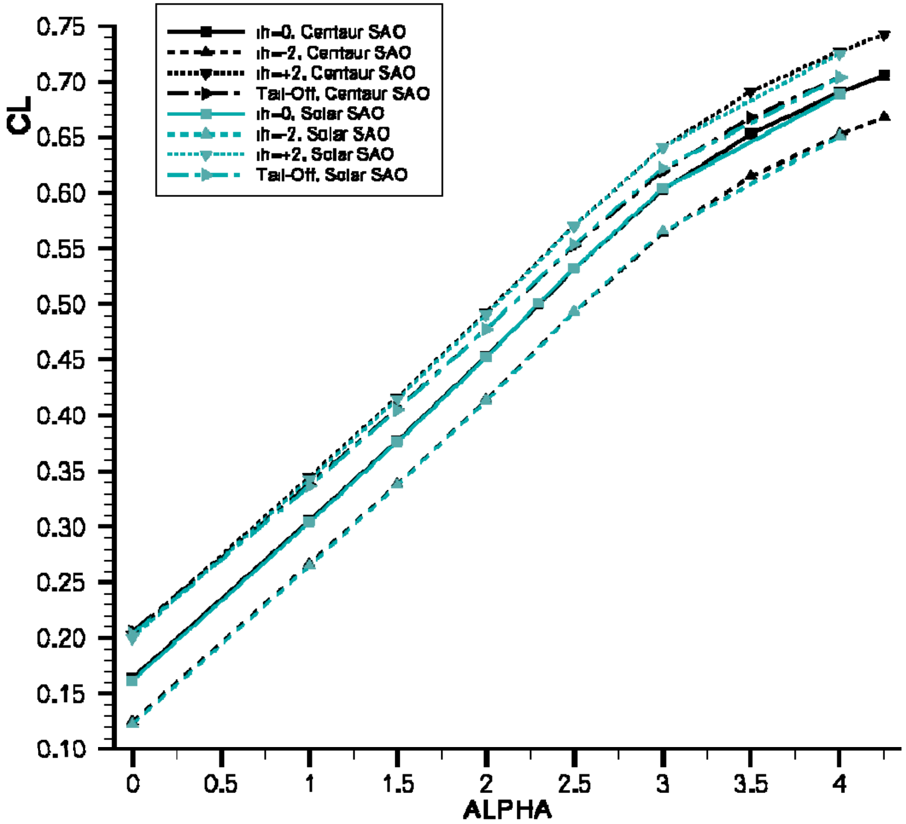
Case 1.2
— C_L-α, Polar, HTP Settings —

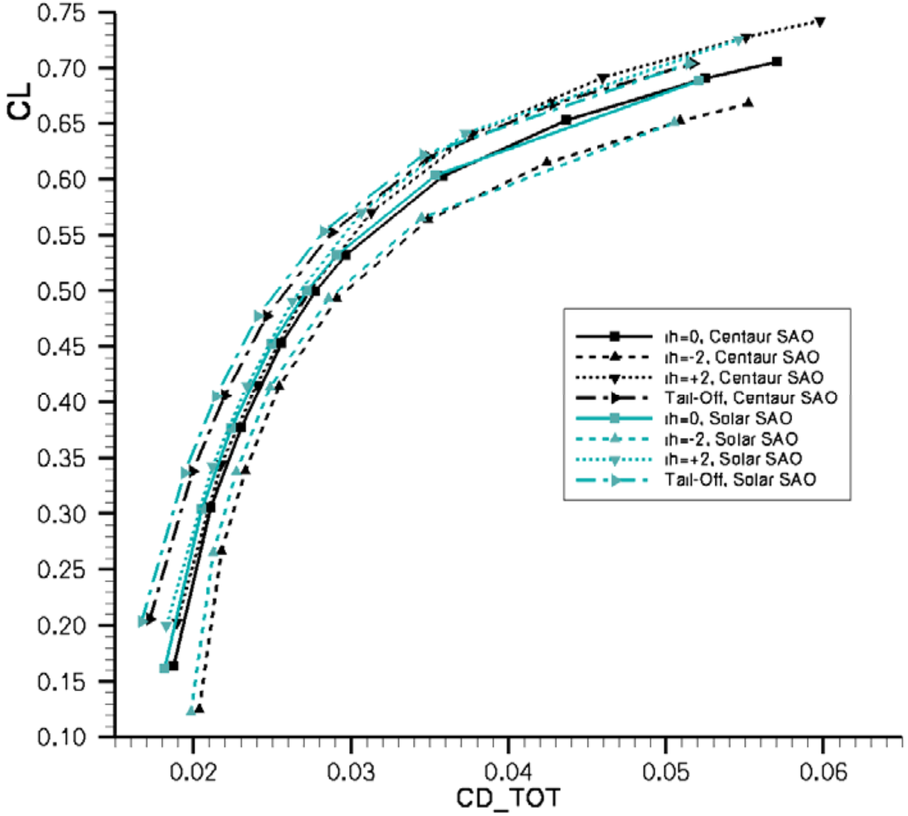




Case 1.2

— C_L-α, Polar, HTP Settings, Grid Type —





