DPW-8/AePW-4 Buffet Working Group: An Overview of Mini Workshops 1 and 2

July 21, 2025

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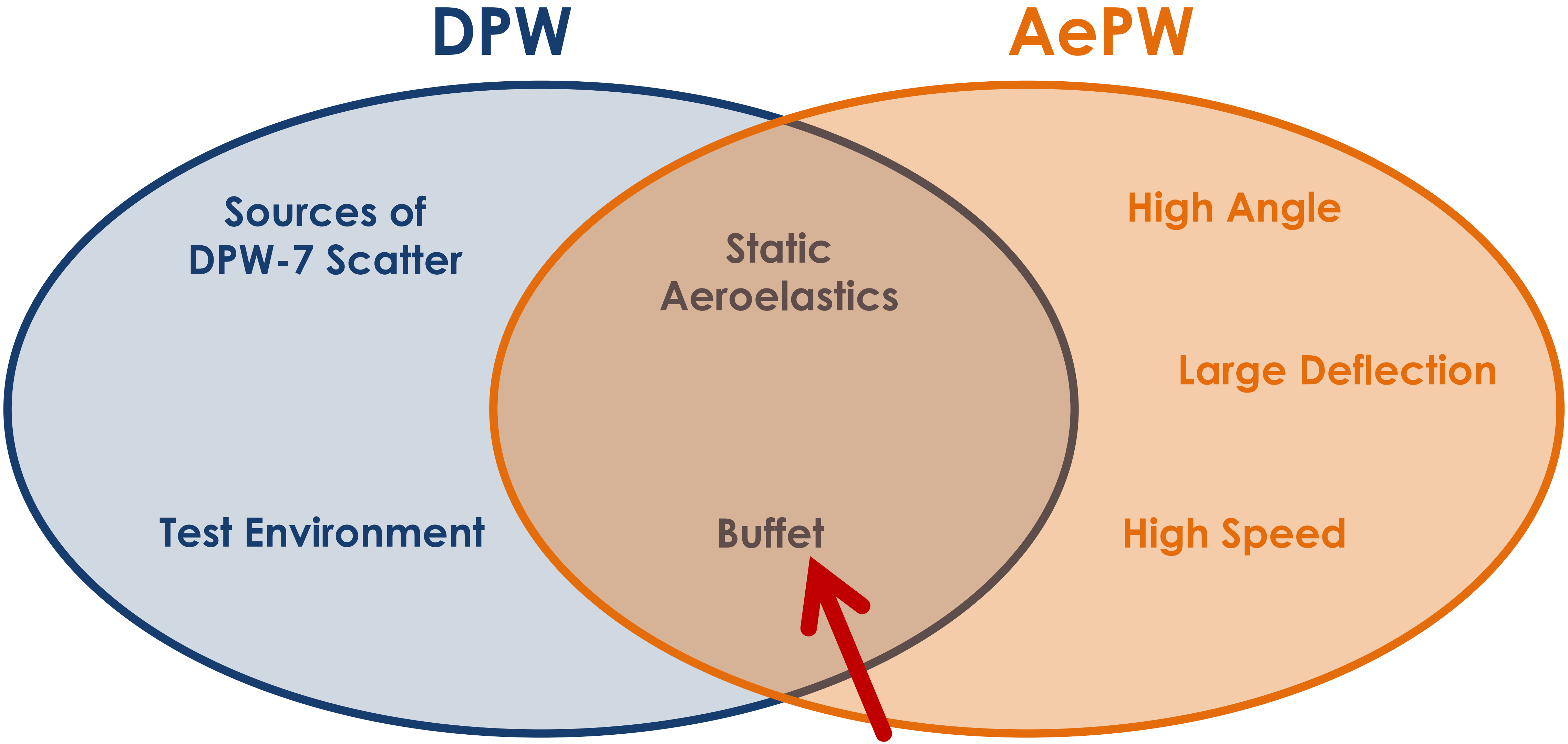
Presentation Outline

- **Buffet Working Group: Motivation and structure**
- **Test Case 1 description**
- **Results**
  - Test Case 1a: RANS results
  - Test Case 1b: Unsteady results
- **Conclusions and way forward**

Working Groups Layout



Motivation and Test Cases

- **Leverage knowledge from both DPW and AePW to advance state of the art for buffet environment**
  – Determine practices that accurately resolve unsteady, fixed-geometry at buffet
  – Exercise capabilities of solvers to simulate unsteady FSI buffet

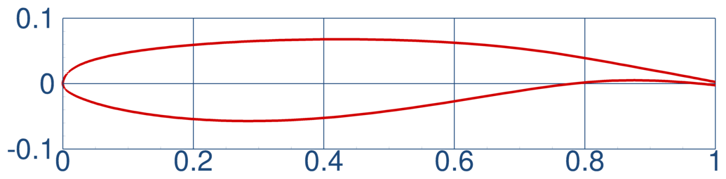
- **Test Case 1: Verification test case**
  – 2D ONERA OAT15A, Re=3 Mil, Mach 0.73
  – Pre-stall and post-stall conditions

- **Test Case 2: Unsteady CFD and rigid wing, Common Research Model (CRM)**
  – Unsteady CFD at committee-supplied deformations (JAXA data, Re=1.5 Mil)

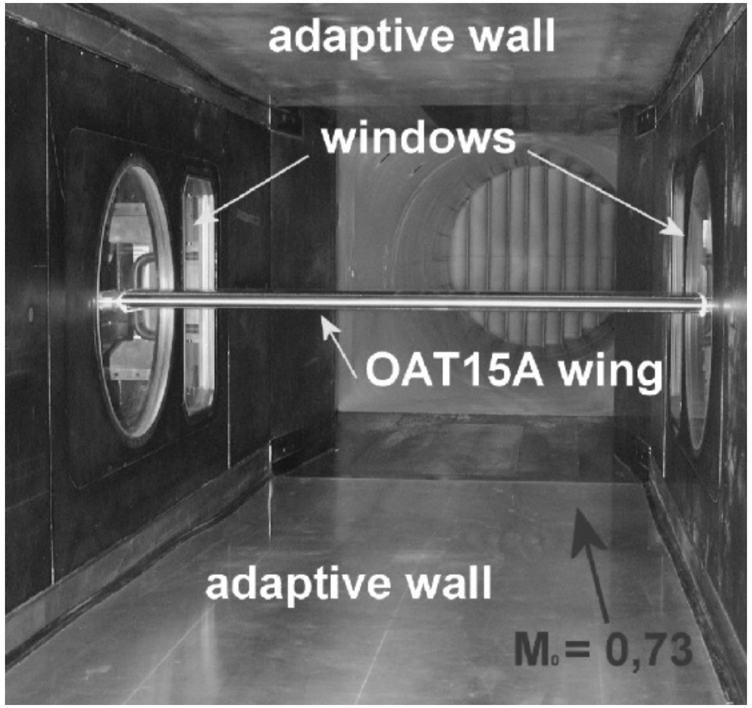
- **Test Case 3: Unsteady CFD and dynamic wing, CRM**
  – Committee-supplied FEM and unloaded geometry (JAXA data, Re=2.3 Mil)

Test Cases 1a and 1b

- **Consistent with workshop-wide efforts**
- **Pre- and post-buffet**
- **Committee-supplied RANS grids**
- **Test Case 1a**
  - Same as rest of workshop, but high-alpha extension
  - RANS
- **Test Case 1b**
  - Same as Test Case 1a
  - Unsteady CFD
  - Required user-generated grids for HRLES and WMLES



ONERA OAT15A profile



Jacquin, et al. "Experimental Study of Shock Oscillation over a Transonic Supercritical Profiles." AIAA Journal, Vol. 47, No. 9, 2009

Participant Summary and Data Submission

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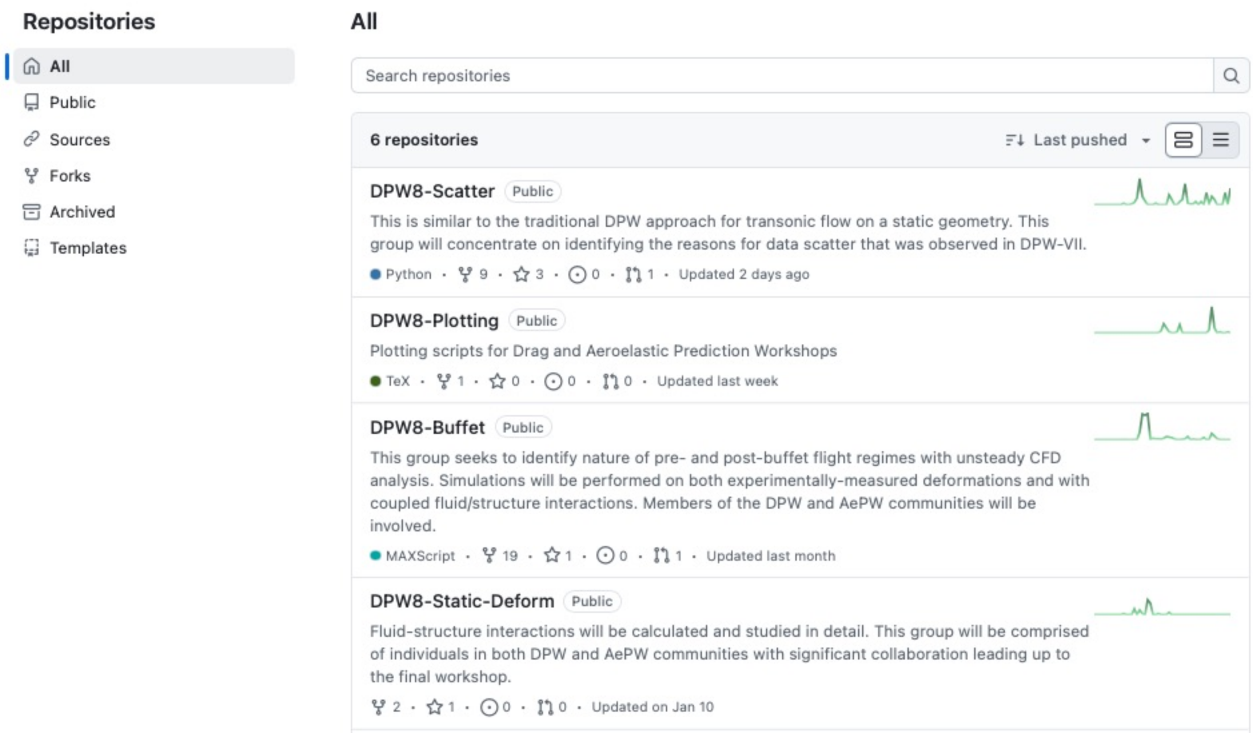
- **17 institutions submitted Test Case 1a/1b data**
  - Nine Countries
  - Five continents
  - Six academic, four commercial, and seven government enterprises
- **70+ submissions**
- **Utilized workshop-wide GitHub website for submissions**



Test Case 1a : Grid Study at α = 3.90◦

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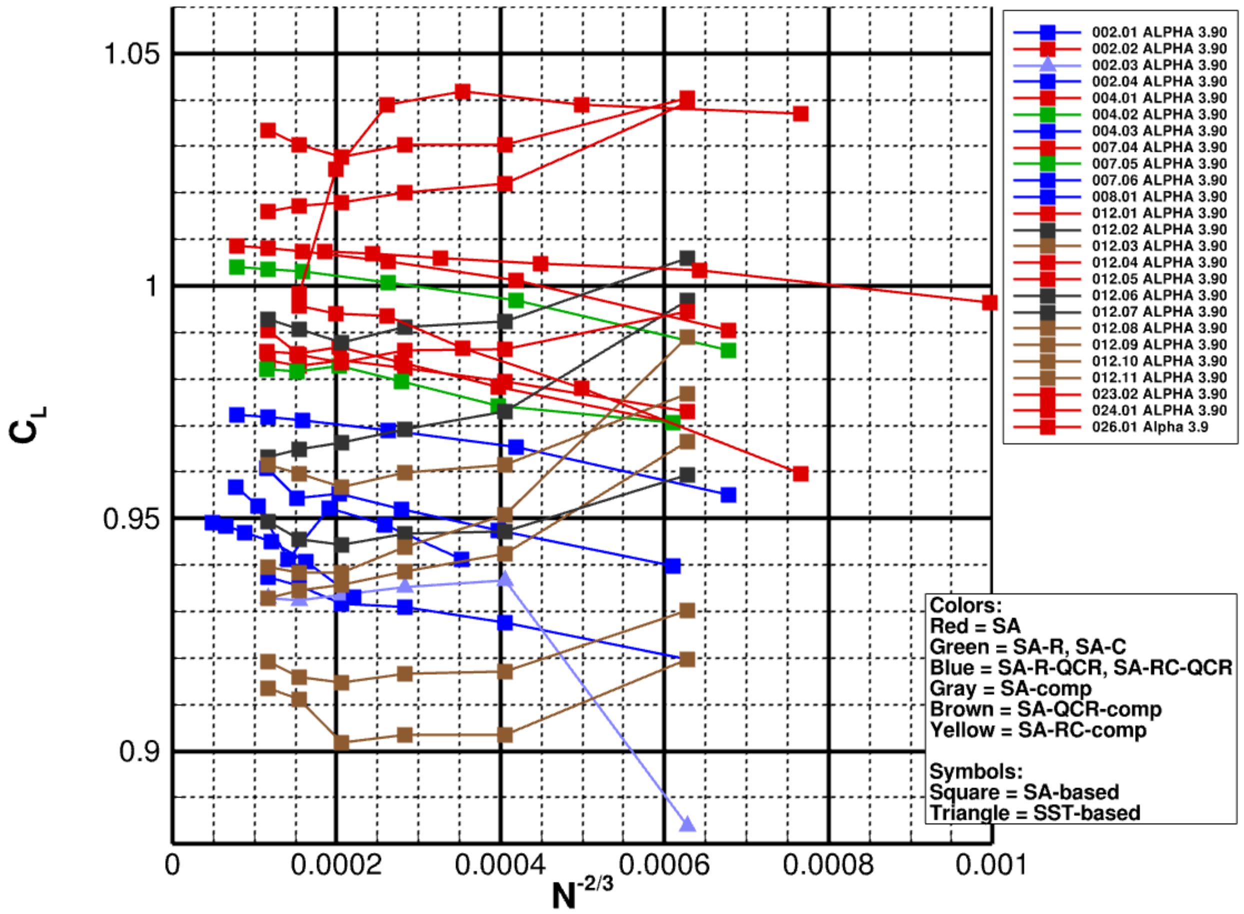
Colored by turbulence model variant



Shown for α = 3.90◦ but generally true for all other angles of attack

- SA, SA-R, SA-C (“SA” group, red and green)
  - Elevated CL
  - Elevated CD
  - Decreased CM
- SA-QCR, SA-comp, SA-QCR-comp, SA-RC-comp (”QCR/comp” group = blue, gray brown)
  - Decreased CL
  - Decreased CD
  - Elevated CM

Few contributions with SST, but they seem to follow the “QCR/comp” group

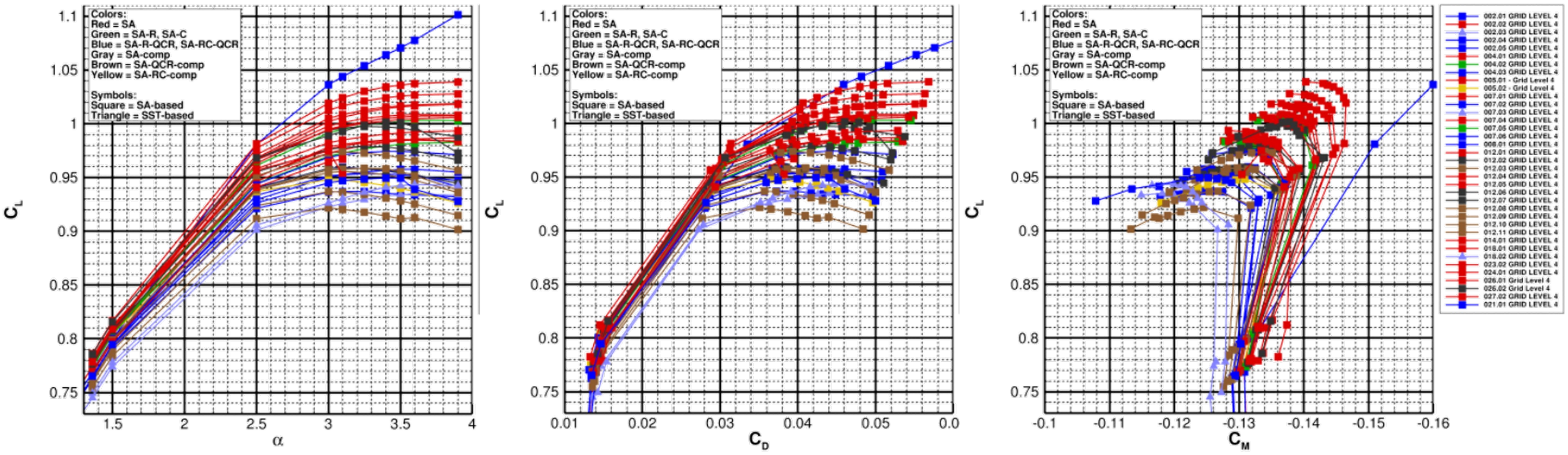
Note: All data are preliminary and are subject to change

Test Case 1a : Integrated F&M

- **Increased scatter relative to DPW-VII (surprising)**
- **For the lowest angle of attack**
  - 30 drag counts and 0.040 CL
- **For the highest angle of attack**
  - 75 drag counts and 0.140 CL

SA
SA-R, SA-C
SA-R-QCR, SA-RC-QCR
SA-comp
SA-QCR-comp
SA-RC-comp

Squares: SA
Triangles: SST



Test Case 1a : Polars (Grid Level 4)

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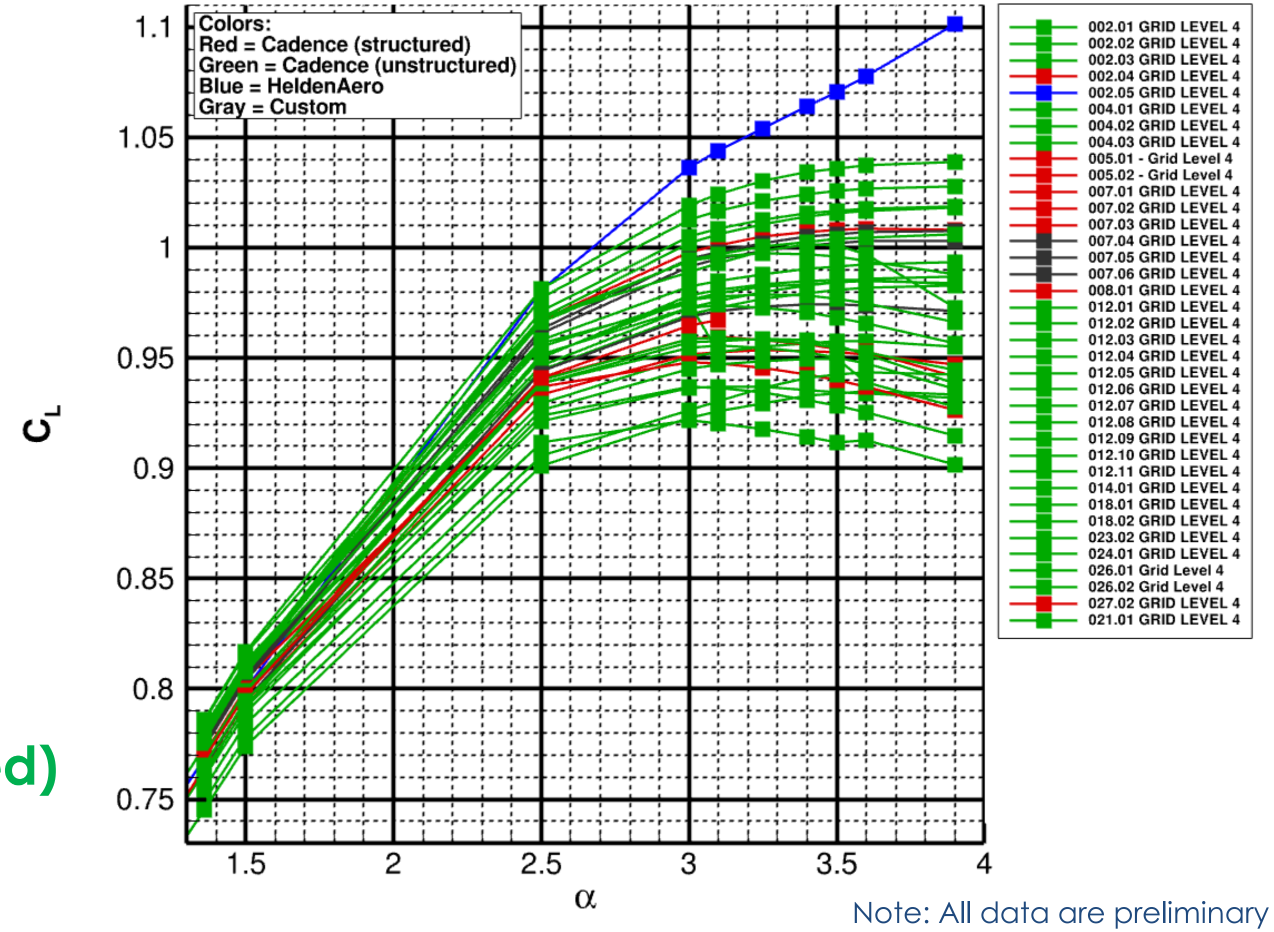
Shown for CL but generally true for CD and CM and other grid levels

Not striking trends due to grid type.

Understanding the metrics of the custom grids will be crucial

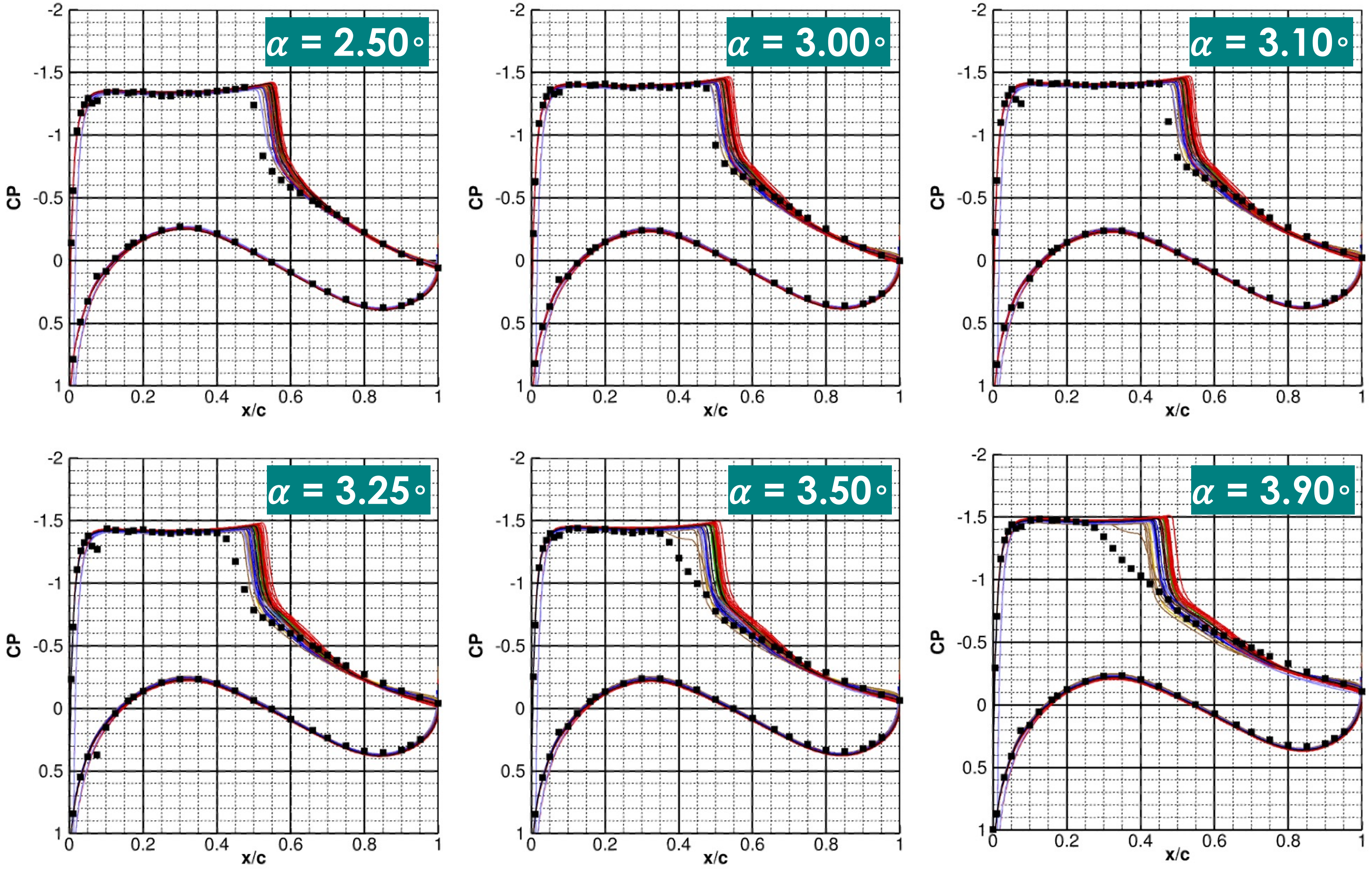
Cadence (structured)
Cadence (unstructured)
HeldenAero
Custom

Colored by grid type



Note: All data are preliminary and are subject to change

Test Case 1a : Cp-cuts



- **Even before onset, most solutions predict the shock too downstream**
  – "-comp" correction improves things but still differences
- **Because of the steady nature of the calculations, the shock does not move and does not capture the smooth (time-averaged) gradient across the shock for post-onset cases**

Note: All data are preliminary and are subject to change

Test Case 1b : Polars (Steady and Unsteady)

