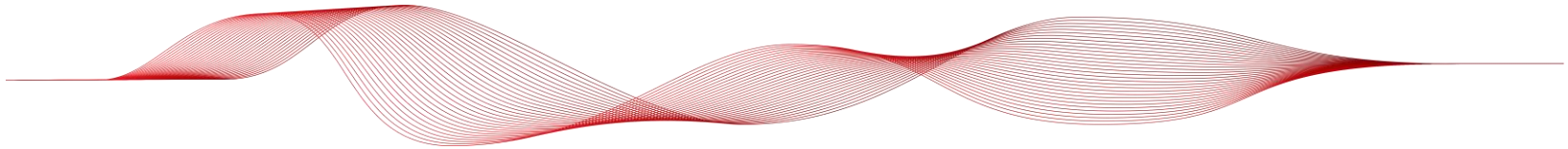


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Innovation through CFD



Evaluation of Hybrid RANS-LES Scale-Resolving Simulations for the DrivAer Notchback Configuration

Anton O. Pylypenko, Angus Lock, Eugene de Villiers

5th Automotive CFD Prediction Workshop

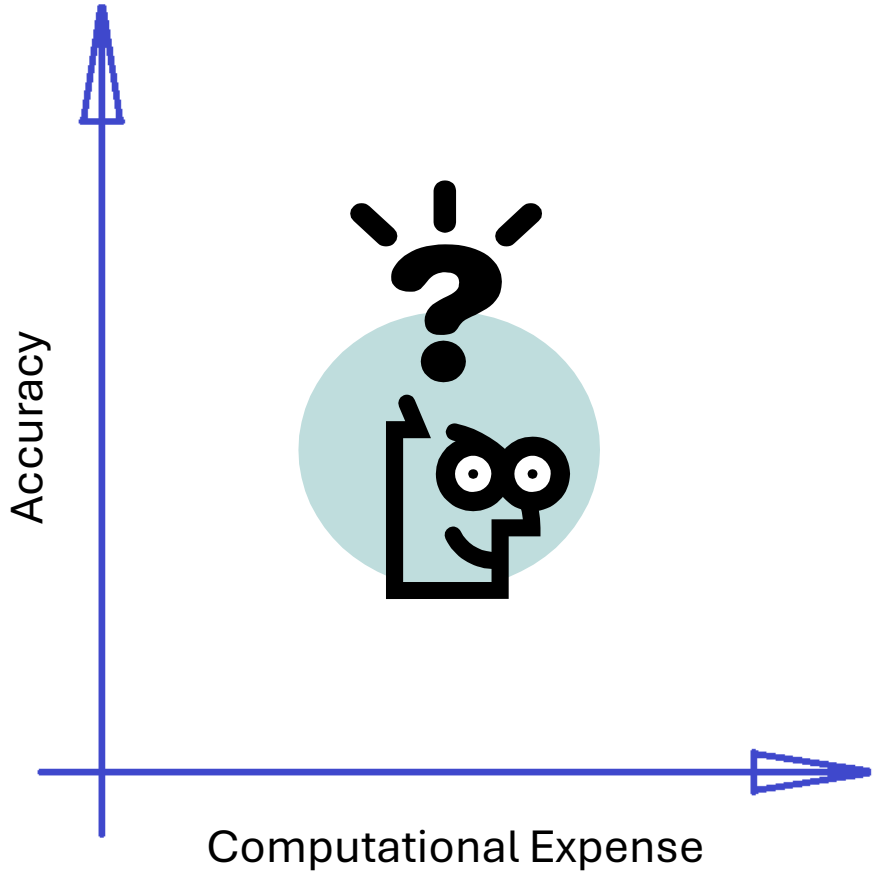
08 October 2026

DAMA Technopole, Bologna, Italy

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Agenda

- Open Road
  - Mesh Resolution
    - *AutoCFD5 Committe Provided*
    - *HelyxHexMesh*
  - Turbulence modeling
    - *DDES-SA + LES filter* ($\Delta_{max}, \widetilde{\Delta}_{\omega}, \Delta_{SLA}$)
    - *DDES-SA + shielding function* (Deck & Renard 2020)
    - *DDES* $k-\omega$ *SST*
  - Solution Strategy
    - *Solver Type (segregated/coupled)*
    - *Precision Arithmetic (double/single)*
    - *Thermodynamic model* ($\rho = const$ *vs.* $p = \rho RT$)
    - *Code implementation – Expression Templates*
- Wind Tunnel

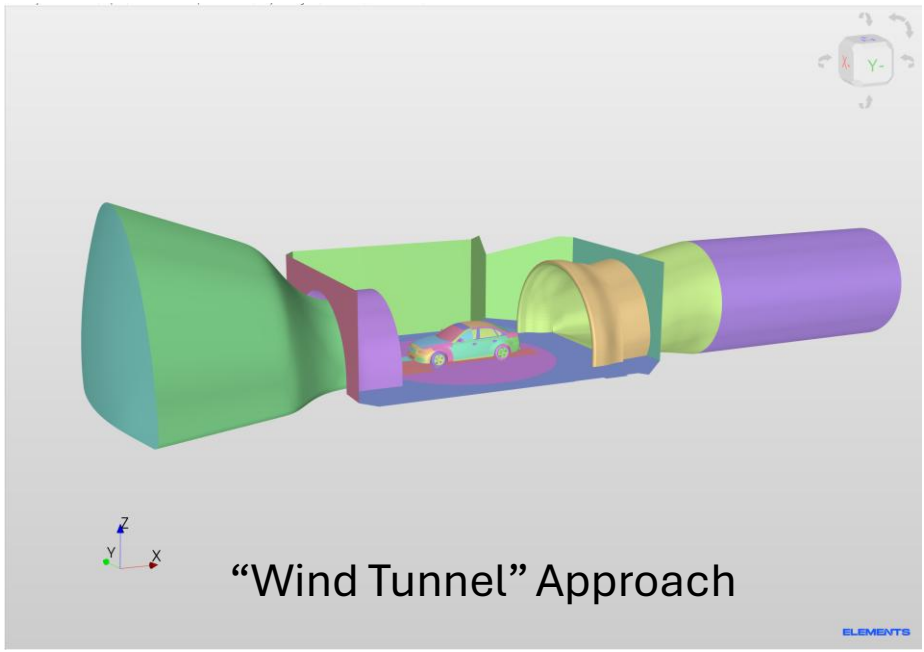


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Methodology

- ELEMENTS v4.5.1/dev
  - Hex-Dominant meshing methodology
  - Finite-Volume-based flow slovers
  - Integrated post-processing capabilities
  - GUI & AeroWizard «templates» allowing for the ease and consistency between different case setups
- Numerical Details
  - Time Step Strategy (OR vs. WT):
    - Total Run Time 5.81 (s) vs. 24.0 (s)
    - Domain “flushing” 3.65 (s) vs. 10.44 (s) at $\Delta t = 5.22 \cdot 10^{-3}$ (s)
    - Final $\Delta t = 2.61 \cdot 10^{-4}$ (s)
    - Start Averaging at 4.03 (s) vs. 14.0 (s)
  - Initialisation – Potential Flow Solution
- In-house HPC Cluster utilizing 192 CPU cores