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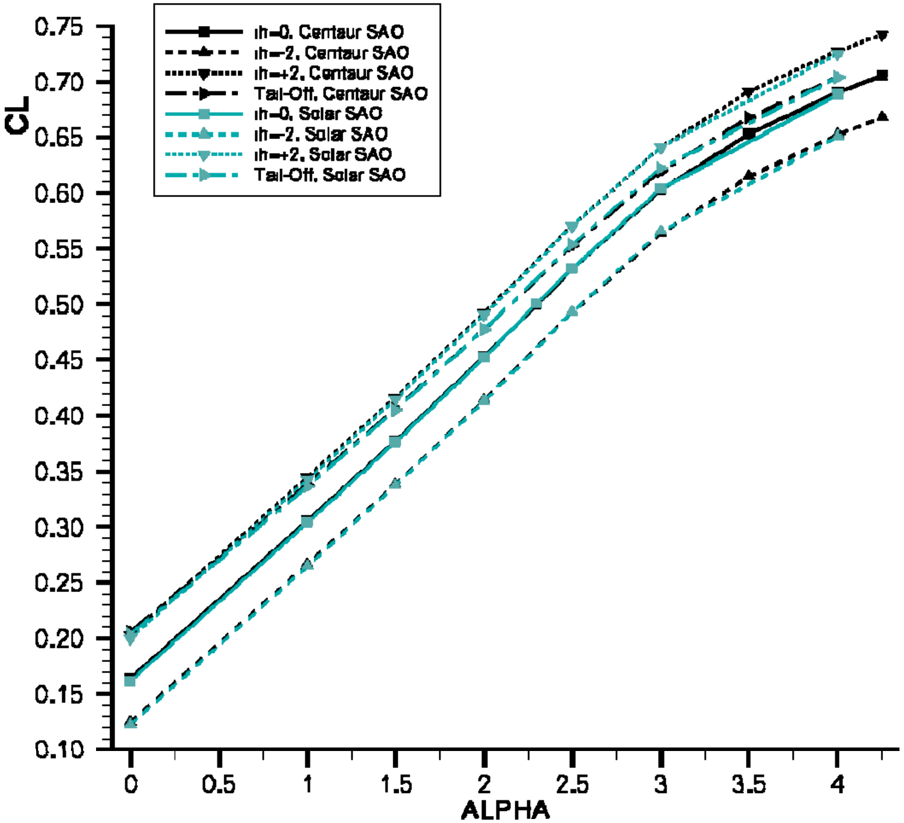
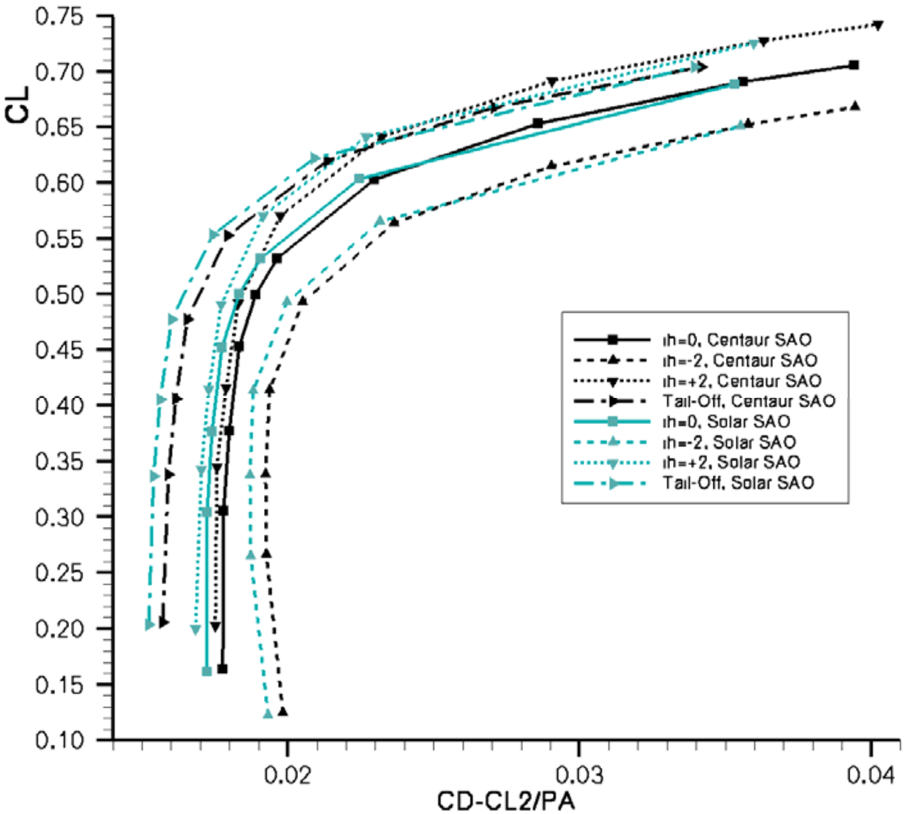
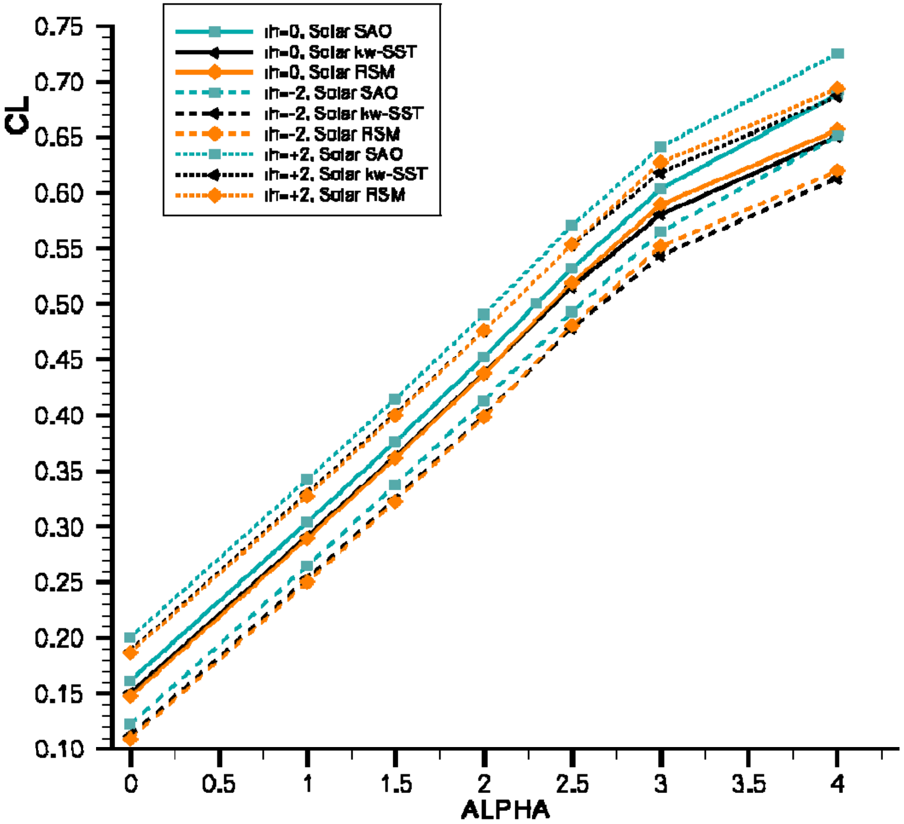
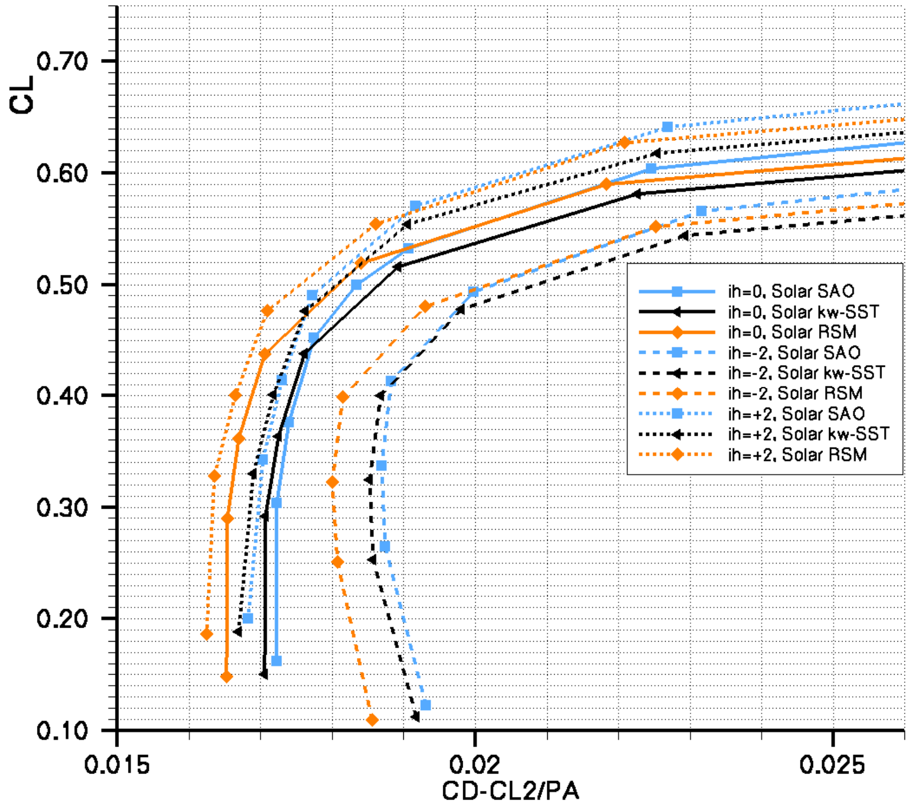