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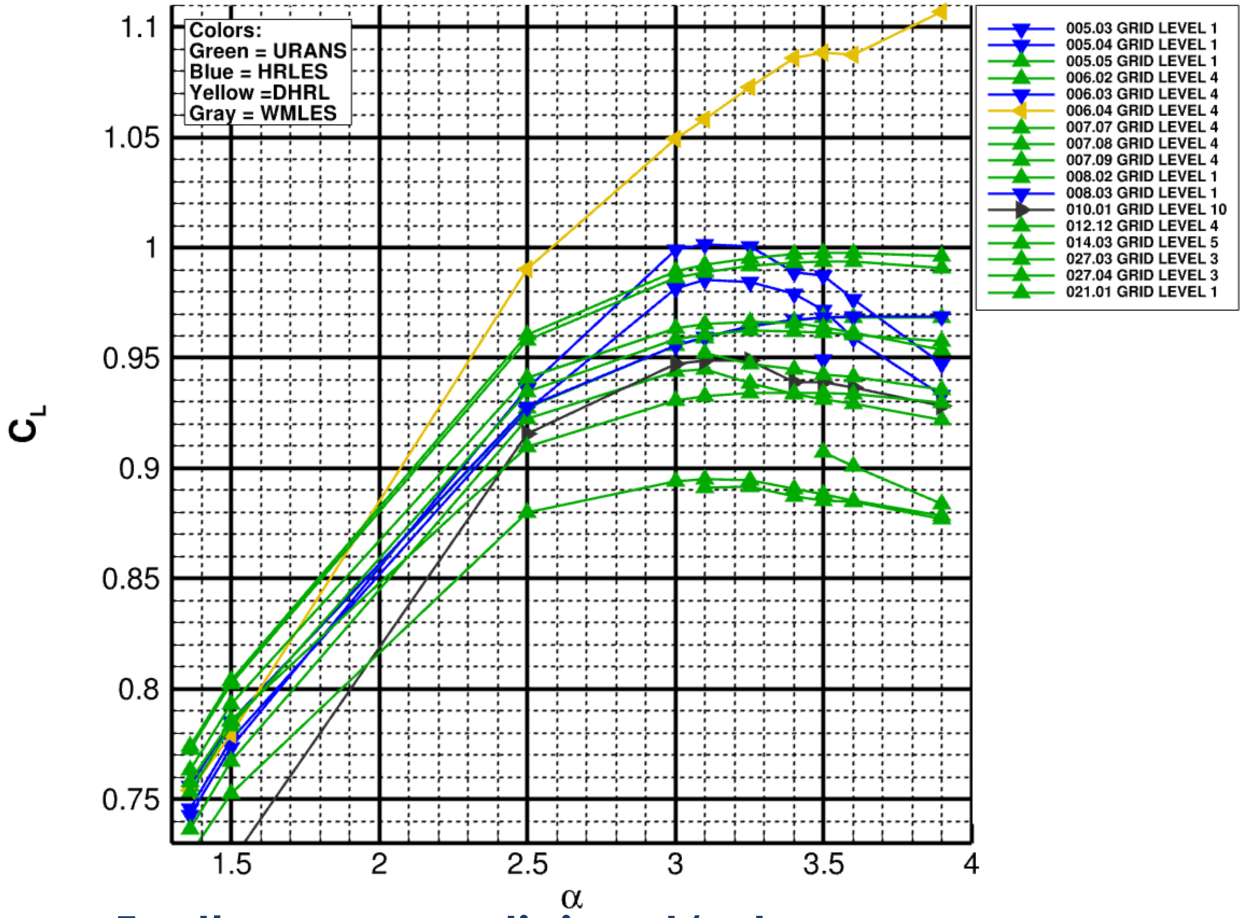
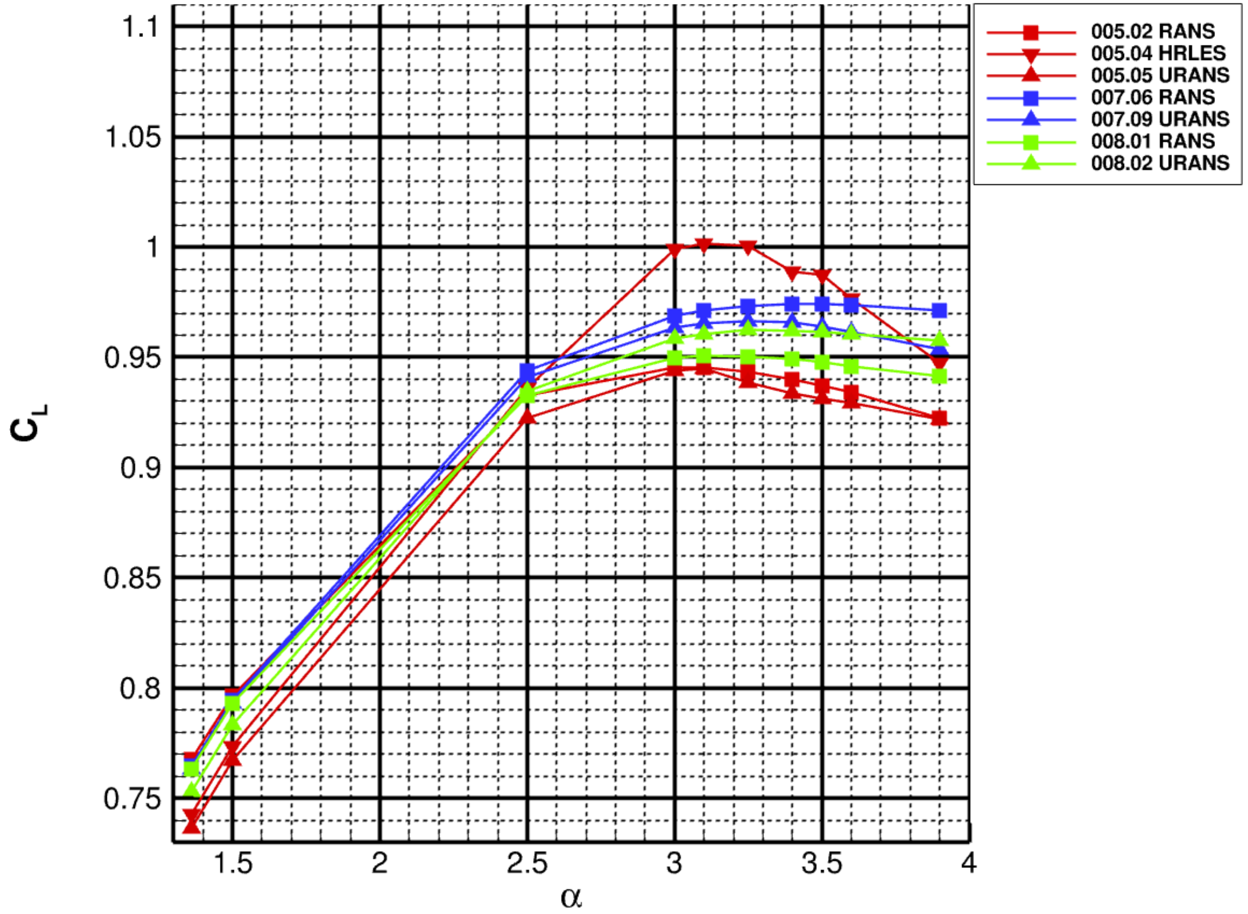
Colored by method



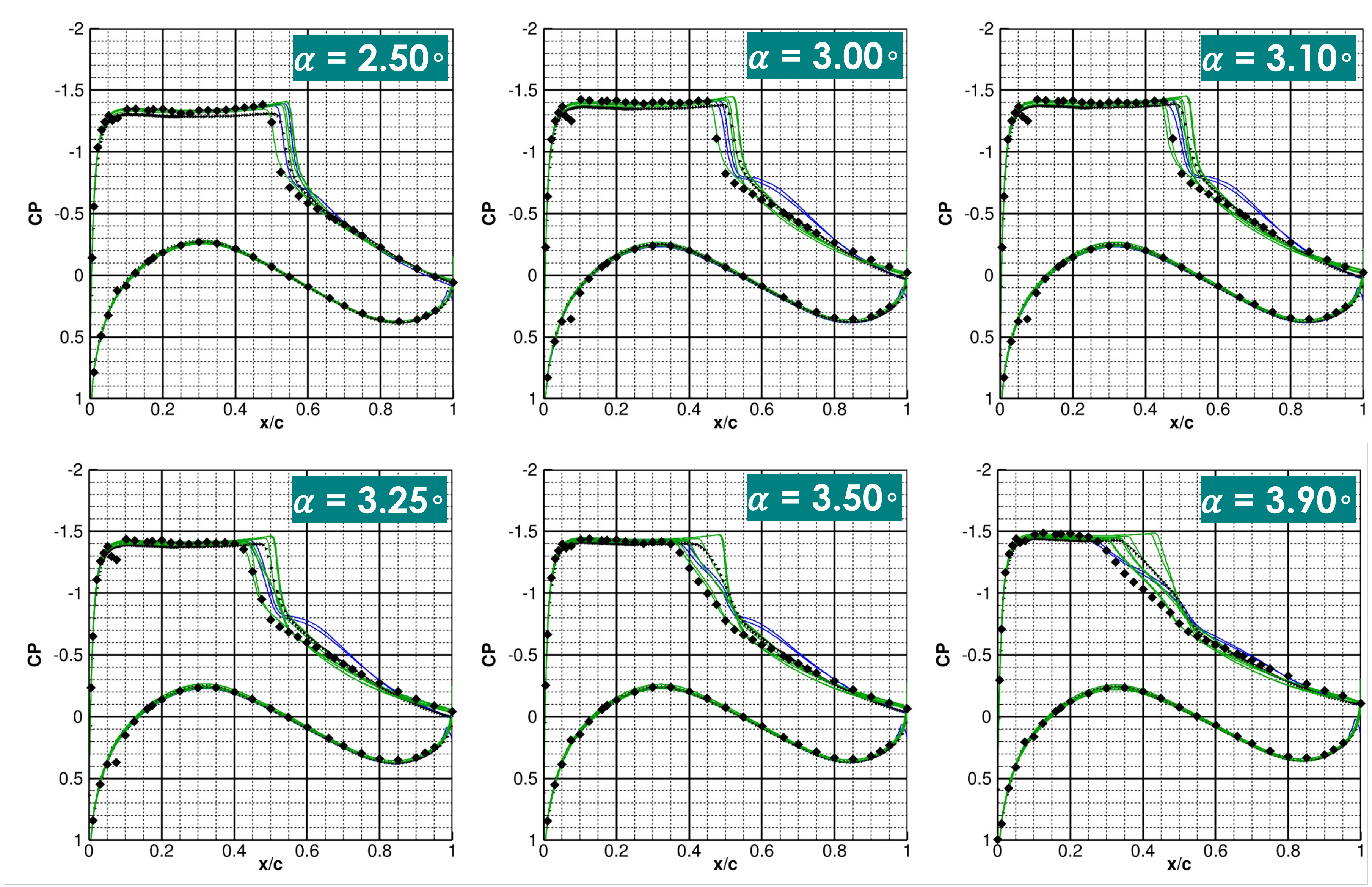
Colored by ID (selected) contributions

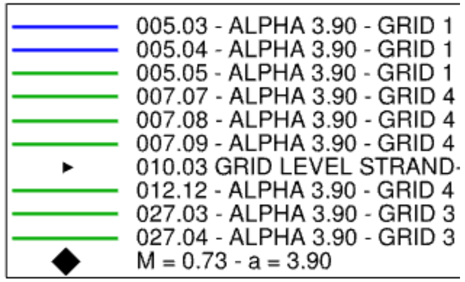


- **For the same participant/setup:**
  - Steady and unsteady values do not match at pre-buffet
  - Early RANS separation anticipated but not necessarily observed

Note: All data are preliminary and are subject to change

Test Case 1b : Cp-cuts (mean)





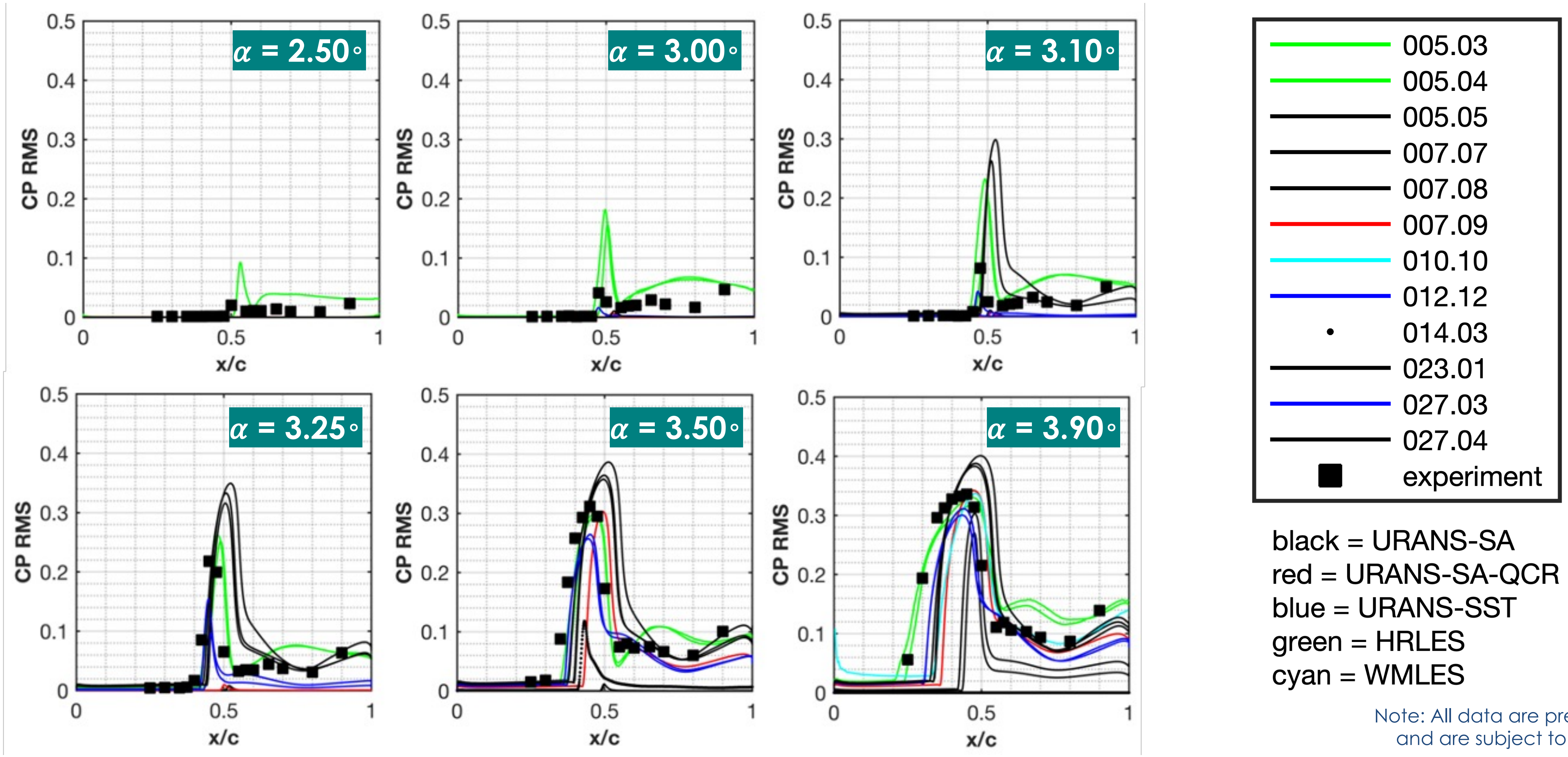
- **Improved agreement at post-onset conditions, but still the shock is too downstream**
  - Notable exception SST-comp-QCR2000
- **Overprediction of suction downstream of the shock for HRLES**

Colors:
Green = URANS
Blue = HRLES

Symbols:
Triangle = WMLES
Diamond = Experiments

Note: All data are preliminary and are subject to change

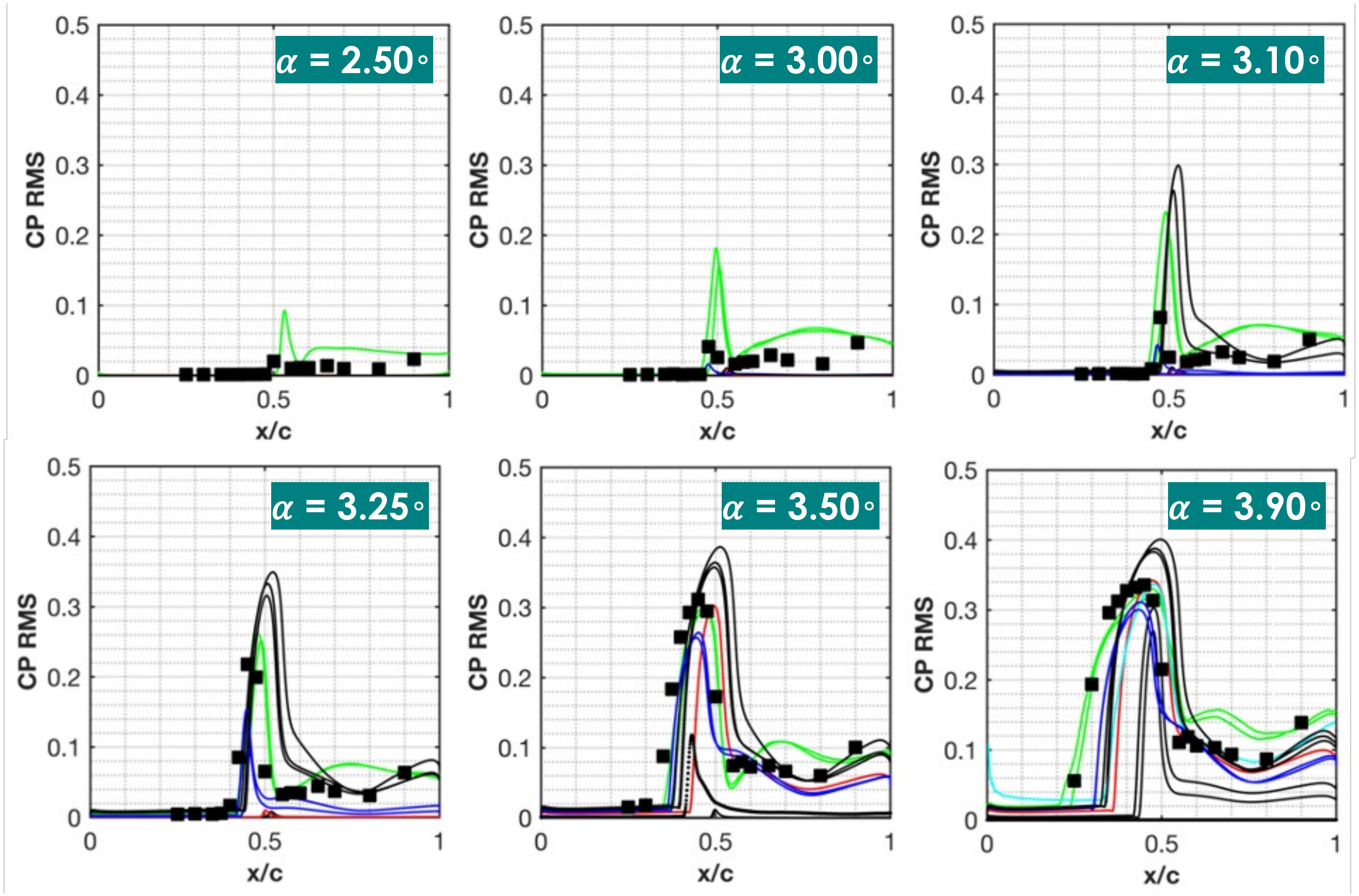
Test Case 1b : Cp-cuts (rms)



black = URANS-SA
red = URANS-SA-QCR
blue = URANS-SST
green = HRLES
cyan = WMLES

Note: All data are preliminary and are subject to change

Test Case 1b : Cp-cuts (rms)



- **HRLES and SA-comp strong fluctuations and early onset**
- **SA-QCR and SST weak fluctuations and delayed onset**
- **Fluctuations peak amplitude, location and width:**
  - URANS fail at predicting the width of the fluctuations amplitude, location and width, but behave well downstream of the interaction
  - Opposite happens for the HRLES solutions
  - For the highest alpha, WMLES behaves best but still differences upstream of the peak

Note: All data are preliminary and are subject to change

Conclusions: General

- **Summary of preliminary data for Buffet Working Group efforts for Test Case 1**

- **A huge thanks to all contributors, leading groups and plotting teams!**

- **Of the 74 datasets provided, only 18 unsteady datasets (mostly URANS)**
  - Possible reasons?
    - increased computational costs
    - difficulties in setting up time-integration parameters

- **Large number of participants used customs grids.**
  - What are the reasons?
  - More investigations on the grid metrics will be done for the final workshop

Conclusions: Results

- **RANS results:**
  - Grid independence not shown
  - Larger scatter than in DPW-VII for a full-aircraft (not the core objective of the Buffet Working Group, but still concerning); questions remain
  - Differences between "SA" and "QCR/comp" groups
  - Shock generally predicted too far downstream even for pre-onset cases
    - How 2D are the experimental data?
    - 3D span-periodic simulations? Sensitivity to span width?
    - What is the effect of corner separations?

- **Unsteady results**
  - Few contributions, difficult to make definite conclusions
  - Large scatter between different methods (URANS, HRLES, WMLES)
  - Improvement of the prediction of shock behavior, but still too downstream
  - Fluctuations are difficult to capture correctly

Way Forward

- **If you find any problems in the presented data, please get in touch (aiaabuffet@gmail.com)**

- **Participants can correct and add datasets for the final workshop**

- **Further work on case 1:**
  - PSD comparisons
  - Custom grid metrics information
  - Transients and statistics collection times
  - Confirmation of different SA flavours

- **Many lessons learnt, but improved communication is needed for the success of the more complex cases 2 and 3 (full-aircraft)**

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aiaabuffet@gmail.com

Back-up Slides

Includes information above, but with more detail

Also includes more plots

Buffet Working Group Leadership

- **Working group leadership**
  - Hadar Ben-Gida 🇮🇱
  - Brent Pomeroy 🇺🇸
  - Daniella Raveh 🇮🇱
  - Andrea Sansica 🇯🇵
  - Bret Stanford 🇺🇸
- **Subgroup leaders**
  - URANS and HRLES :
    - Jeff Housman 🇺🇸
    - Fulvio Sartor 🇫🇷
  - WMLES & Beyond:
    - Johan Jansson 🇸🇪

Point of Contact: AIAA Buffet Group (aiaabuffet@gmail.com)

Buffet – Motivation with More Detail

- **Leverage knowledge from both DPW and AePW to advance state of the art**
  - Increase understanding within each field, individually
  - Synthesize methods to increase understanding of buffet predictions
- **Determine practices that accurately resolve unsteady, fixed-geometry at buffet conditions**
- **Exercise capabilities of solvers to simulate unsteady FSI buffet**
- **To provide an impartial forum for evaluating the effectiveness of existing tools and methods**
- **Provide guidance for simulations while relying upon users to implement code's best practices**
- **Establish workshop model for future multidisciplinary communities**

Buffet – Test Cases with More Detail

- **Test Case 1: Verification test case**
  - ONERA OAT15A profile, Re=3 Mil
  - Test Case 1a: RANS
  - Test Case 1b: Unsteady calculations

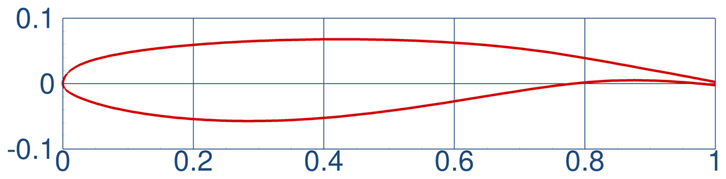
- **Test Case 2: Unsteady CFD and rigid wing**
  - JAXA's 2.16% scale CRM wing-body-tail, Re=1.5 Mil
  - Static wing deformation measurements used to deform the wing
  - Unsteady calculations at both pre- and post-buffet onset

- **Test Case 3:**
  - JAXA's 2.16% scale CRM wing-body-tail, Re=2.3 Mil
  - Contains FSI, FEM is provided
  - Static and dynamic response at one pre- and one post-buffet onset alpha

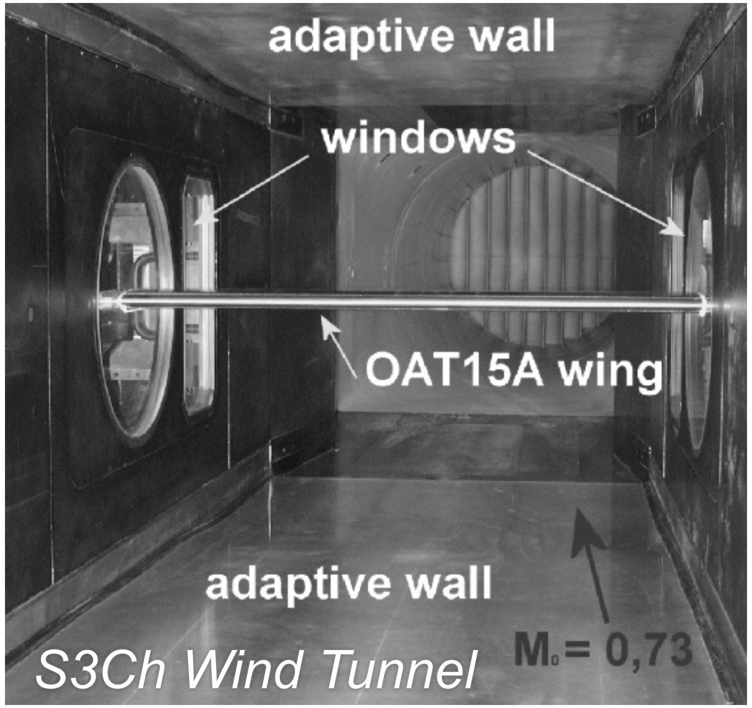
Test Case 1 Description

Test Case 1: Geometry and Experimental Data

- **Jacquin et al, AIAA Journal (2009) [https://doi.org/10.2514/1.30190]**
- **Transonic S3Ch Wind Tunnel of the ONERA-Meudon Center**
- **Geometry:**
  - 2D OAT15A profile (chord = 230 mm, blunt trailing-edge)
  - Span = 780 mm (AR ~ 3.4)
  - Available at : https://aiaa-dpw.larc.nasa.gov/geometry.html#oat.
- **Flow conditions:**
  - M = 0.73, Re = 3 Mil
  - P_st = 10^5 Pa and T_st = 300 K
  - Angle of attack (α) = 1.36 - 3.90◦ (buffet onset α ~ 3.10◦)
  - The flow is considered span-homogeneous
- **Experimental results available at :**
  - Available at: https://aiaa-dpw.larc.nasa.gov/experiment.html
  - Mean and rms pressure from 36 unsteady Kulite transducers
  - Oil flow



ONERA OAT15A profile



Jacquin, et al. "Experimental Study of Shock Oscillation over a Transonic Supercritical Profiles." AIAA Journal, Vol. 47, No. 9, 2009

Test Case 1a : Workshop-Wide Validation

- **Detailed case description:**
  - https://aiaa-dpw.larc.nasa.gov/WorkingGroups/Group3/TestCases/buffet-case1-v3.pdf.