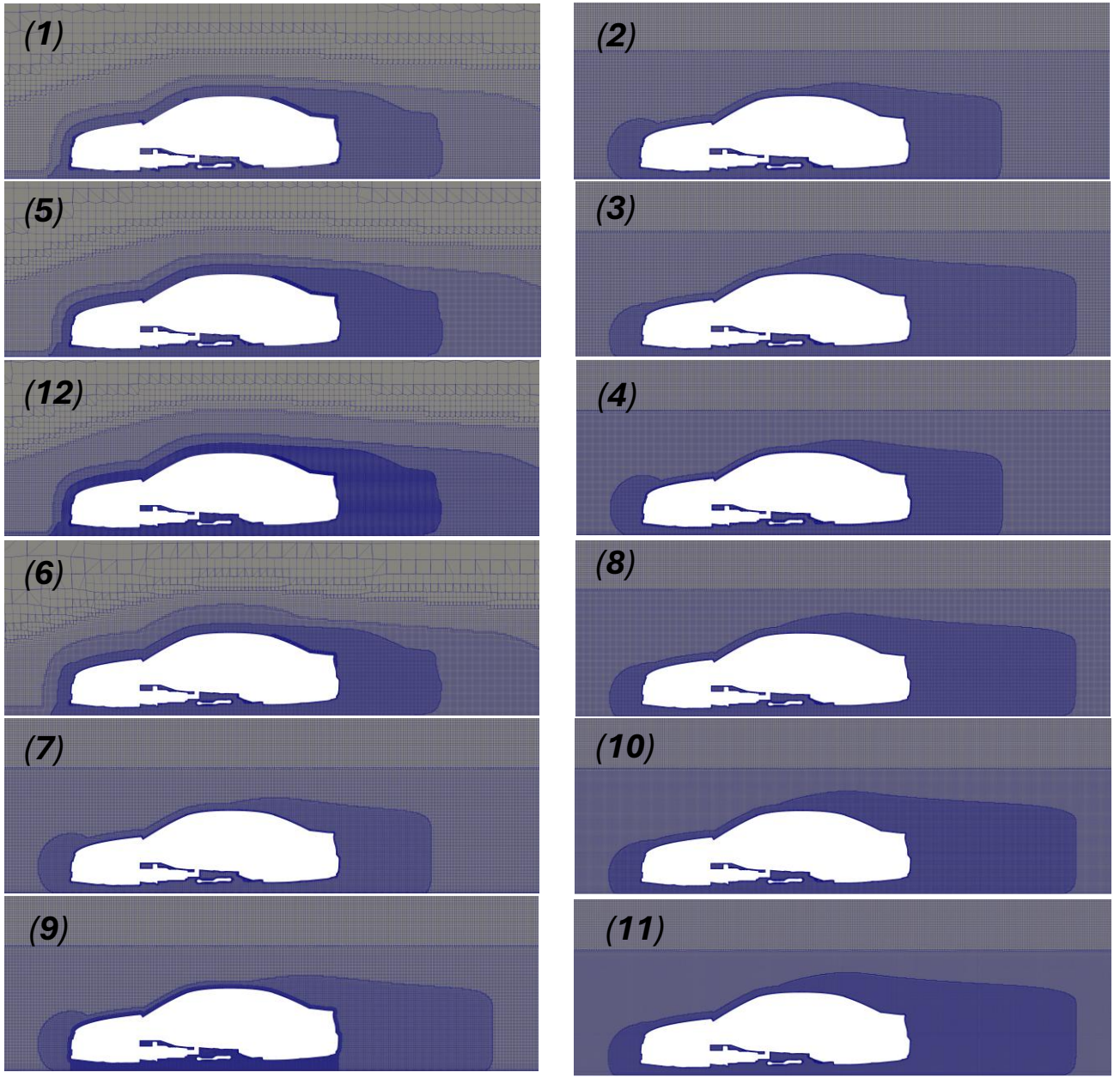




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Open Road | Mesh Resolution | Case 2a

- Committee provided:
  - Coarse (***1***), Medium (***5***), Fine (***12***)
- HelyxHexMesh:
  - Best Practice (***2***)
  - Larger Wake Zone & less layers on the floor (***3***)
  - Uniform Surface Refinement (***4***)
  - Committee provided Volume Refinement “Boxes” + recommended refinement cell sizes (***6***)
  - More Layers on the body + volume distance refinement (***7, 9***)
  - Smaller Mesh Cell Sizes - Setup as in Mesh 3, but with smaller base mesh sizes (***8,10, 11***)
- Standard DDES-SA (Δ_{max})