Case 1.2

— C_L-α, Polar, Turbulence Model, HTP Setting —





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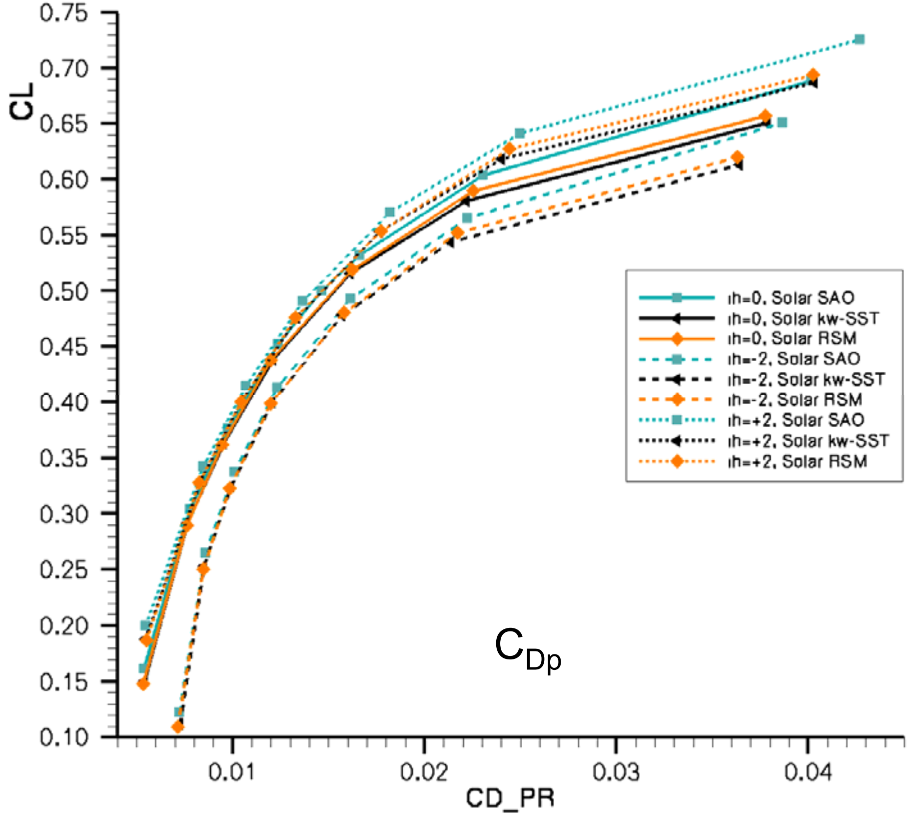
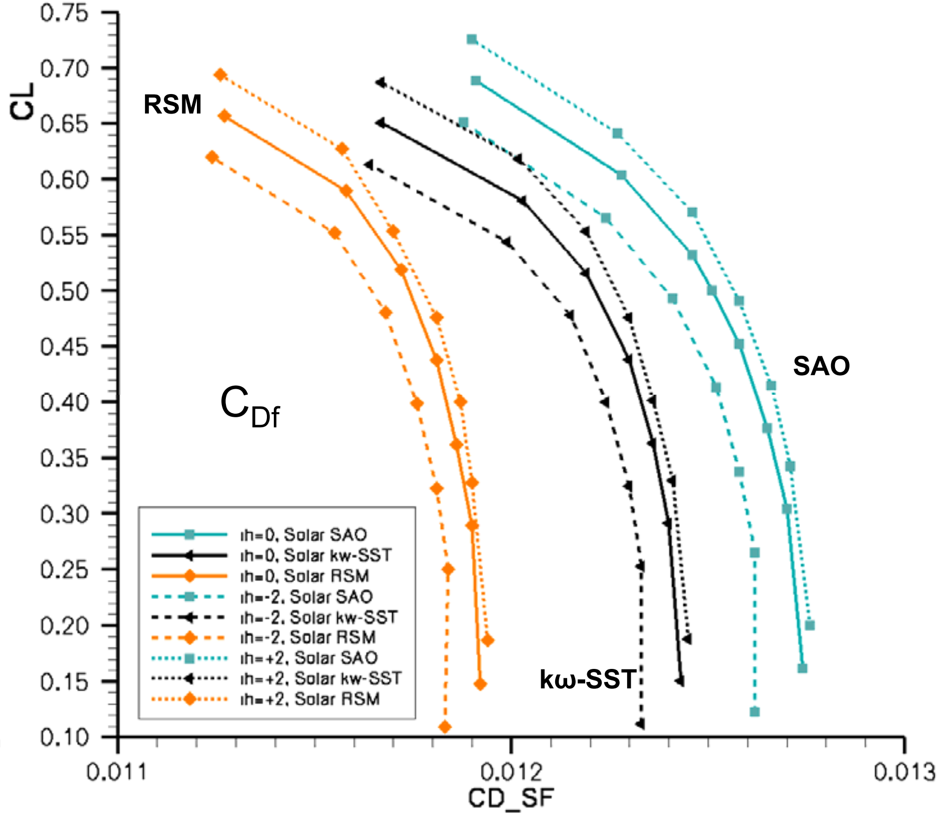
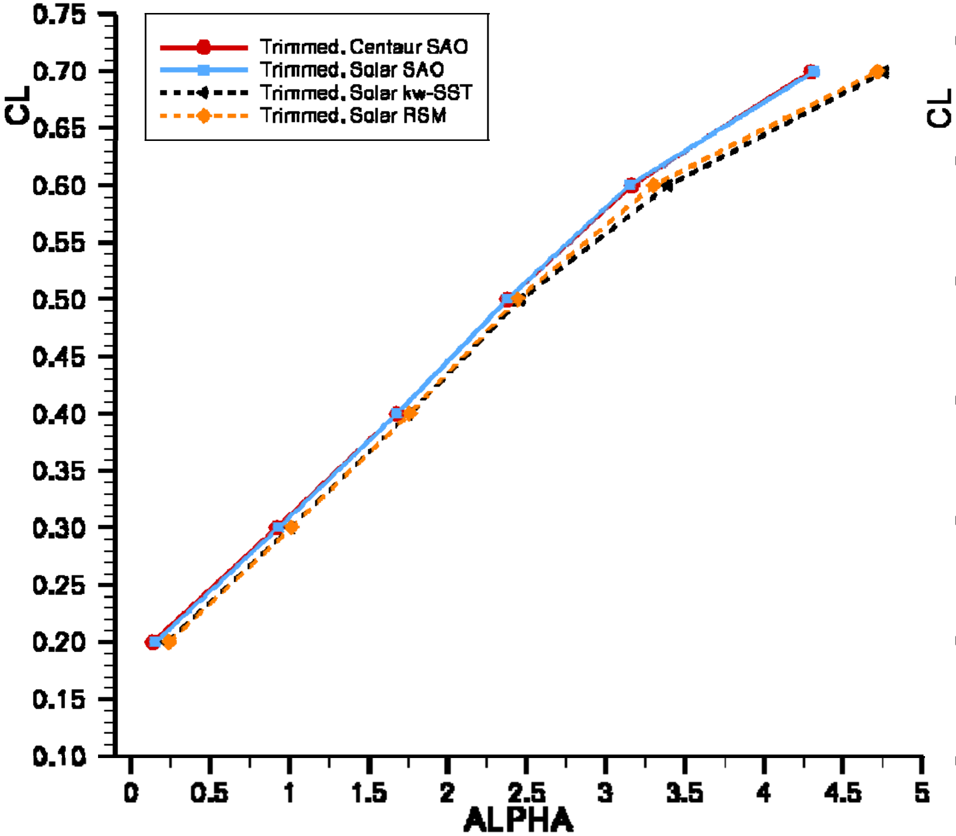
Case 1.2
— $C_{Dp/f}$ Polar, Turbulence Model, HTP Setting —

