3rd Automotive CFD Prediction Workshop

Cadence Design Systems

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22 Sep. 2022

cadence®

About Cadence Computational Fluid Dynamics

- 9000+ employees worldwide across multiple industries
- Close to 30 years of experience in CFD
- Expertise in the simulation of fluid flows, heat transfers and Multiphysics
- State-of-the art algorithms and methodology

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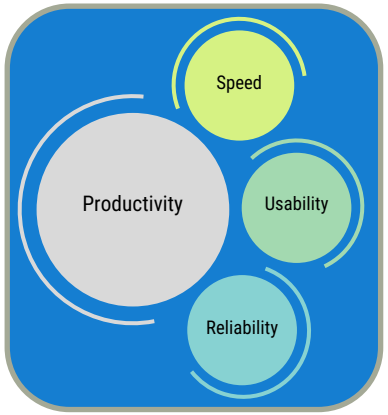
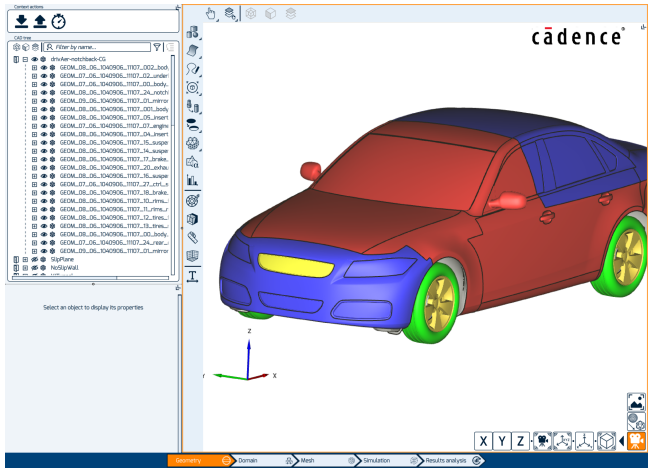
Fidelity: a CFD platform for end-to-end system analysis

- A fully-integrated, parallel & **multidisciplinary environment for end-to-end simulations**, design exploration and optimization (1D, CAD, CFD, CAA, FEA, MDO)
- Set-up and co/post-process all your simulation projects in a **single environment**, compatible with all our solvers and with in-house and research codes
- Optimized for high performance **parallel** (HPC) computations
- Runs on **CPU** and **GPU**

Multiple **Unit Systems**

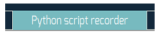
Copy/Paste for all objects



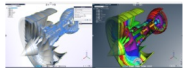


Undo/Redo for all actions

Integrated editable **tooltips**

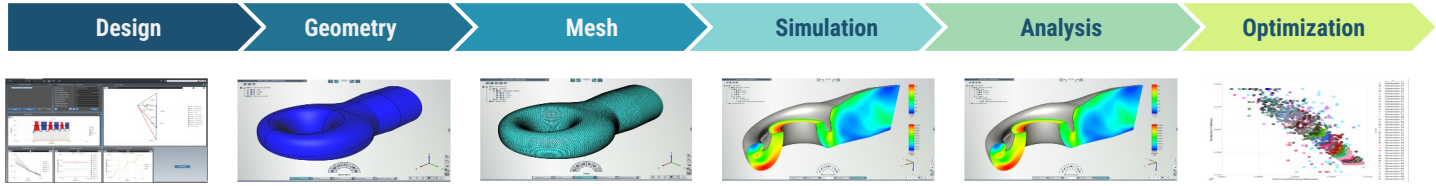


Automatic **Python script** recording



Customizable user interface

Multilingual interface



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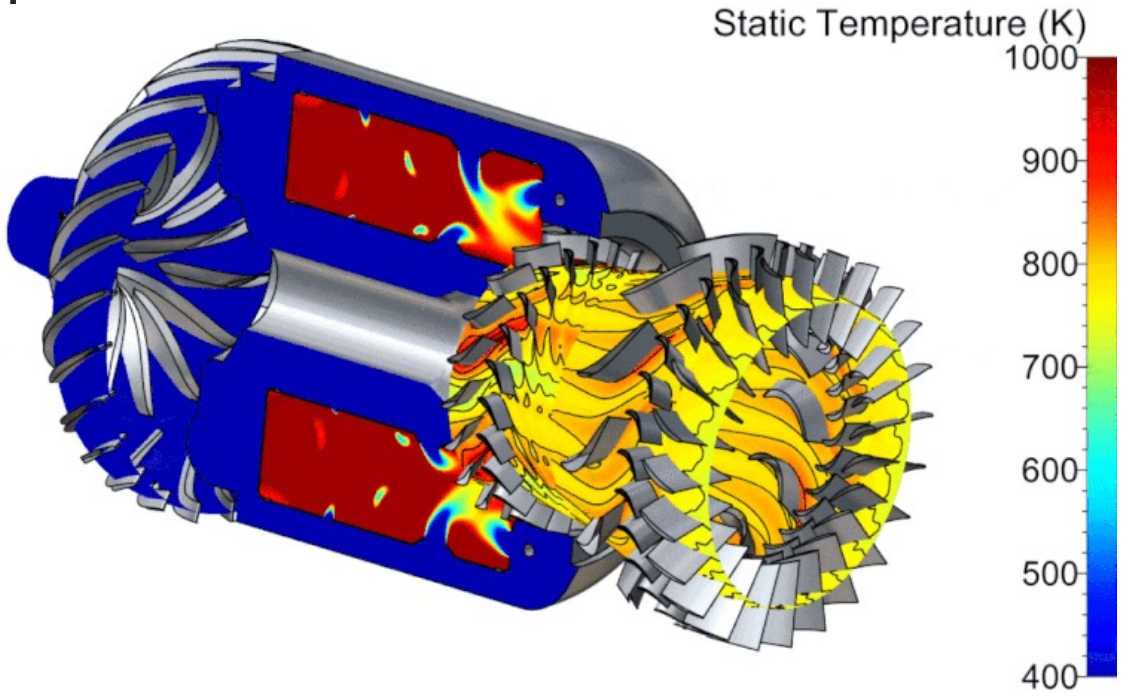
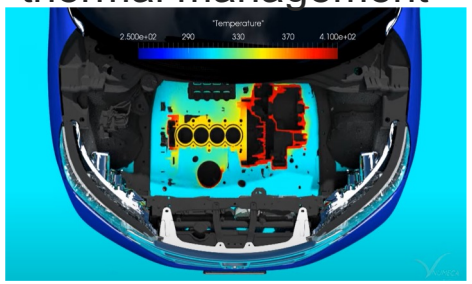
Fidelity Open – Fast and Versatile Multiphysics Flow Solver

From incompressible and low-speed to high-speed flows with a **variety of physical models**

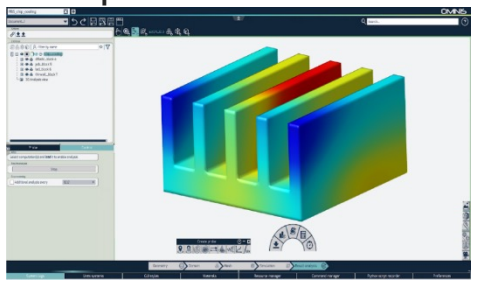
- Incompressible, compressible
- Rotating domains, with mixing plane, MRF, or AMI
- Porous media
- Conjugate heat transfer
- Radiation
- Tabulated thermodynamics
- Cavitation
- Variable time steps
- Calibration of BC, source terms, etc. with OpenLabs