- **Settings**
  - Steady CFD (e.g., RANS)
  - Prefer some version of SA, multiple turbulence models can be submitted

- **Grids**
  - Committee-provided six-member RANS grid family (Cadence and Helden Aero)
  - One-cell wide
  - Encourage use of committee-supplied grids; user-generated grids are acceptable

- **Conditions**
  - Pre-buffet conditions the same as other working groups: 1.36, 1.50, 2.50, 3.00, 3.10◦
  - Buffet working group supplement (post-onset): 3.25, 3.40, 3.50, 3.60, and 3.90◦

Test Case 1b : Unsteady CFD Validation

- **Buffet Working Group supplement. Validation of unsteady CFD analysis**
- **Mostly the same as Test Case 1a**
- **Settings**
  - Unsteady CFD (URANS, hybrid RANS/LES, WMLES, LES, etc.)
  - Prefer some version of SA, multiple turbulence models can be submitted
- **Grids**
  - Same geometry as Test Case 1a
  - Specialized grids for unsteady schemes will likely be generated by participants
- **Conditions**
  - Same as Test Case 1a
- **Data**
  - All data in this presentation are preliminary and are subject to change for the workshop

Data Submission and Participants List

Data Submission

- **Submissions taken from both Scatter Reduction Working Group (focused on low angles of attack) and Buffet Working Group**

- **Data submissions collected on the shared Github repository (16 May 2025):**
  - https://github.com/Drag-Prediction-Workshop/DPW8-Buffet
  - Repository is open to contributors
  - Additional datasets are accepted for the final workshop

- **Dataset status:**
  - An overview was given in May at the Mini-Workshop 2
  - Some corrections have been requested (some amended, some not)
  - Some exclusions have been made. Some mistakes have been made on our side!
  - The idea is for this to be corrected for the final workshop

Participant List

ID	Team	Organization	Solver	Method	Turbulence Model	Grid
002	Mestriner	Embraer	CFD++	RANS	SA, SA-RC-QCR SST	Cadence structured, Cadence unstructured, HeldenAero
004	Pomeroy, Jamal, Pandya	NASA (Langley CAB)	USM3D-ME	RANS	SA, SA-R, SA-QCR2000	Cadence unstructured
005	Housman	NASA (Ames)	LAVA	RANS URANS HRLES	SA-neg, SA-neg-RC-comp	Cadence structured Deck extruded
006	Jirasek	US Air Force Academy	Loci/CHEM	RANS, URANS, HRLES	k-w-Wilkox 1998k, SST	Cadence unstructured
007	Sansica, Lusher, Matsuzaki	JAXA	FaSTAR	RANS, URANS	SA-noft2, SA-noft2-R, SA-noft2-R-QCR, SST	Cadence structured, Custom
008	Batten, Bachchan, Kovvali	Metacomp	CFD++	RANS, URANS, HRLES	SA-neg-RC-QCR	Cadence structured, Deck extruded
009	Petropoulos, Sartor	ONERA (DAAA)	elsA	RANS	SA, SST	Cadence structured, Cadence unstructured, Custom, HeldenAero
010	Goc, Clark	Boeing (BCA Technology)	charLES	WMLES	Dynamic Smagorinski	Custom
012	Chwalowski Massey Jacobson	NASA (Langley AEL)	FUN3D	RANS, URANS	SA-neg, SA-neg-comp SA-neg-comp-QCR, SA-neg-RC-comp-QCR, SST-comp-QCR	Cadence unstructured, Custom adapted
014	Udupa, Venkatraman	IIS	SU2	RANS, URANS	SA-Edwards	Cadence unstructured
018	Darbyshire, Wainwright, Allan	Zenotech	zCFD	RANS	SA-neg, SST-V-2003	Cadence unstructured
021	Lamberson, Lynch, Jamal, Pomeroy	CREATE-AV NASA Langley	Kestrel	RANS, URANS	SA-RC-QCR	Cadence unstructured
023	Arnould, Radigue, Laurendau	Polytechnique Montreal	CHAMPS	RANS	SA	Cadence unstructured
024	Nash, Timme	Univ. of Liverpool	TAU	RANS	SA-neg	Cadence unstructured
026	Eldrige-Allegra, McGowan	Corvid Tech.	Raven	RANS	SA, SA-comp	Cadence unstructured
027	Candon, Gerner	RMIT	N/A	RANS, URANS	SA, SA-C, SST, SST-C	Cadence structured
032	Jansson	KTH	N/A	Adaptive Euler	N/A	Custom

- **Dataset submitted:**
  - 18 groups
  - 74 datasets submitted
- **Method:**
  - RANS: 56 datasets
  - URANS: 11 datasets
  - Hybrid RANS/LES: 5 datasets
  - WMLES: 1 dataset
  - Adaptive Euler: 1 dataset
- **Grid:**
  - Cadence structured: 15 datasets
  - Cadence unstructured: 35 datasets
  - Custom: 21 datasets
  - Helden Aerospace: 3 datasets

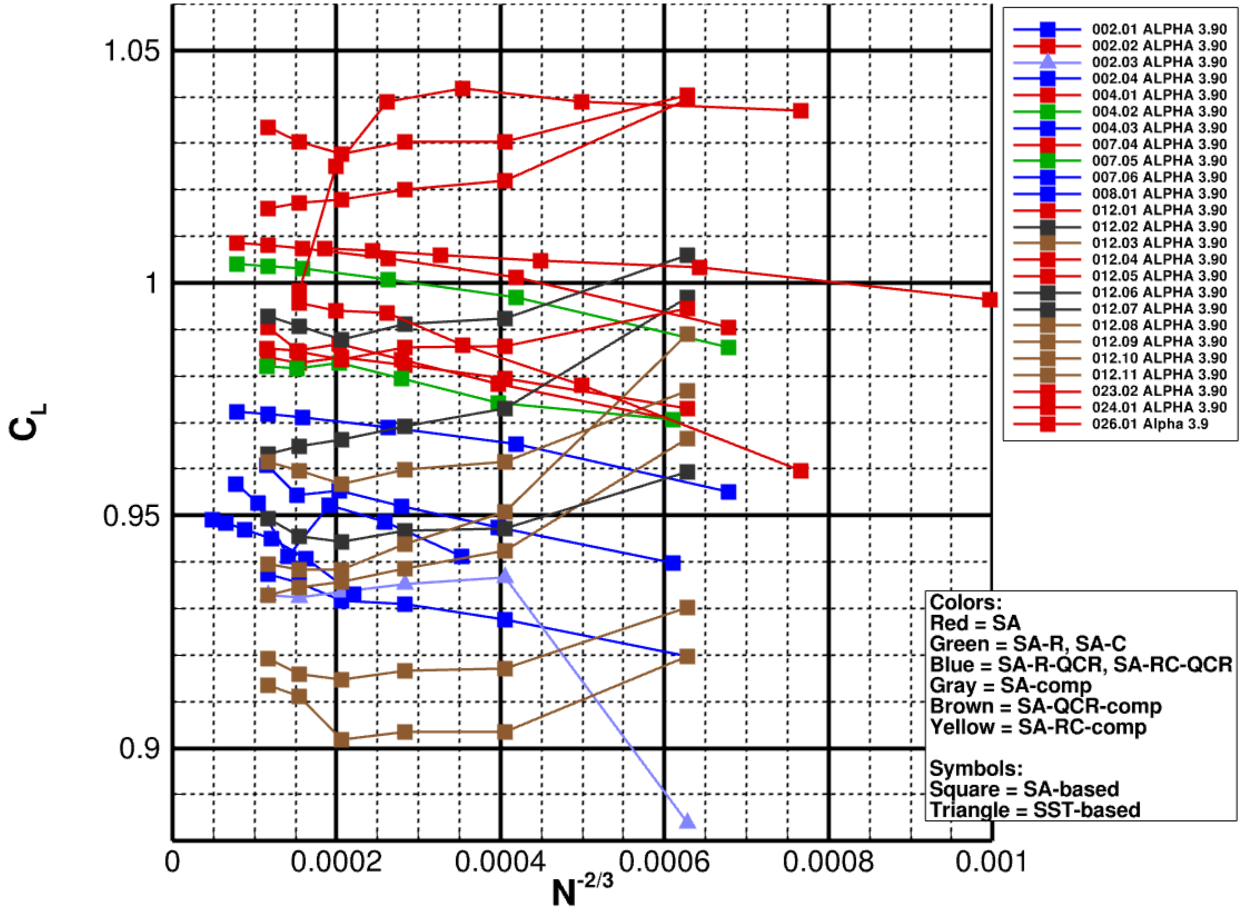
Note: All data are preliminary and are subject to change

Test Case 1a:
RANS Results

Grid Study

Test Case 1a : Grid Study at α = 3.90◦

Colored by turbulence model variant



Shown for α = 3.90◦ but generally true for all other angles of attack

SA, SA-R, SA-C ("SA" group s= red and green) tend to give higher values of CL and CD and lower values of CM compared to SA-QCR, SA-comp, SA-QCR-comp, SA-RC-comp ("QCR/comp" group = blue, gray brown)

Few contributions with SST, but they seem to follow the "QCR/comp" group

Note: All data are preliminary and are subject to change

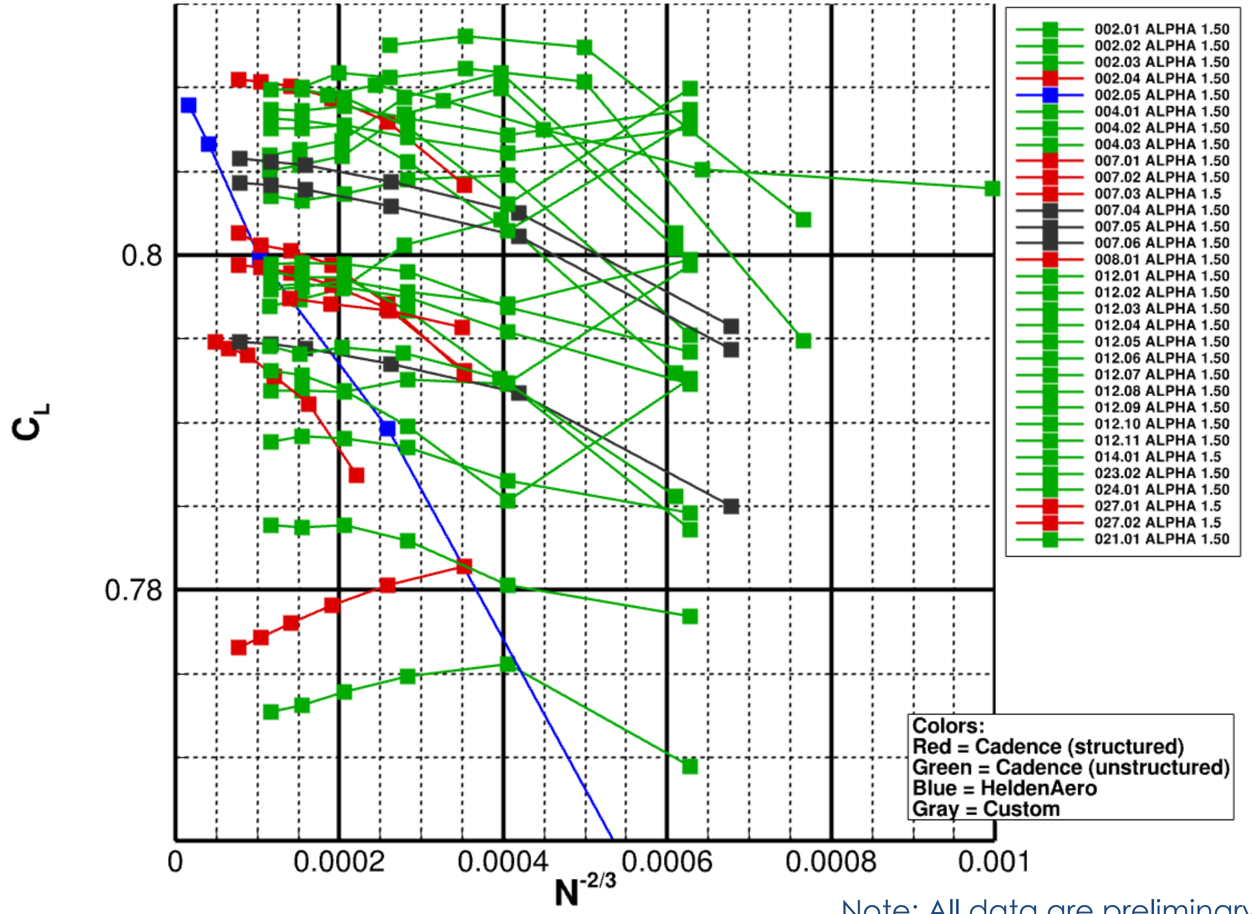
Test Case 1a : Grid Study at α = 1.50°

Colored by grid type

Shown for α = 3.90° but generally true for all other angles of attack

Not striking trends due to grid type.

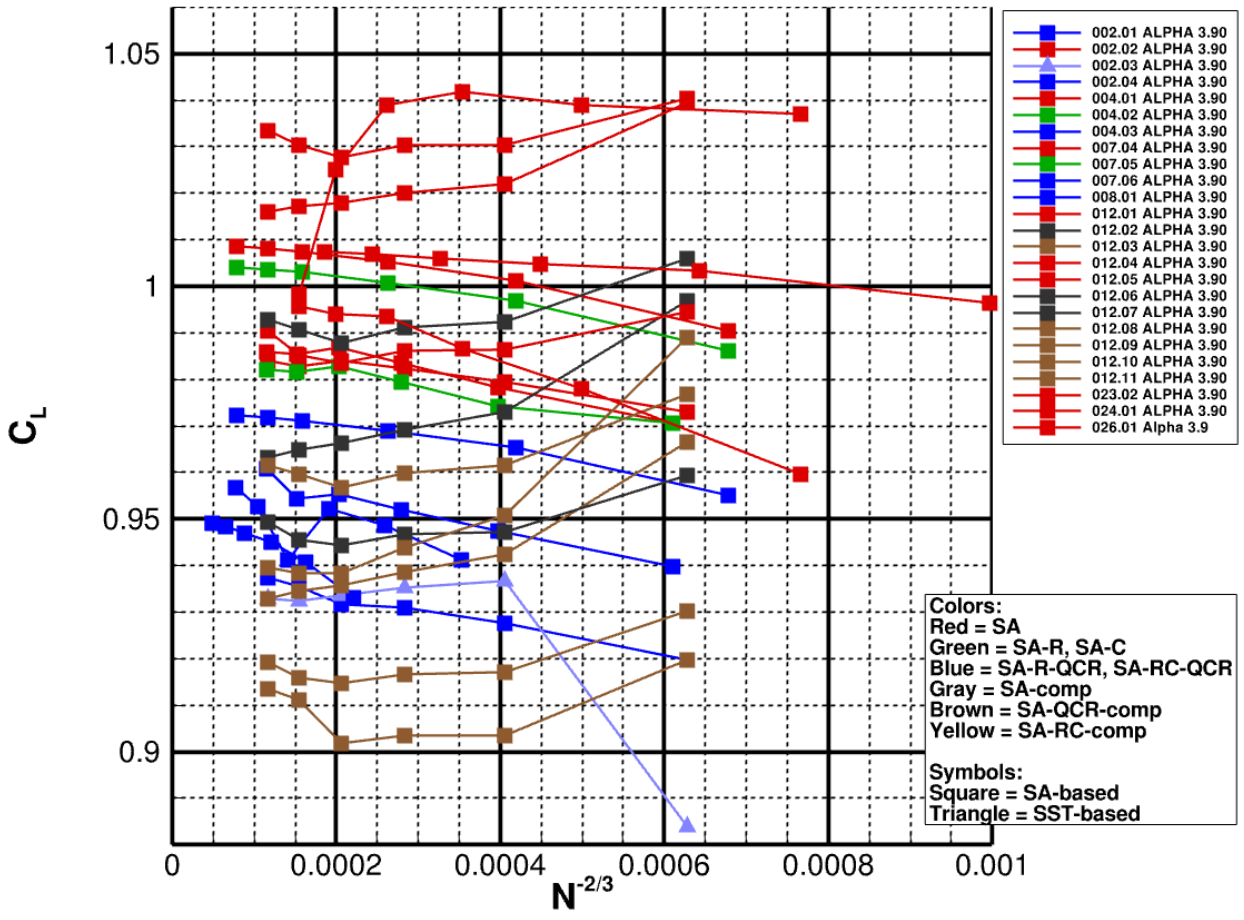
However, most of the participants used custom grids and the metrics are unknown (now requested)



Note: All data are preliminary and are subject to change

Test Case 1a : Grid Study at α = 3.90◦

Colored by turbulence model variant



Shown for α = 3.90◦ but generally true for all other angles of attack

Grid convergence not shown

Large scatter (fine grid available):

- α = 3.10◦: 10 CD-counts, 35
- α = 3.50◦: 50 CD-counts, 95 CL-counts
- α = 3.90◦: 90 CD-counts, 120 CL-counts

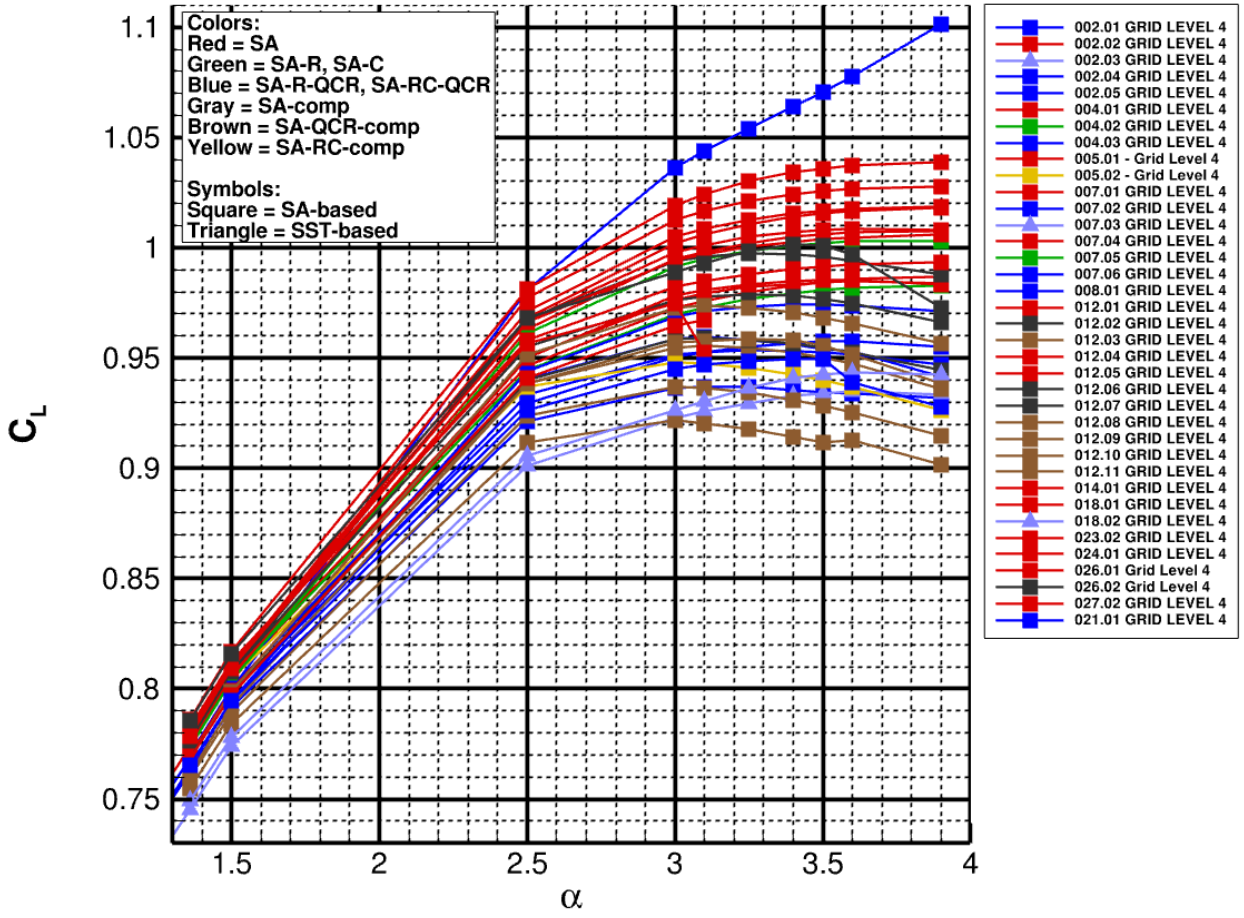
Note: All data are preliminary and are subject to change

Test Case 1a: RANS Results

Polars

Test Case 1a : Polars (Grid Level 4)

Colored by turbulence model variant



Shown for CL but generally true for CD and CM and other grid levels

Similarly to for the grid study, "SA" group (SA, SA-R, SA-C; red and green) tends to give higher values of CL and CD and lower values of CM compared to the "QCR/comp" group (SA-QCR, SA-comp, SA-QCR-comp, SA-RC-comp; blue, gray brown).

SST closer to the "QCR/comp" group

Note: All data are preliminary and are subject to change

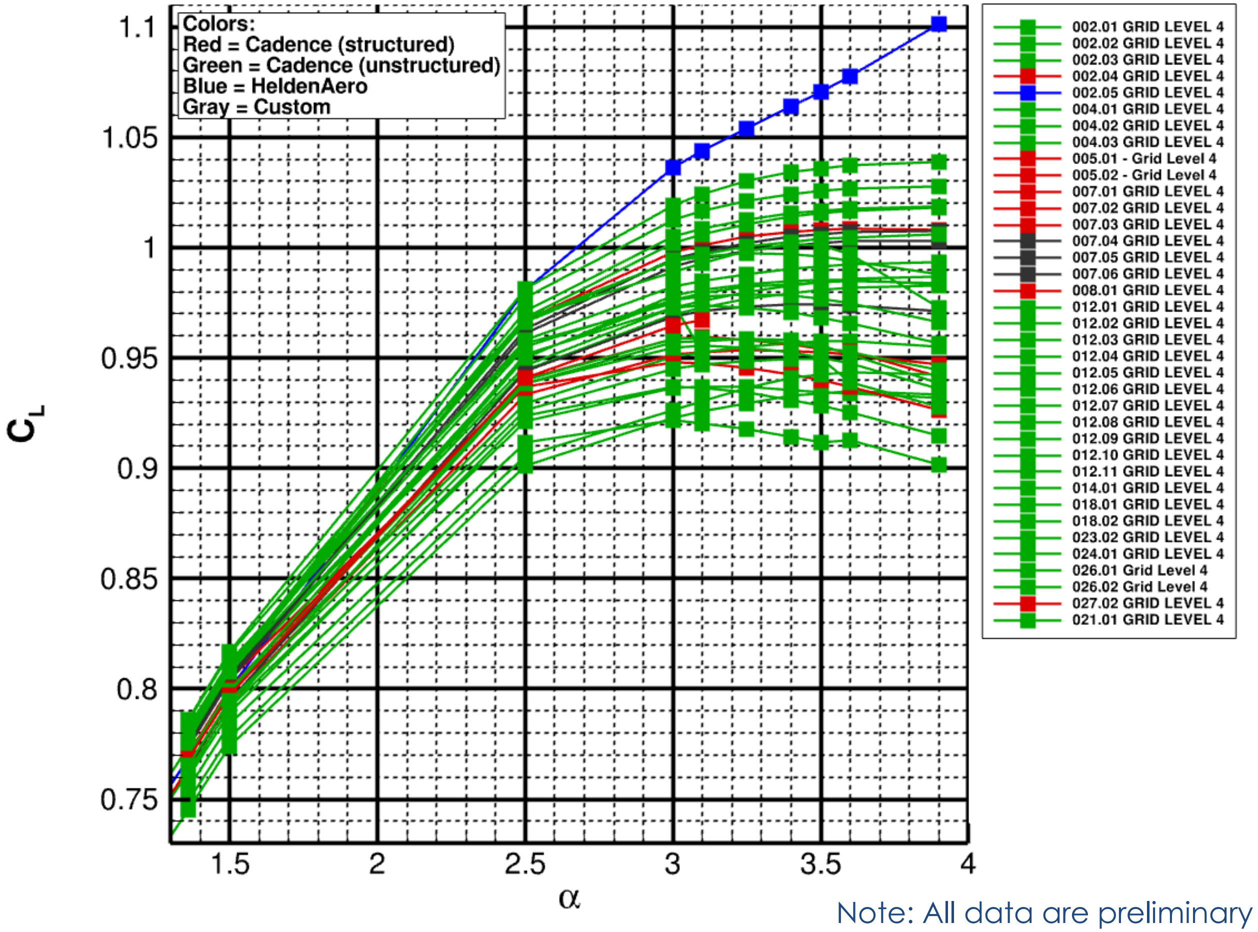
Test Case 1a : Polars (Grid Level 4)

Shown for CL but generally true for CD and CM and other grid levels

Not striking trends due to grid type.

Understanding the metrics of the custom grids will be crucial

Colored by grid type



Note: All data are preliminary and are subject to change

Test Case 1a : Polars (Grid Level 4)

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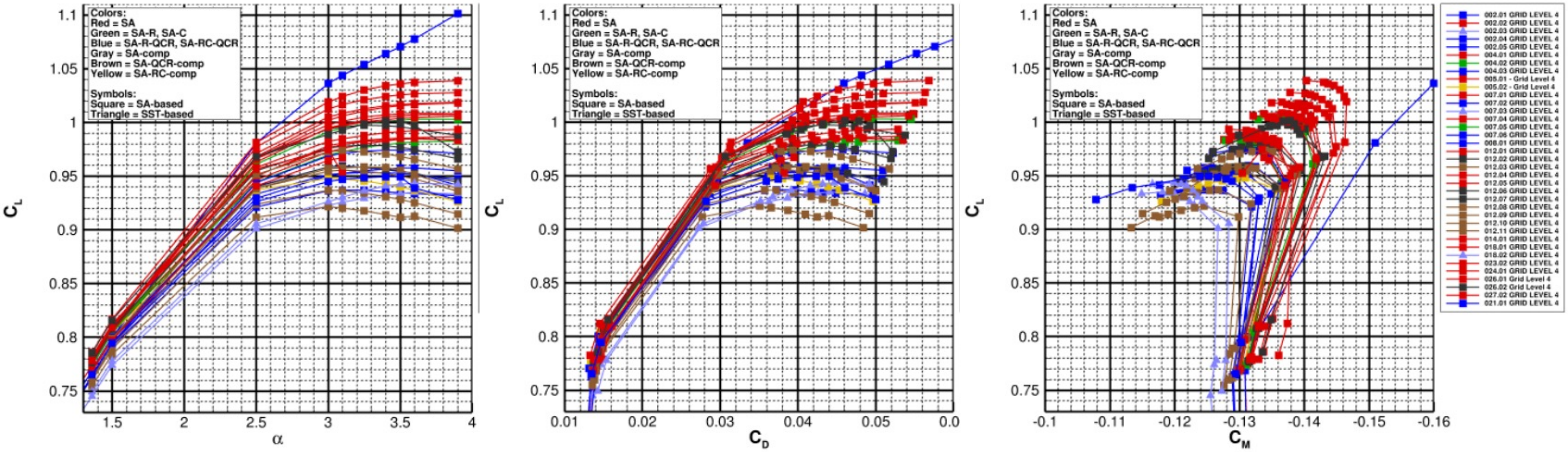
Colored by turbulence model variant