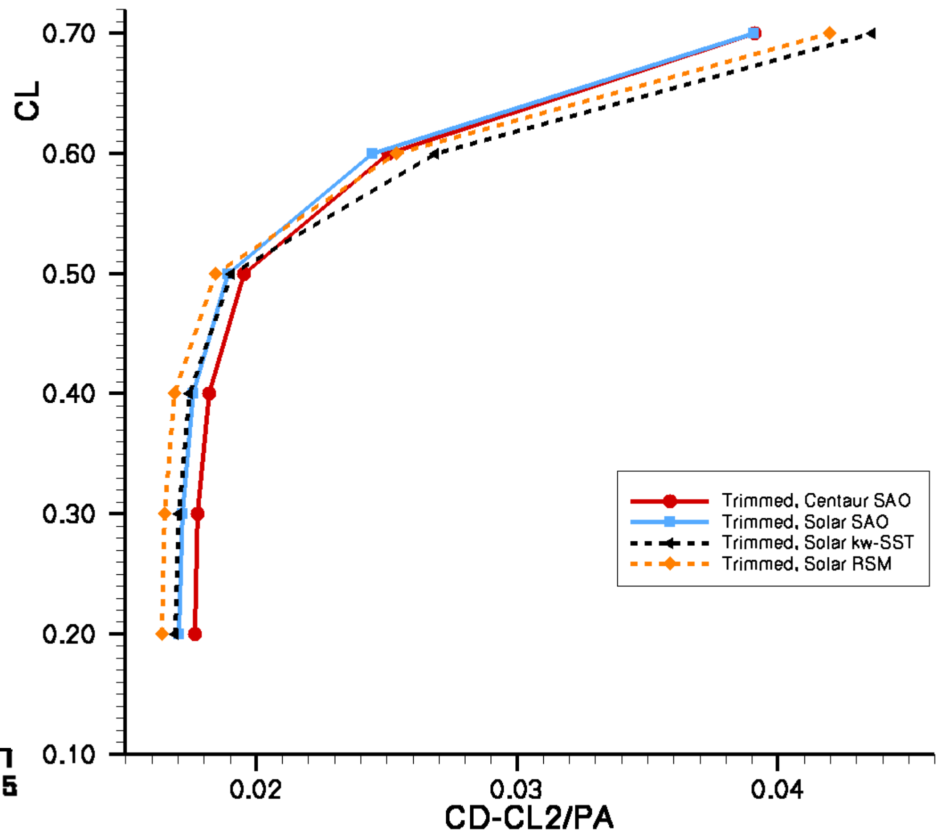




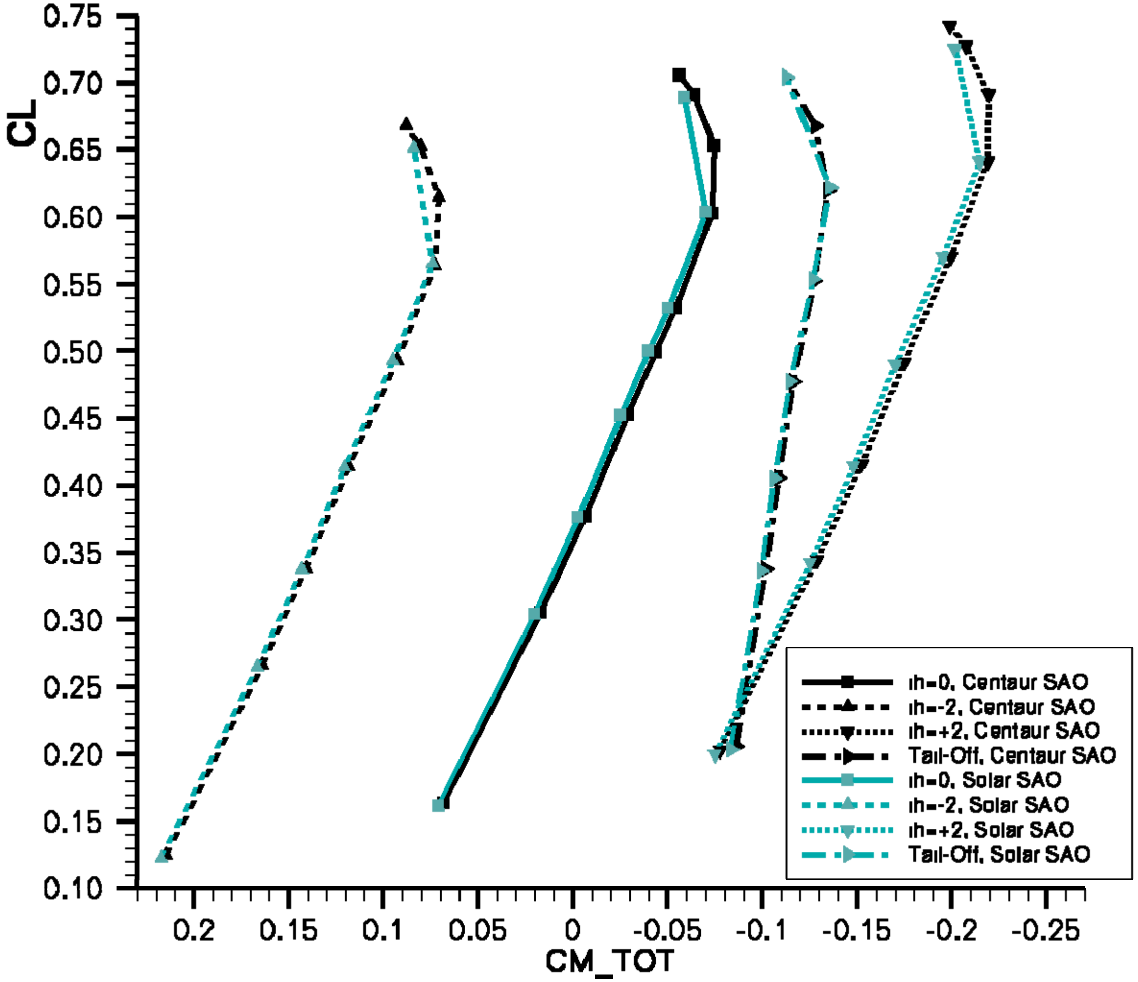
Case 1.2

— C_L-α, Polar, Trimmed, Turbulence Model, Grid Type —

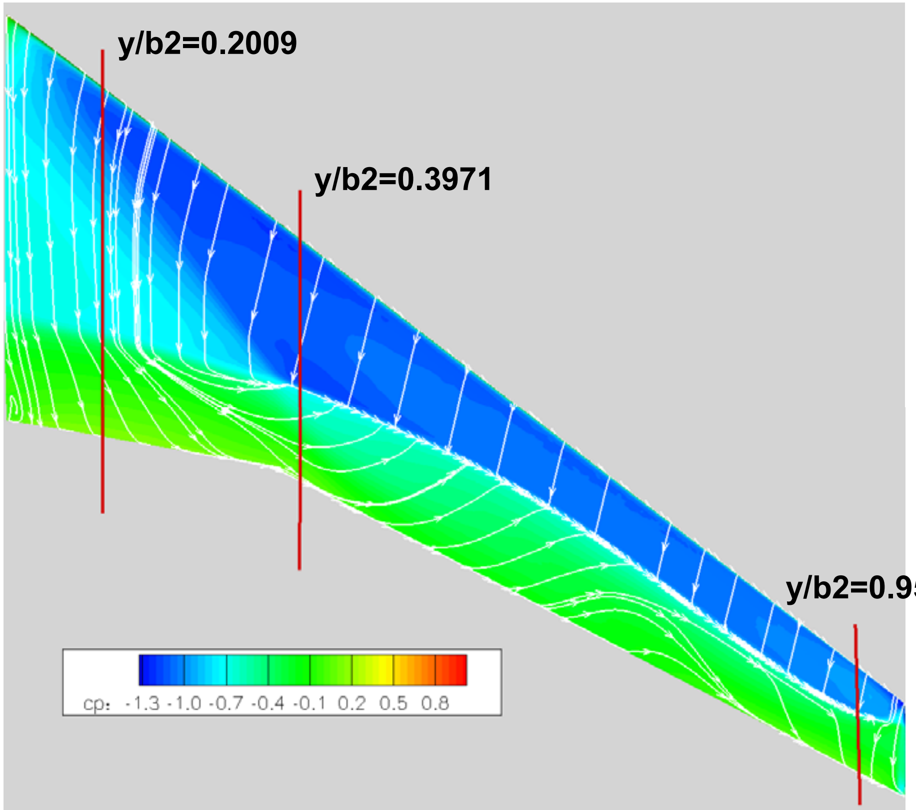




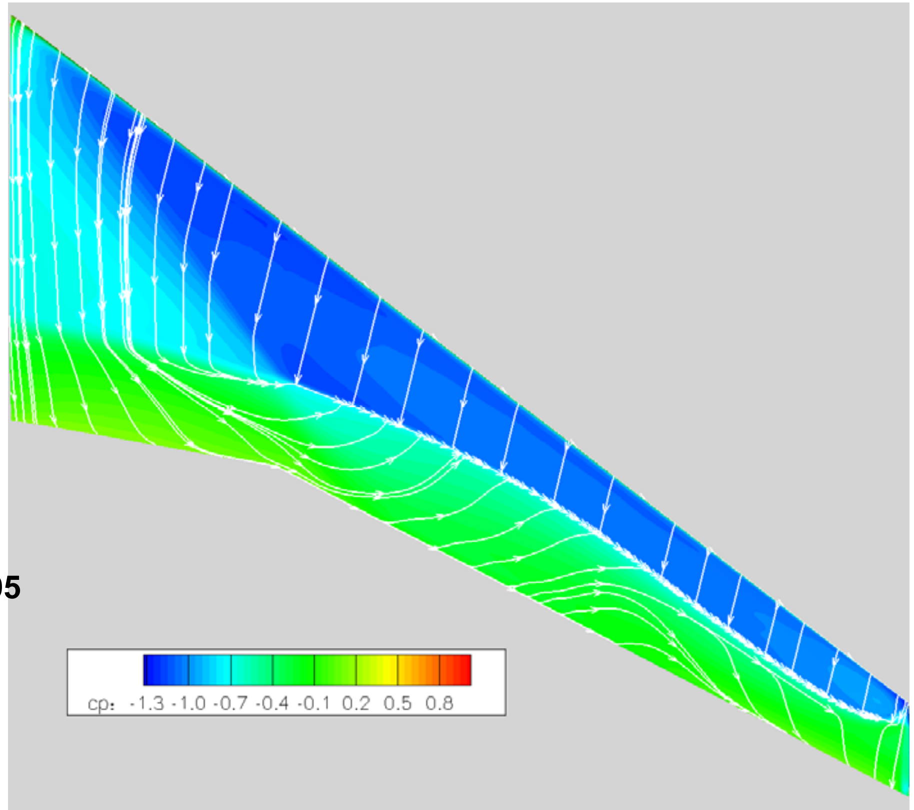
Case 1.2
— C_L-C_M, Grid Type —



— Flow Features, α=4.0°, Grid Type —

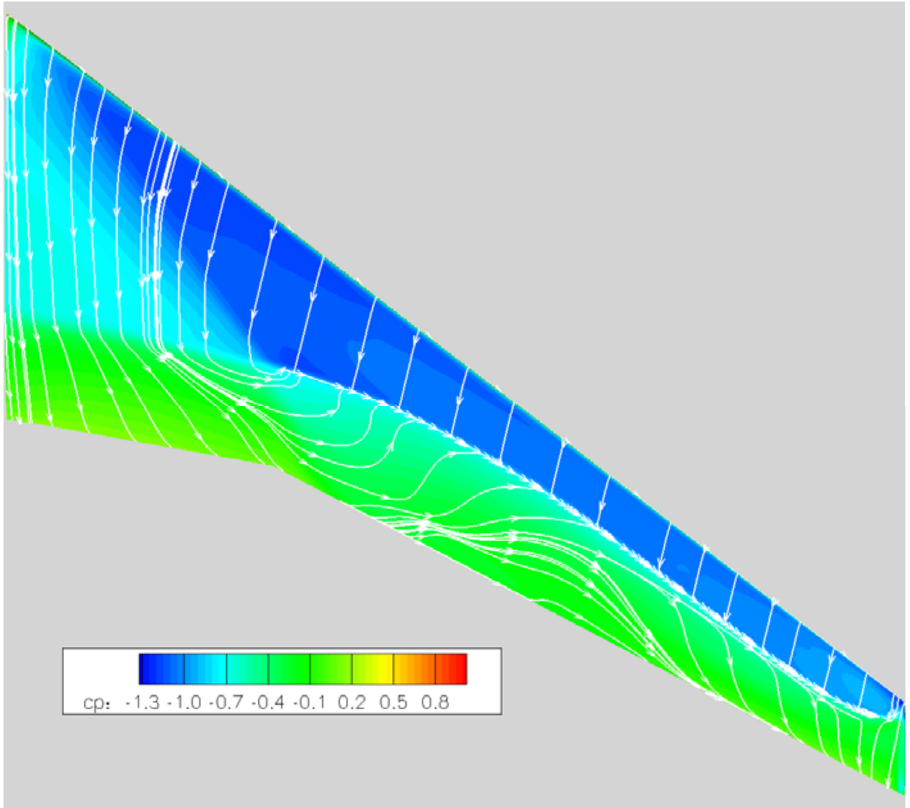


SAO, Centaur medium grid

