

Sixth High-Lift Prediction Workshop (HLPW-6)

RANS Technical Focus Group (TFG)

Test Case 1 (TC1) First Mini-Workshop

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Preliminary results for use by HLPW-6 TFG teams – do not distribute

RANS TFG Key Questions:

Question(Q), Tentative Answer (TA)

Q: Can we compute iteratively and grid converged RANS solutions for TC1?

TA: Yes

Q: Can we achieve agreement between converged RANS solutions computed by different solvers for TC1 at low, middle, and high angles of attack?

TA: Yes

Q: Is TC1 geometry prone to spurious 'pizza slice' separation patterns similar to those observed in RANS solutions at high angles of attack for the HLPW-5 TC 2.2-2.4?

TA: Yes

Q: Can spurious separation be mitigated with better grid resolution and/or iterative convergence? If yes, what are requirements for grid resolution (both on surface and in volume) and levels of convergence to avoid spurious separation?

TA: Different opinions

RANS TFG Key Questions (Continued):

Q: Do we observe multiple solutions of the Spalart-Allmaras (SA) turbulence model for TC1 and, if we do, what changes in the turbulence model should be made to ensure well-posedness?

TA: We observe multiple solutions. Regularization constraints are required

Q: What lessons learned from TC1 can be applicable to more complex CRM-HL configurations, e.g., TC 2.4?

TA: To be decided

Optional:

Q: How do geometrical features (bracket shape / spacing between brackets, anything else) affect spurious separation in the RANS solutions?

TA: Strong influence

Submitted RANS Solutions

• Discretization Approaches

- Node-centered, finite-volume, 2nd order : 5 solvers, 13 sets
- Cell-centered, finite-volume, 2nd order : 7 solvers, 9 sets
- Node-centered, continuous finite-element : 1 solver, 2 sets

• RANS Models

- SA/SA-neg equations : 10 solvers, 19 sets
- SA with corrections equations : 1 solver, 2 sets
- Two-equation models : 2 solvers, 3 sets