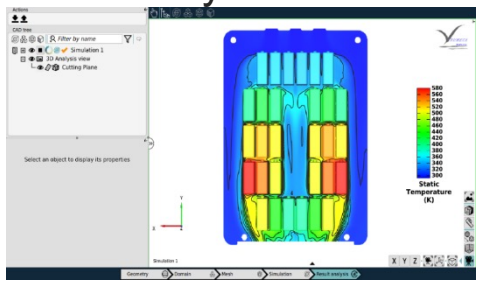
Car Under-hood thermal management



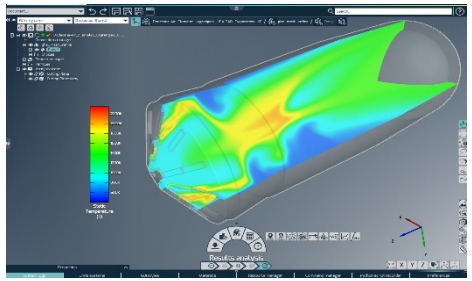
Electronic components



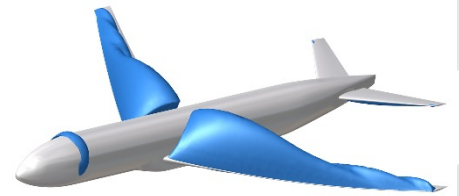
EV Battery



Combustion chamber



Transonic aircraft



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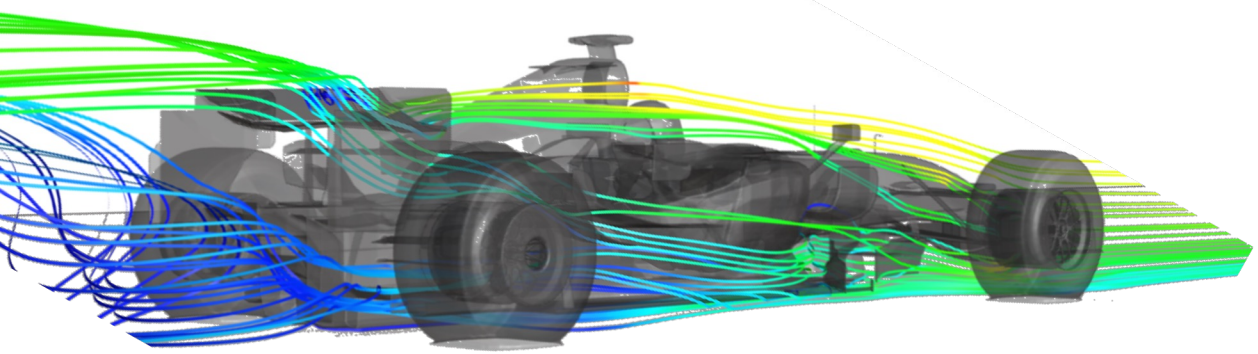
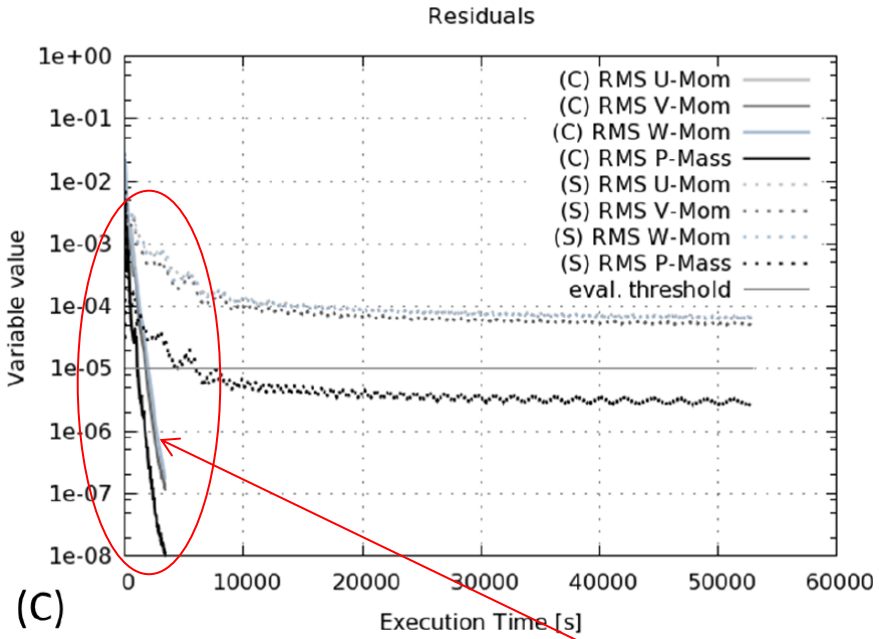
Fidelity Open PBS: a fully coupled solver

- Full coupling of pressure, momentum, and energy:
  - **Robust and fast** thanks to pressure-momentum coupling and efficient implicit AMG solver
  - Allows for large time steps in unsteady simulations
  - **Mesh-size independent** convergence
  - **Fast convergence of CHT** applications thanks to energy coupling
- Pressure based, all-speed (all Mach)
  - General purpose
  - Incompressible, compressible





Fast smooth of low frequency errors

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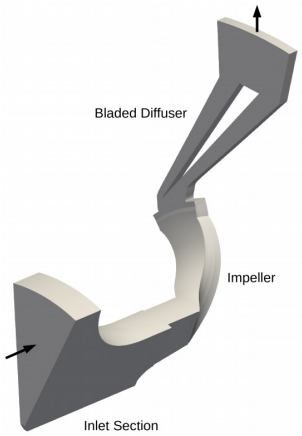
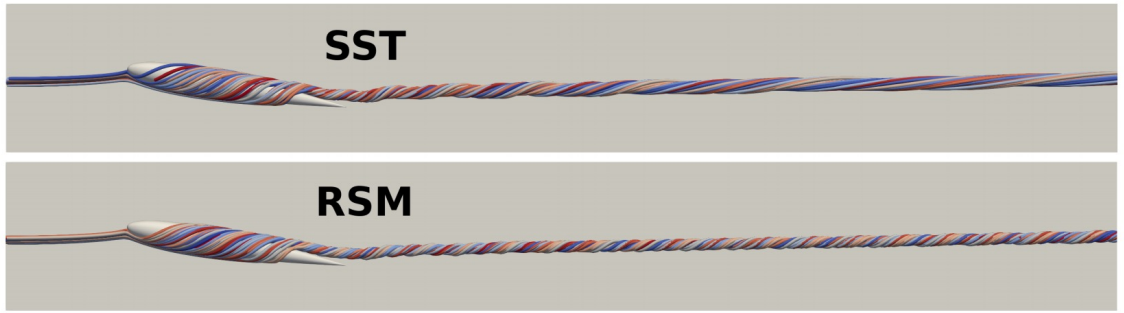
The RSM model offers a perfect balance of accuracy and speed

Modeling each term of the Reynolds stress tensor yields:

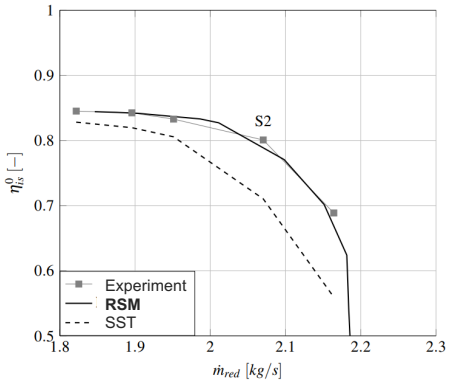
- **Speed** thanks to the steady-state nature of the model
- **Robustness** thanks to its implementation in a coupled pressure-based framework
- **Accuracy** thanks to the low diffusivity of the model
- **Reliability** thanks to anisotropic nature of the turbulence modeling allowing for a much finer physical representation of complex turbulent flows





Low diffusion: good for vortex and wake prediction

SST RSM



Anisotropic: good for flow prediction around complex geometries with strong curvatures and complex flow interactions.