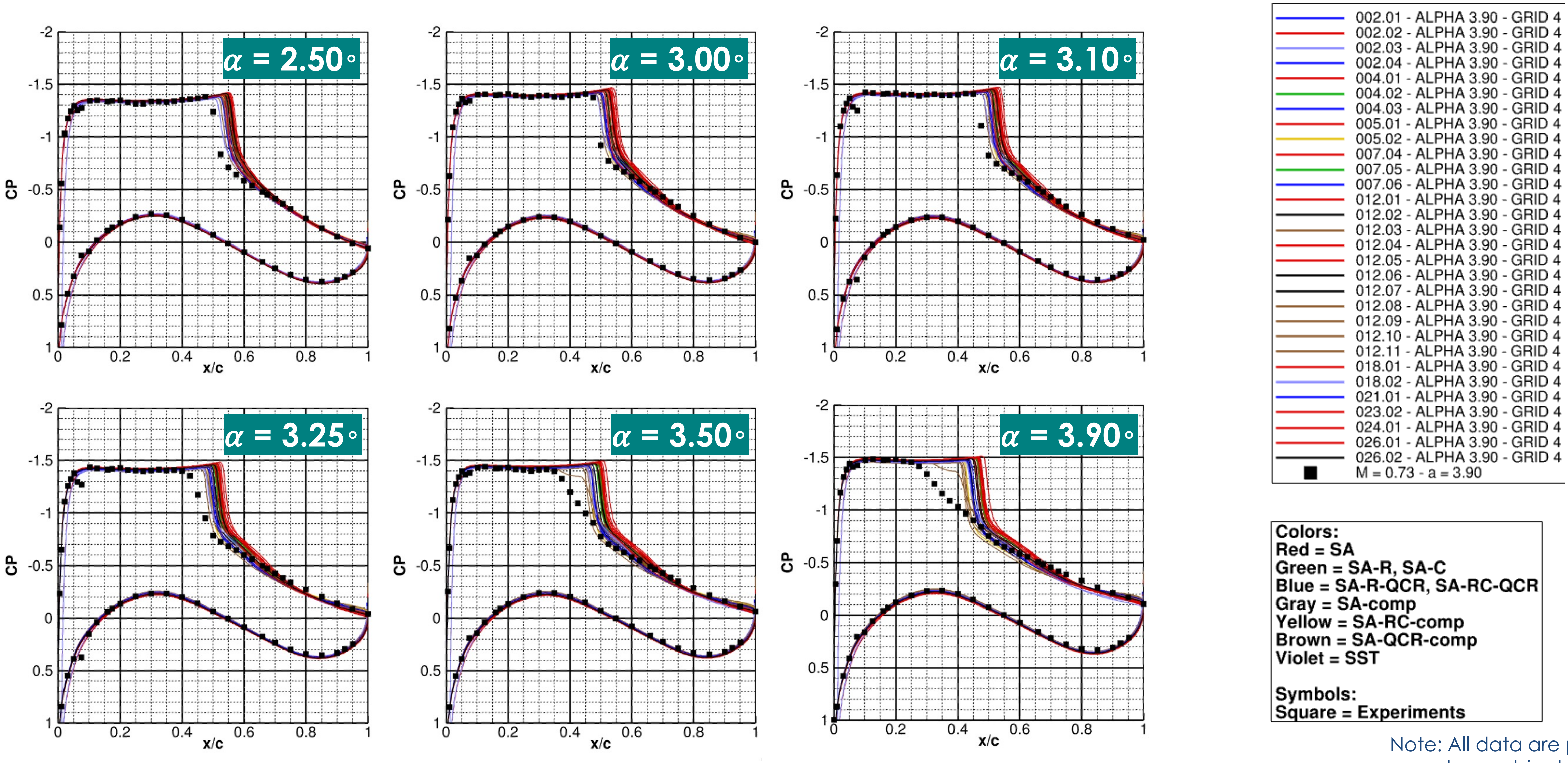
- **Larger scatter than for the full-aircraft (DPW-7):**
  - For the lowest angle of attack, about 30 CD-counts and 40 CL-counts
  - For the highest angle of attack, 75 CD-counts and 140 CL-counts

Note: All data are preliminary and are subject to change

Test Case 1a:
RANS Results

CP-cuts

Test Case 1a : Cp-cuts

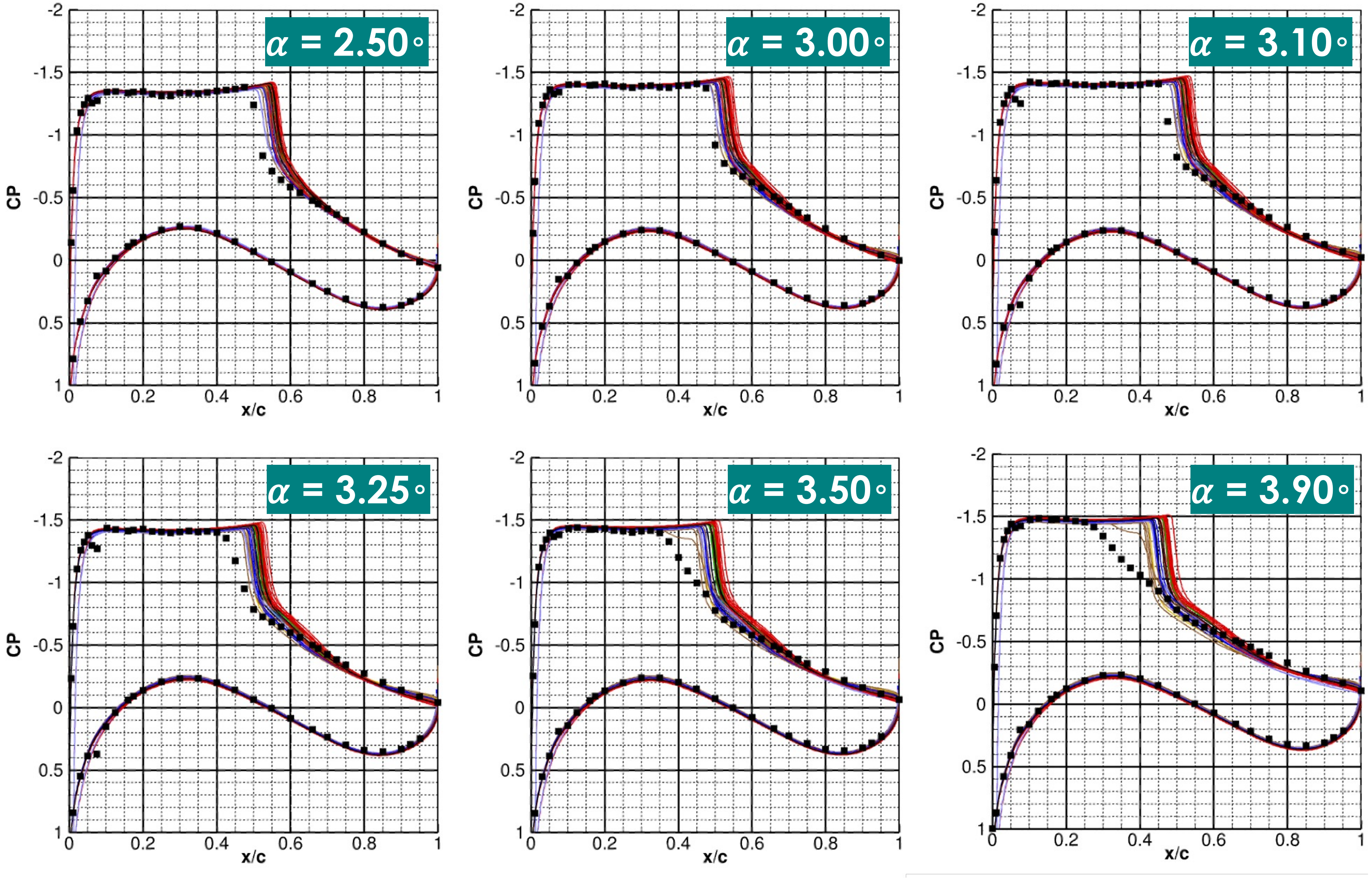


Colors:
Red = SA
Green = SA-R, SA-C
Blue = SA-R-QCR, SA-RC-QCR
Gray = SA-comp
Yellow = SA-RC-comp
Brown = SA-QCR-comp
Violet = SST

Symbols:
Square = Experiments

Note: All data are preliminary and are subject to change

Test Case 1a : Cp-cuts



- **Even before onset, most solutions predict the shock too downstream**
  - “-comp” correction improves things but still differences
- **Because of the steady nature of the calculations, the shock does not move and does not capture the smooth (time-averaged) gradient across the shock for post-onset cases**

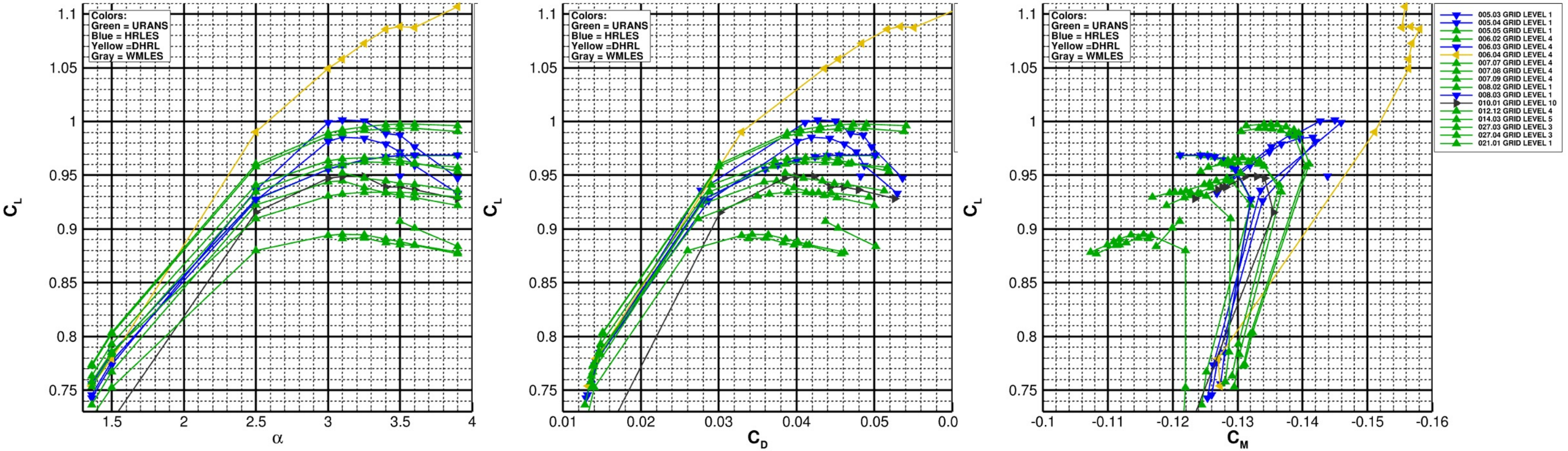
Note: All data are preliminary and are subject to change

Test Case 1b:
Unsteady Results

Polars

Test Case 1b : Polars

Colored by method



- **Few contributions, mostly URANS, but some HRLES and WMLES submitted**
- **Again, larger scatter**
- **Time-averaged results, but unclear how transients and statistics collections times were decided (future work)**

Note: All data are preliminary and are subject to change

Test Case 1b : Polars (steady vs unsteady)

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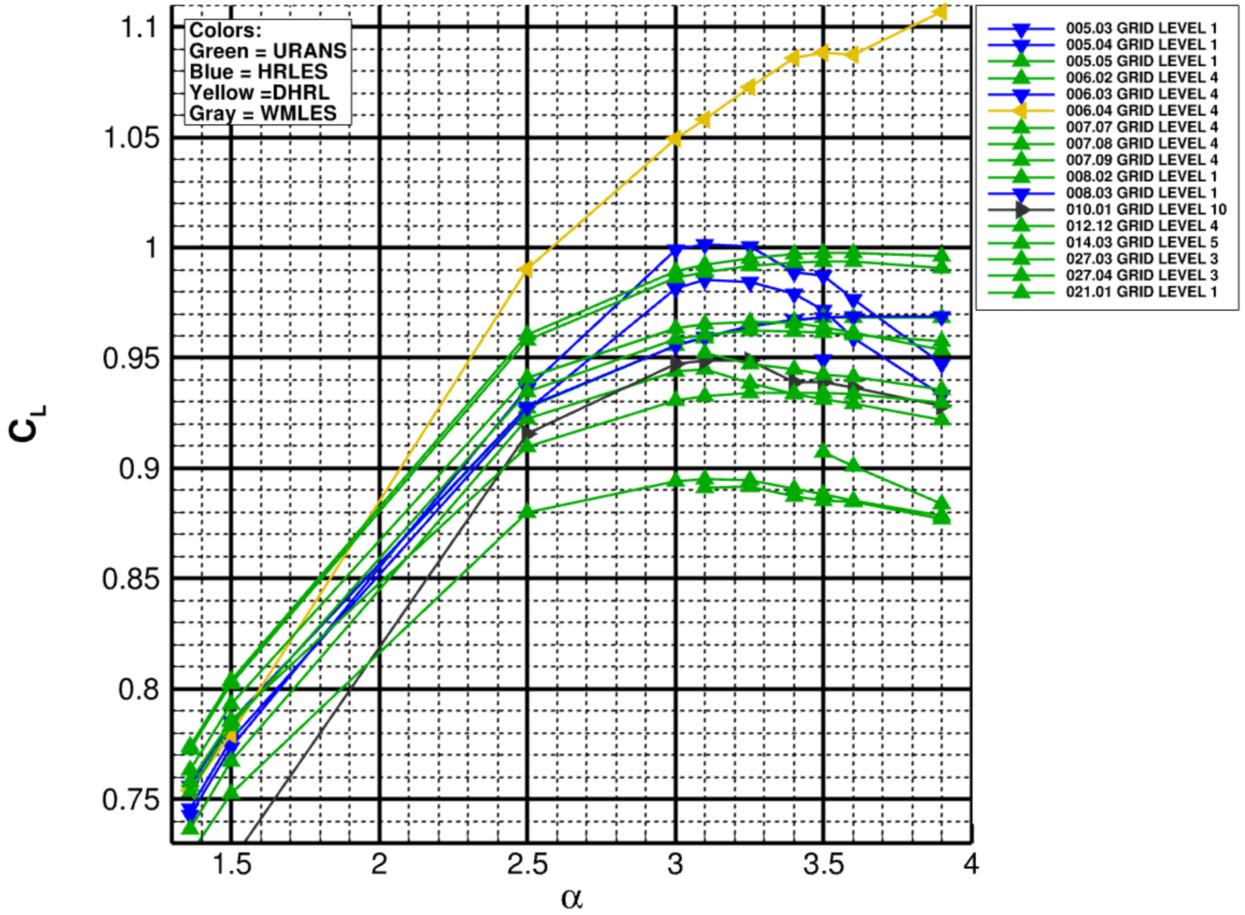
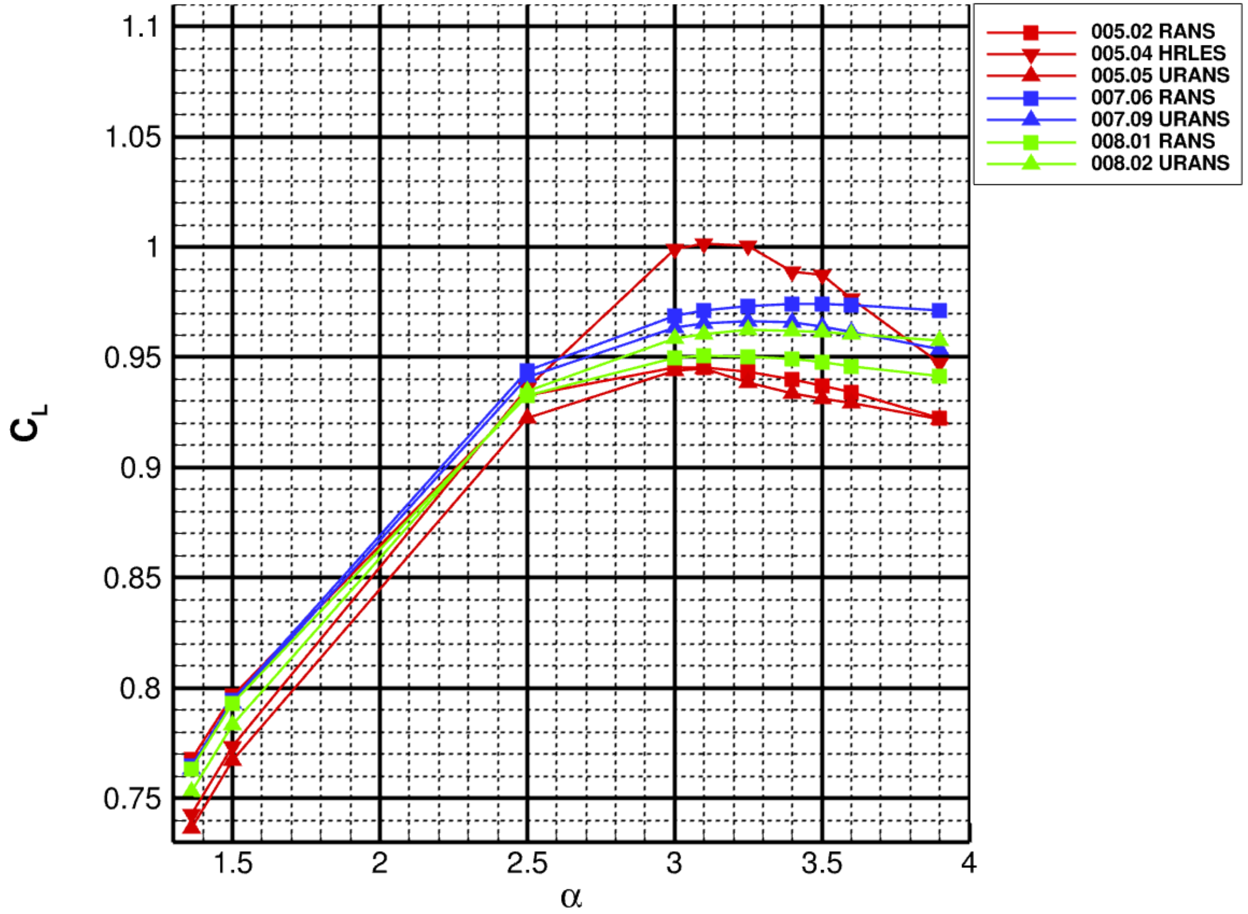
Colored by method



Colored by ID (selected) contributions



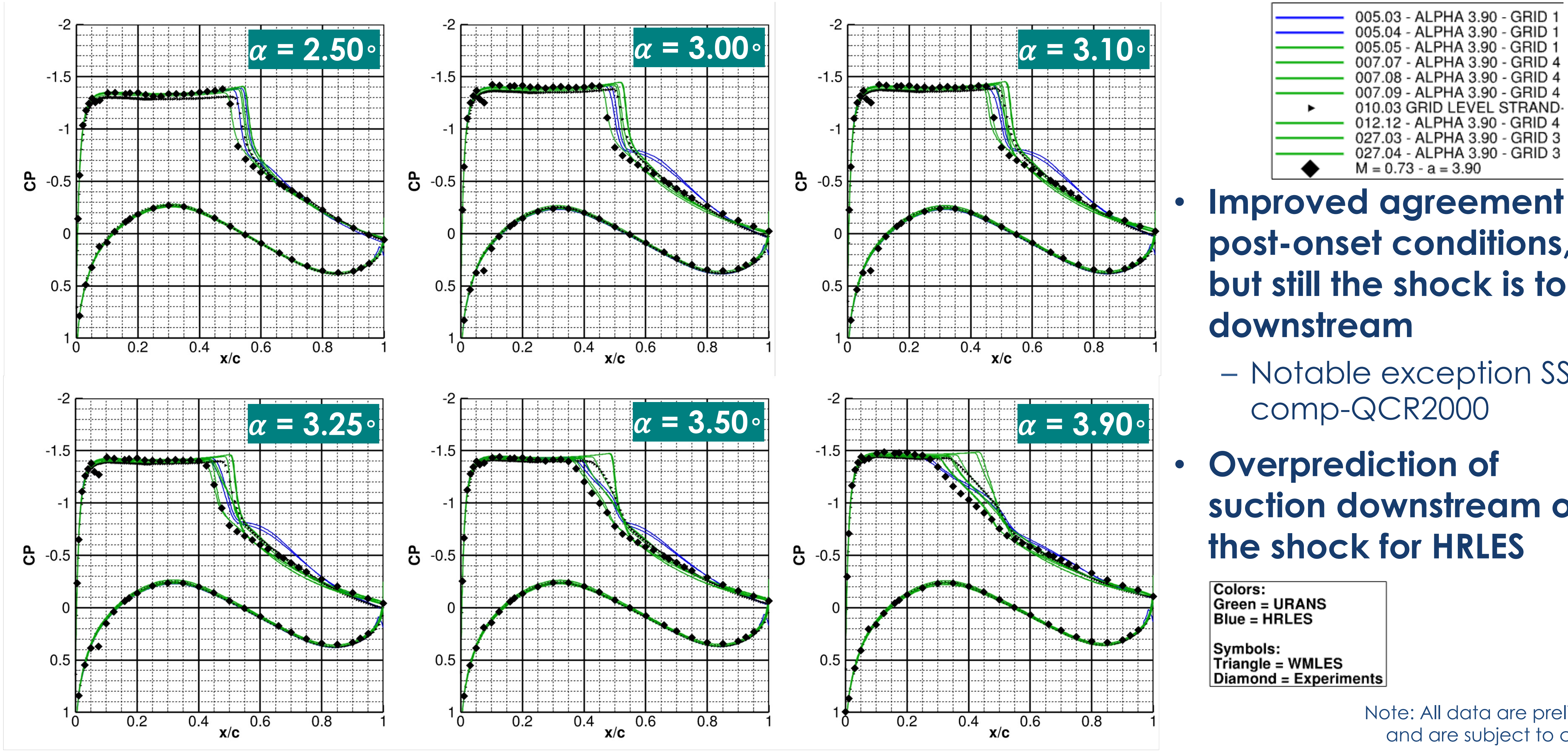
- **For the same participant/setup:**
  - Steady and unsteady values do not match at pre-buffet
  - Time-averaged unsteady values should be lower than steady, but they are not

Note: All data are preliminary and are subject to change

Test Case 1b: Unsteady Results

CP-cuts

Test Case 1a : Cp-cuts (mean)



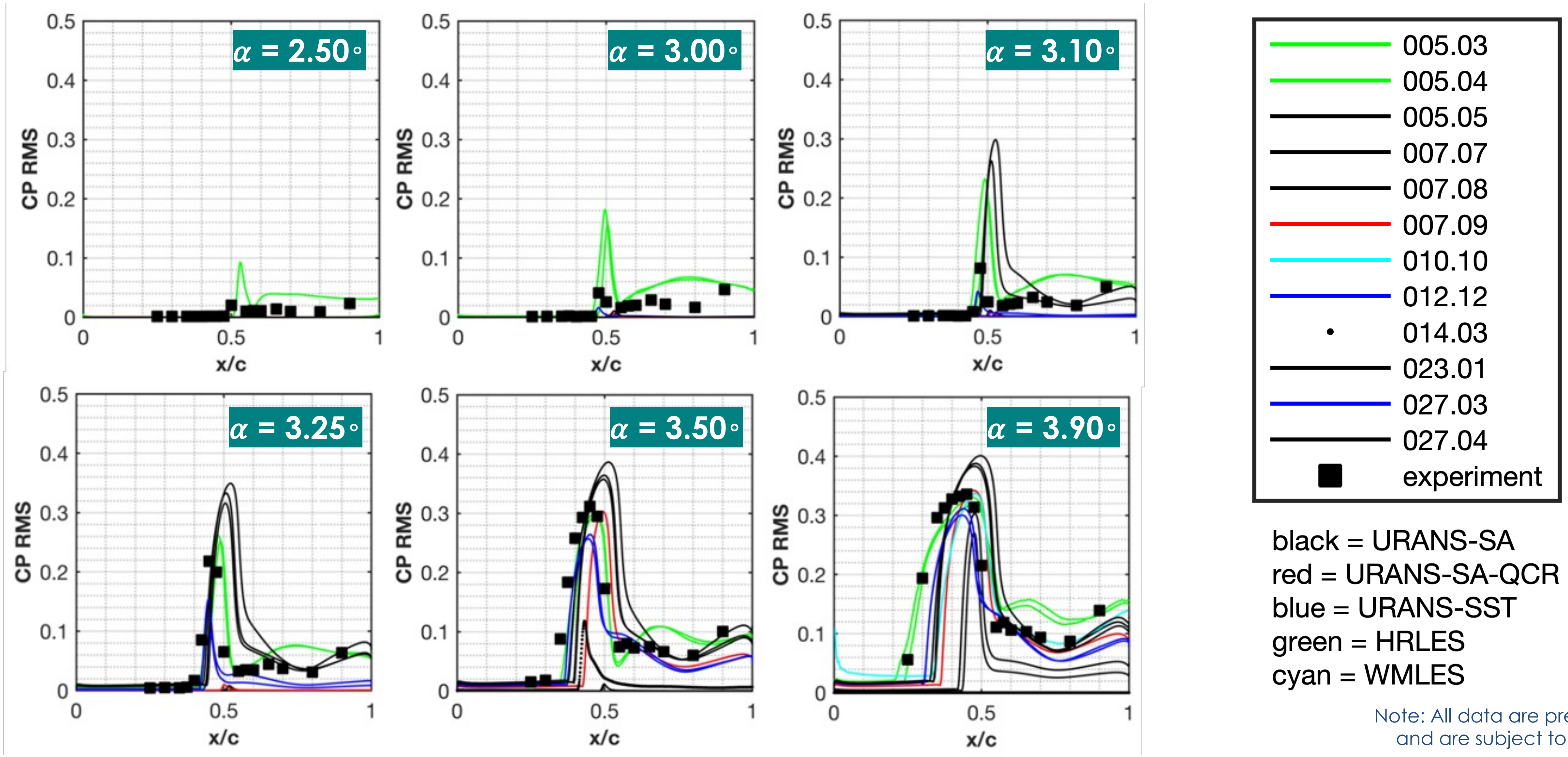
- **Improved agreement at post-onset conditions, but still the shock is too downstream**
  - Notable exception SST-comp-QCR2000
- **Overprediction of suction downstream of the shock for HRLES**

Colors:
Green = URANS
Blue = HRLES

Symbols:
Triangle = WMLES
Diamond = Experiments

Note: All data are preliminary and are subject to change

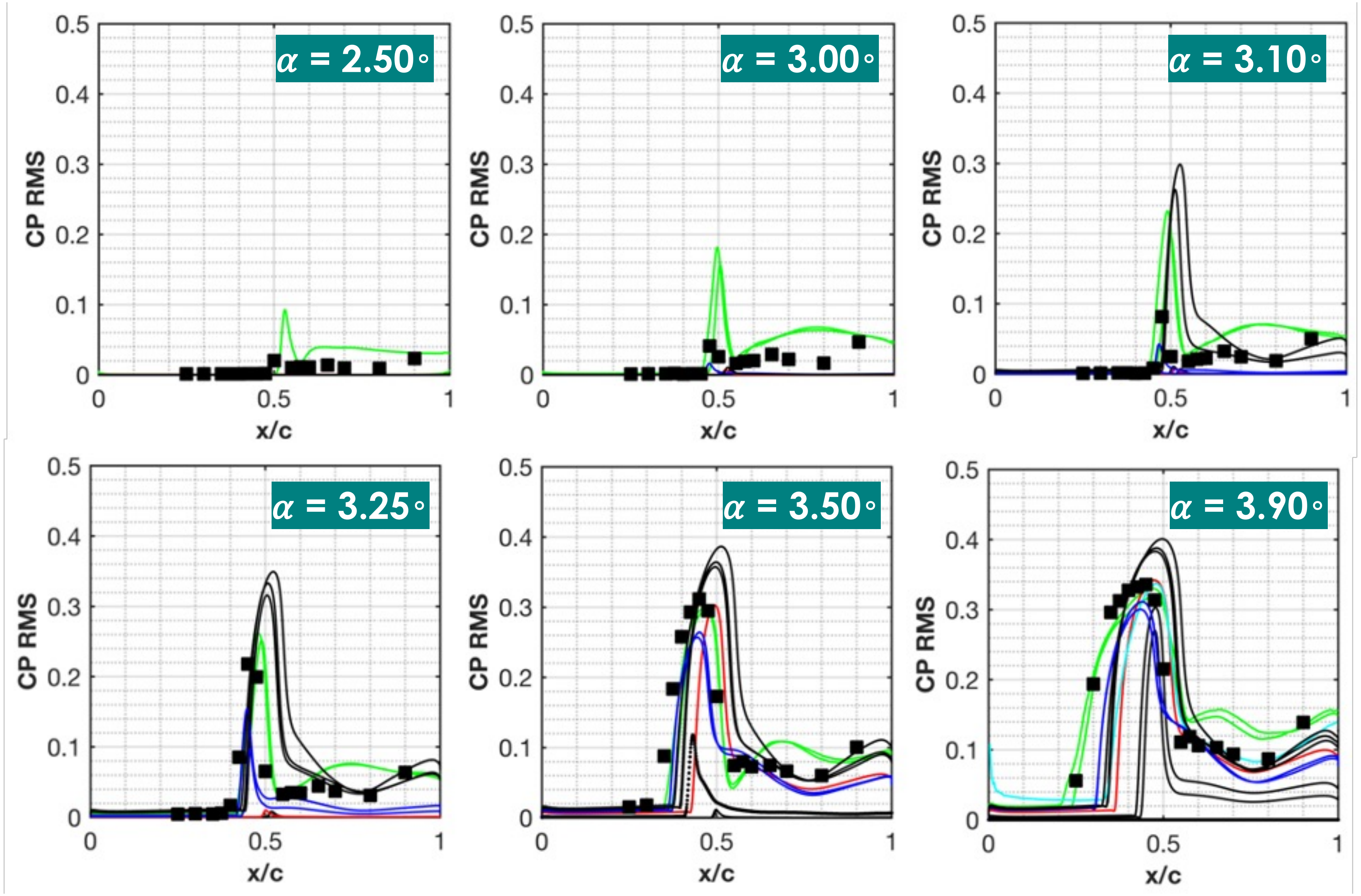
Test Case 1a : Cp-cuts (rms)



black = URANS-SA
red = URANS-SA-QCR
blue = URANS-SST
green = HRLES
cyan = WMLES

Note: All data are preliminary and are subject to change

Test Case 1a : Cp-cuts (rms)



- **HRLES and SA-comp strong fluctuations and early onset**
- **SA-QCR and SST weak fluctuations and delayed onset**
- **Fluctuations peak amplitude, location and width:**
  - URANS fail at predicting the width of the fluctuations amplitude, location and width, but behave well downstream of the interaction
  - Opposite happens for the HRLES solutions
  - For the highest alpha, WMLES behaves best but still differences upstream of the peak

Note: All data are preliminary and are subject to change

Conclusions and Way Forward

Conclusions: General

- **Summary of preliminary data for Buffet Working Group efforts for Test Case 1**
- **A huge thanks to all contributors, leading groups and plotting teams!**
- **Of the 74 datasets provided, only 18 unsteady datasets (mostly URANS)**
  - Possible reasons?
    - increased computational costs
    - difficulties in setting up time-integration parameters
- **Large number of participants used customs grids.**
  - What are the reasons?
  - More investigations on the grid metrics will be done for the final workshop

Conclusions: Results

- **RANS results:**
  - Grid independence not shown
  - Larger scatter than in DPW-7 for the full-aircraft (not objective of the Buffet Working Group, but still concerning)
  - Differences between “SA” and “QCR/comp” groups
  - Shock generally predicted too downstream even for pre-onset cases
    - Are the experiments truly 2D?
    - 3D span-periodic simulations? Sensitivity to span width?
    - What is the effect of corner separations?