• Grid Families

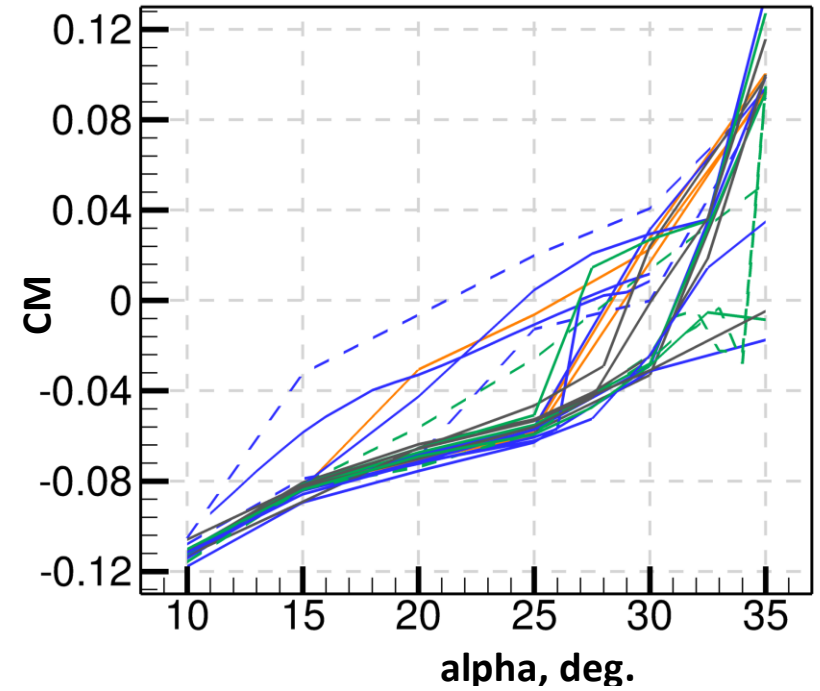
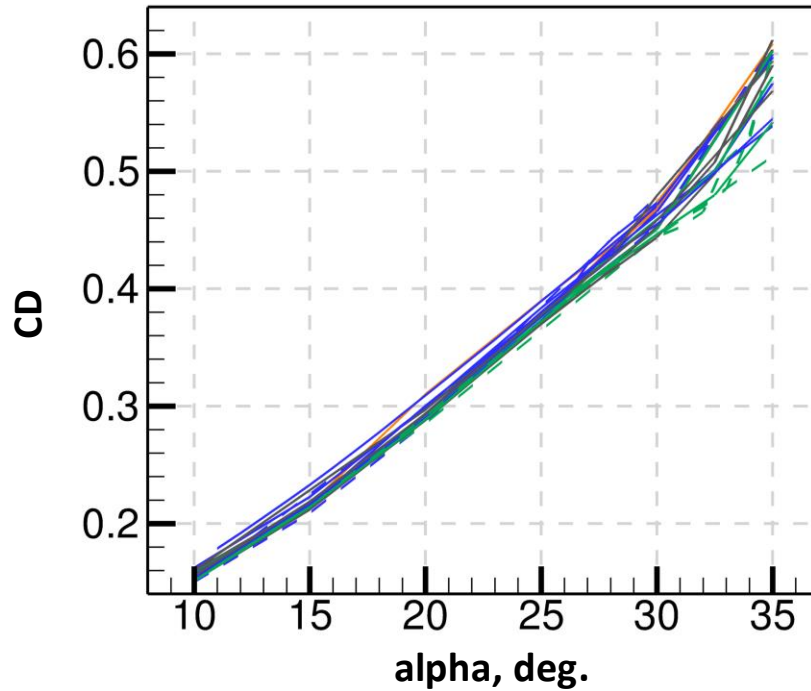
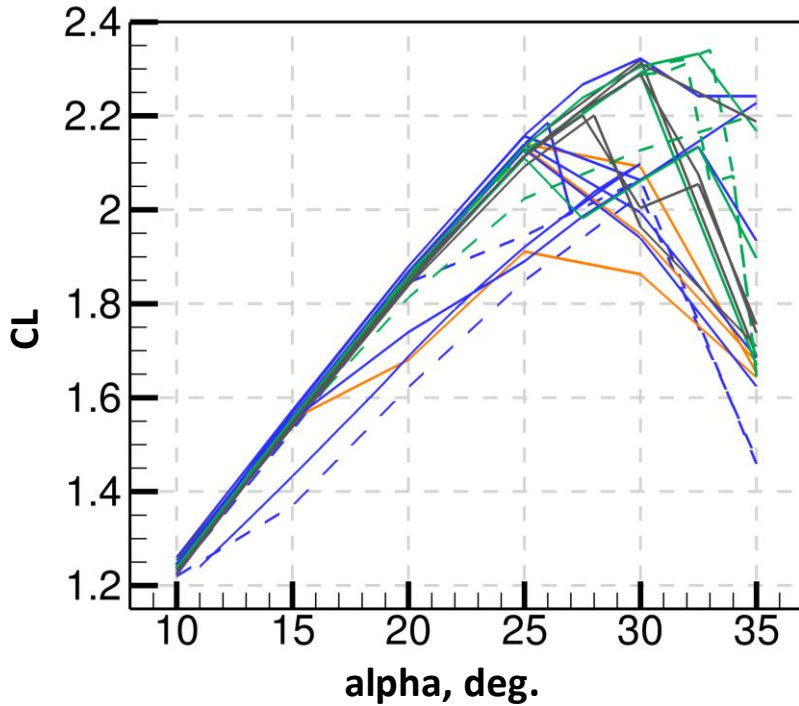
- R.1.TC1.01 (HM Fixed) : 5 solvers 7 sets
- R.1.TC1.02 (HM Adapt) : 2 solver, 3 sets
- R.1.TC1.03 (PW Hex/Voxel) : 5 solvers, 8 sets
- Custom grids : 5 solvers, 5 sets
- Adapted grids : 1 solver, 1 set

RANS TFG Activities:

not pre-planned, initiated by community needs

- **Activity 1: Visualization and Characterization of Bracket Wakes**
 - Provided recommendations and macros for post-processing of TC1 solutions
- **Activity 2: Criteria for Iterative and Grid Convergence**
 - Recognized that perfect criteria are not possible
 - Provided guidance on determining the desirability of further iterations
- **Activity 3: Verification and Understanding of Multiple Solutions**
 - Established multiple solutions for high and low angles of attack
 - Working on strategies for treatment of multiple solutions
- **Activity 4: Verification of SST-Vm model**
 - Prepared and posted the document describing the verification case
 - Generated grids
- **Activity 5: Sensitivity of Solutions to Bracket Shape**
 - Established high sensitivity of RANS solutions to bracket shape
 - Summarized practical experience on designing brackets