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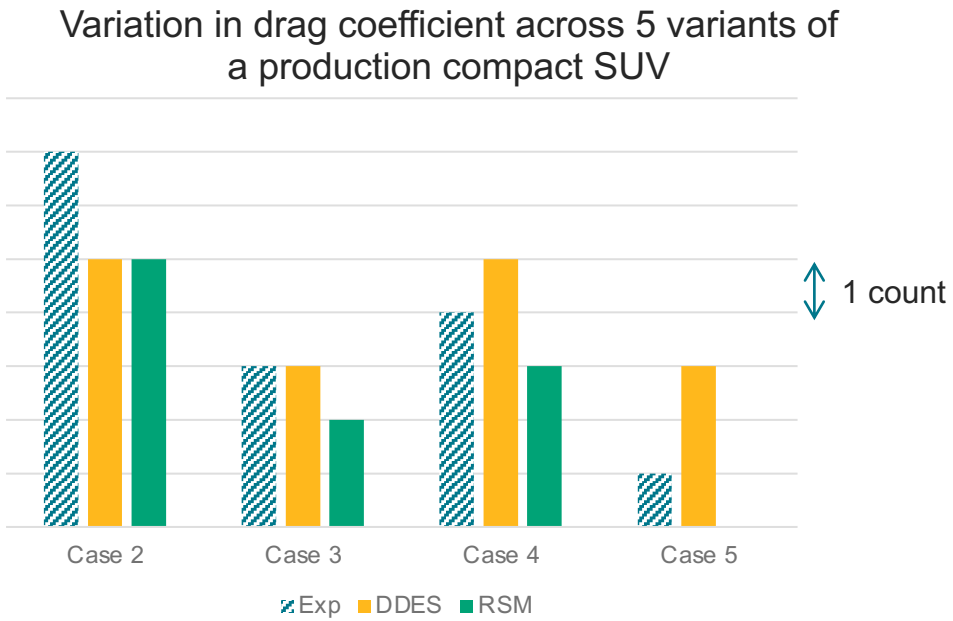
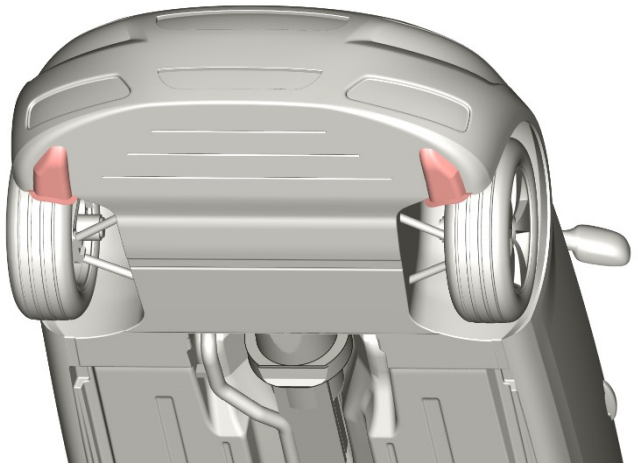
Industrial computations for certification

- Typical industrial regulatory simulations require to predict changes in drag from small geometrical modifications such as wheel changes (diameter change, rim geometry change), addition of deflectors of flaps close to wheels, addition of side sills, spoilers, etc.
- The picture below show prediction of drag coefficient change from such variations on production compact SUV with RSM and DDES.
- RSM matches the accuracy of DDES within a few counts.





Example of accessory addition (in red) on the DrivAer model

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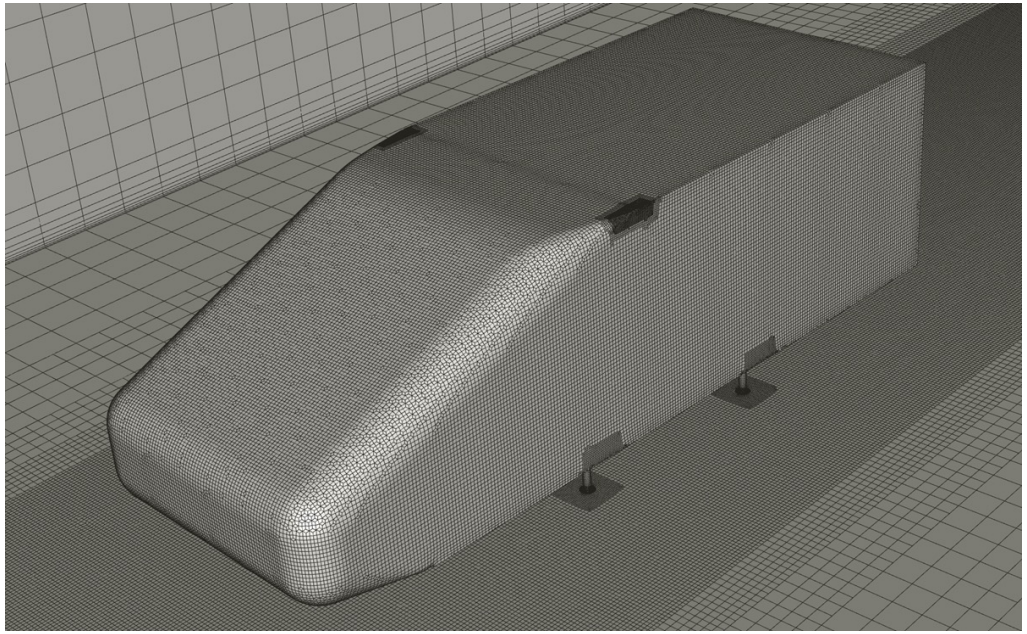
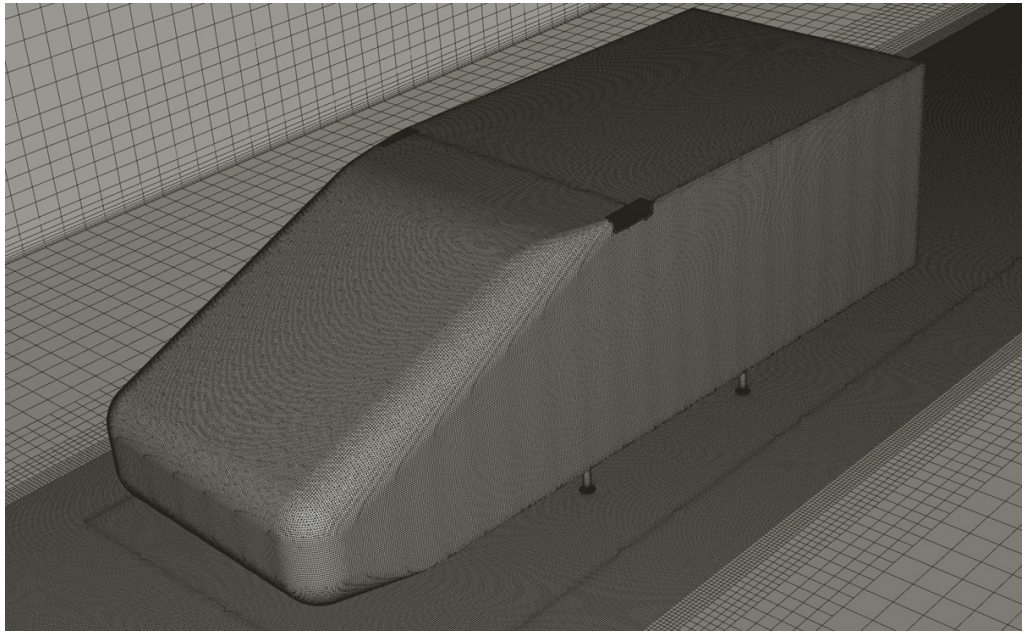
Case 1: Windsor body at 2° yaw