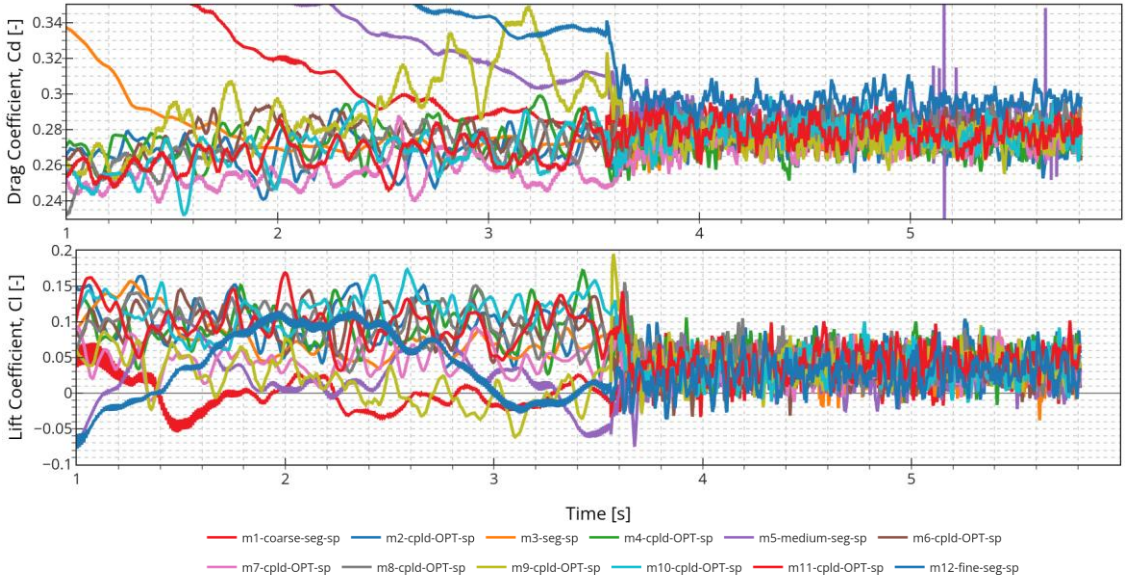


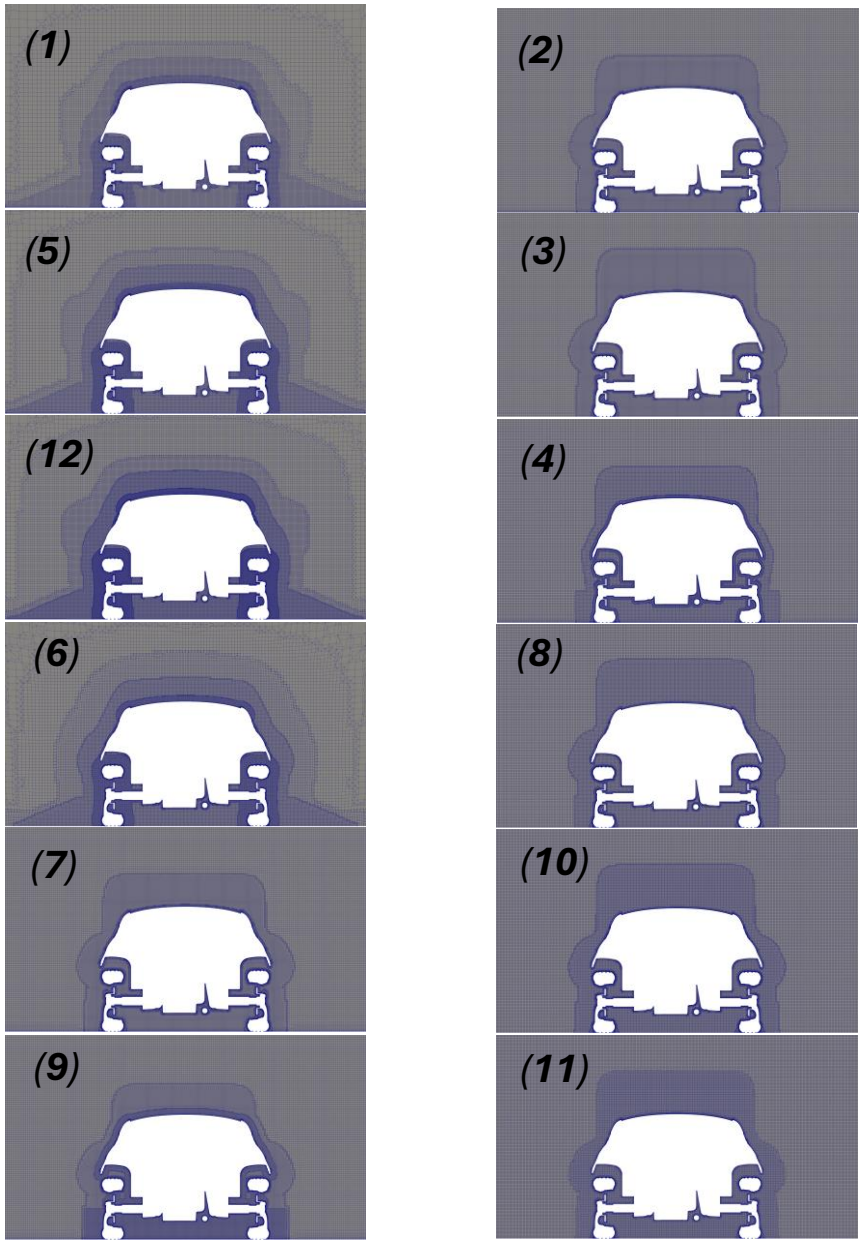
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Open Road | Mesh Resolution | Case 2a

Case	Cd	Cl	Cl_f	Cl_r	N Cells	Meshing time	Run time
m1-coarse-seg-sp	0.280 (9.80%)	0.030 (-22.35%)	-0.064 (-16.08%)	0.094 (-6.67%)	66,151,909	N/A	5h 23m 22.2s
m2-cpld-OPT-sp	0.272 (6.67%)	0.043 (-17.25%)	-0.051 (-10.98%)	0.094 (-6.67%)	96,123,326	0h 12m 23.4s	5h 28m 41.2s
m3-seg-sp	0.276 (8.24%)	0.028 (-23.14%)	-0.062 (-15.29%)	0.090 (-8.24%)	100,268,752	0h 14m 40.4s	8h 38m 13.3s
m4-cpld-OPT-sp	0.273 (7.06%)	0.046 (-16.08%)	-0.070 (-18.43%)	0.117 (2.35%)	108,320,578	0h 13m 32.1s	8h 05m 0.5s
m5-medium-seg-sp	0.283 (10.98%)	0.025 (-24.31%)	-0.067 (-17.25%)	0.092 (-7.45%)	123,430,798	N/A	16h 53m 31.6s
m6-cpld-OPT-sp	0.281 (10.20%)	0.032 (-21.57%)	-0.064 (-16.08%)	0.096 (-5.88%)	124,807,559		10h 11m 0.16s
m7-cpld-OPT-sp	0.273 (7.06%)	0.037 (-19.61%)	-0.058 (-13.73%)	0.095 (-6.27%)	145,200,240	0h 16m 35.0s	11h 13m 24.7s
m8-cpld-OPT-sp	0.281 (10.20%)	0.043 (-17.25%)	-0.052 (-11.37%)	0.095 (-6.27%)	151,864,639	0h 22m 25.1s	15h 17m 20.1s
m9-cpld-OPT-sp	0.275 (7.84%)	0.040 (-18.43%)	-0.065 (-16.47%)	0.105 (-2.35%)	173,959,289	0h 17m 50.3s	10h 18m 21.5s
m10-cpld-OPT-sp	0.280 (9.80%)	0.038 (-19.22%)	-0.060 (-14.51%)	0.098 (-5.10%)	183,457,095	0h 25m 56.0s	19h 02m 43.3s
m11-cpld-OPT-sp	0.279 (9.41%)	0.044 (-16.86%)	-0.055 (-12.55%)	0.099 (-4.71%)	202,944,144	0h 29m 23.3s	22h 40m 12.6s
m12-fine-seg-sp	0.296 (16.08%)	0.030 (-22.35%)	-0.065 (-16.47%)	0.095 (-6.27%)	259,682,879	N/A	44h 30m 12.16s
Experiment	0.255	0.087	-0.023	0.111	-	-	-