Forces and Moments – Nominal Grid



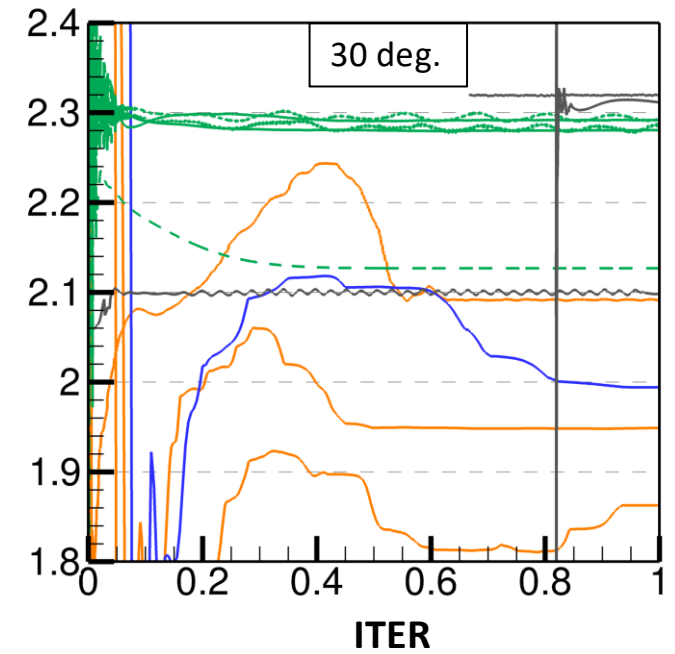
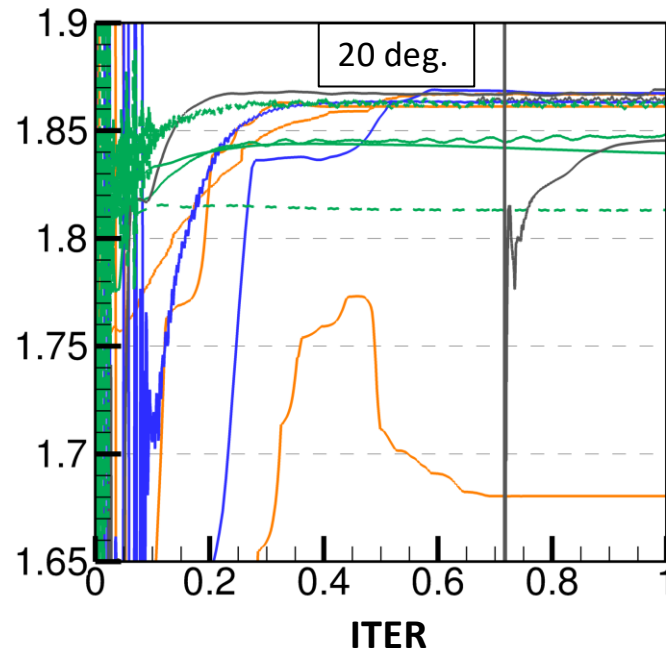
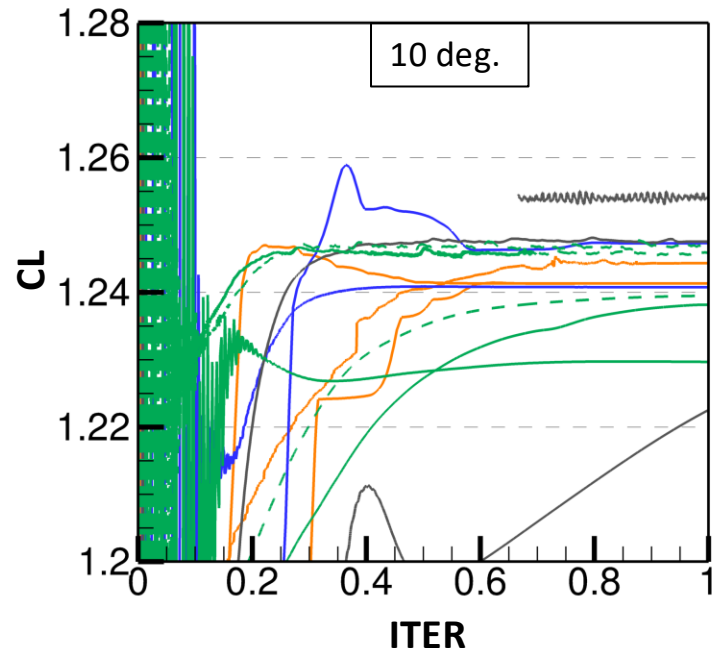
- **23** curves
All data sets uploaded by June 9th included
- Line style by turbulence model
[SA, SA-neg] = solid lines
[SST2003,SSTV2003,kw88,SA-R,SA-R23] = dashed lines.
- Color by grid family:
R.1.TC1.01 = blue
R.1.TC1.02 = red
R.1.TC1.03 = green
Custom = black