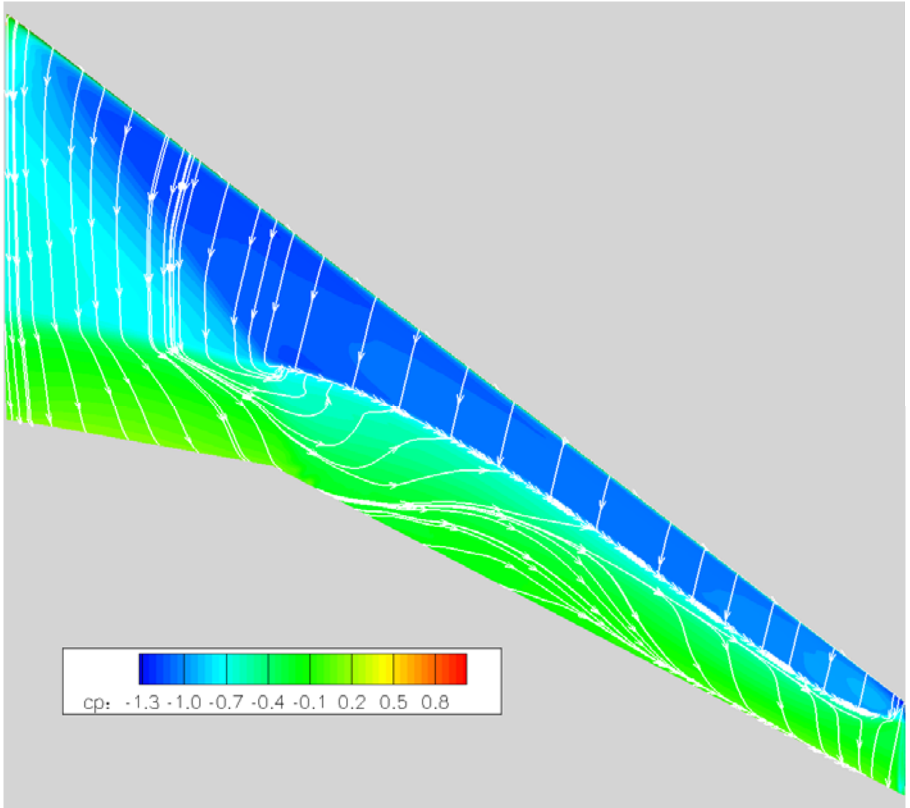


SAO, Solar medium grid

Case 1.2
— Flow Features, α=4.0°, Turbulence Model —



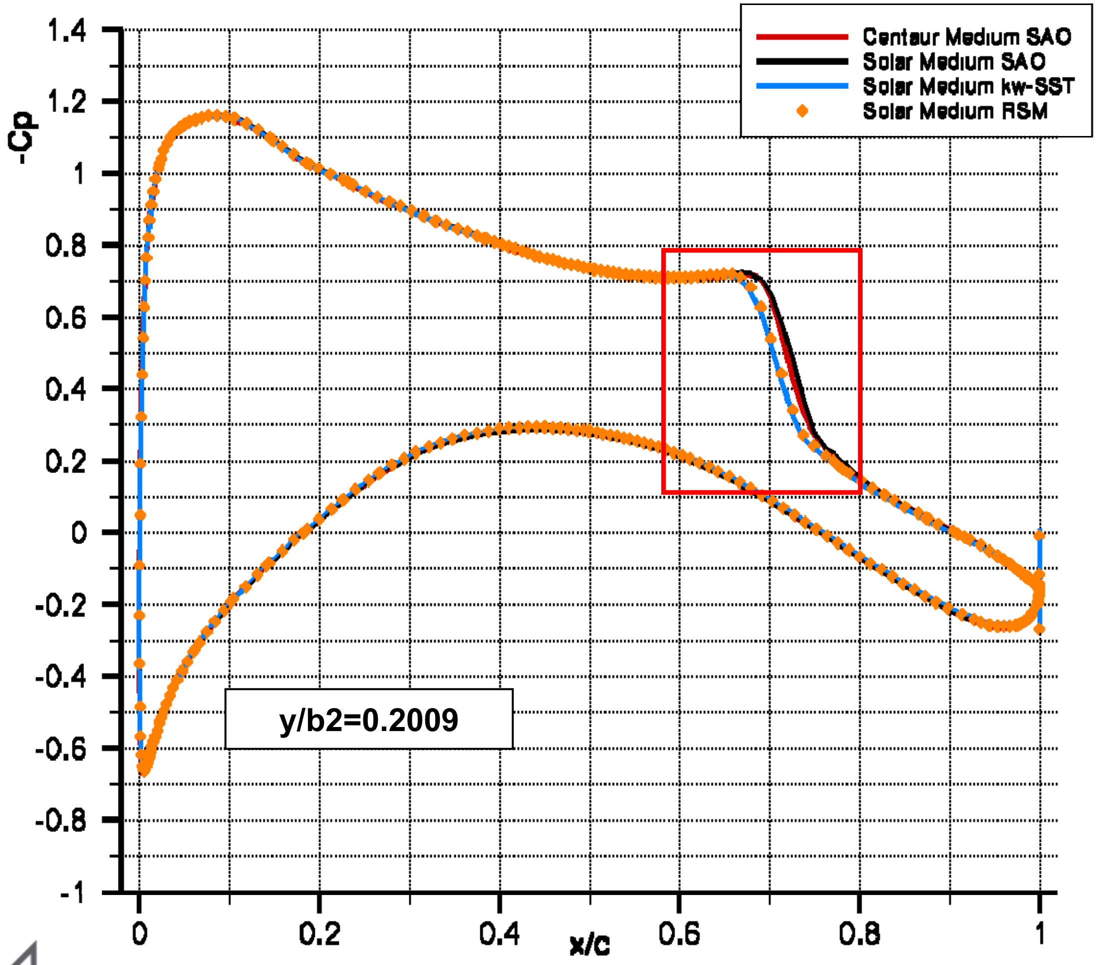
Menter kω-SST, Solar medium grid



RSM, Solar medium grid

Case 1.2

— Pressure Distribution, α=4.0°, Turbulence Model —



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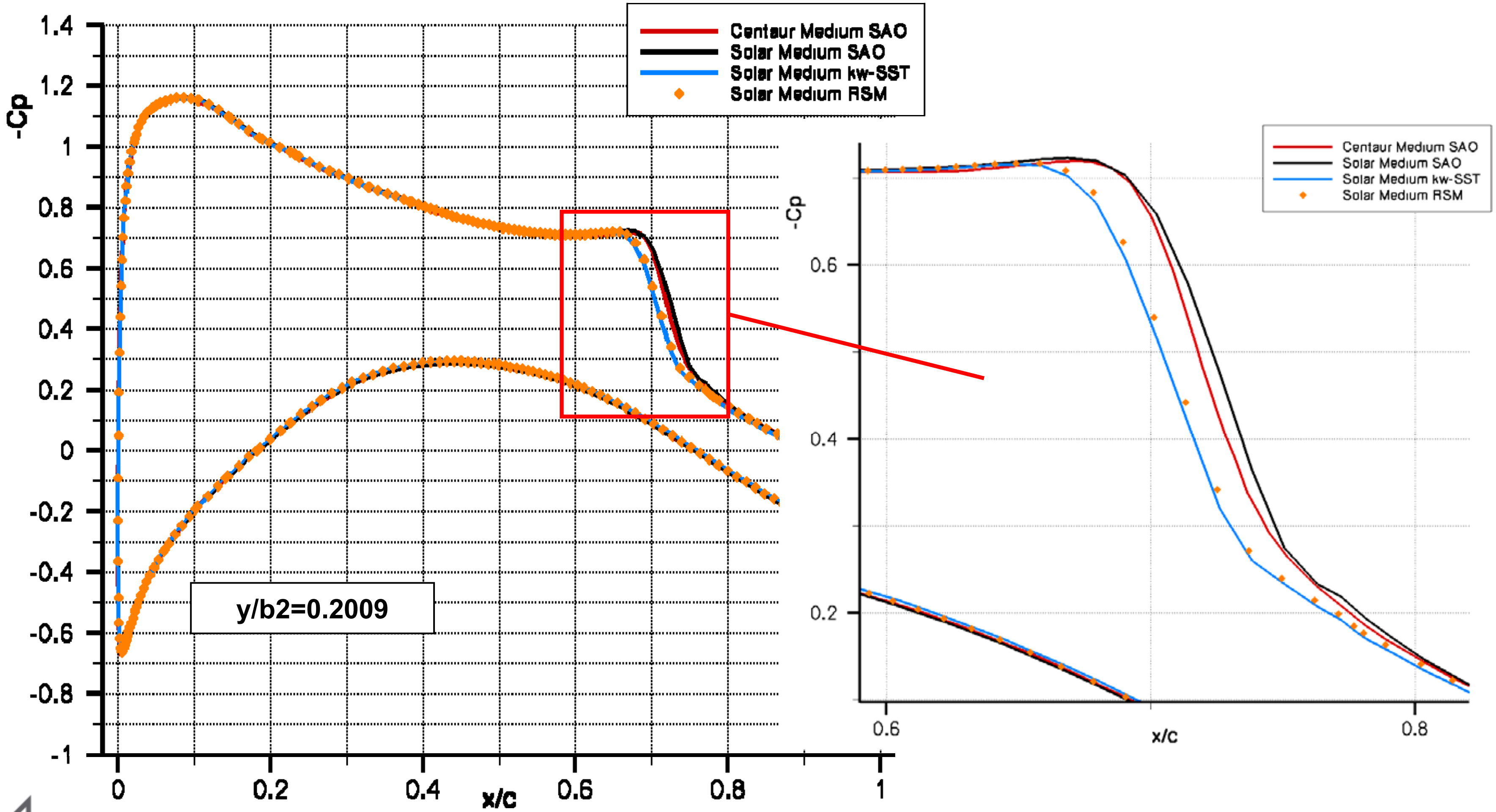