Estimated time

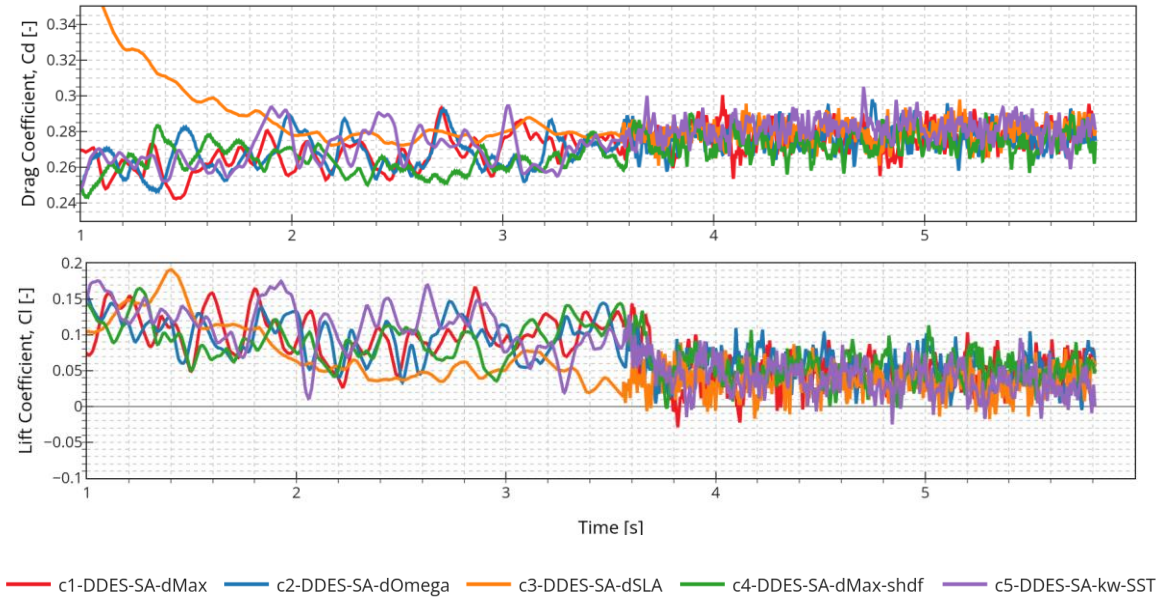


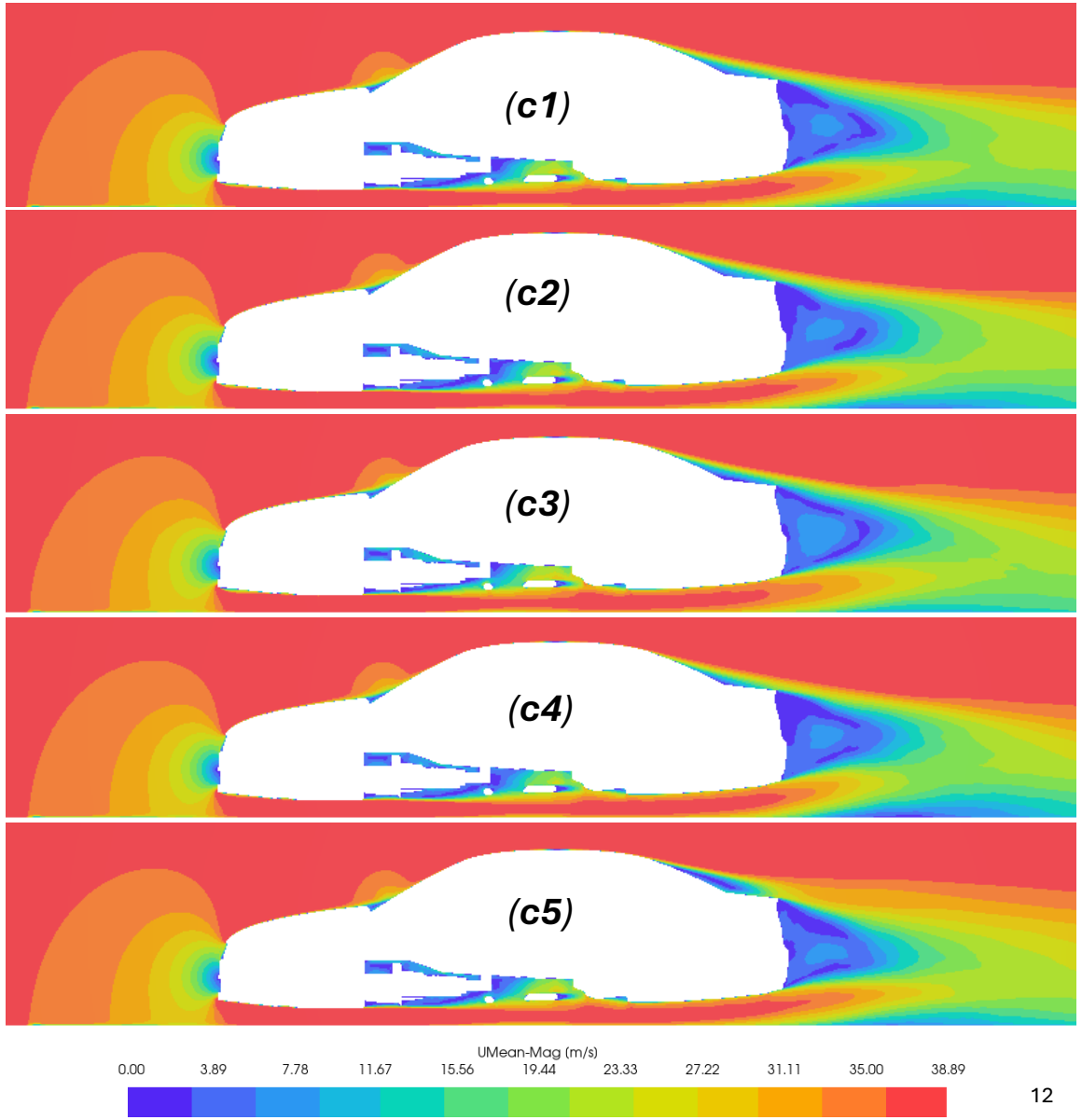


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Open Road | Turbulence Model | Case 2a

Case	Cd	Cl	Cl_f	Cl_r	N Cells	Meshing time	Run time
c1-DDES-SA-dMax	0.277 (8.63%)	0.047 (-15.69%)	-0.047 (-9.41%)	0.094 (-6.67%)	100,268,752	0h 14m 40.4s	6h 24m 0.8s
c2-DDES-SA-dOmega	0.278 (9.02%)	0.053 (-13.33%)	-0.044 (-8.24%)	0.097 (-5.49%)	100,268,752	0h 14m 40.4s	7h 50m 47.0s