- 005 USM3D-ME SA-neg GRID R.1.TC1.02.F
- 015 LAVA SA-neg GRID Custom
- 016 FUN3D-FV SST2003 GRID R.1.TC1.01.D
- 016 FUN3D-FV SSTV2003M GRID R.1.TC1.01.D
- 016 FUN3D-SFE SA-neg GRID R.1.TC1.02.E Upper Branch
- 016 FUN3D-SFE SA-neg GRID R.1.TC1.02.E Lower Branch
- 016 FUN3D-SFE SA-neg GRID R.1.TC1.01.D
- 016 FUN3D-FV SA-neg GRID R.1.TC1.01.F
- 017 cflow SA-neg GRID R.1.TC1.01.E
- 018 DRAGON SA-neg GRID R.1.TC1.03.D
- 018 DRAGON k- ω GRID R.1.TC1.03.C
- 019 CODA SA-neg GRID R.1.TC1.01.D Upper Branch
- 019 CODA SA-neg GRID R.1.TC1.01.C Lower Branch
- 024 OpenFOAM SA-neg GRID Custom
- 025 TAS SA-noft2-R(Crot=1) GRID R.1.TC1.03.C
- 025 TAS SA-noft2-R23(Crot=1) GRID R.1.TC1.03.C
- 027 Flow360 SA-neg GRID Custom
- 027 Flow360 SA-neg GRID R.1.TC1.01.E
- 027 Flow360 SA-neg GRID R.1.TC1.03.C
- 033 SU2 SA-neg GRID Custom
- 033 SU2 SA-neg GRID R.1.TC1.01.E
- 033 SU2 SA-neg GRID R.1.TC1.03.C
- 034 eLSA SA-neg GRID Custom

Additional RANS TFG Summary Presentations to Follow

- **Andrew Wick (Helden Aerospace): Solution Sensitivity to Bracket Shape**
- **Malte Wegener (DLR): Evidence for Multiple Solutions**