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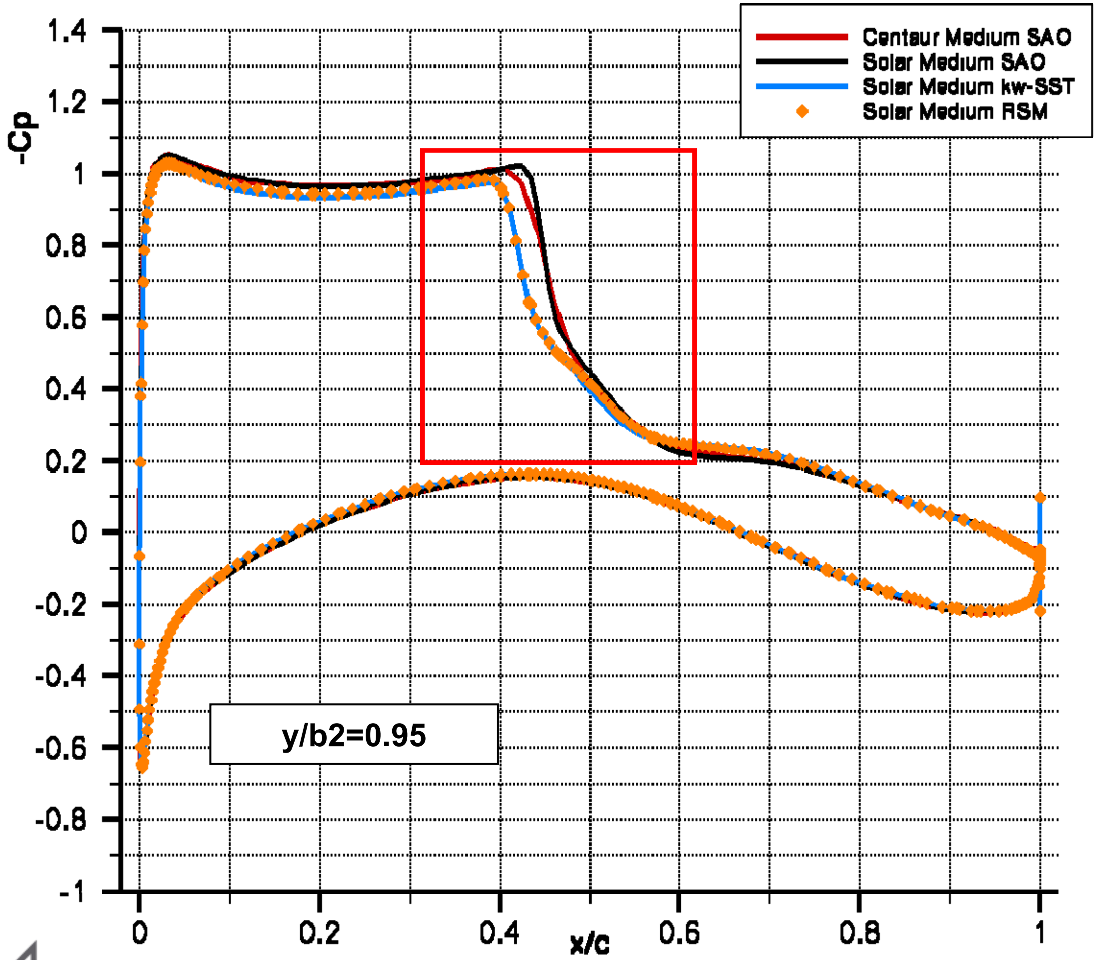

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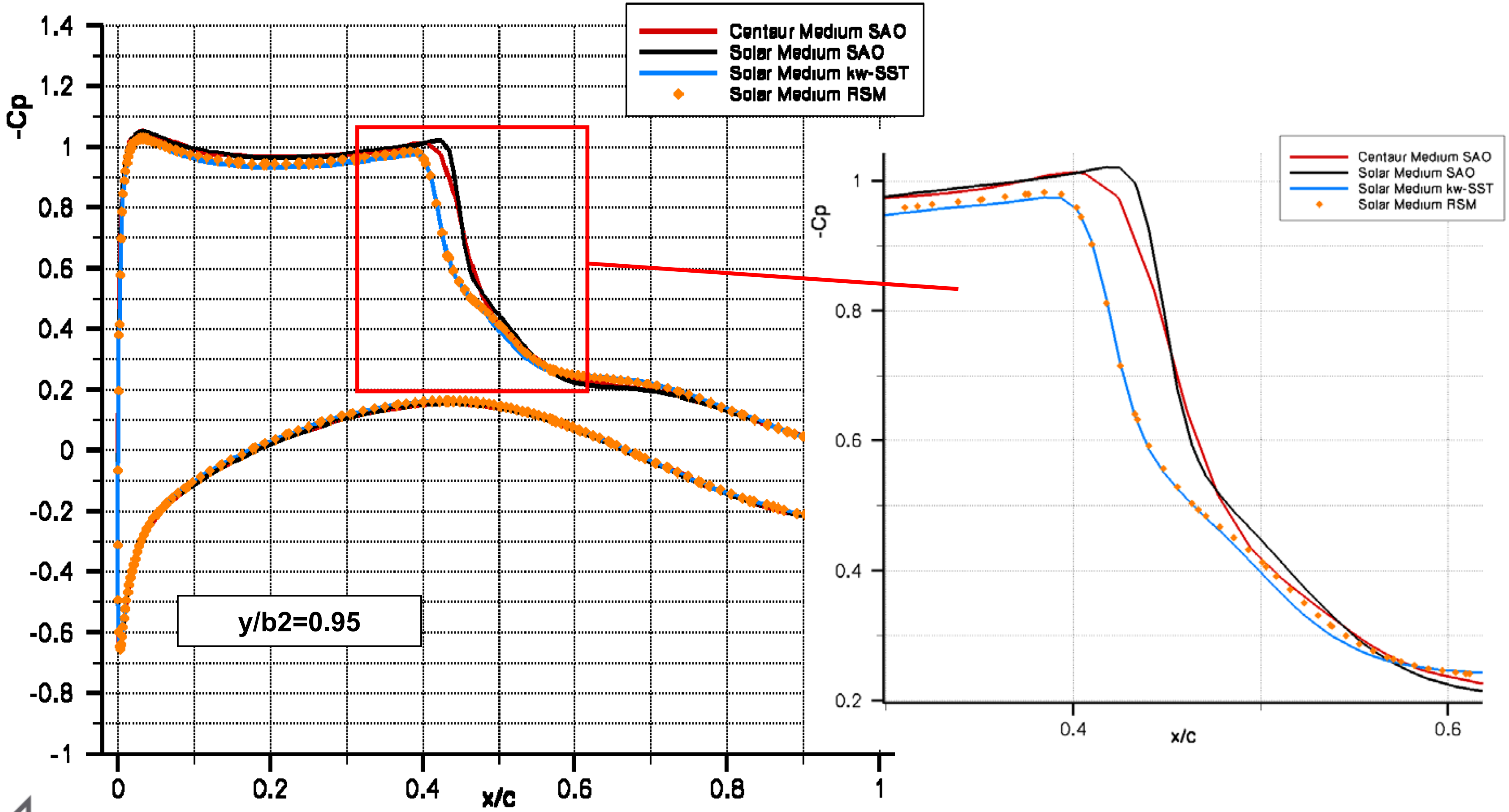
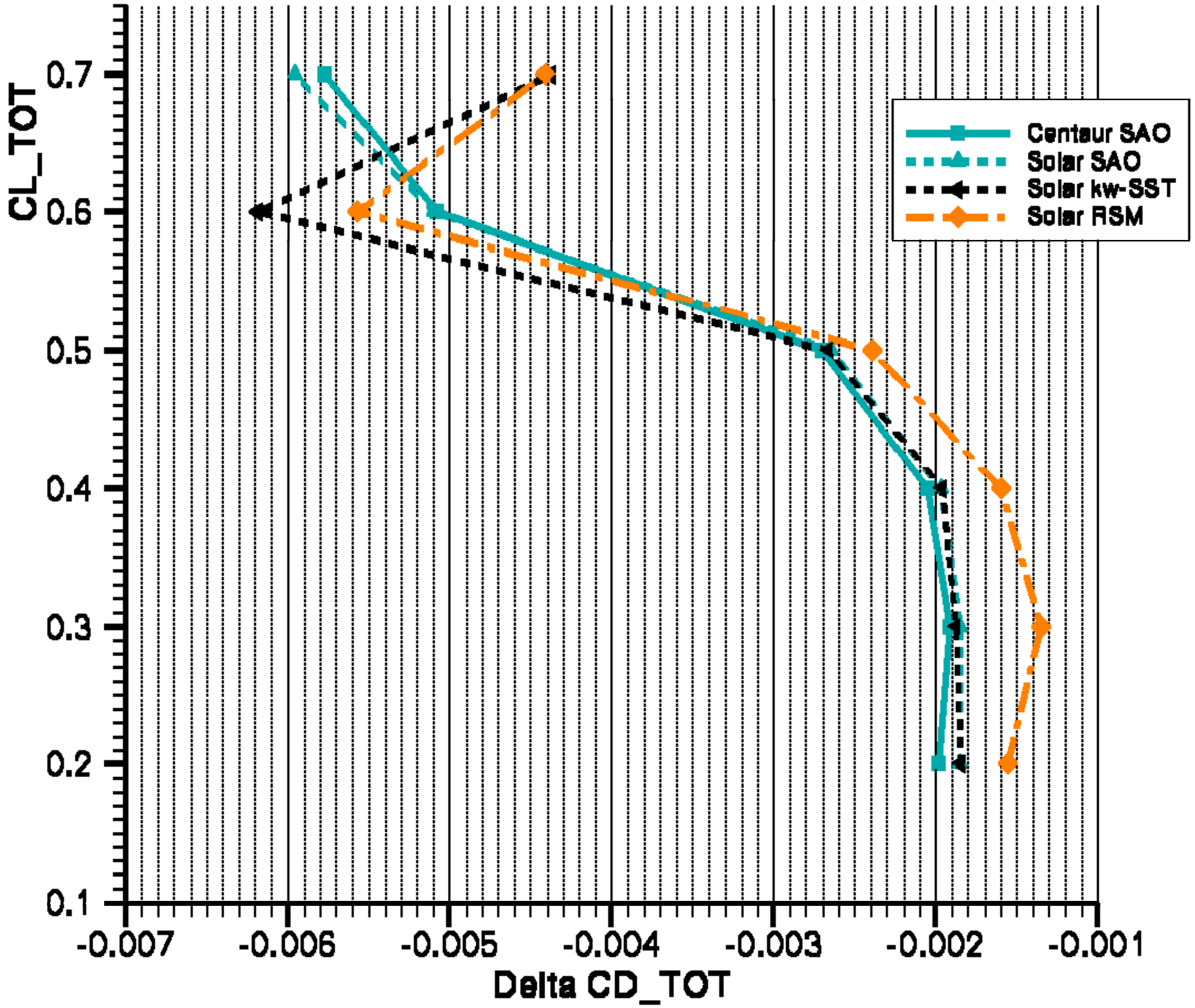