c3-DDES-SA-dSLA	0.280 (9.80%)	0.036 (-20.00%)	-0.060 (-14.51%)	0.095 (-6.27%)	100,268,752	0h 14m 40.4s	7h 54m 23.8s
c4-DDES-SA-dMax-shdf	0.274 (7.45%)	0.053 (-13.33%)	-0.046 (-9.02%)	0.099 (-4.71%)	100,268,752	0h 14m 40.4s	8h 49m 2.0s
c5-DDES-SA-kw-SST	0.282 (10.59%)	0.036 (-20.00%)	-0.064 (-16.08%)	0.100 (-4.31%)	100,268,752	0h 14m 40.4s	6h 55m 19.5s
Experiment	0.255	0.087	-0.023	0.111	-	-	-



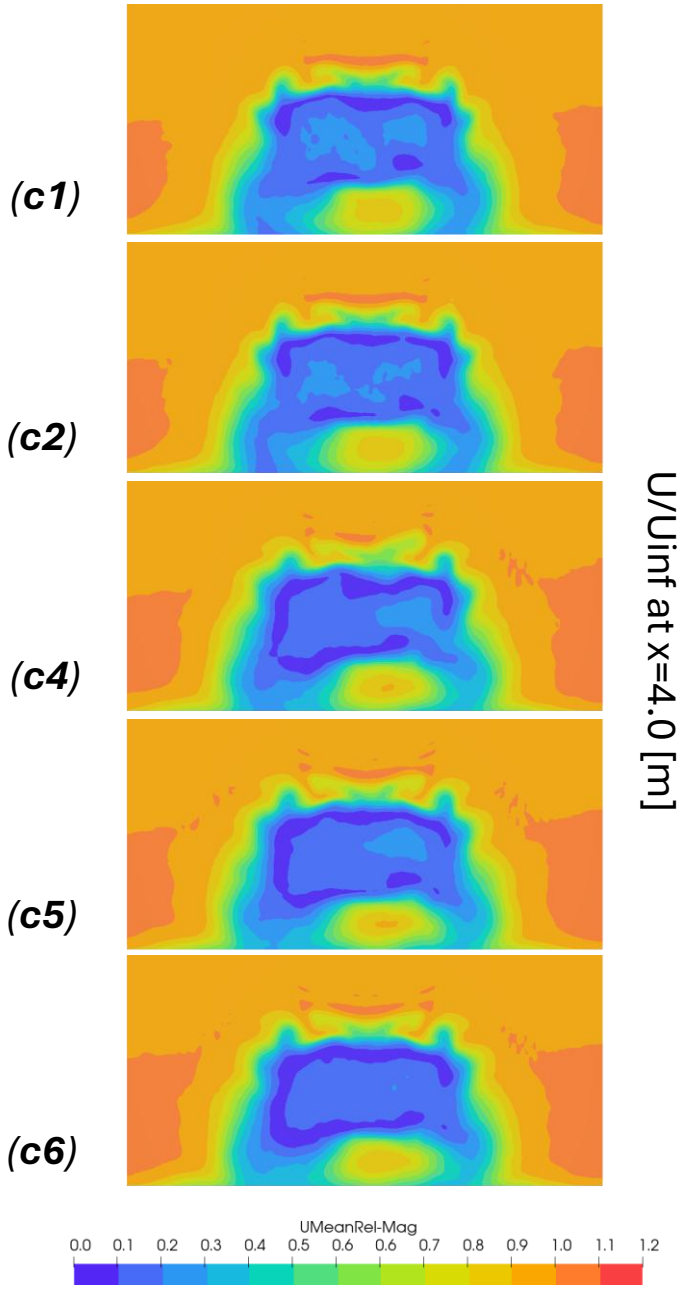


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Open Road | Solution Strategy | Case 2a