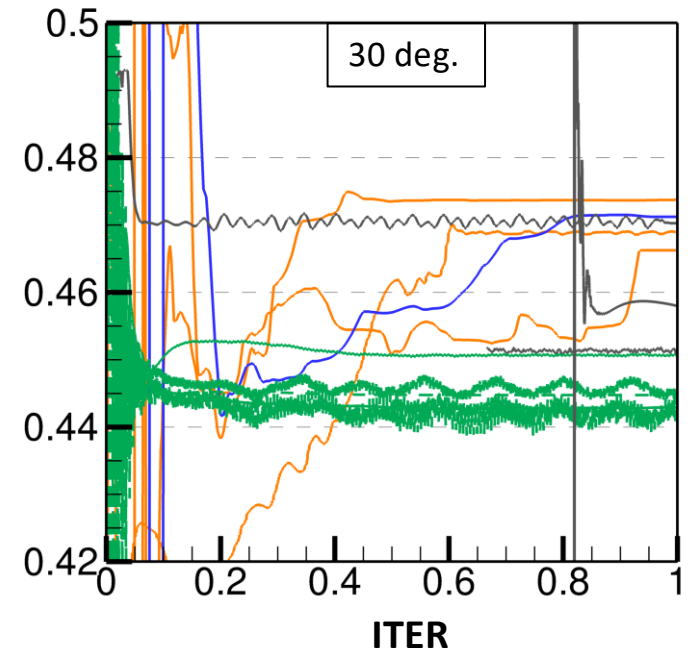
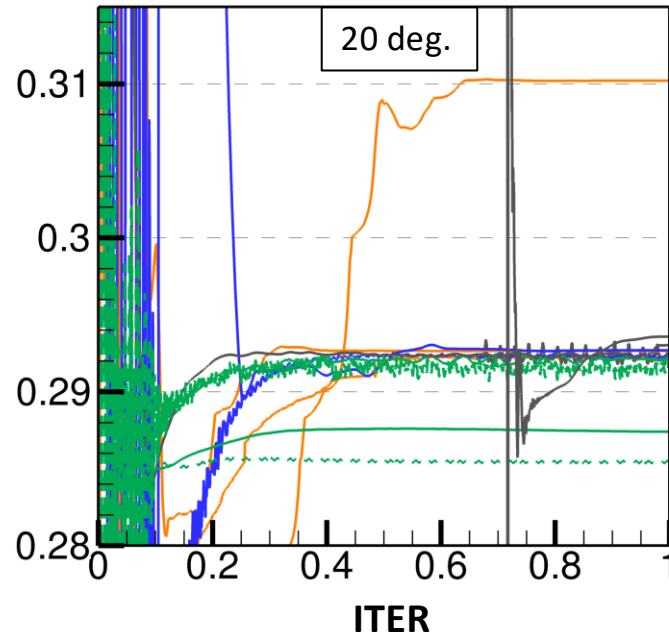
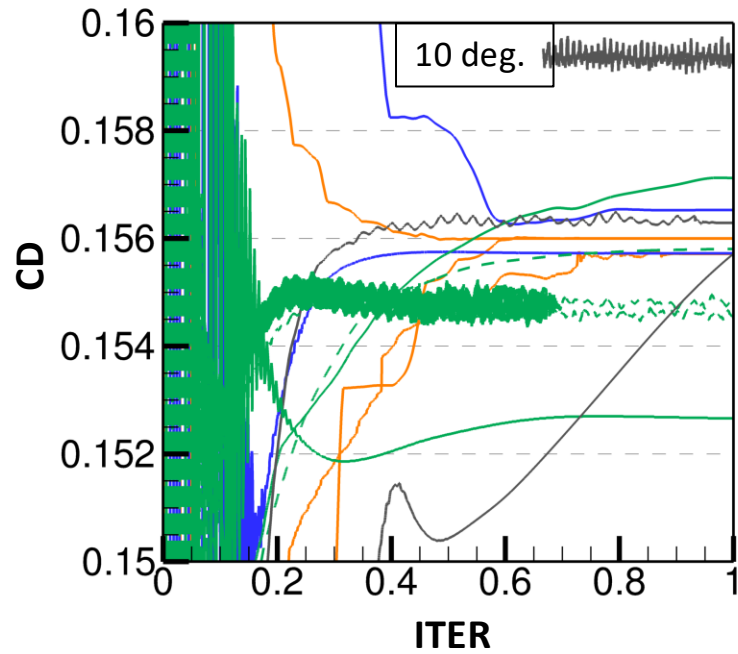
Iterative Convergence of Lift



- Nominal grid iterative convergence trends for lift
- Solid line = SA, SA-neg
Dashed line = kw88, SA-R, SA-R23
- 015: time-accurate URANS
- 2 distinct branches at 20 deg., possibly multiple ones at 30 deg.

- 005 USM3D-ME SA-neg GRID R.1.TC1.02.F
- 015 LAVA SA-neg GRID Custom
- 016 FUN3D-SFE SA-neg GRID R.1.TC1.02.E Upper Branch
- 016 FUN3D-SFE SA-neg GRID R.1.TC1.02.E Lower Branch
- 016 FUN3D-SFE SA-neg GRID R.1.TC1.01.D
- 016 FUN3D-FV SA-neg GRID R.1.TC1.01.D
- 018 DRAGON SA-neg GRID R.1.TC1.03.D
- - - 018 DRAGON k- ω GRID R.1.TC1.03.C
- 024 OpenFOAM SA-neg GRID Custom
- - - 025 TAS SA-noft2-R(Crot=1) GRID R.1.TC1.03.C
- - - 025 TAS SA-noft2-R23(Crot=1) GRID R.1.TC1.03.C
- 027 Flow360 SA-neg GRID R.1.TC1.03.C
- 034 eLSA SA-neg GRID Custom