- Mesh generated in Fidelity Hexpress following workshop guidelines for g1 and g2
- Full hexahedral mesh with good quality
- Comparison with experimental data from *Varney, et al. (2020): Windsor Model Experimental Aerodynamic Dataset.*

Variant	Mesh size [M]	Mesh size (committee) [M]	Max OF skewness	Max non orthogonality
g1	**6.68**	**6.31**	2.42	61.33
g2	**37.7**	**37.3**	2.13	61.27



g1



g2

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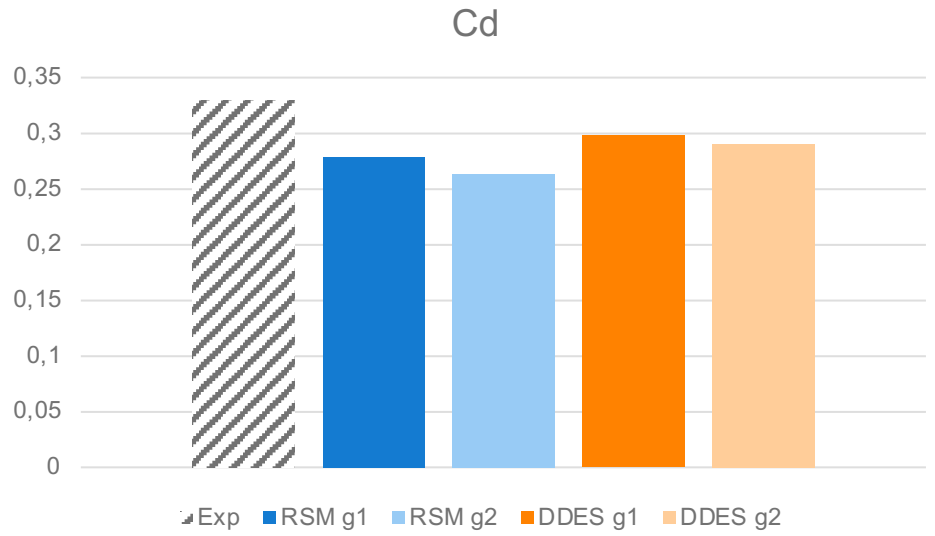
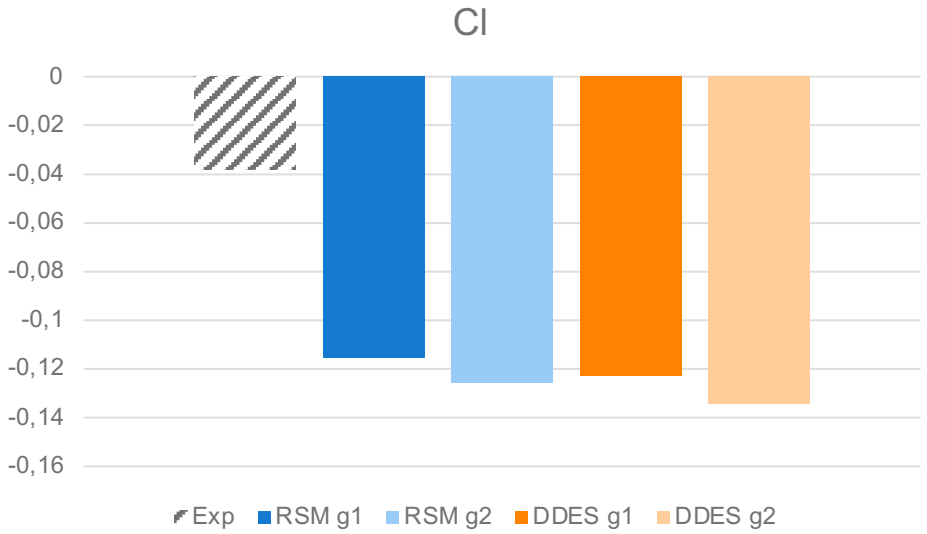
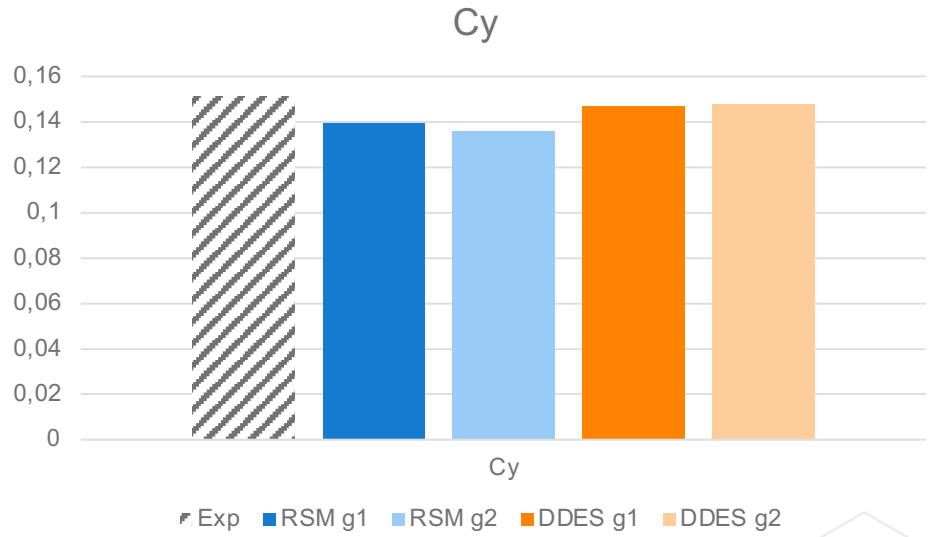
Case 1: Windsor body at 2° yaw
Forces

- Grid 1 is clearly not sufficiently converged
- Both RSM and DDES underpredict Cd
- DDES predicts drag better than RSM in this case, probably because on the strong bluff body separation