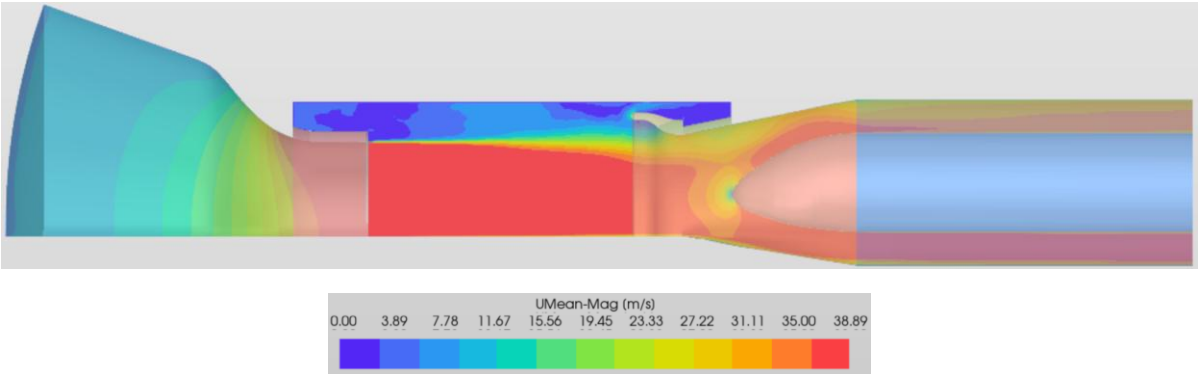
Case	Cd	Cl	Cl_f	Cl_r	N Cells	Meshing time	Run time
c1-seg-dp	0.277 (8.63%)	0.030 (-22.35%)	-0.059 (-14.12%)	0.089 (-8.63%)	100,268,752	0h 14m 40.4s	15h 06m 21.9s
c2-seg-sp	0.276 (8.24%)	0.028 (-23.14%)	-0.062 (-15.29%)	0.090 (-8.24%)	100,268,752	0h 14m 40.4s	8h 38m 13.3s
c3-seg-pg-sp	0.272 (6.67%)	0.030 (-22.35%)	-0.059 (-14.12%)	0.089 (-8.63%)	100,268,752	0h 14m 40.4s	7h 19m 35.8s
c4-cpld-sp	0.283 (10.98%)	0.068 (-7.45%)	-0.041 (-7.06%)	0.109 (-0.78%)	100,268,752	0h 14m 40.4s	10h 52m 31.7s
c5-cpld-ET-sp	0.278 (9.02%)	0.046 (-16.08%)	-0.046 (-9.02%)	0.092 (-7.45%)	100,268,752	0h 14m 40.4s	7h 26m 5.7s
c6-cpld-OPT-sp	0.277 (8.63%)	0.047 (-15.69%)	-0.047 (-9.41%)	0.094 (-6.67%)	100,268,752	0h 14m 40.4s	6h 24m 0.8s
Experiment	0.255	0.087	-0.023	0.111	-	-	-

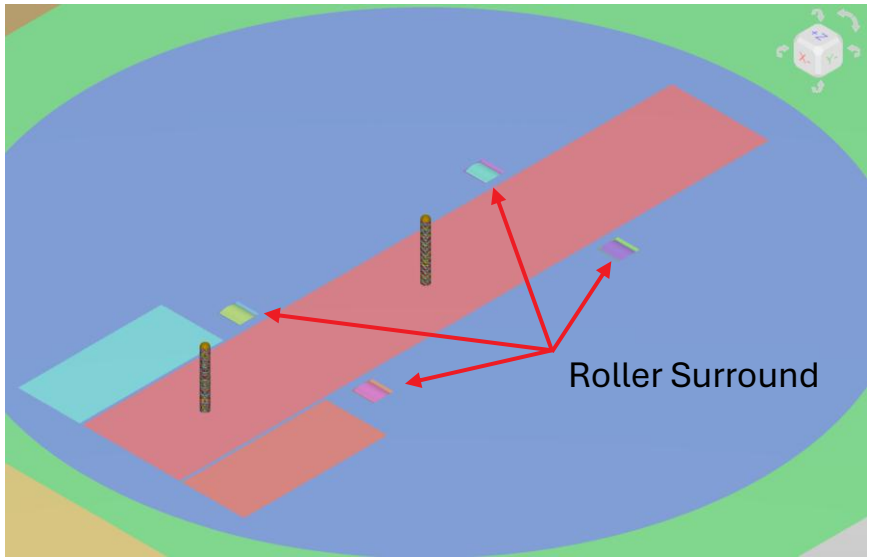


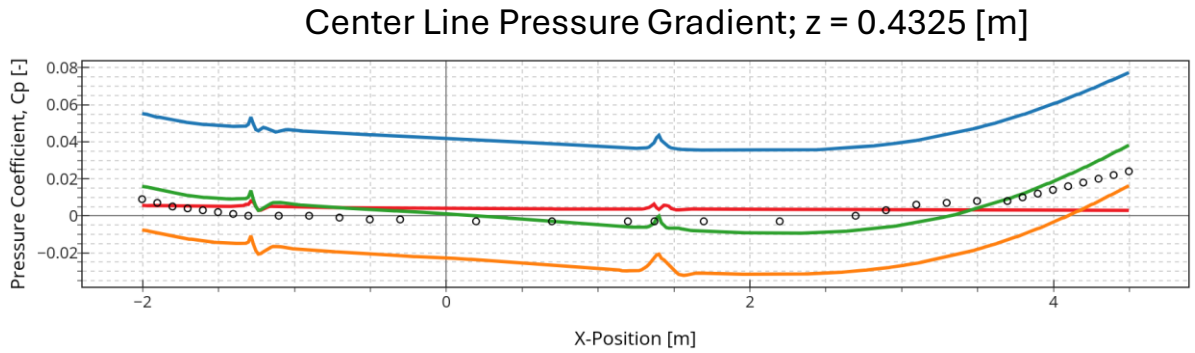


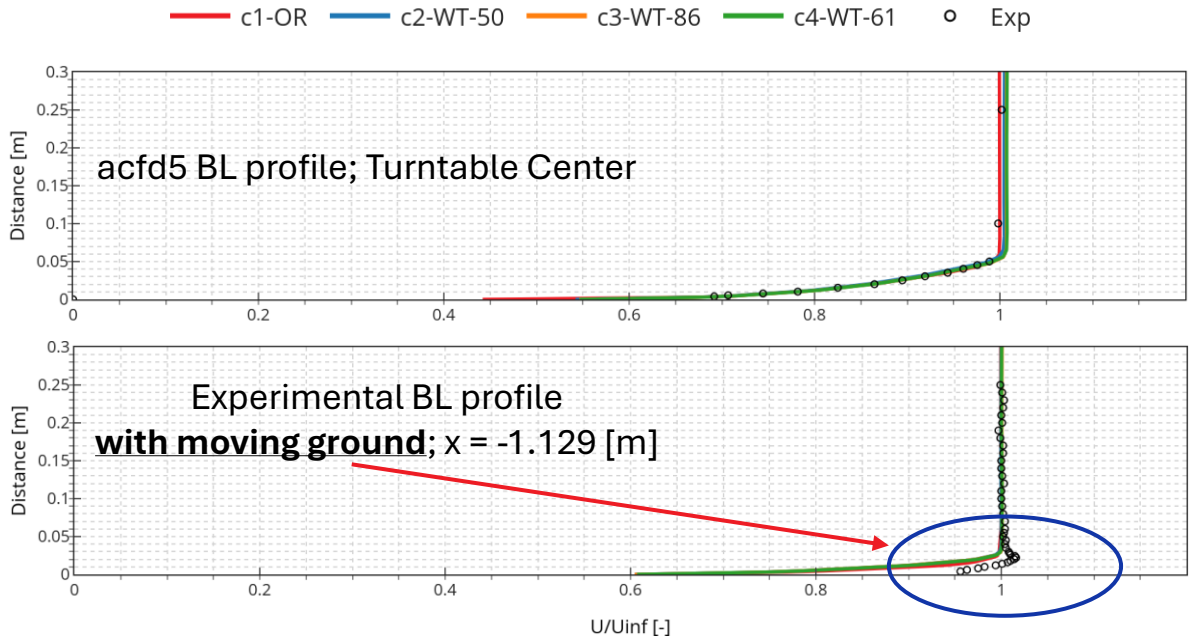
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Wind Tunnel | Calibration of Empty Tunnel