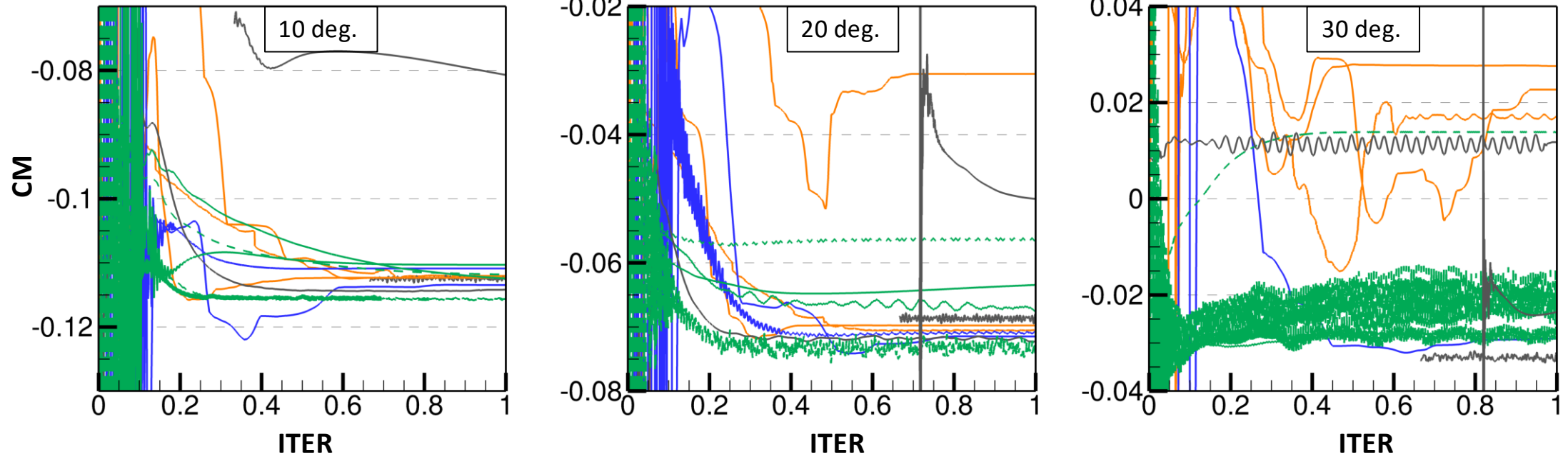
Iterative Convergence of Drag



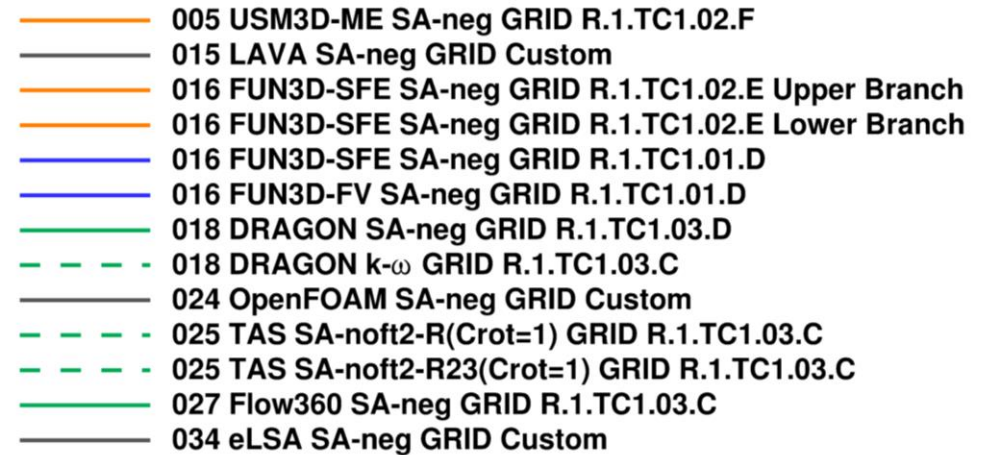
- Nominal grid iterative convergence trends for drag
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- 015 LAVA SA-neg GRID Custom
- 016 FUN3D-SFE SA-neg GRID R.1.TC1.02.E Upper Branch
- 016 FUN3D-SFE SA-neg GRID R.1.TC1.02.E Lower Branch
- 016 FUN3D-SFE SA-neg GRID R.1.TC1.01.D
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- - - 025 TAS SA-noft2-R23(Crot=1) GRID R.1.TC1.03.C
- 027 Flow360 SA-neg GRID R.1.TC1.03.C
- 034 eLSA SA-neg GRID Custom