- **Unsteady results**
  - Few contributions, difficult to make definite conclusions
  - Large scatter between different methods (URANS, HRLES, WMLES)
  - Improvement of the prediction of shock behavior, but still too downstream
  - Fluctuations are difficult to capture correctly

Way Forward

- **If you find any problems in the presented data, please get in touch (aiaabuffet@gmail.com)**

- **Participants can correct and add datasets for the final workshop**

- **Further work on case 1:**
  - PSD comparisons
  - Custom grid metrics information
  - Transients and statistics collection times
  - Confirmation of different SA flavours

- **Many lessons learnt, but improved communication is needed for the success of the more complex cases 2 and 3 (full-aircraft)**

Test Case 1a:
RANS Results

Grid Study

Test Case 1a : Grid Study at $\alpha = 1.50°$

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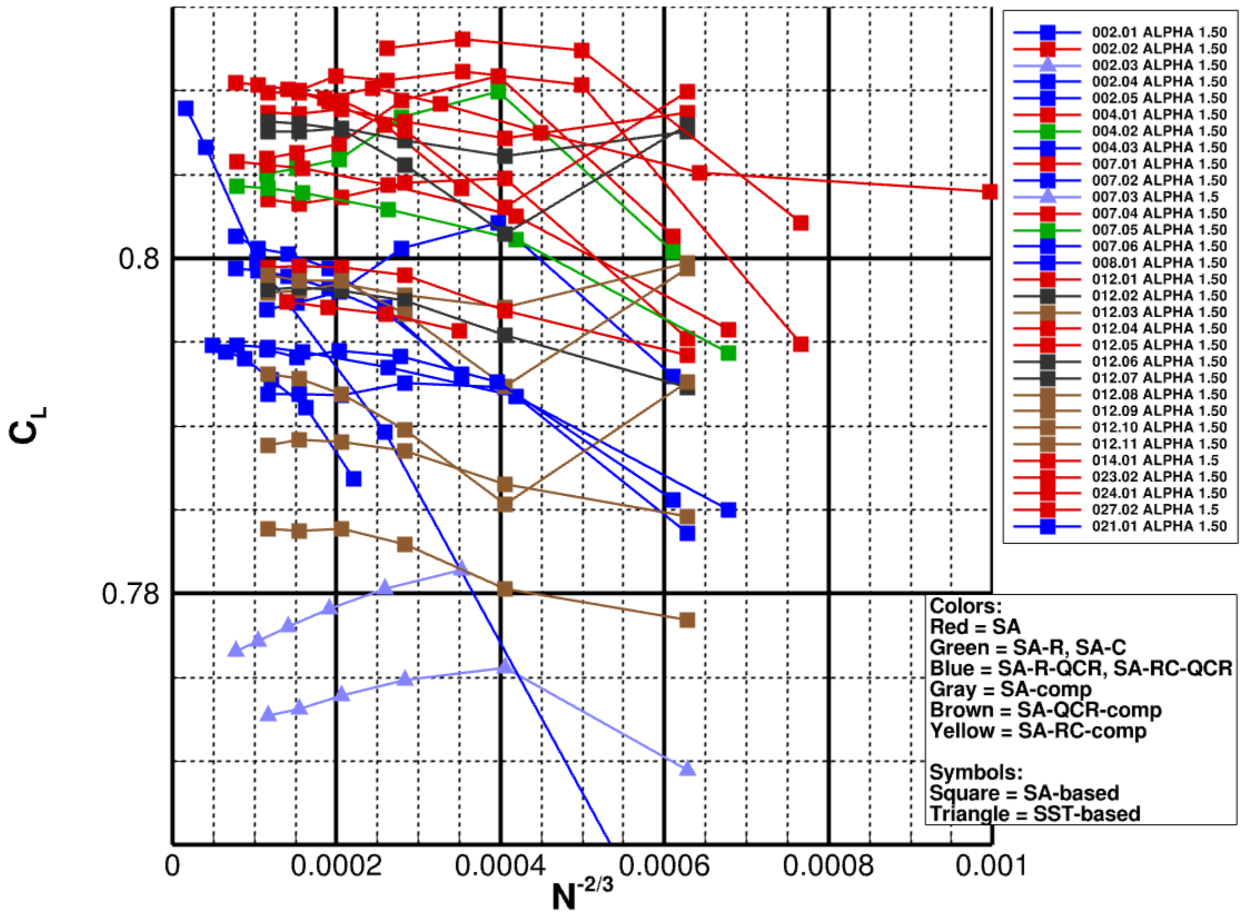
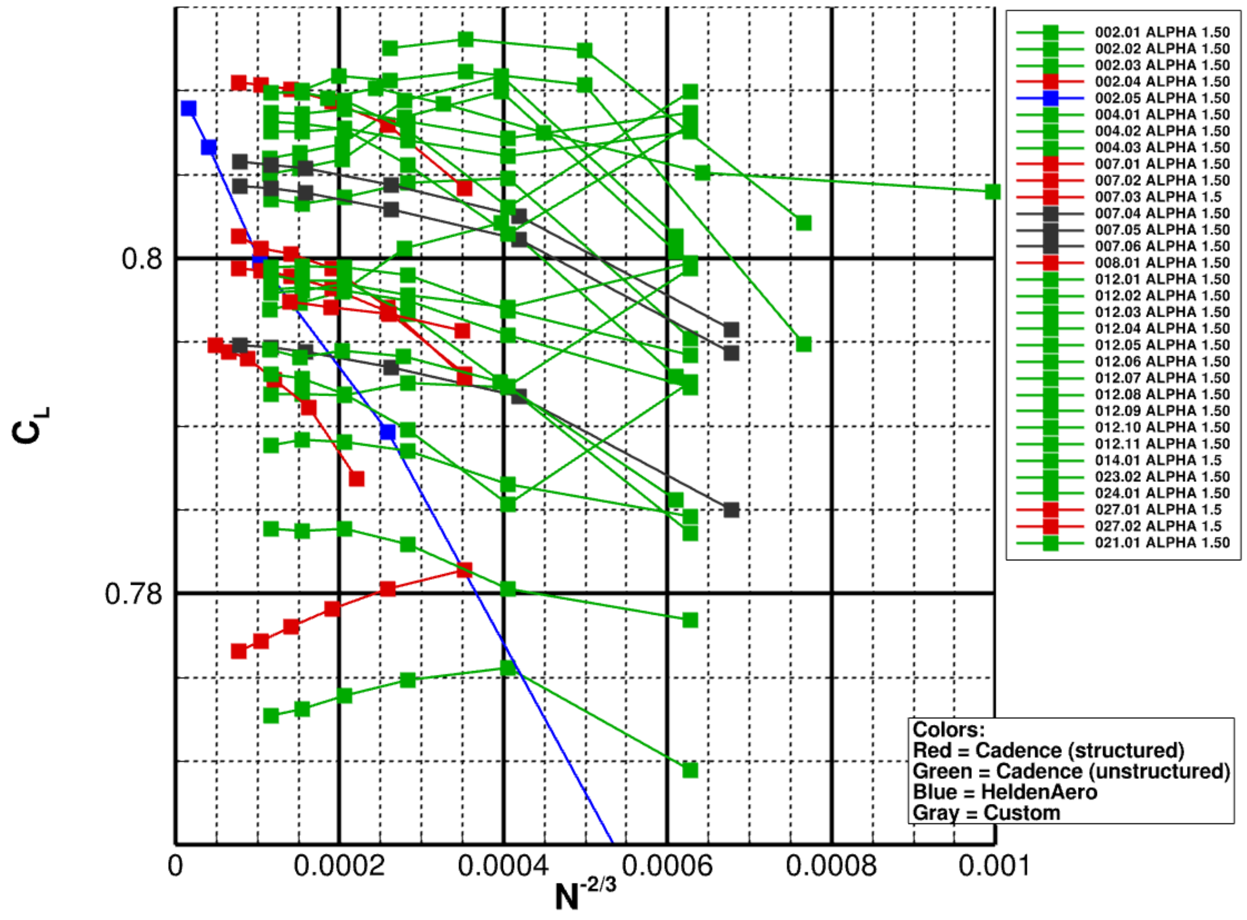
Colored by turbulence model variant

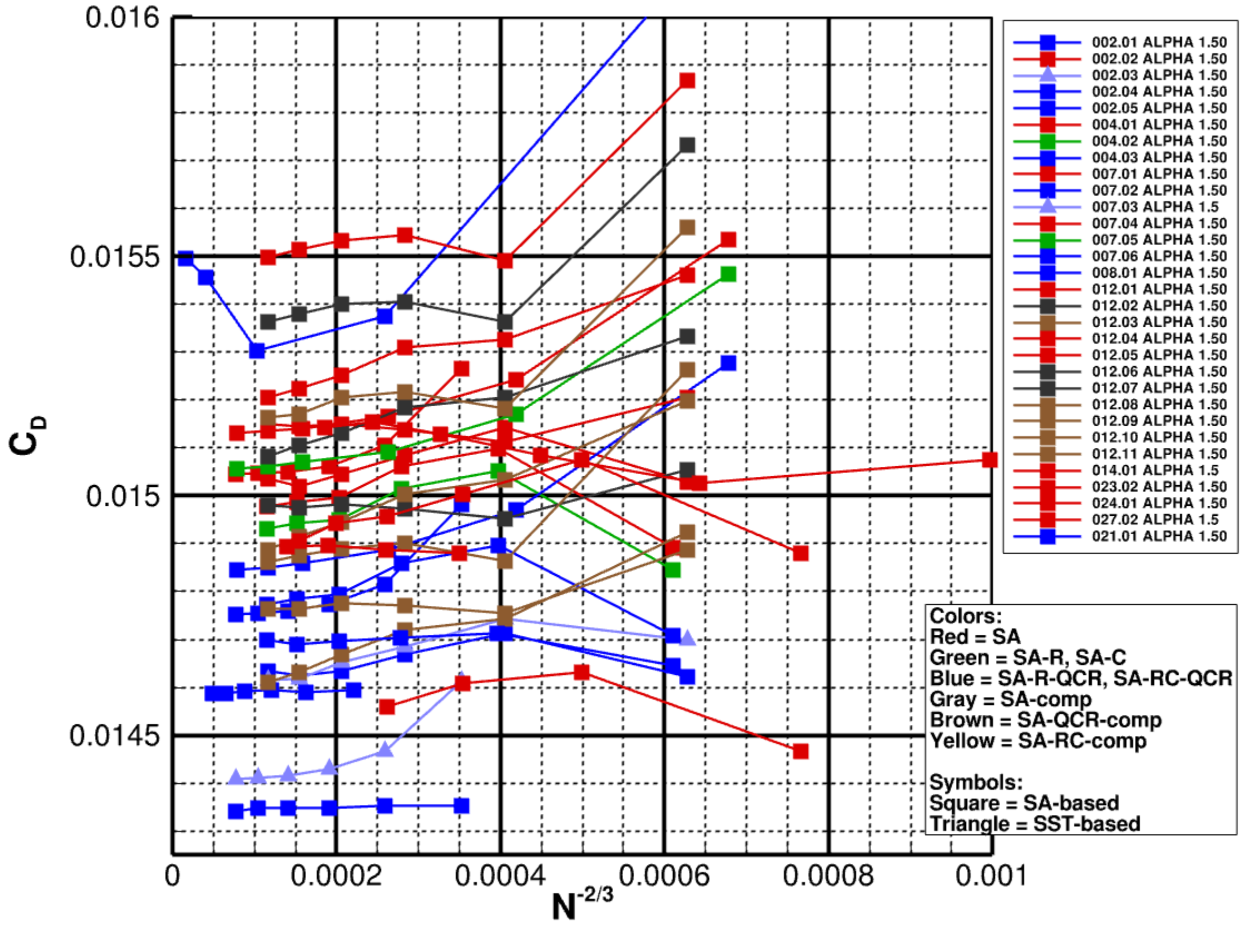


Colored by grid type

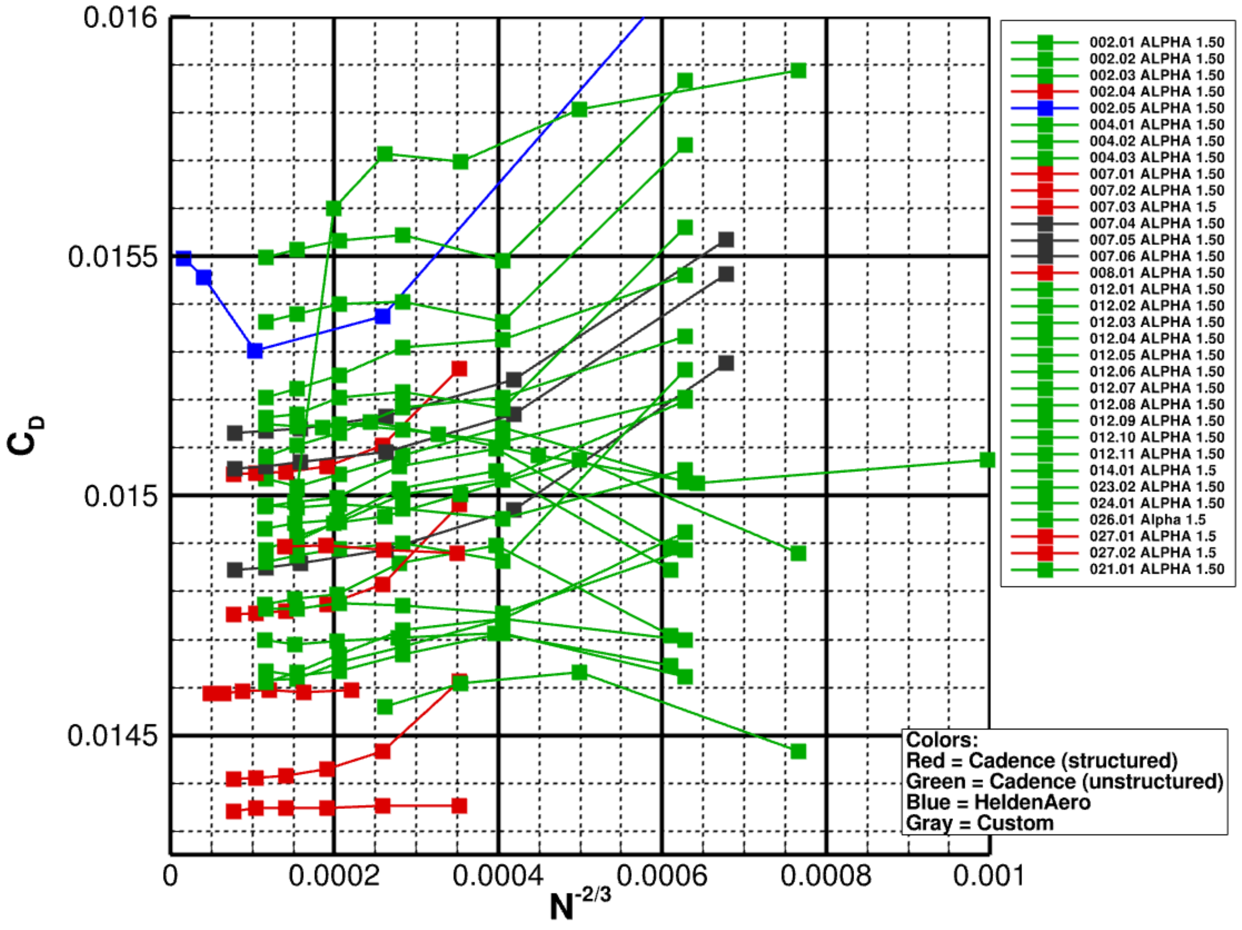


Test Case 1a : Grid Study at $\alpha = 1.50^\circ$

Colored by turbulence model variant



Colored by grid type



Test Case 1a : Grid Study at α = 1.50°

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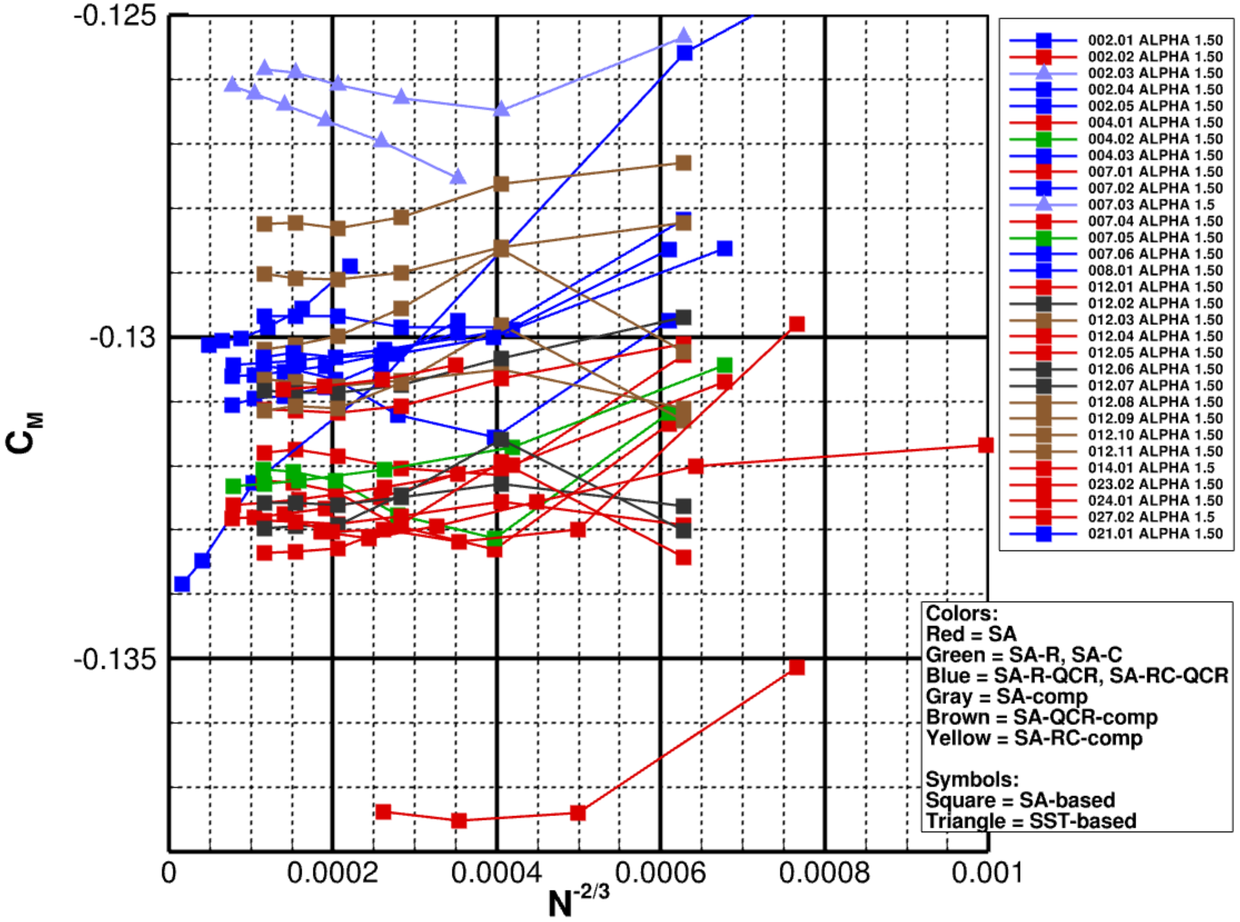
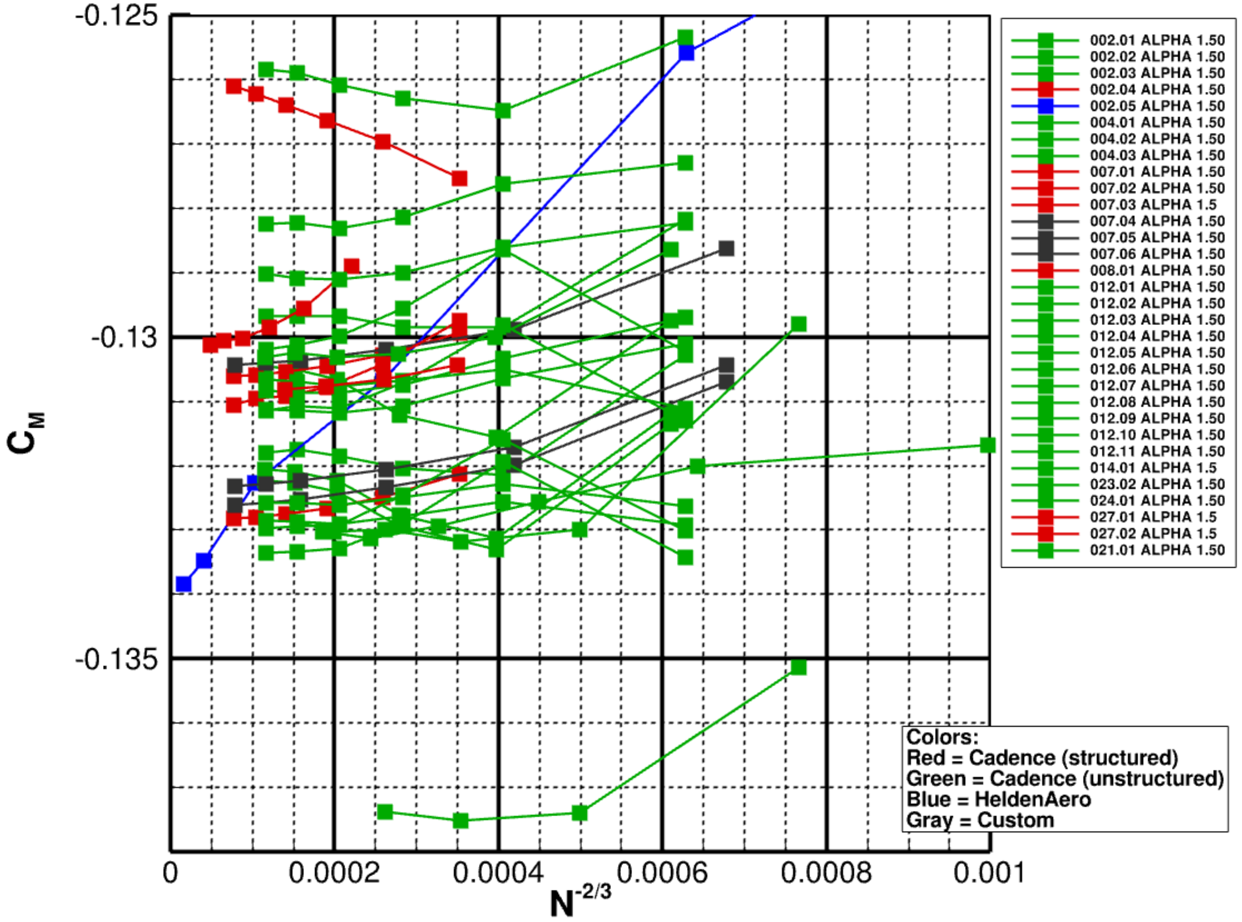
Colored by turbulence model variant