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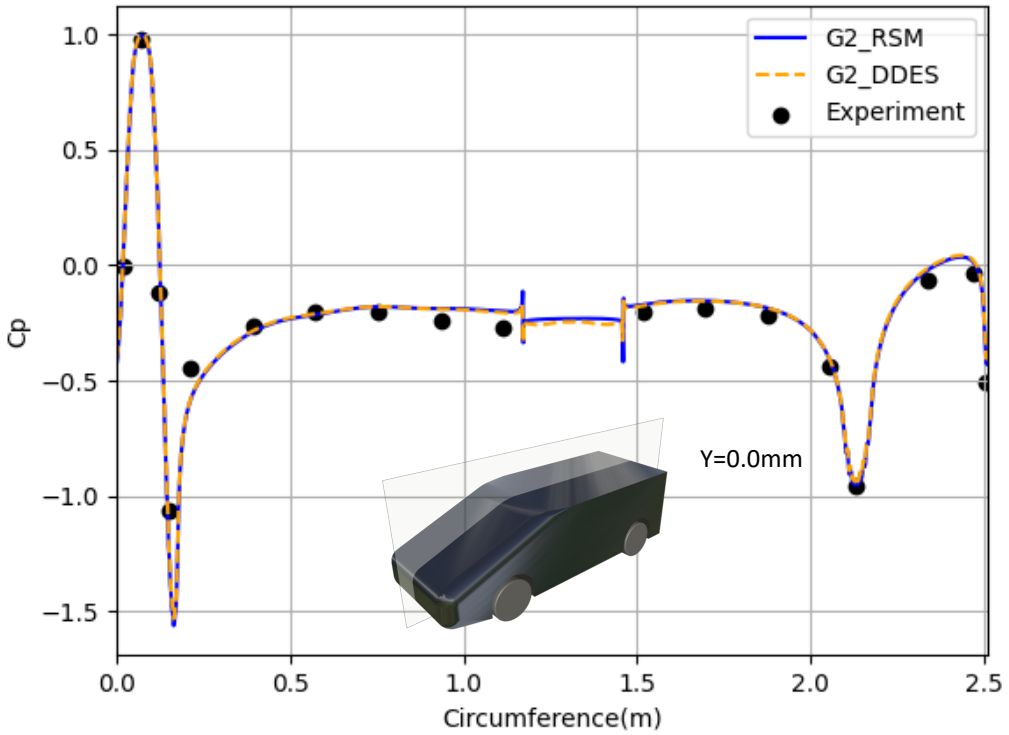
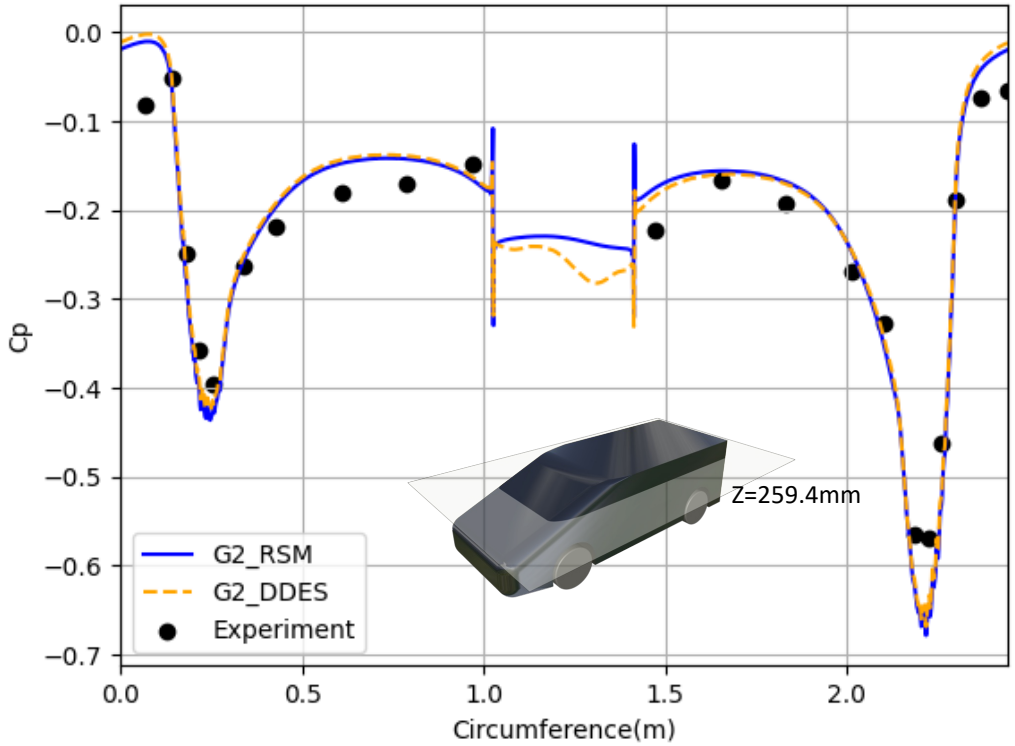
Case 1: Windsor body at 2° yaw

Pressure coefficient on the body

- Pressure measurements indicate too much suction on the suction side, and incorrect pressure levels on the pressure sides
- This could be due to the behavior of the wall model in the presence of strong pressure gradients.





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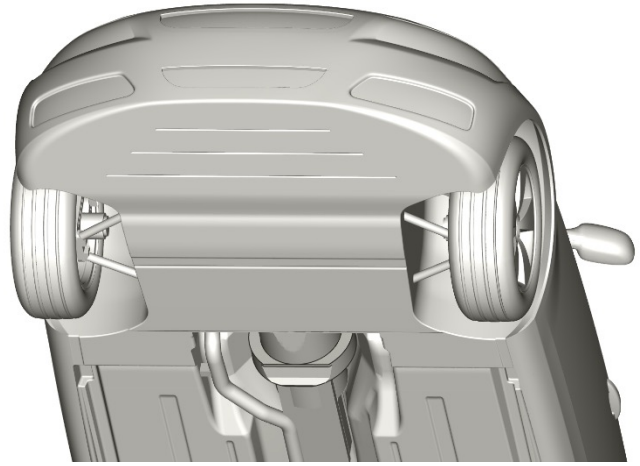
Case 2: DrivAer notchback with/out wheel deflector

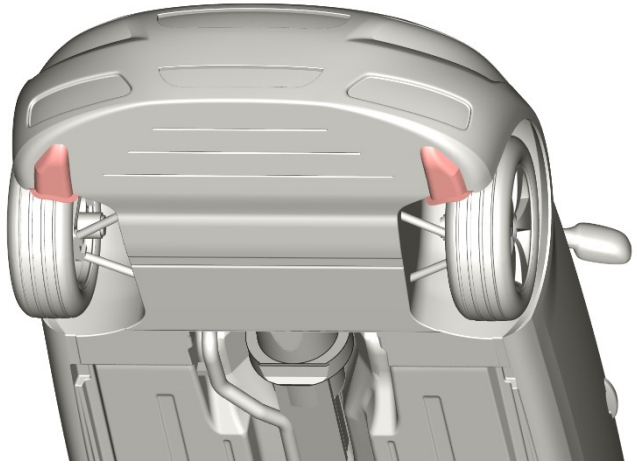
Case setup and meshes used

- Meshes generated in Fidelity™/Hexpress following the workshop guidelines.
- Two configurations considered:
  - Without deflector (nD)
  - With deflector (wD)
- High Re meshes generated for each configuration
- An empty wind tunnel simulation was run with identical mesh and simulation settings, yielding a δ_{99}=50mm, the reference provided value was 55mm.
- SST, RSM, and SST-DDES models used.