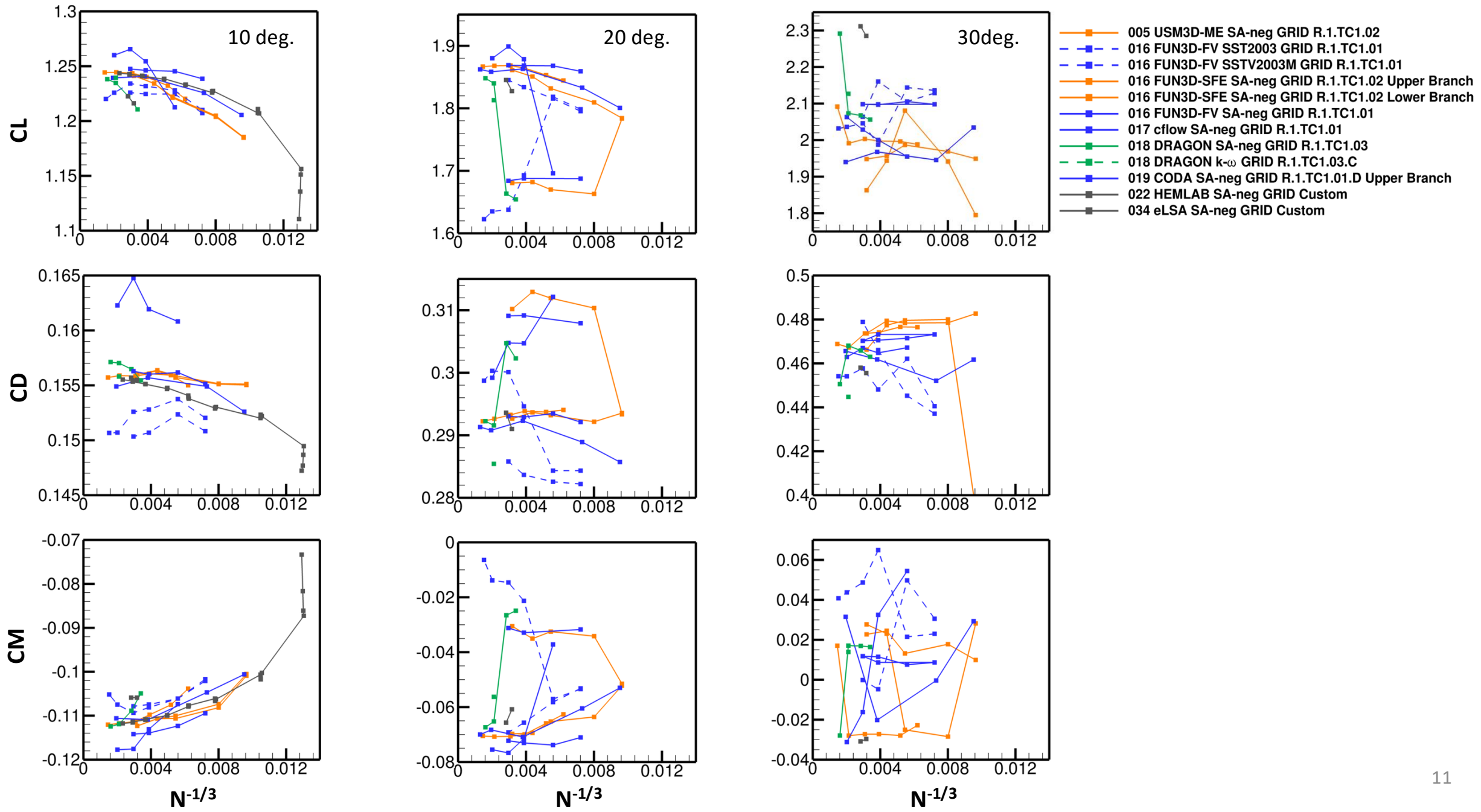
Iterative Convergence of Moment



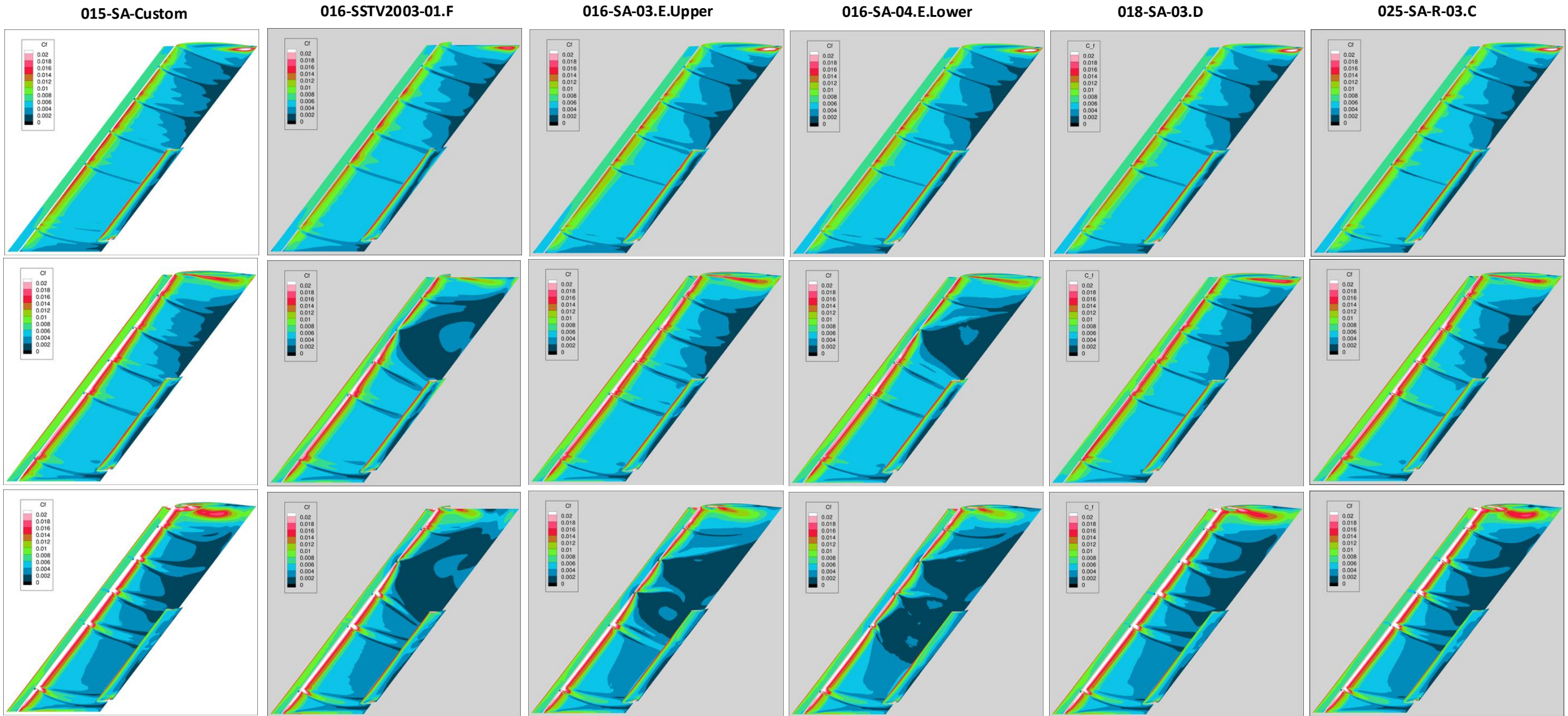
- Nominal grid iterative convergence trends for moment.
- Solid line = SA, SA-neg
Dashed line = kw88, SA-R, SA-R23
- 015: time-accurate URANS
- 2 distinct branches at 20 deg., possibly multiple ones at 30 deg.



Grid Convergence



Surface Skin-friction Magnitude Contours



- Results for 10 deg. (top row), 20 deg. (middle row) and 30 deg. (bottom row) covering different grids, models and branches