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Wind Tunnel | Cases 2a, 2b

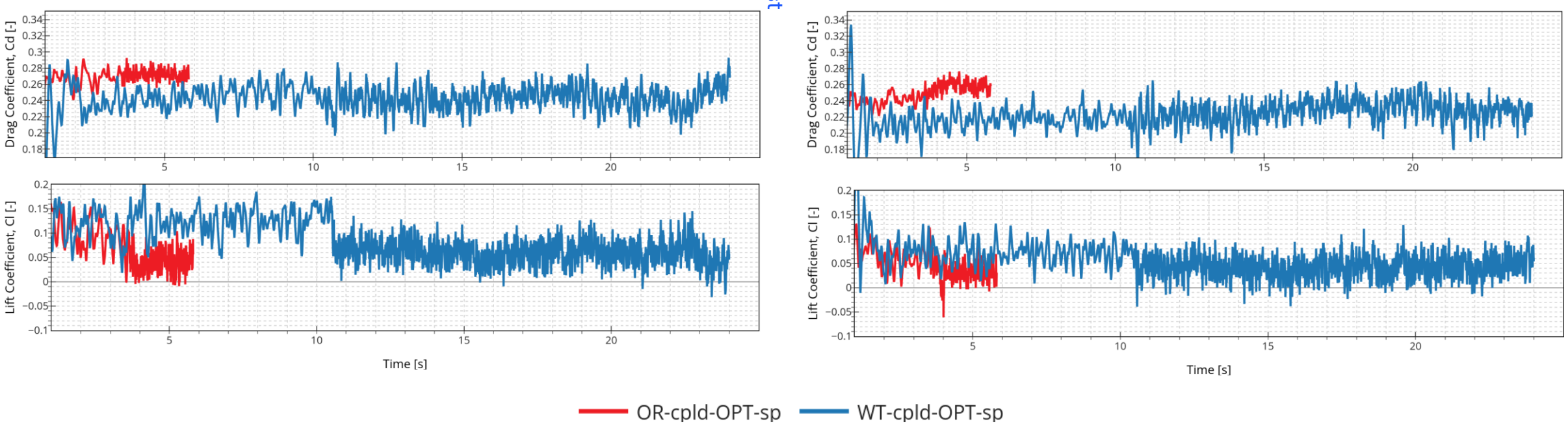
Case 2a

Case	Cd	Cl	Cl_f	Cl_r	N Cells	Meshing time	Run time
OR-cpld-OPT-sp	0.272 (6.67%)	0.043 (-17.25%)	-0.051 (-10.98%)	0.094 (-6.67%)	96,123,326	0h 12m 23.4s	5h 28m 41.2s
OR-cpld-OPT-v2-sp	0.271 (6.27%)	0.039 (-18.82%)	-0.055 (-12.55%)	0.094 (-6.67%)	96,123,326	0h 12m 23.4s	3h 25m 33.4s
WT-cpld-OPT-sp	0.244 (-4.31%)	0.058 (-11.37%)	-0.056 (-12.94%)	0.114 (1.18%)	135,730,397	0h 15m 43.8s	54h 32m 11.7s
Experiment	0.255	0.087	-0.023	0.111	-	-	-

Latest

Case 2b

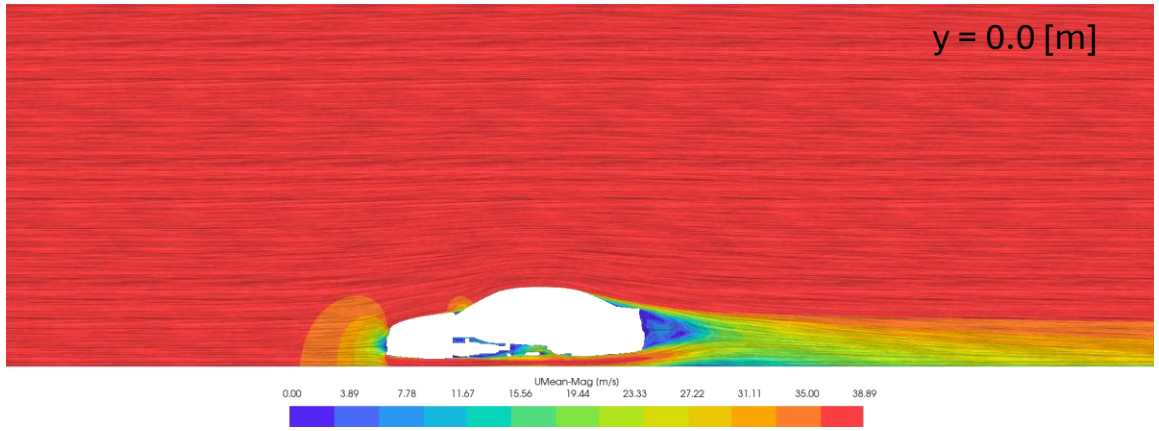
Case	Cd	Cl	Cl_f	Cl_r	N Cells	Meshing time	Run time	ΔC_D
OR-cpld-OPT-sp	0.259 (7.02%)	0.033 (-20.25%)	-0.053 (-14.05%)	0.086 (-6.20%)	96,163,093	0h 12m 31.9s	5h 27m 31.1s	-0.013
WT-cpld-OPT-sp	0.230 (-4.96%)	0.042 (-16.53%)	-0.060 (-16.94%)	0.102 (0.41%)	136,359,333	0h 15m 38.7s	54h 53m 8.7s	-0.014
Experiment	0.242	0.082	-0.019	0.101	-	-	-	-0.013