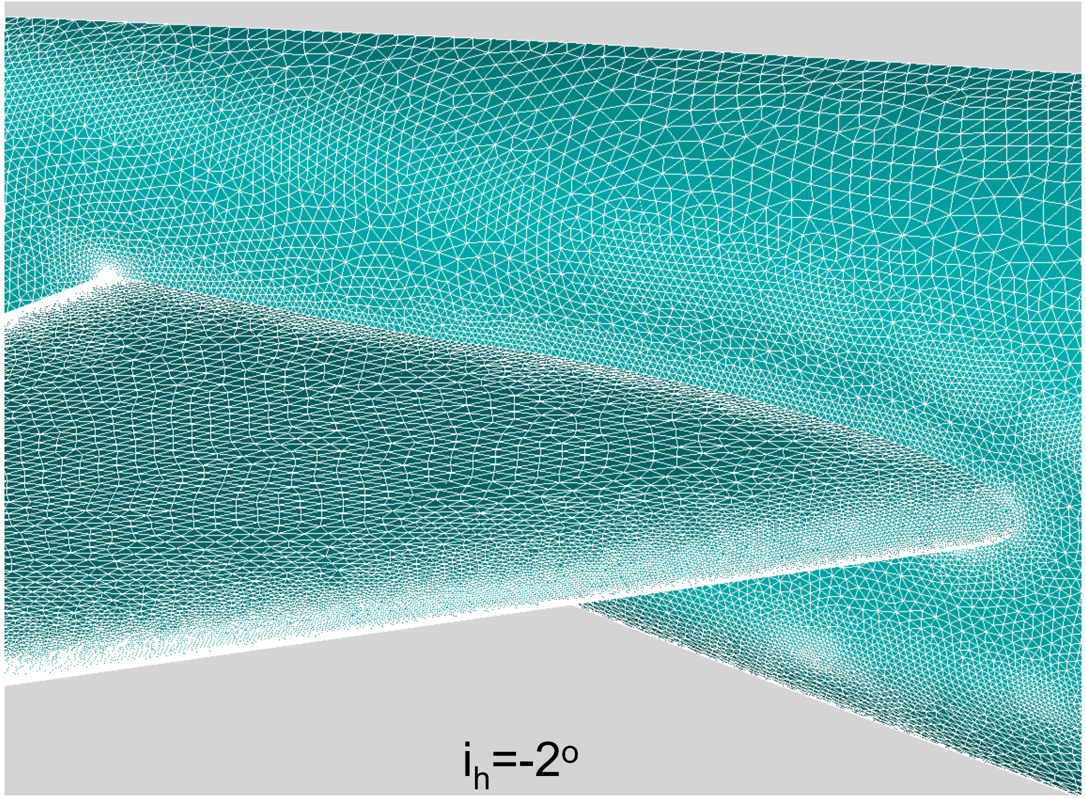
Case 1.2
— Delta Drag, Turbulence Model —

- Tail-off minus trimmed configuration



Case 1.2
— HTP Setting Modification —

- Iterative modification of i_h during CFD calculations towards C_M=0, C_L=0.5
- Mesh deformation used based on radial basis functions
- Differences to interpolated data are small
- $\Delta i_h = 0.0029^o$
- $\Delta\alpha = 0.000018^o$



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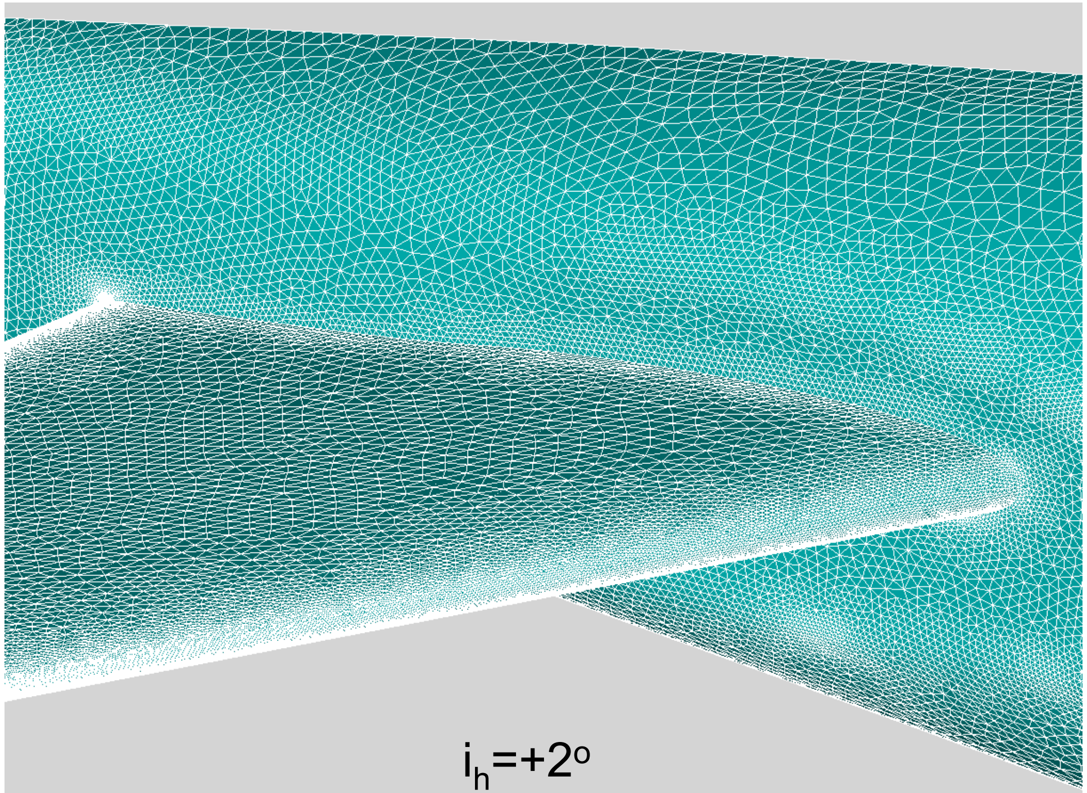
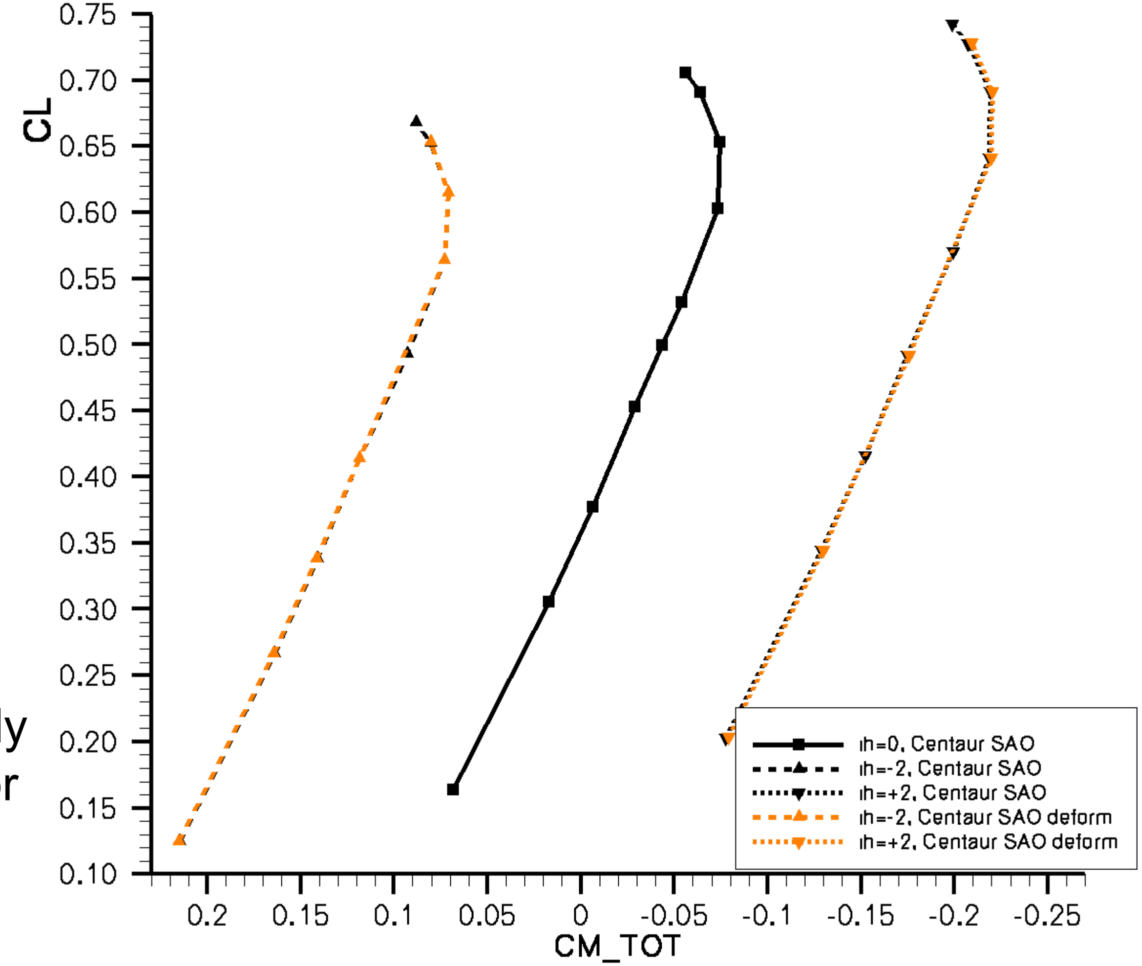