Variant	Mesh size [M]	Mesh size (committee) [M]	Max skewness	Max non-orthogonality
nD	~ 128	~ 128	3.44	87.5
wD	~ 130	~ 128	3.44	87.9



nD



wD

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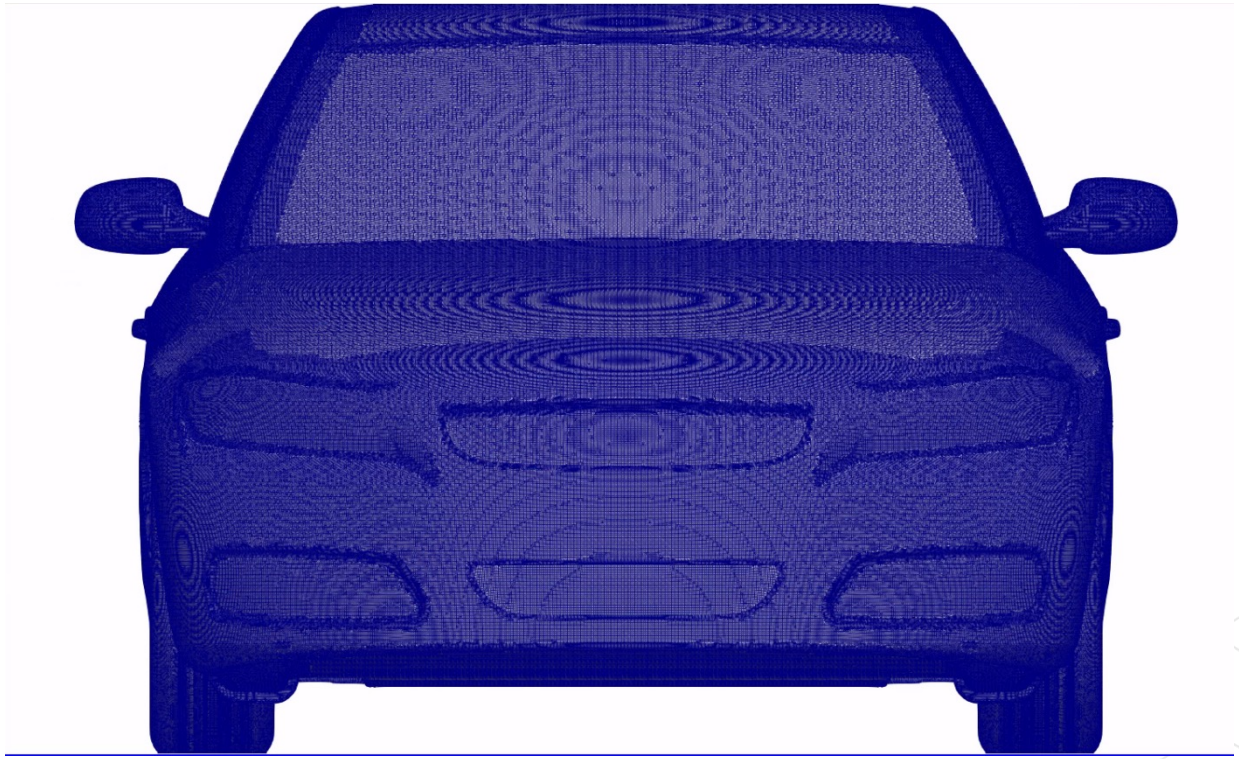
Case 2: DrivAer notchback with/out wheel deflector

Comparison of cadence and committee meshes

Cadence mesh



Committee mesh

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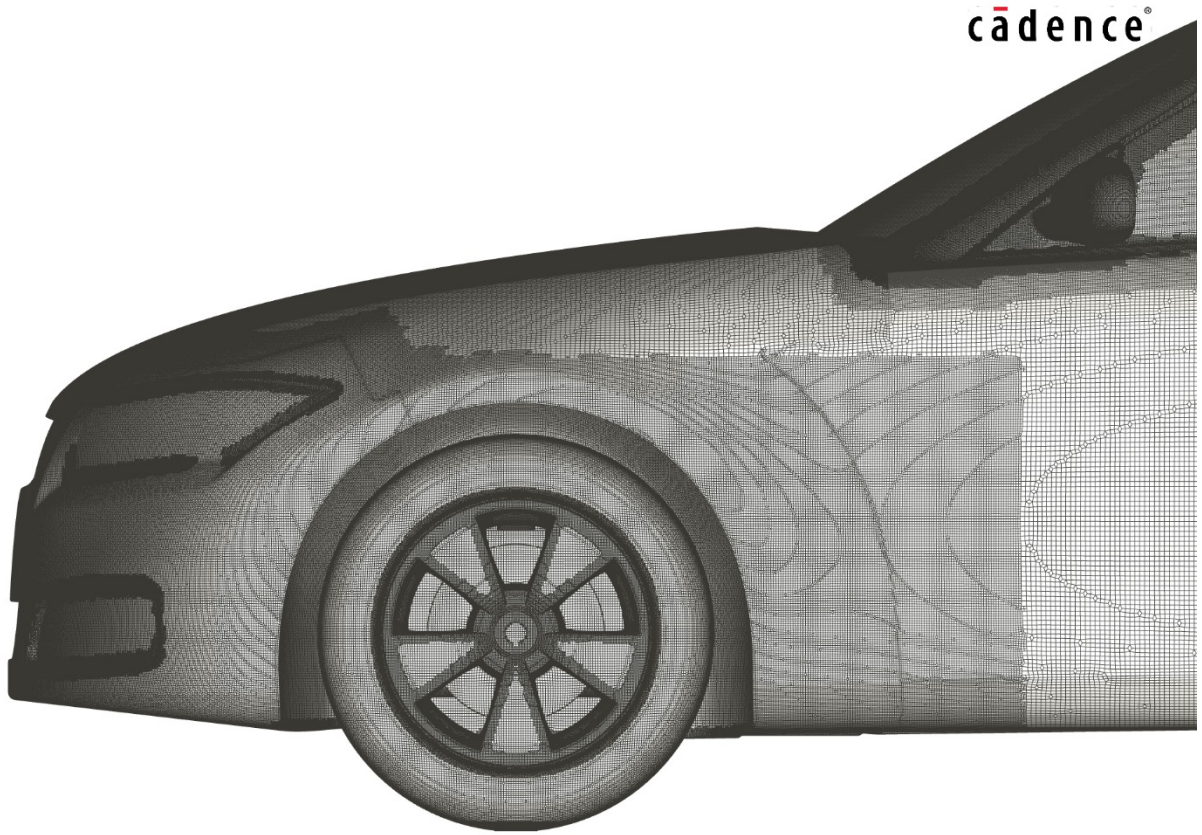
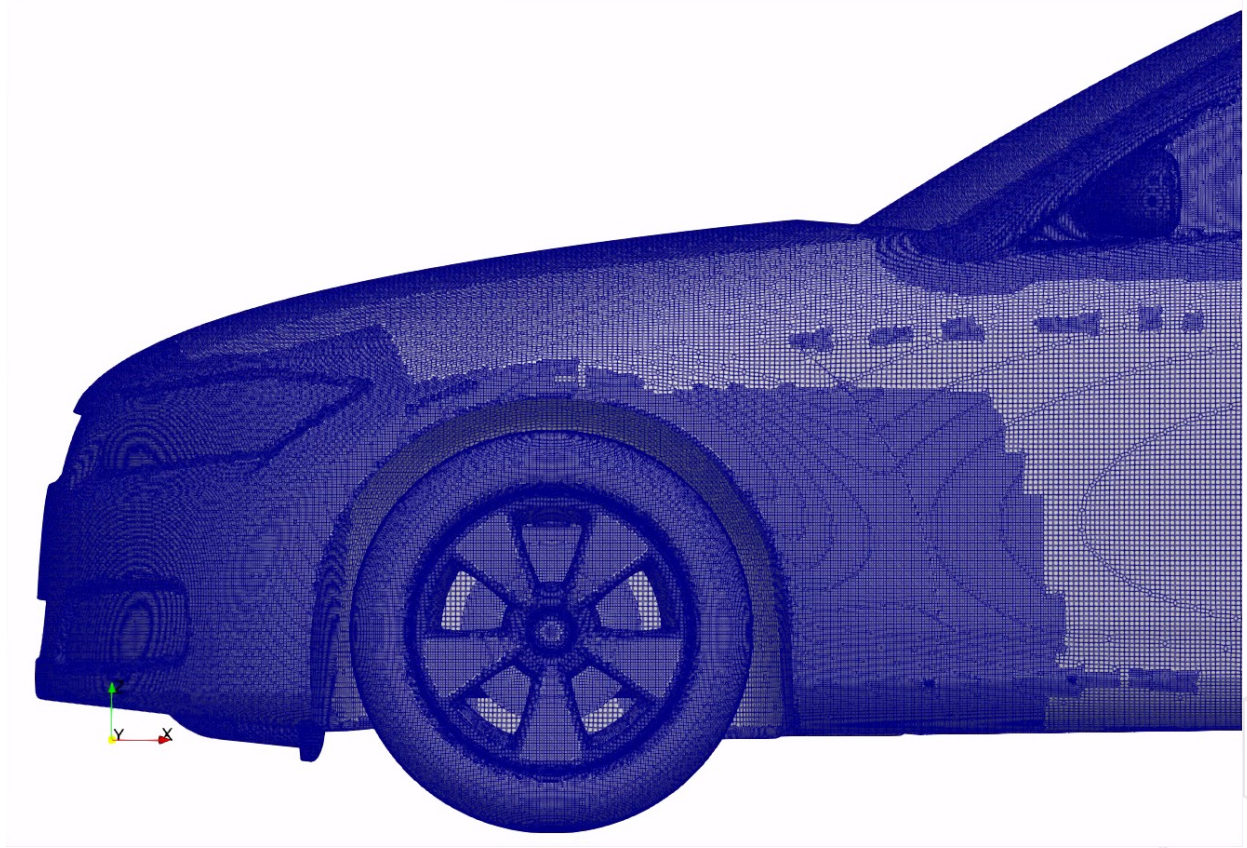
Case 2: DrivAer notchback with/out wheel deflector