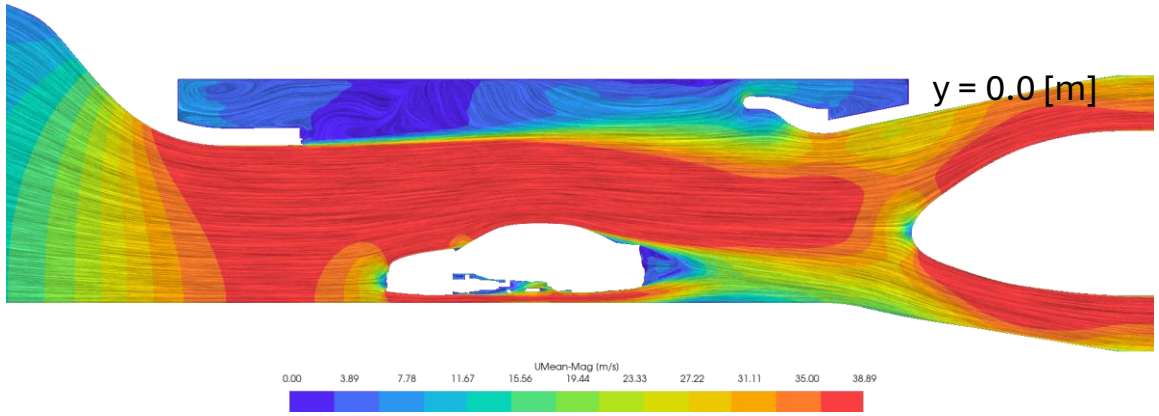


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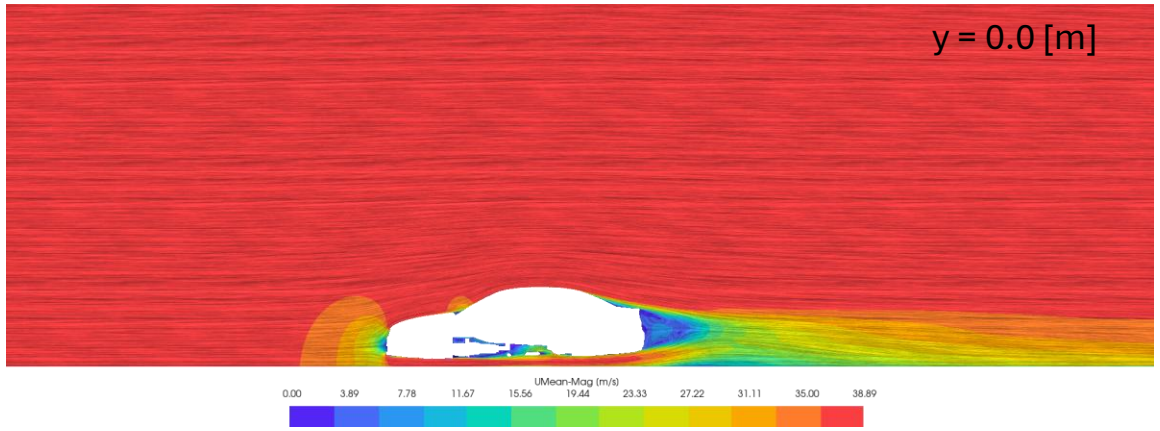
Wind Tunnel | Cases 2a, 2b

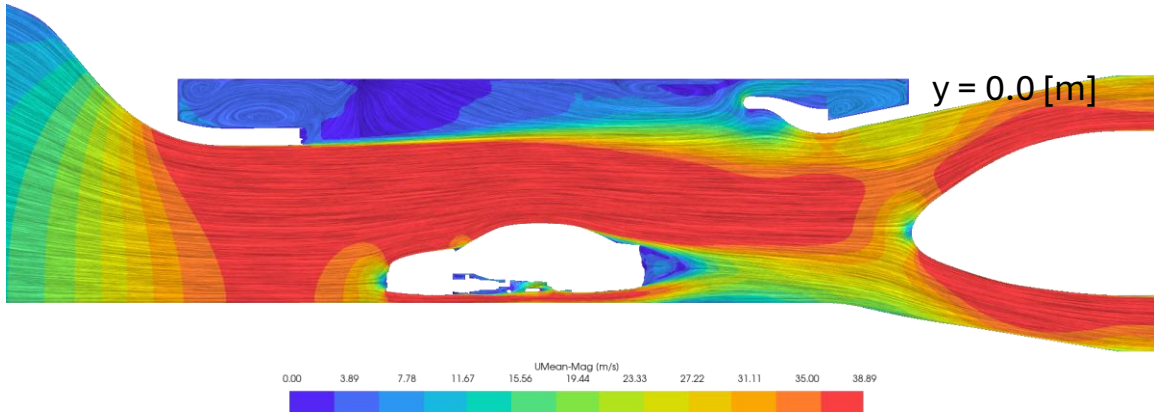
Case 2a





Case 2b





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Summary

- Open Road
  - Mesh Resolution – the work with mesh resolution has shown that larger meshes do not always equate to more accurate results, a conclusion also reached by a number of presentations at the 2026 SAE WCX.
  - Turbulence modeling – different LES filters do not show significant improvements in results, however the enhanced shielding function by Deck & Renard does improve accuracy, albeit at a significant performance cost. We will investigate this further to see if we can reduce the run times.
  - Solution Strategy – single precision has consistently shown 40% reduction in run times, with minimal (~1-3 counts) difference in results. Furthermore the new coupled solver from our GPU codebase has shown substantial improvements over segregated. Finally using Perfect Gas, rather than an incompressible formulation, has shown both performance and accuracy improvements, however the robustness is not currently to the same level as our current approach so needs further work.
- Wind Tunnel
  - A quick investigation into the use of the wind tunnel test section, rather than a very large open domain, has shown notable improvements in absolute numbers whilst maintaining the already good prediction of delta values achieved by the open road approach.
  - Further improvements in accuracy could easily be achieved by tuning the inlet velocity and outlet pressure, but the question has to be asked as to whether this is worthwhile given the significant increase in run times incurred by this approach.

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Questions?



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