Case 1.2
— HTP Setting Modification —

- Iterative modification of i_h during CFD calculations towards $C_M=0$, $C_L=0.5$
- Mesh deformation used based on radial basis functions
- Differences to interpolated data are small
- $\Delta i_h=0.0029^o$
- $\Delta\alpha=0.000018^o$
- C_M for deformed grids nearly identical to C_M calculated for separately generated grids.



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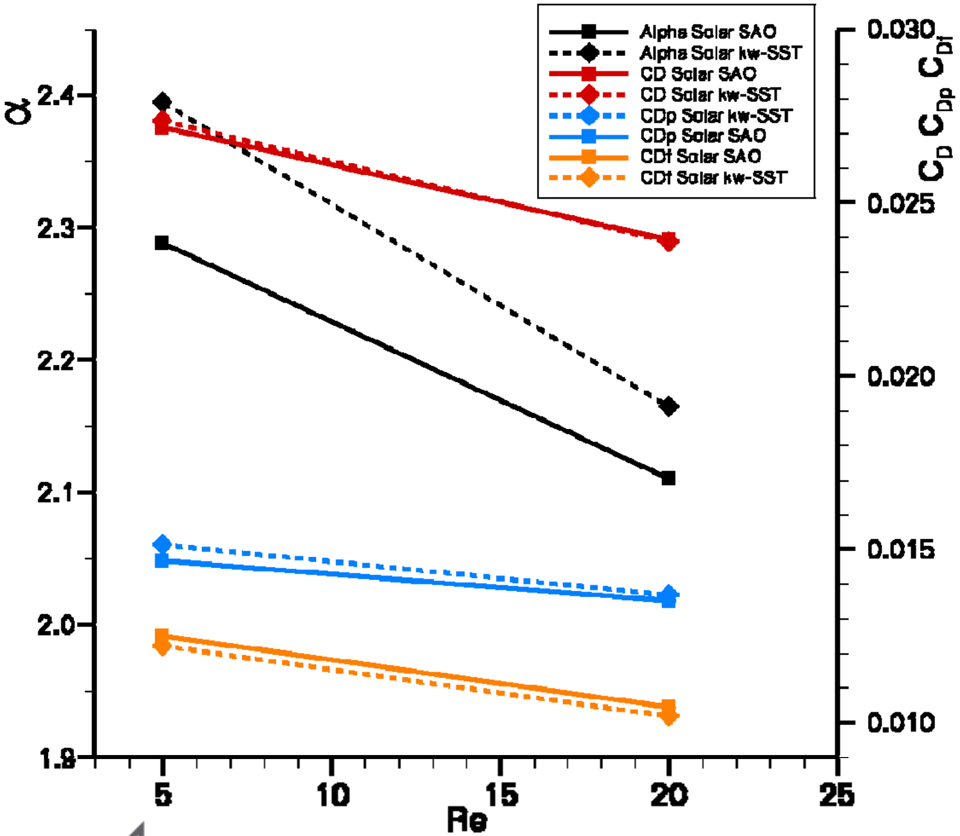
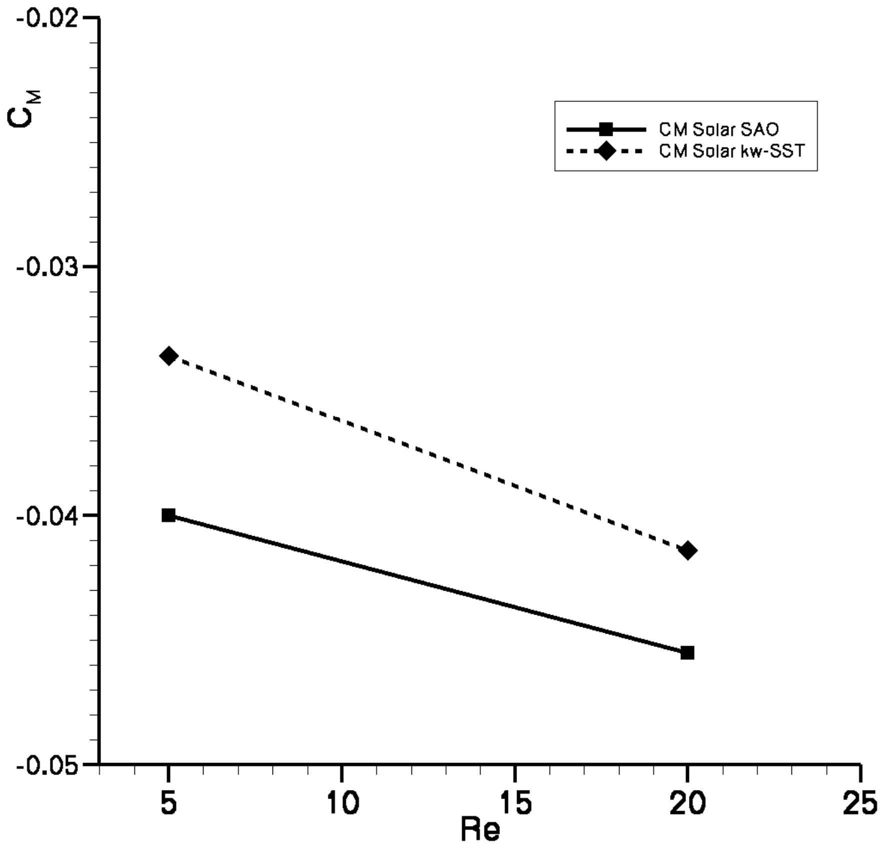
Case 3
— Re Influence, Turbulence Model —

$\Delta\alpha \approx$ 8-10%, $\Delta C_D \approx$ 12-13%, $\Delta C_M \approx$ 14-23%





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Conclusions (Preliminary)
— Lessons Learned —

- Solar quad-dominant unstructured surface meshes and hex-BL-resolution technique produce very good hierarchy of grids with high quality.
- Better leading edge and shock resolution with less overall nodes achievable.
- Aerodynamic coefficients and deltas for medium Centaur/Solar grids are similar.
- Grid refinement indicates a nearly linear behaviour for $1/N^{2/3}$.
- Wing fuselage separation is influenced by the grid type/size.
- Trailing edge separation size is mainly influenced by the turbulence model.
- Trimmed polars: the grid influence is less important than the turbulence model.
- Iterative setting variation of HTP in CFD loop towards $C_M=0$ for $C_L=0.5$:
  - Very small differences of i_h and α for trimmed configuration compared to interpolation method based on results from separately generated grids.