Comparison of cadence and committee meshes



Cadence mesh



Committee mesh

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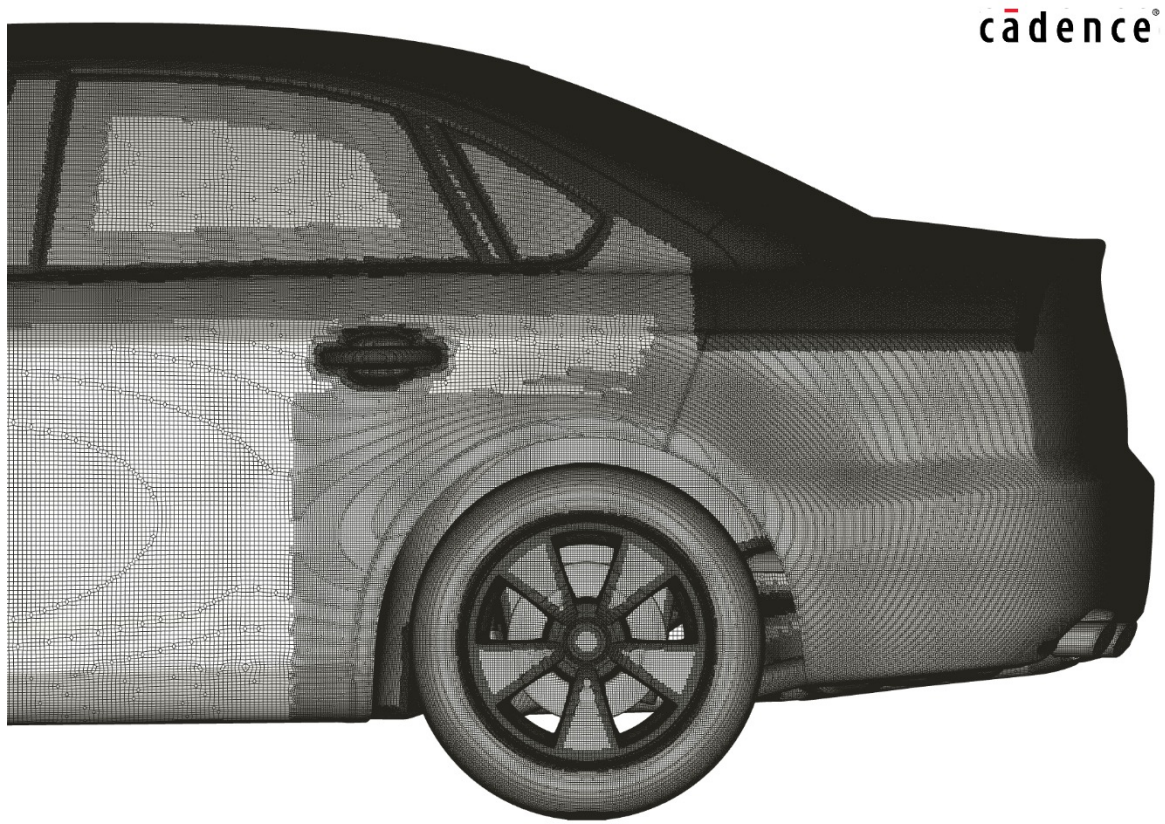
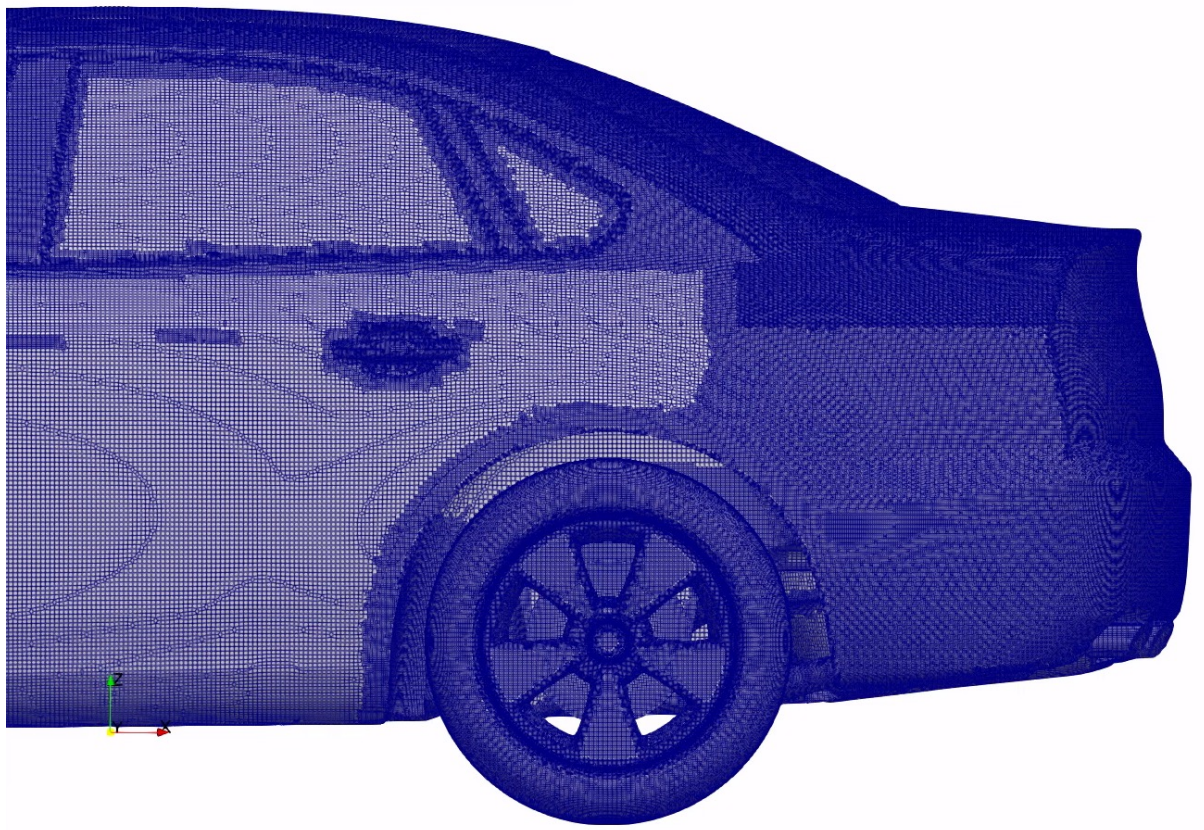
Case 2: DrivAer notchback with/out wheel deflector