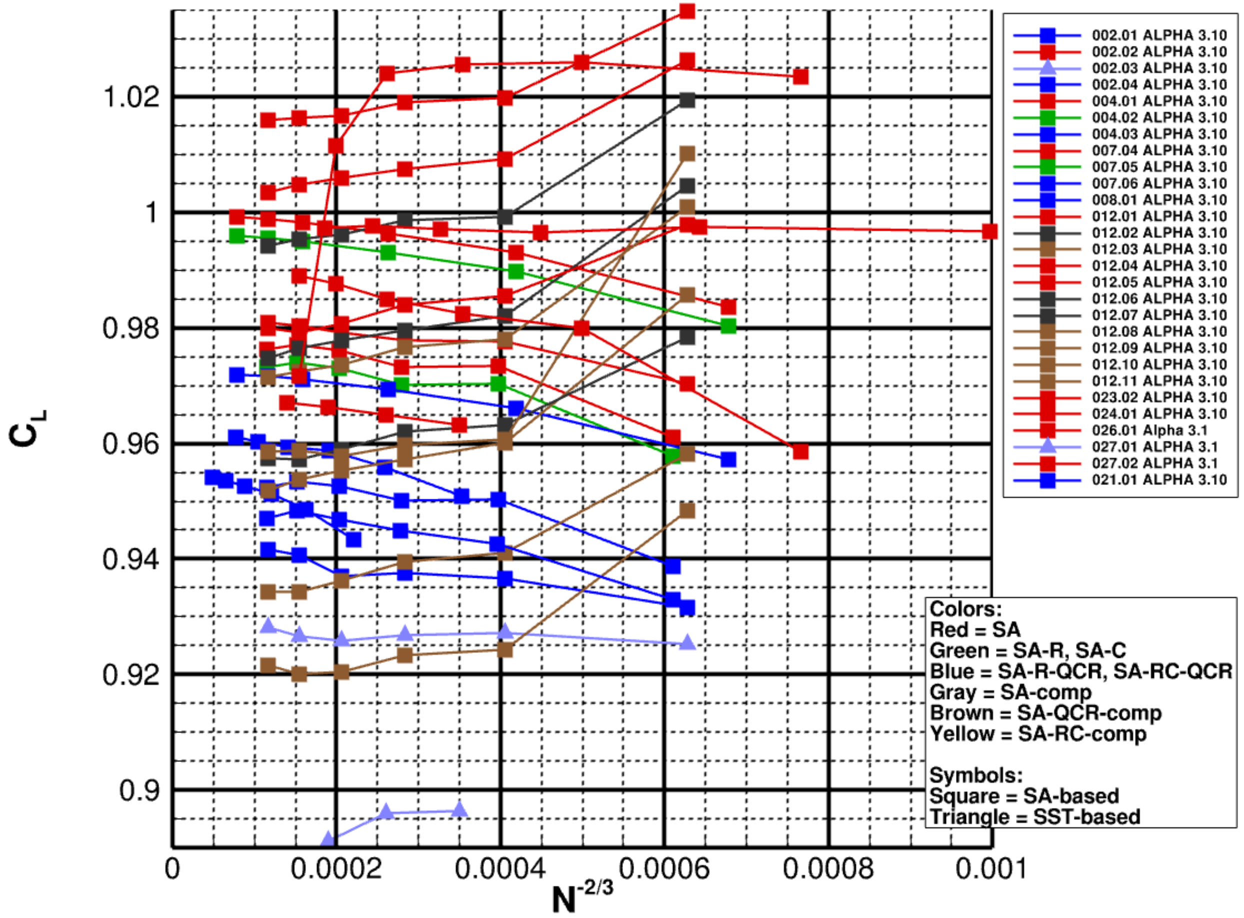


Colored by grid type

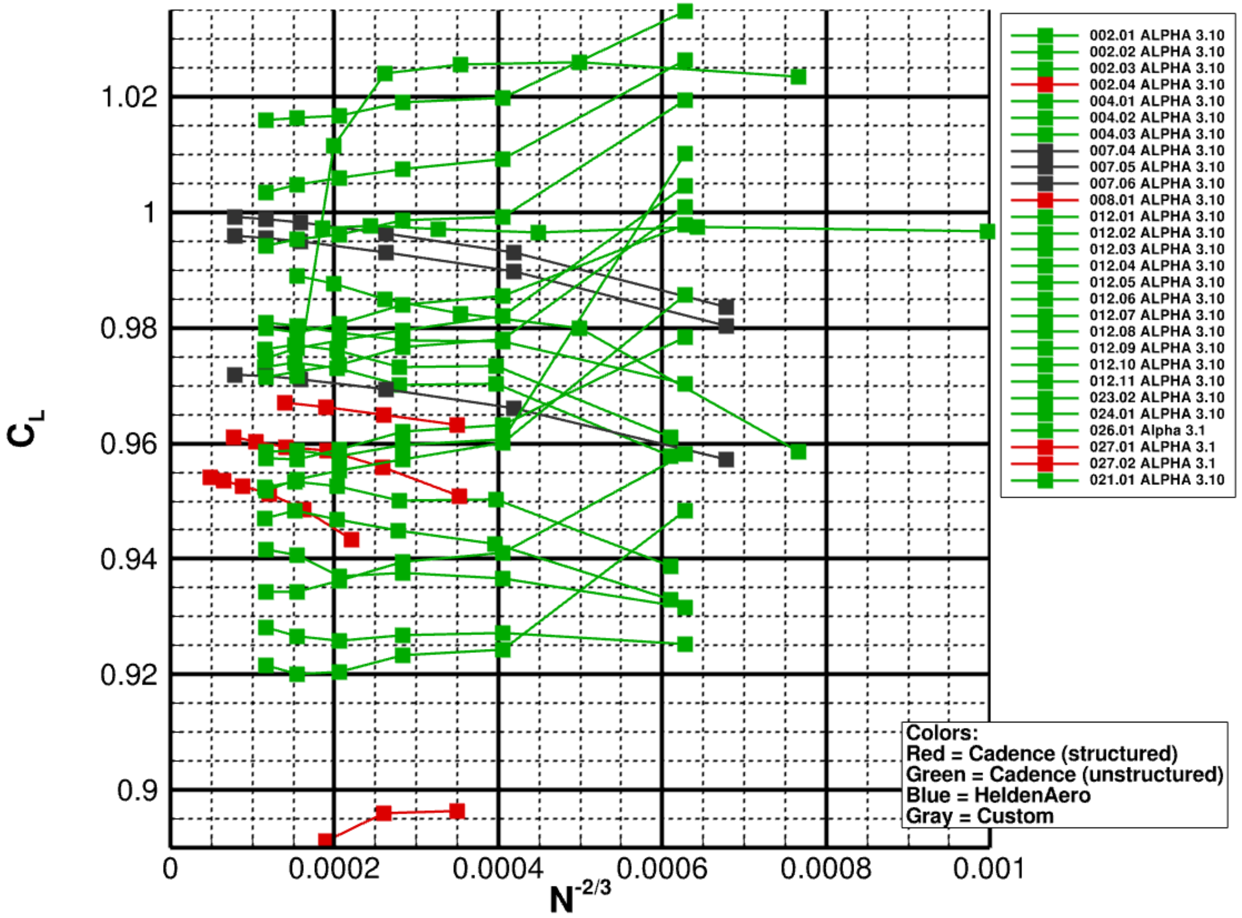


Test Case 1a : Grid Study at $\alpha = 3.10^{\circ}$

Colored by turbulence model variant

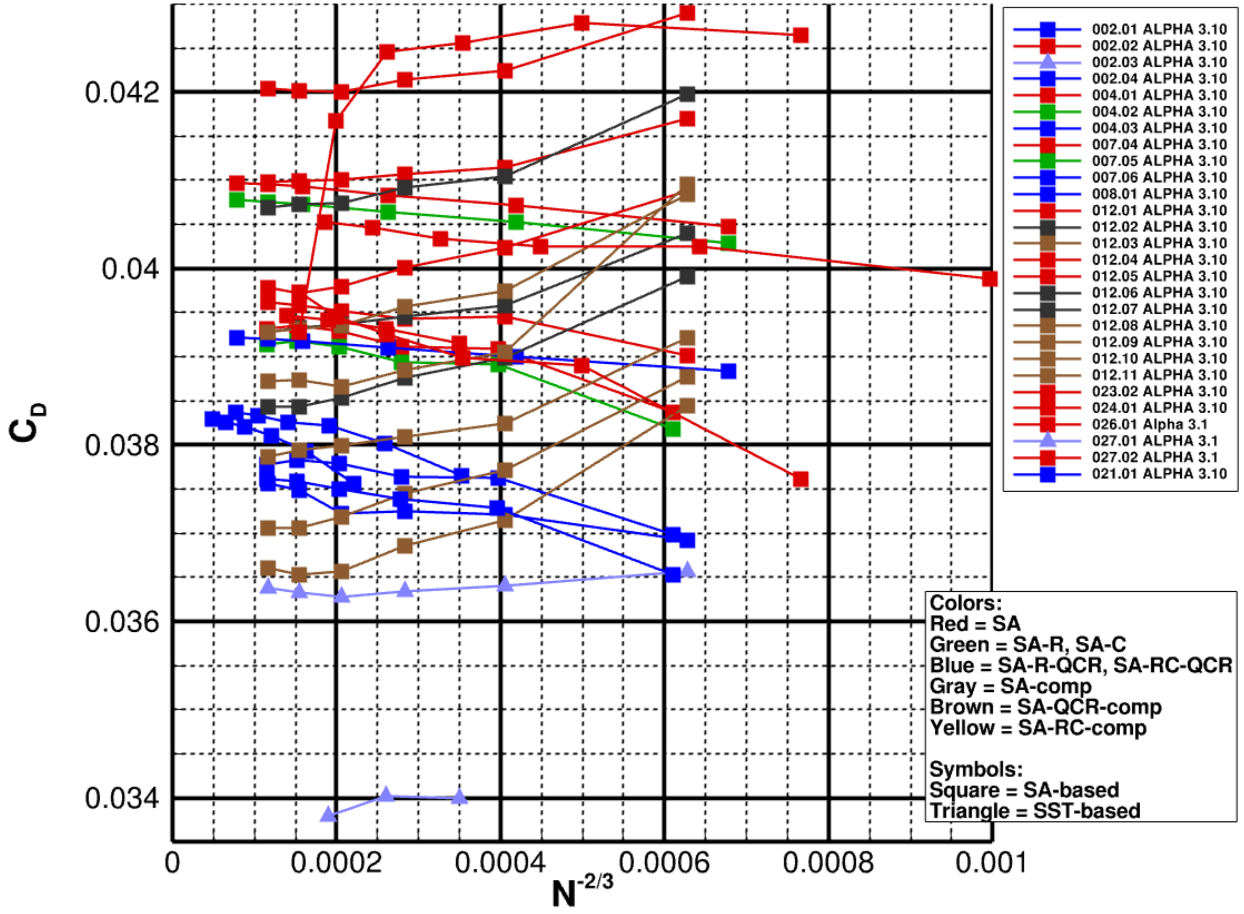


Colored by grid type

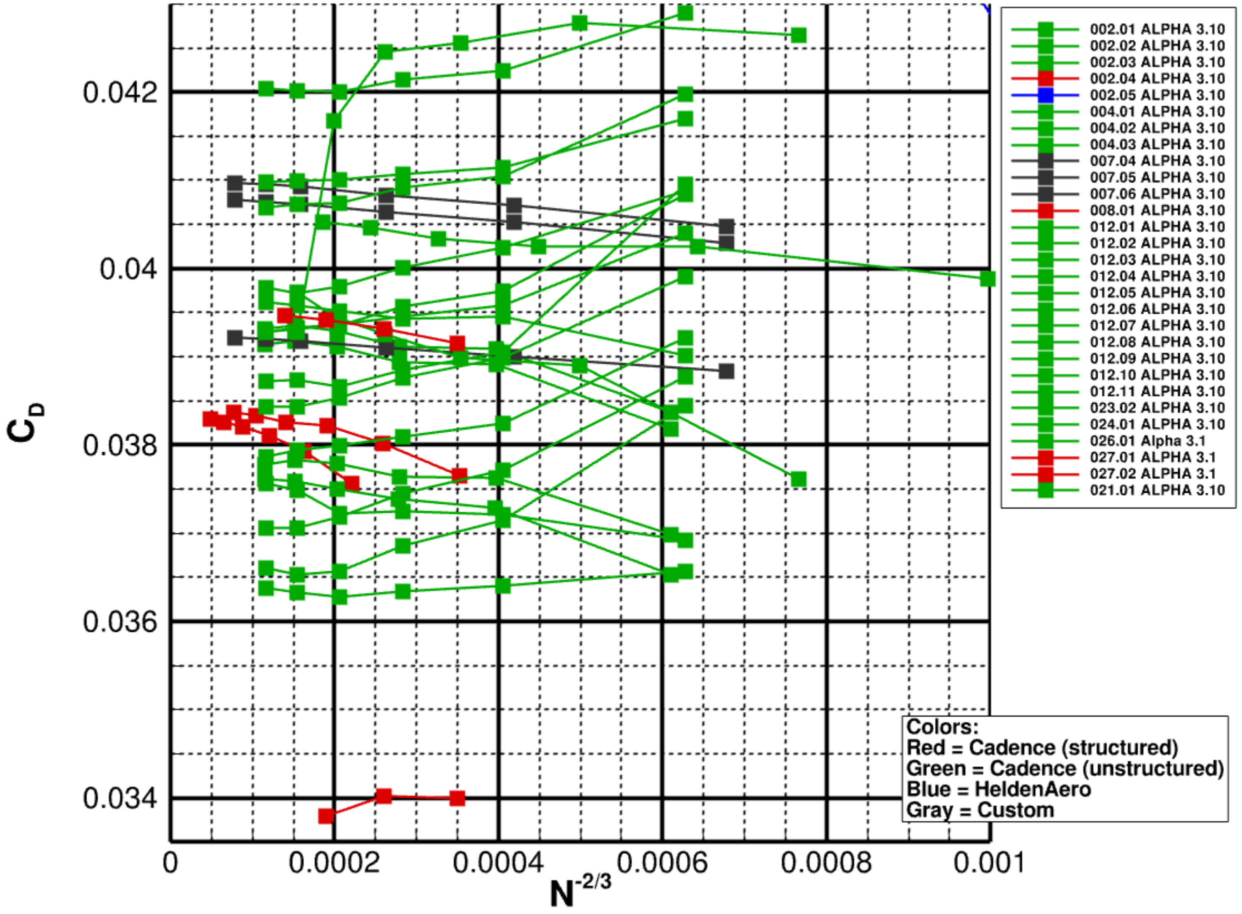


Test Case 1a : Grid Study at α = 3.10°

Colored by turbulence model variant

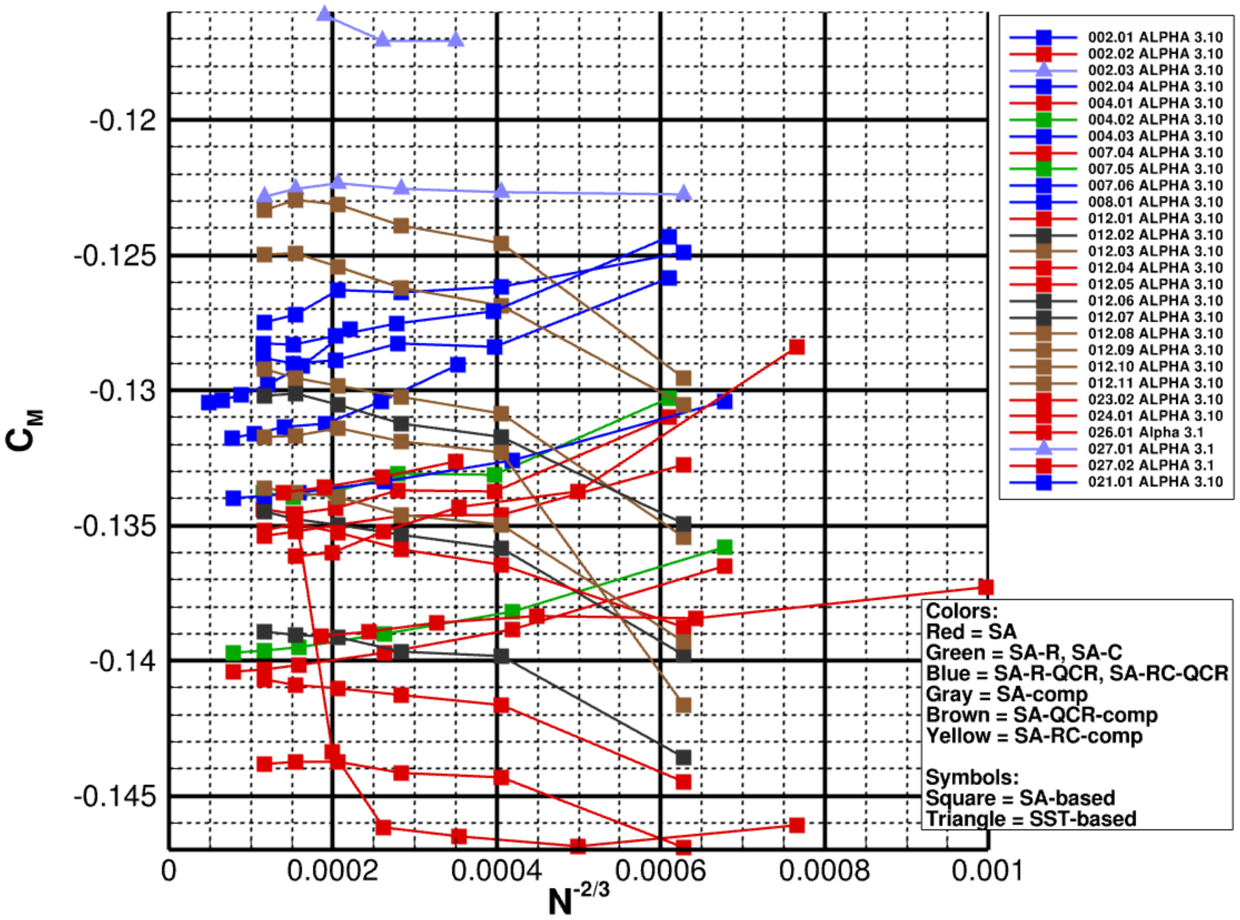


Colored by grid type



Test Case 1a : Grid Study at α = 3.10°

Colored by turbulence model variant



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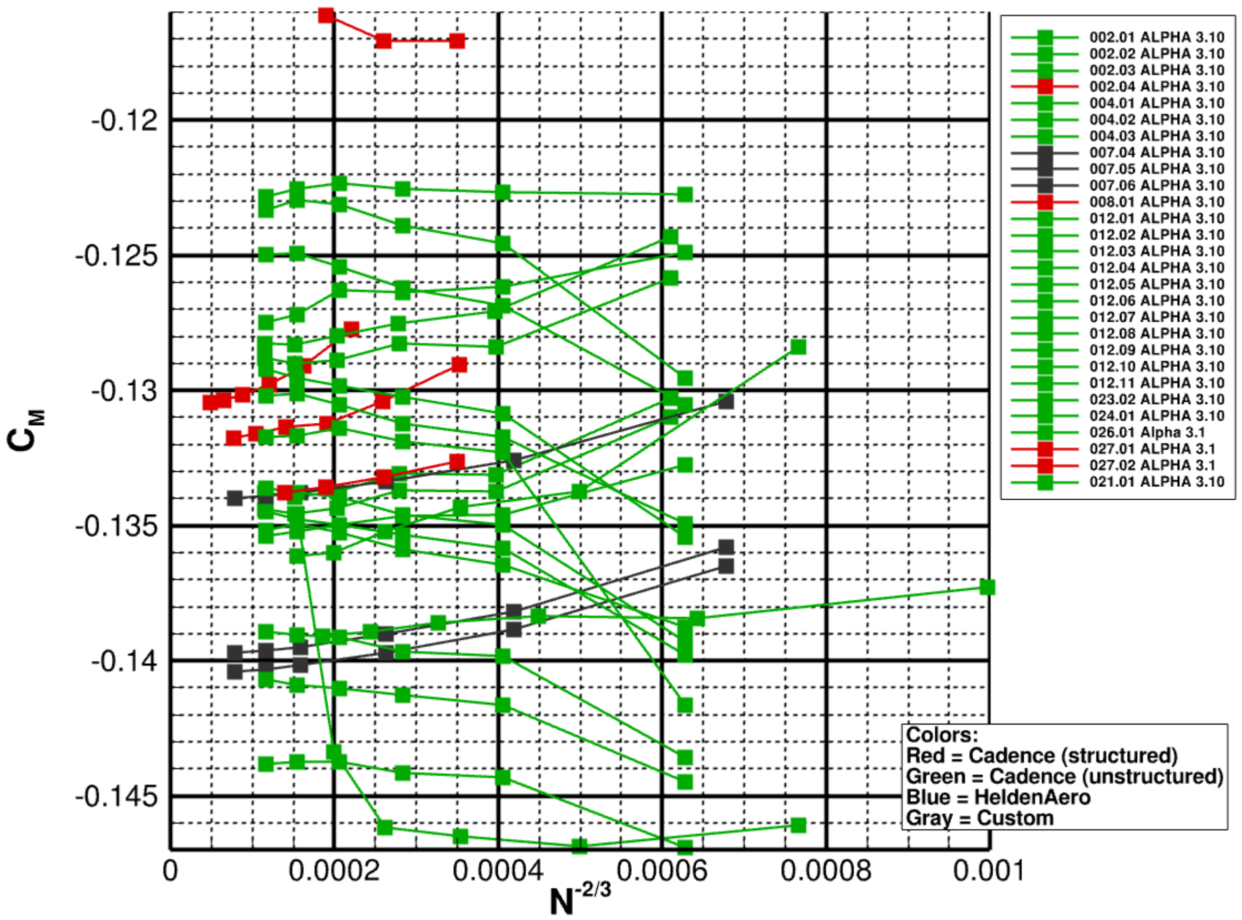
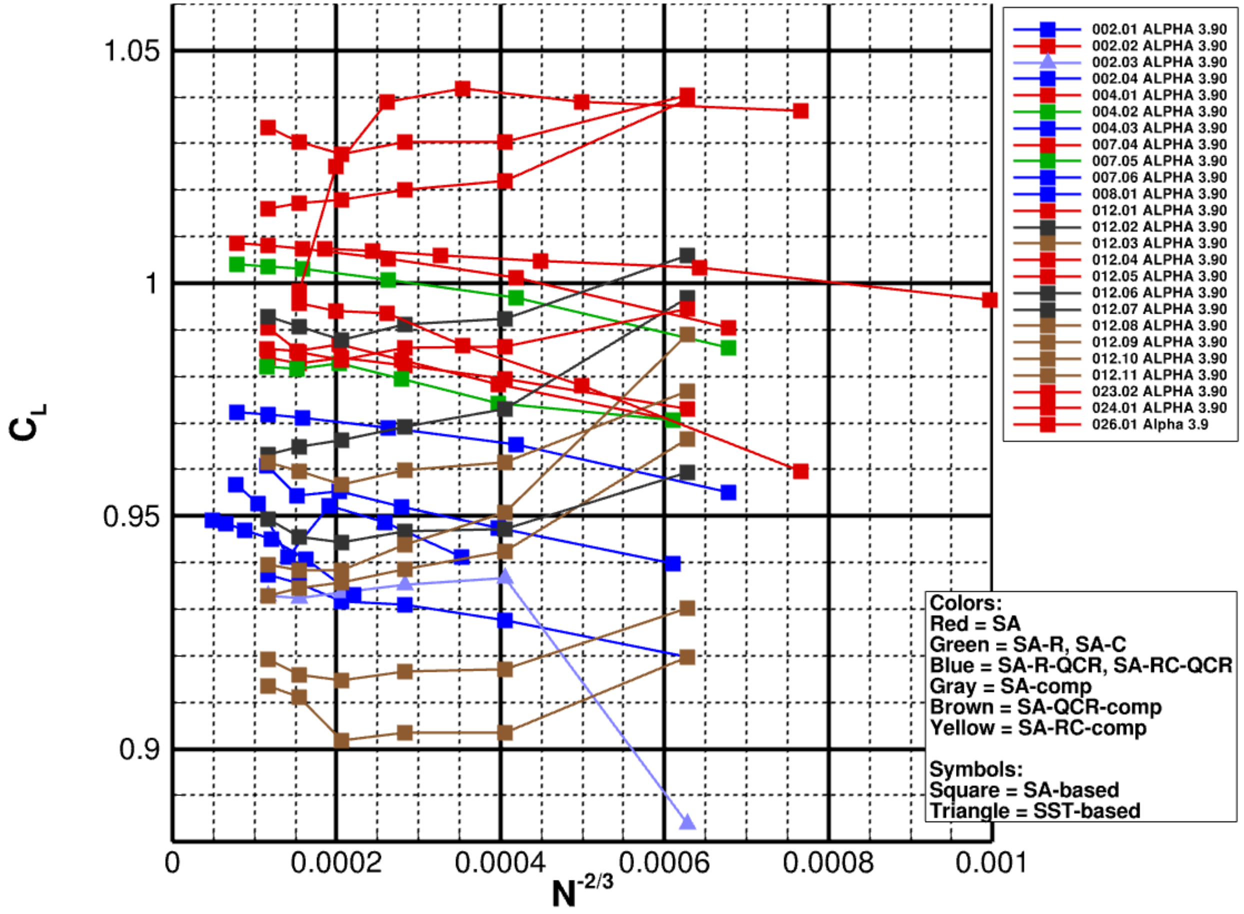


Test Case 1a : Grid Study at α = 3.90°

Colored by turbulence model variant



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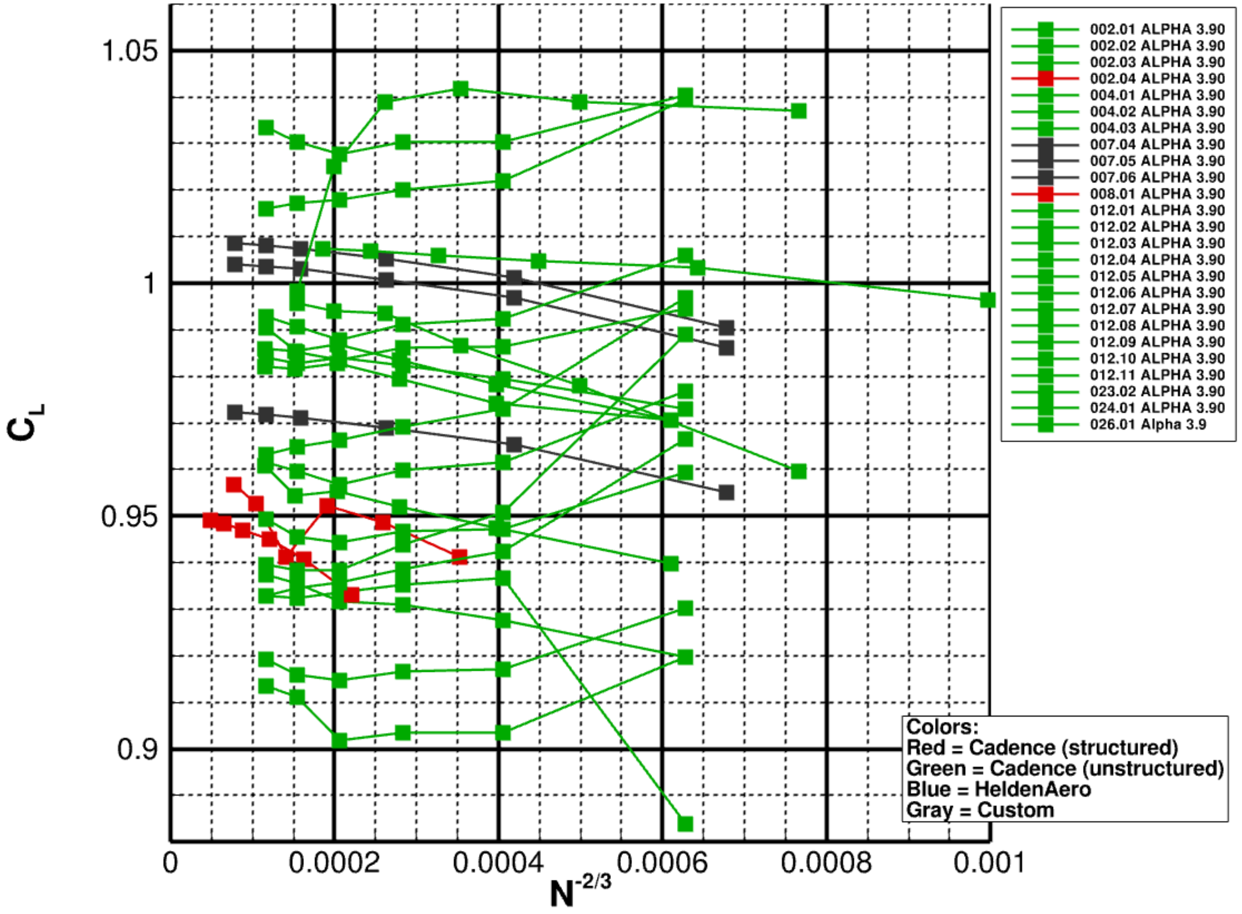
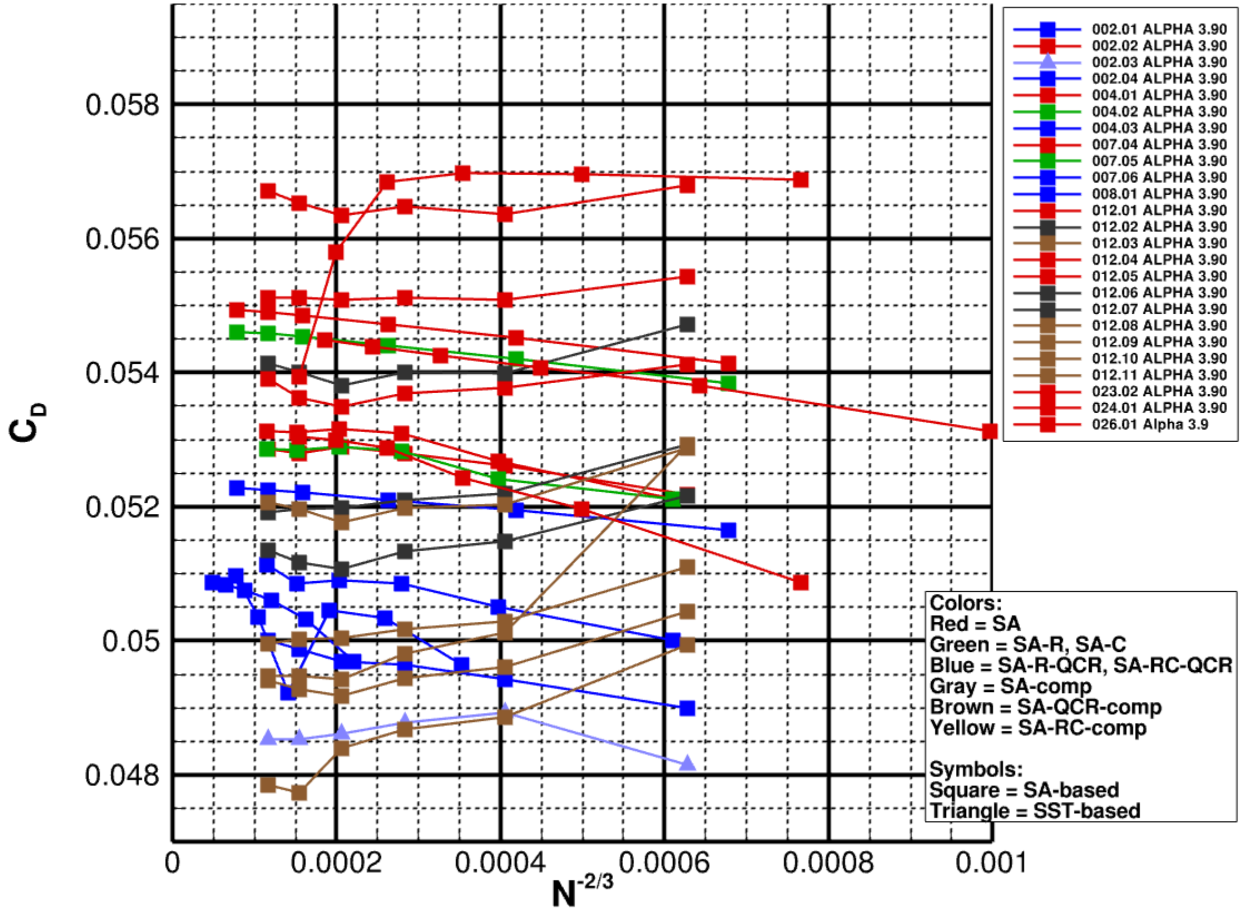


Test Case 1a : Grid Study at $\alpha = 3.90^{\circ}$

Colored by turbulence model variant



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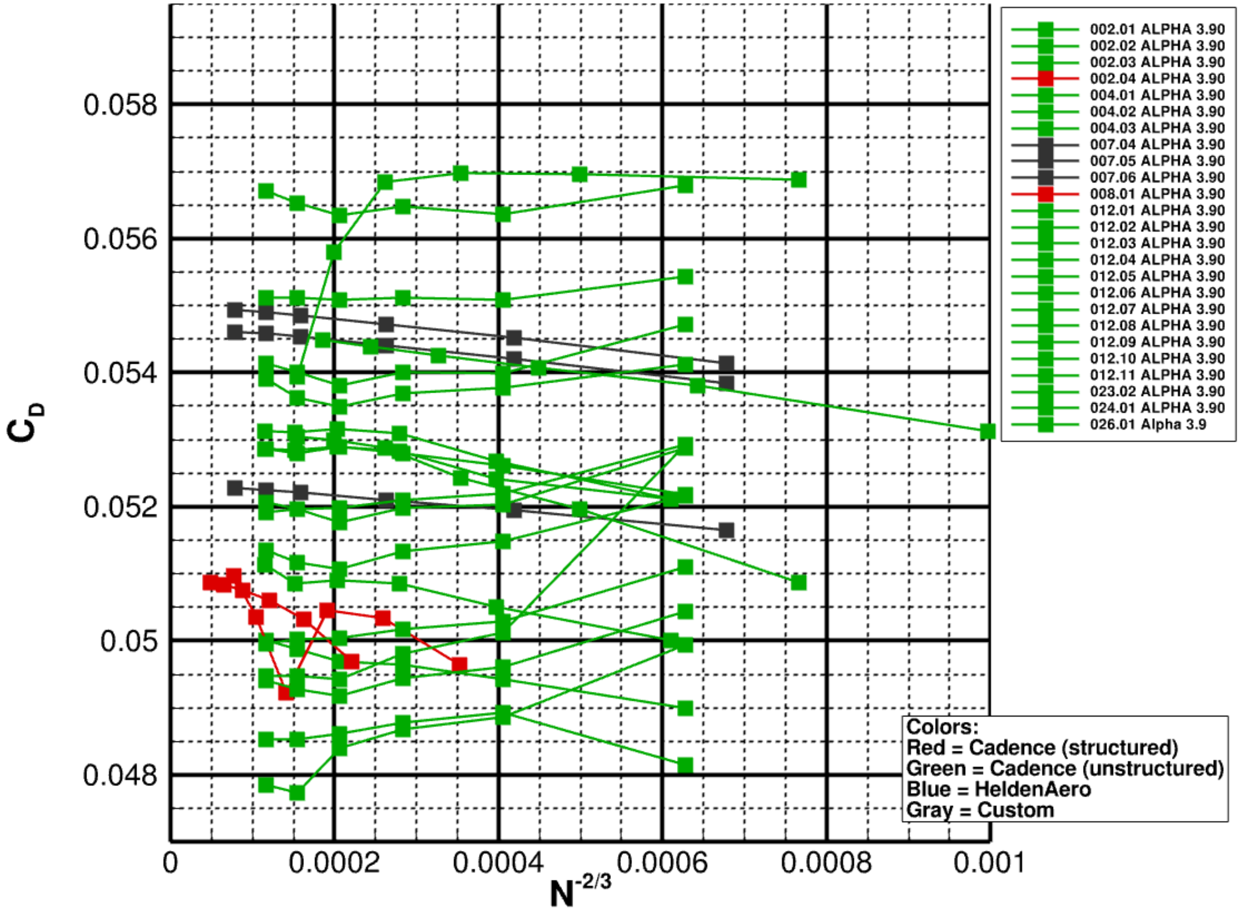
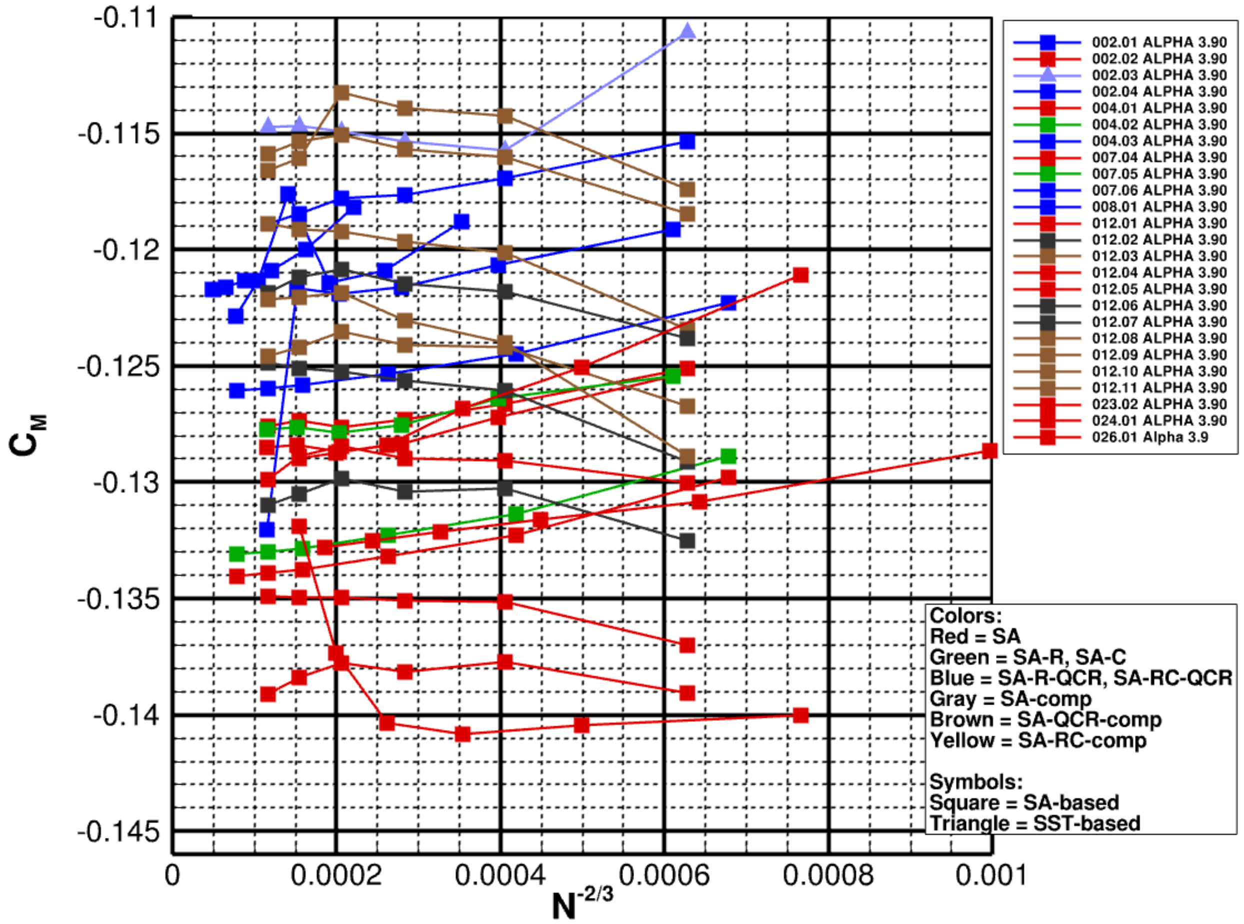


Test Case 1a : Grid Study at $\alpha = 3.90^{\circ}$

Colored by turbulence model variant



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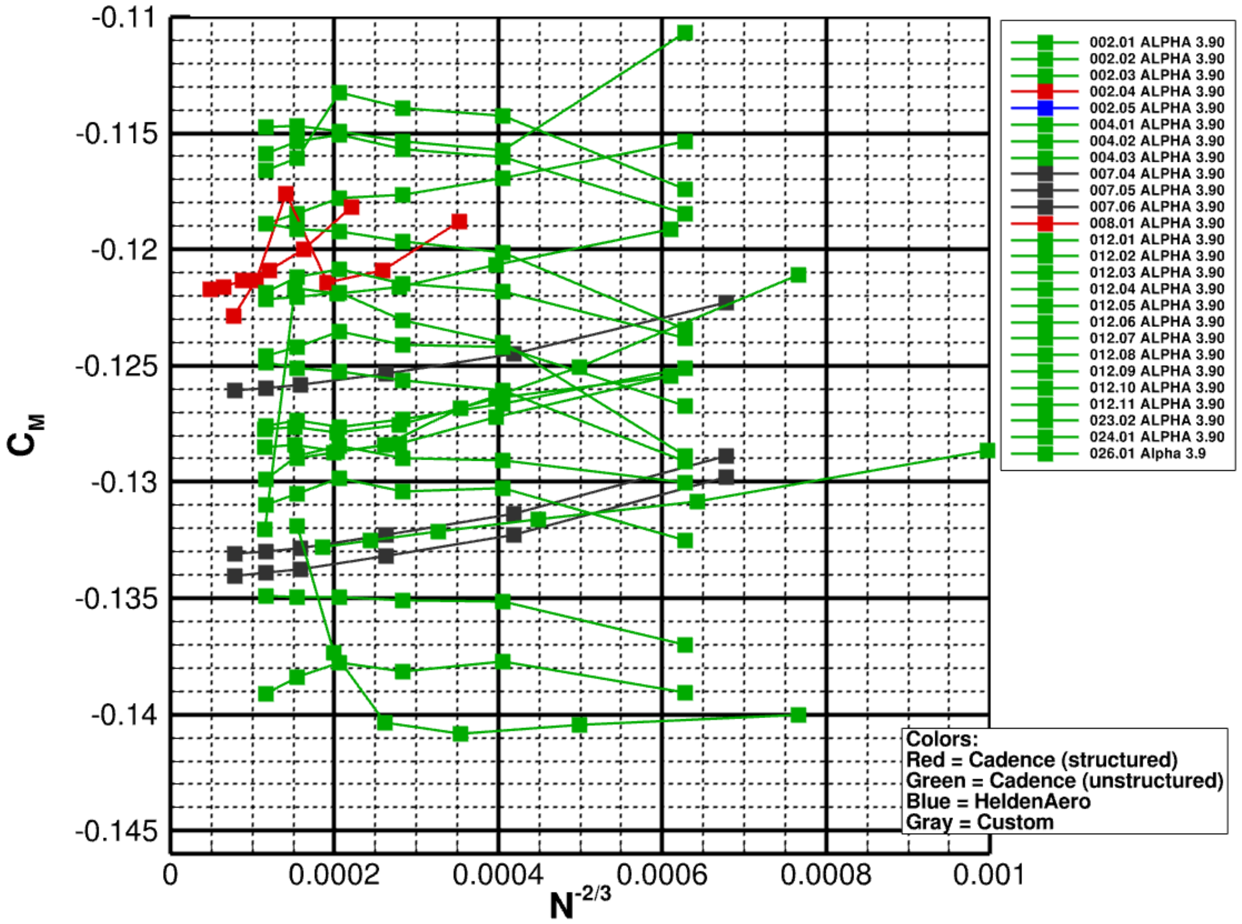
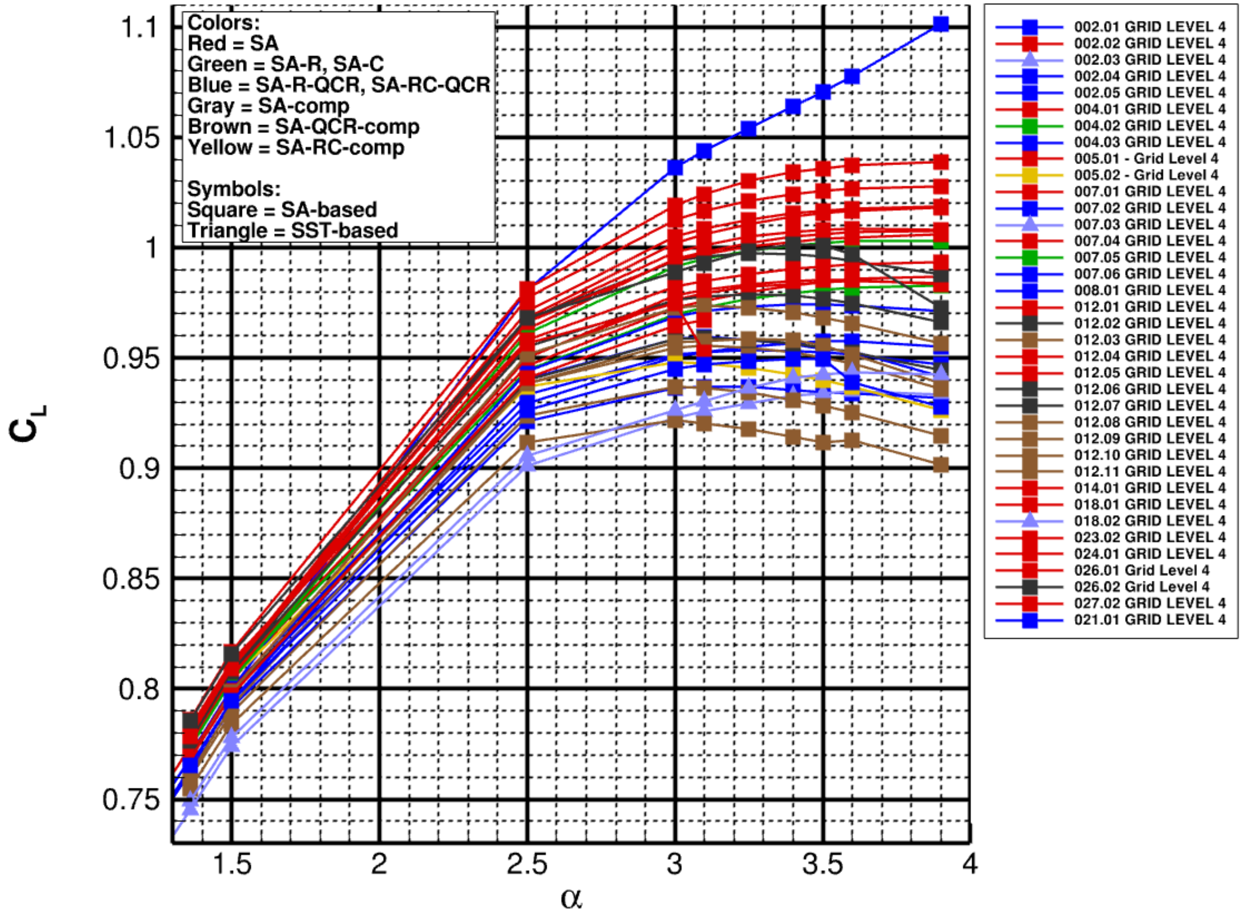


Test Case 1a:
RANS Results

Polars

Test Case 1a : Polars

Colored by turbulence model variant



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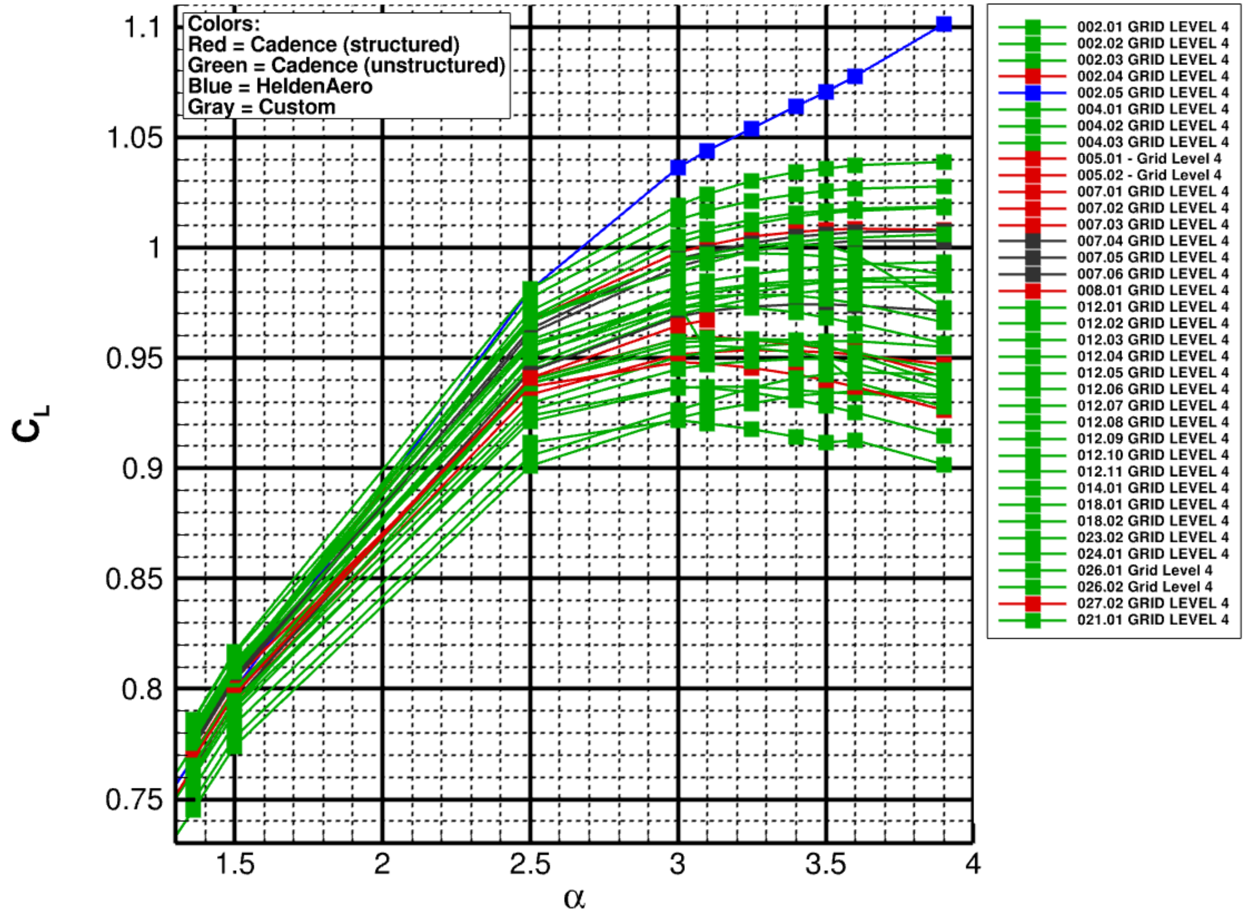

Test Case 1a : Polars

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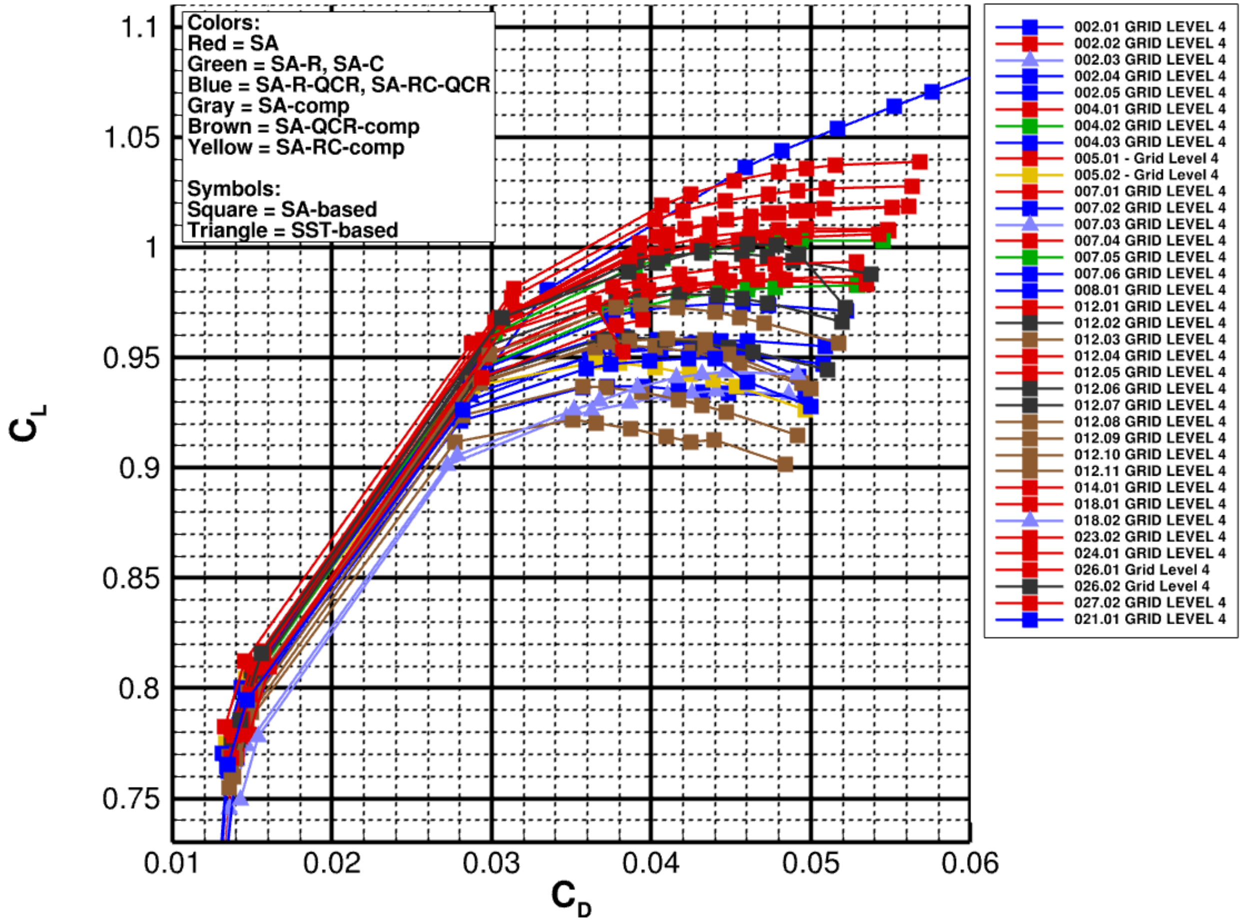
Colored by turbulence model variant



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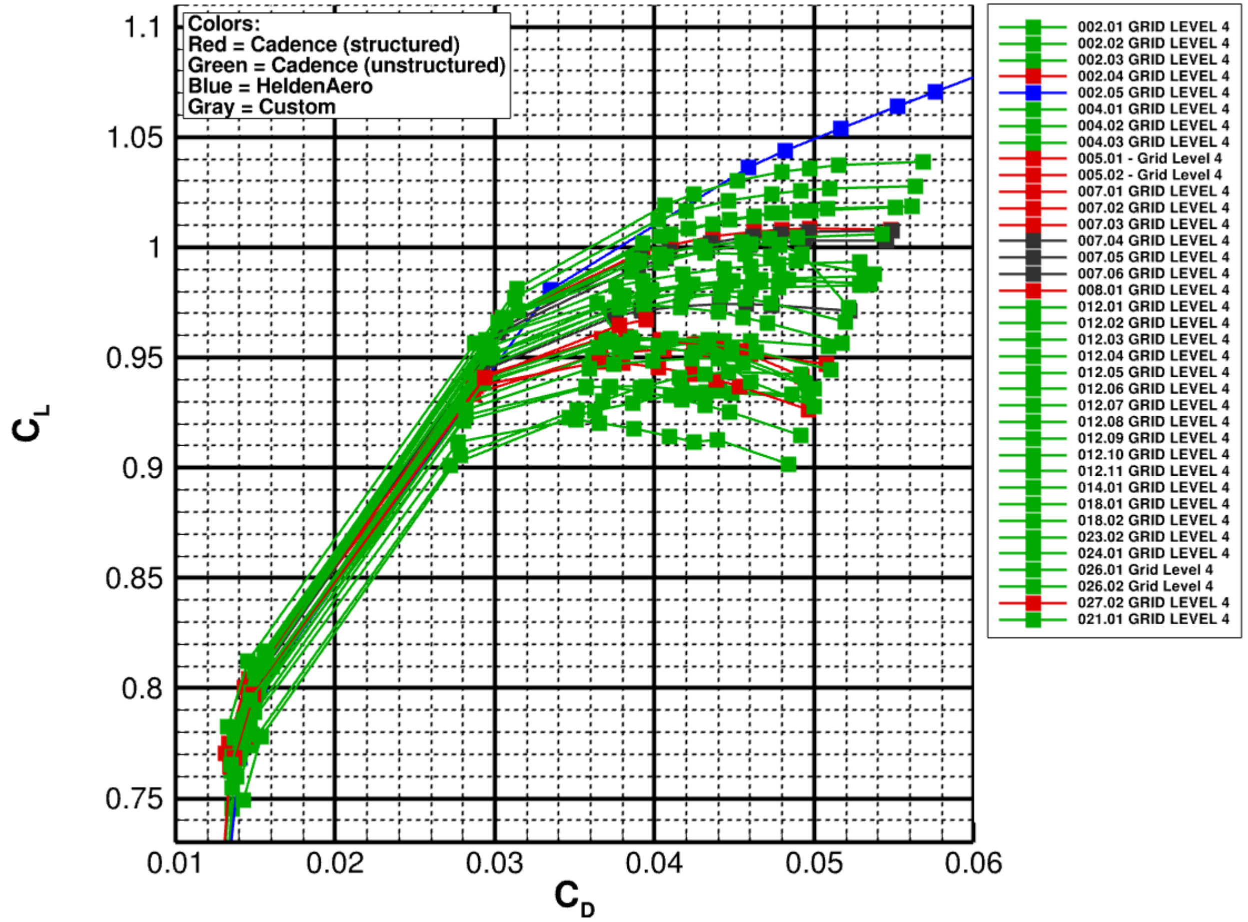
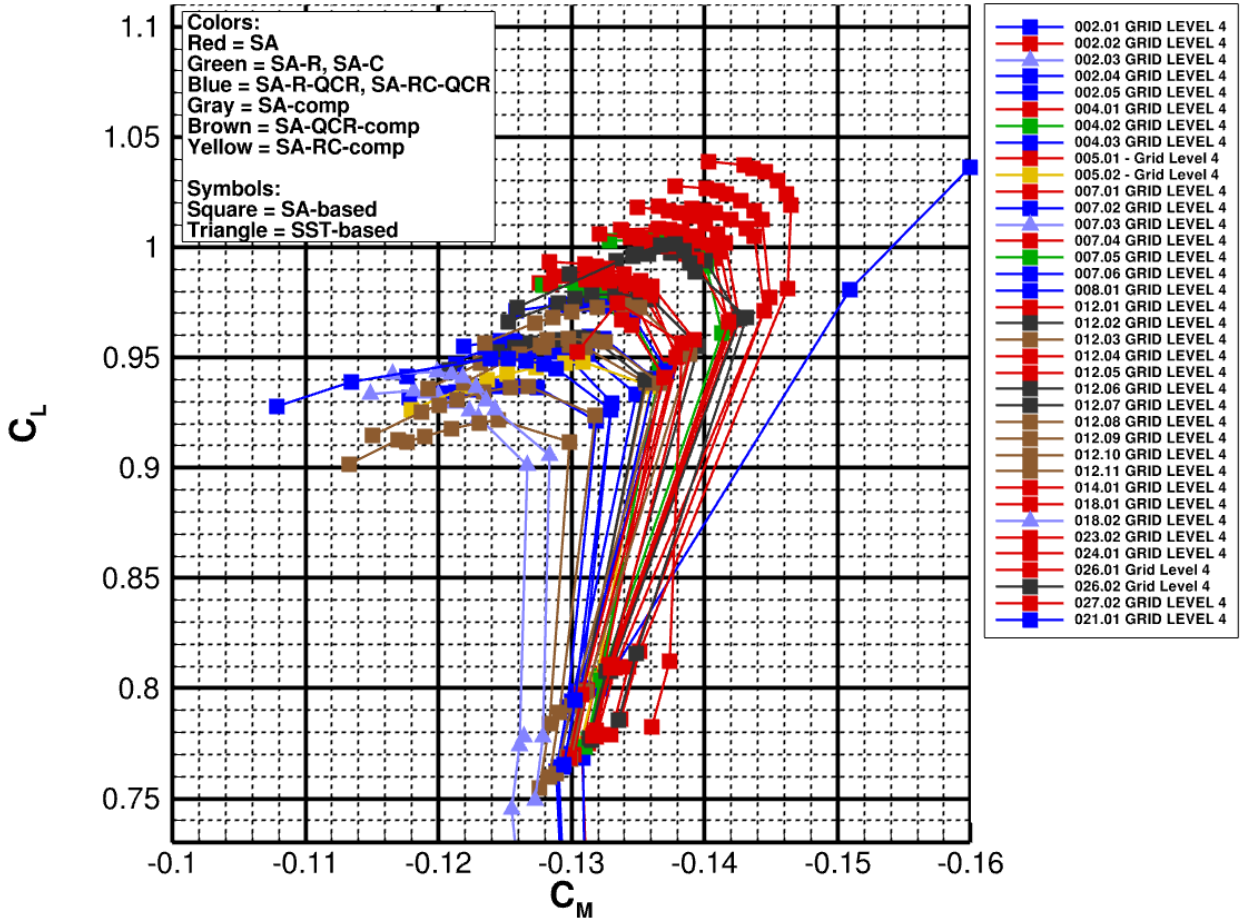


Test Case 1a : Polars

Colored by turbulence model variant



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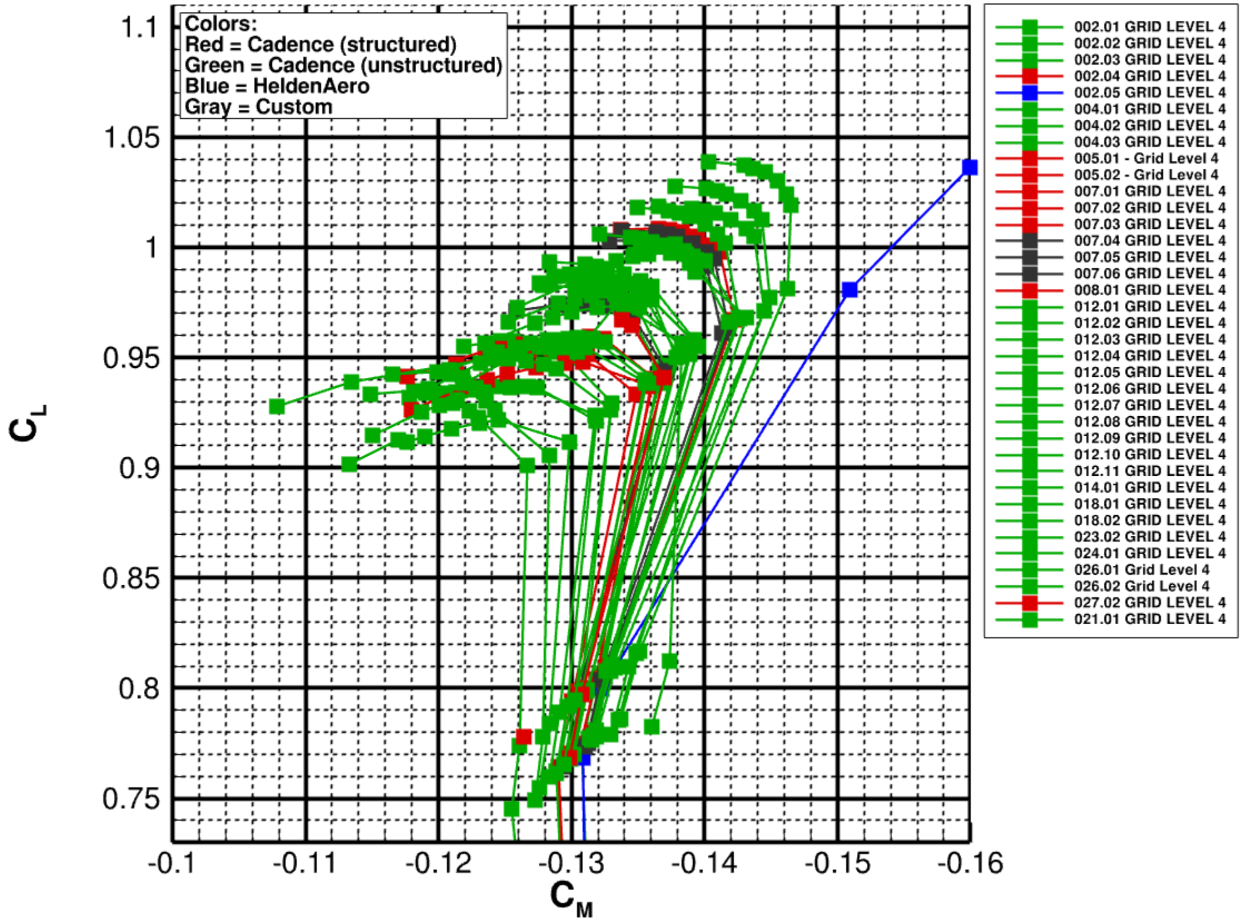
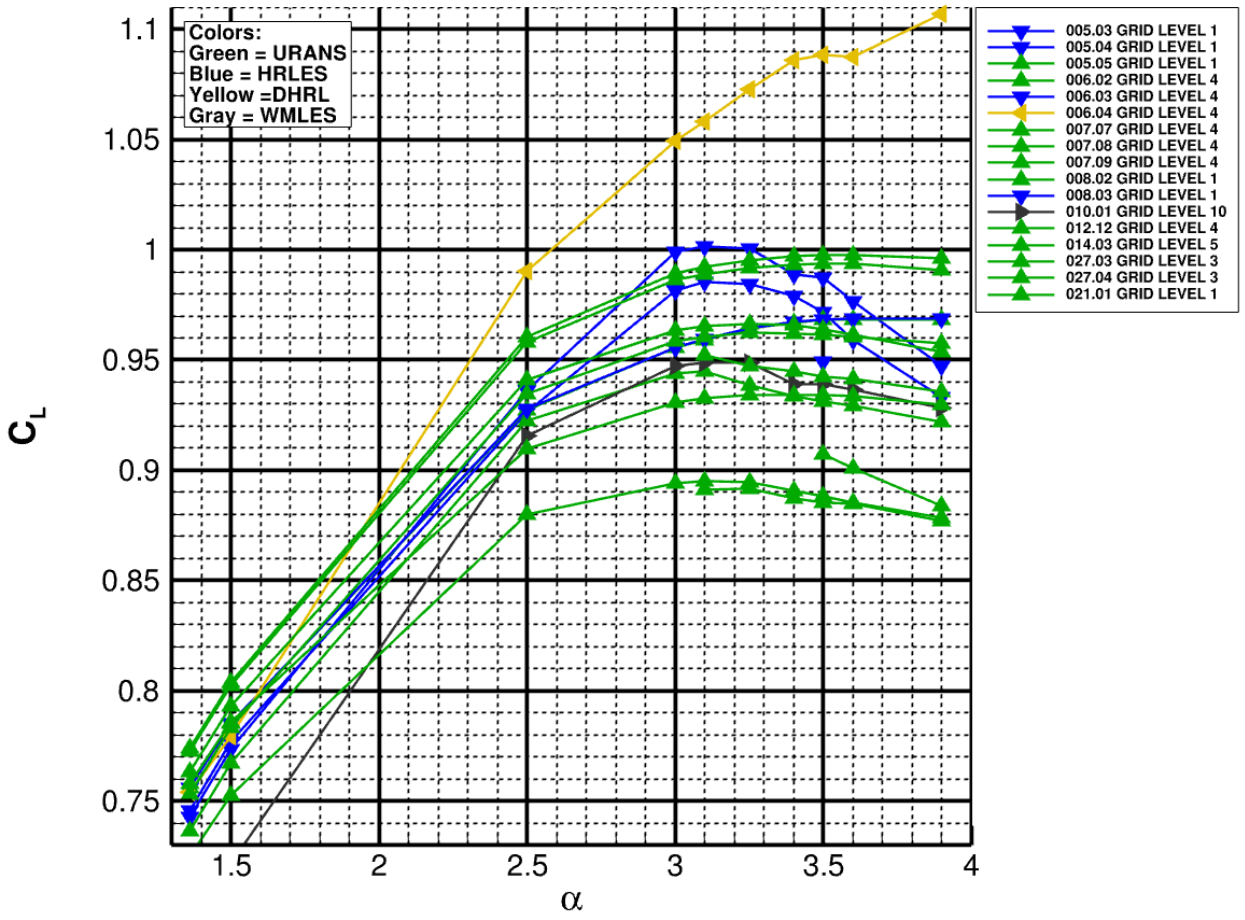


Test Case 1b: Unsteady Results

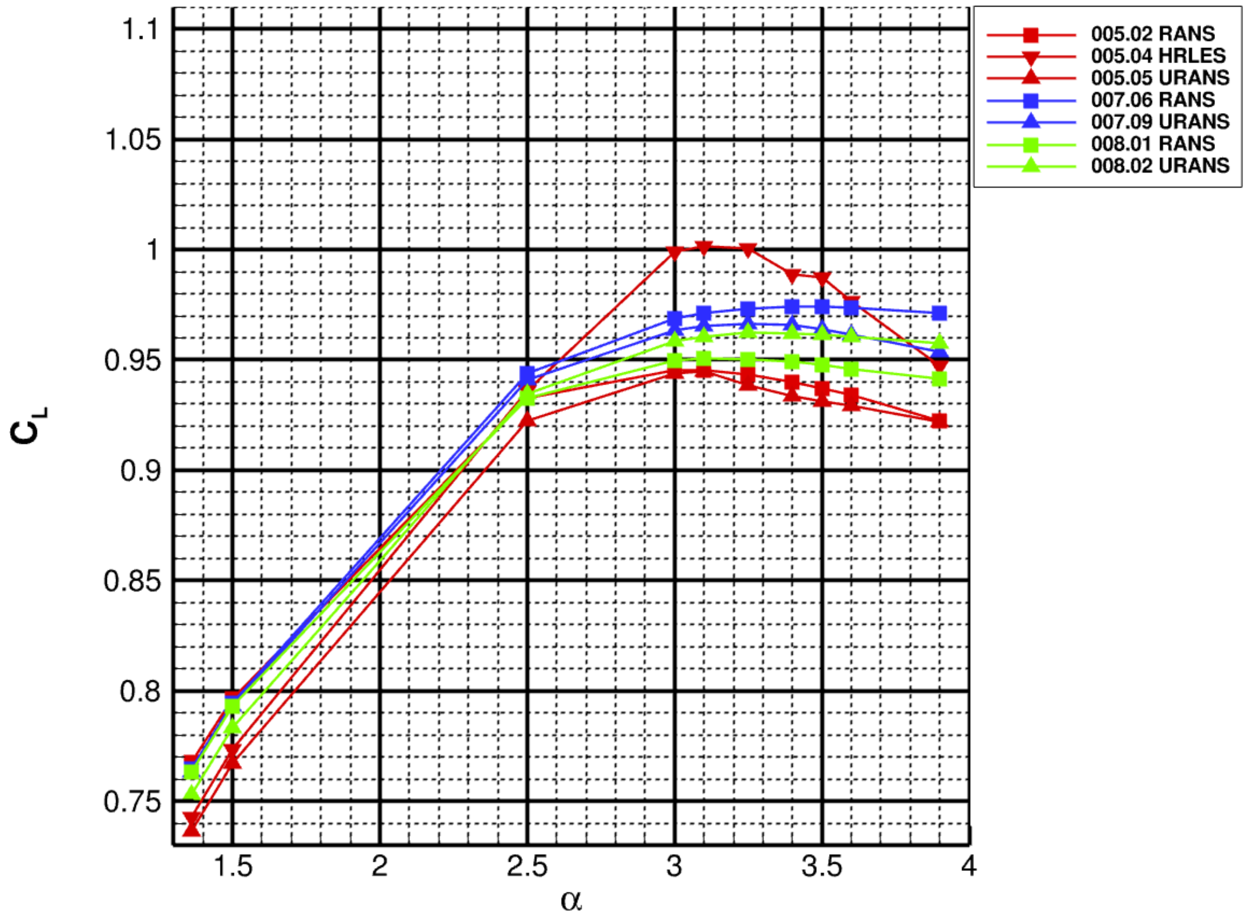
Polars

Test Case 1b : Polars

Colored by method

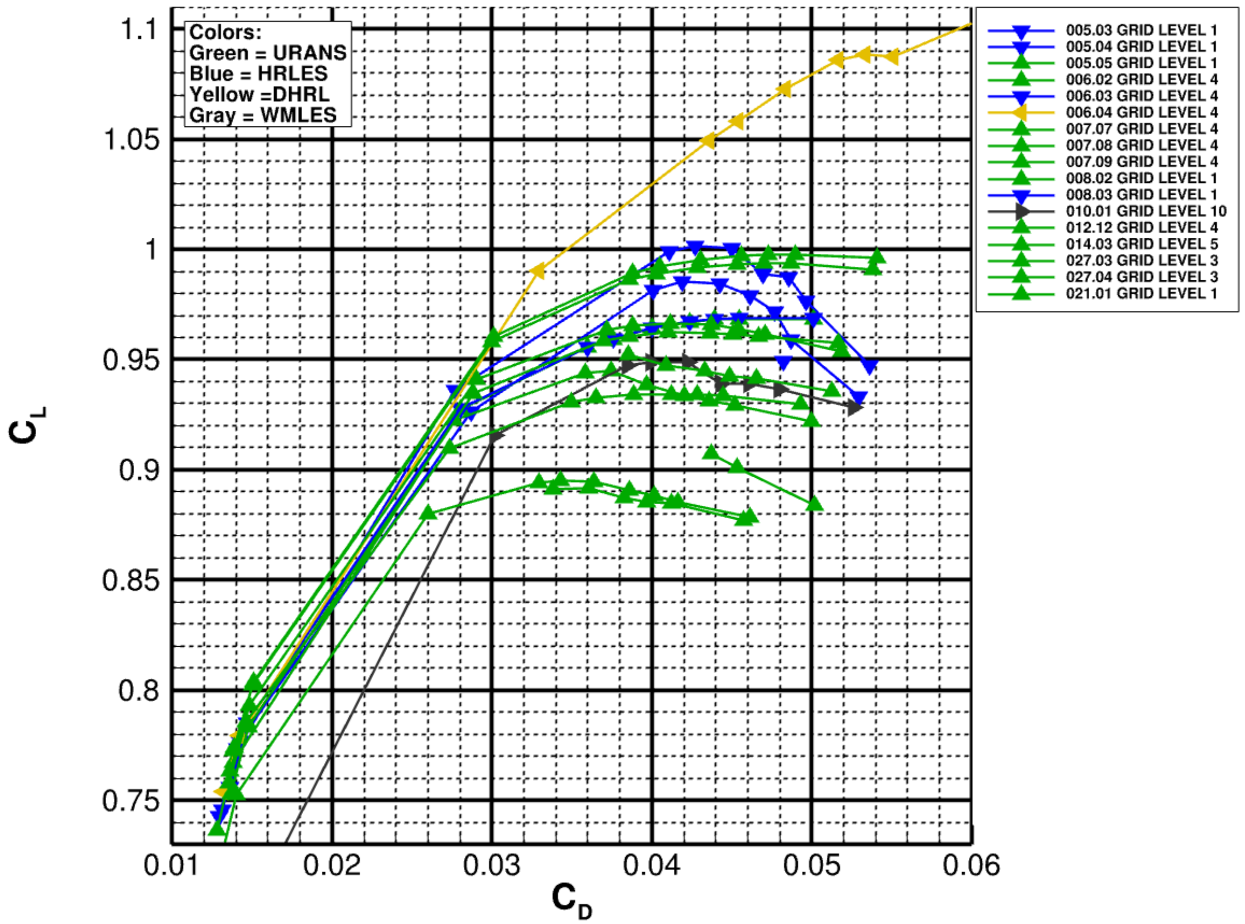


Steady vs Unsteady contributions

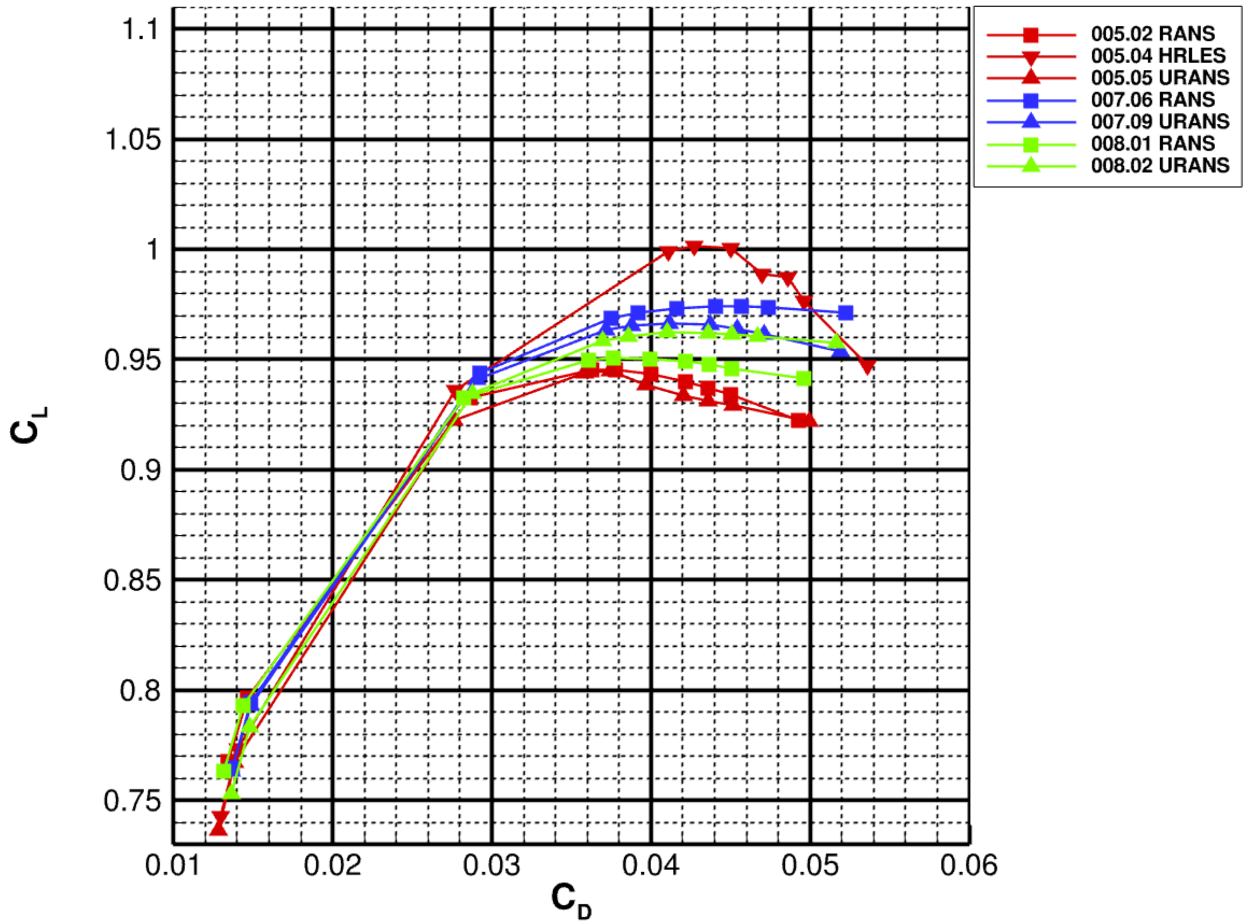


Test Case 1b : Polars

Colored by method



Steady vs Unsteady contributions



Test Case 1b : Polars

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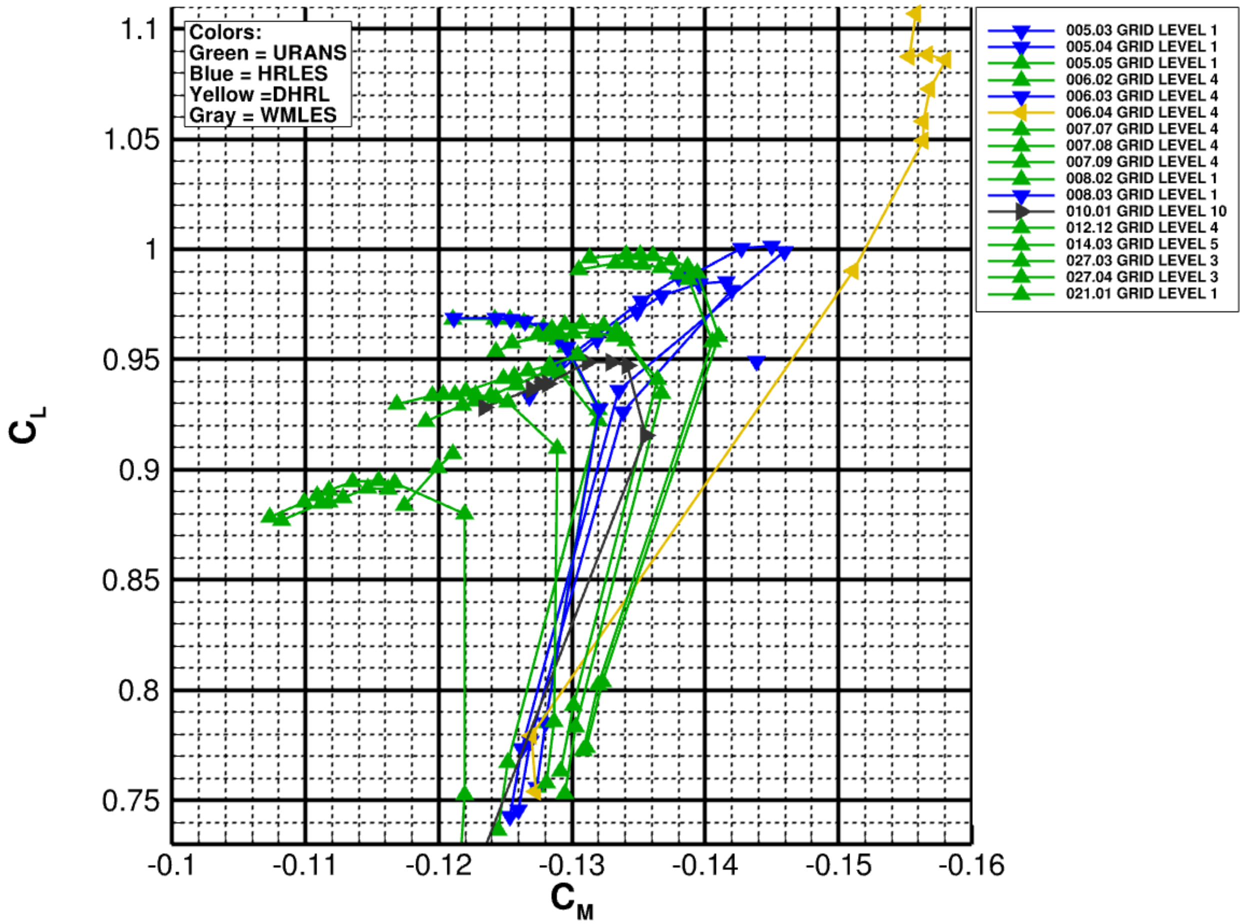

Steady vs Unsteady contributions