Comparison of cadence and committee meshes



Cadence mesh



Committee mesh

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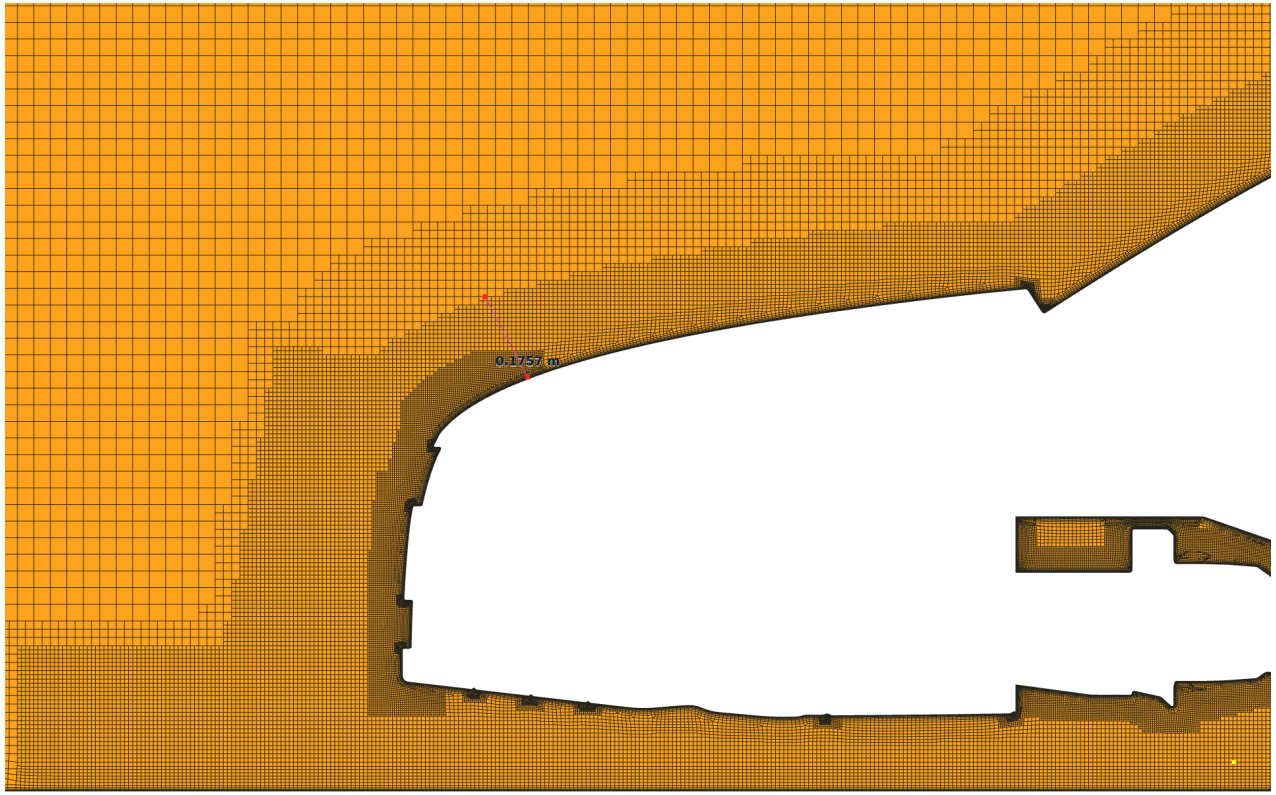
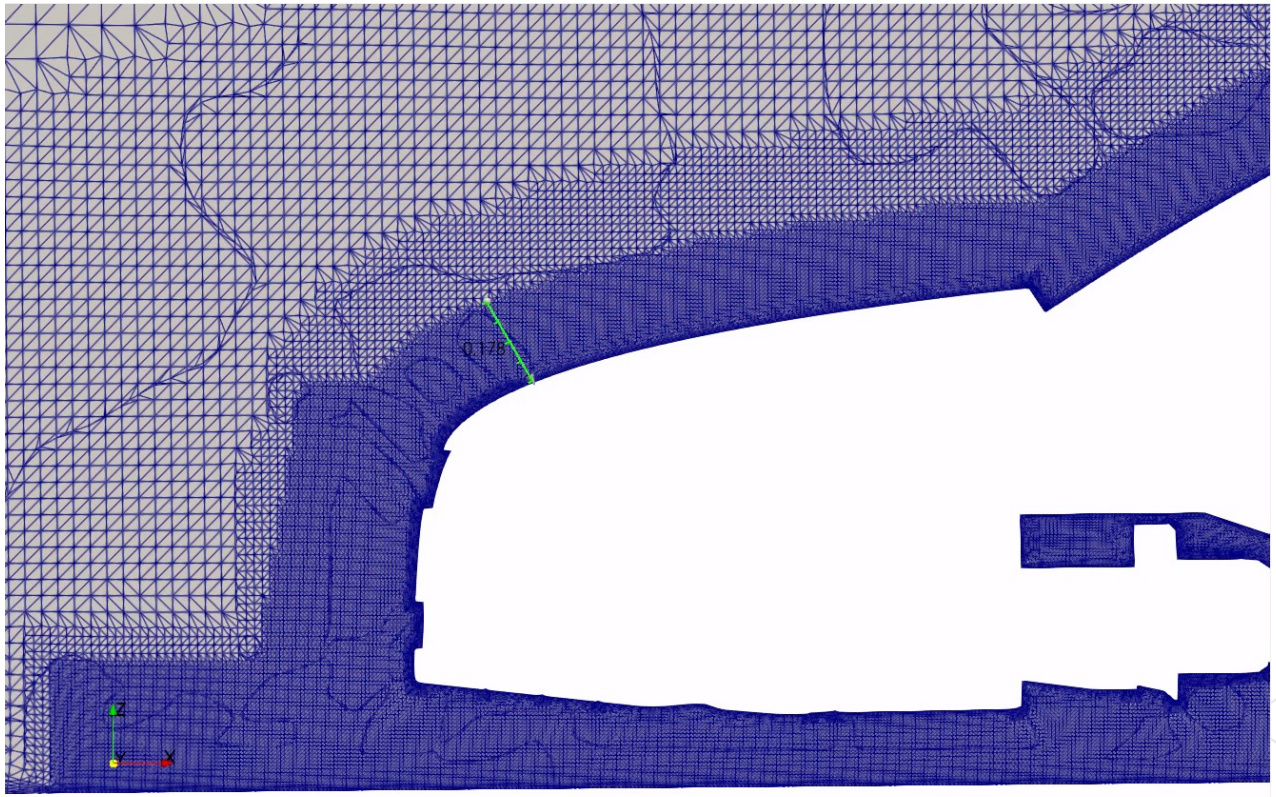
Case 2: DrivAer notchback with/out wheel deflector

Comparison of cadence and committee meshes



Cadence mesh



Committee mesh

Note the cut was triangulated, and therefore looks denser, although the same grid size is used.

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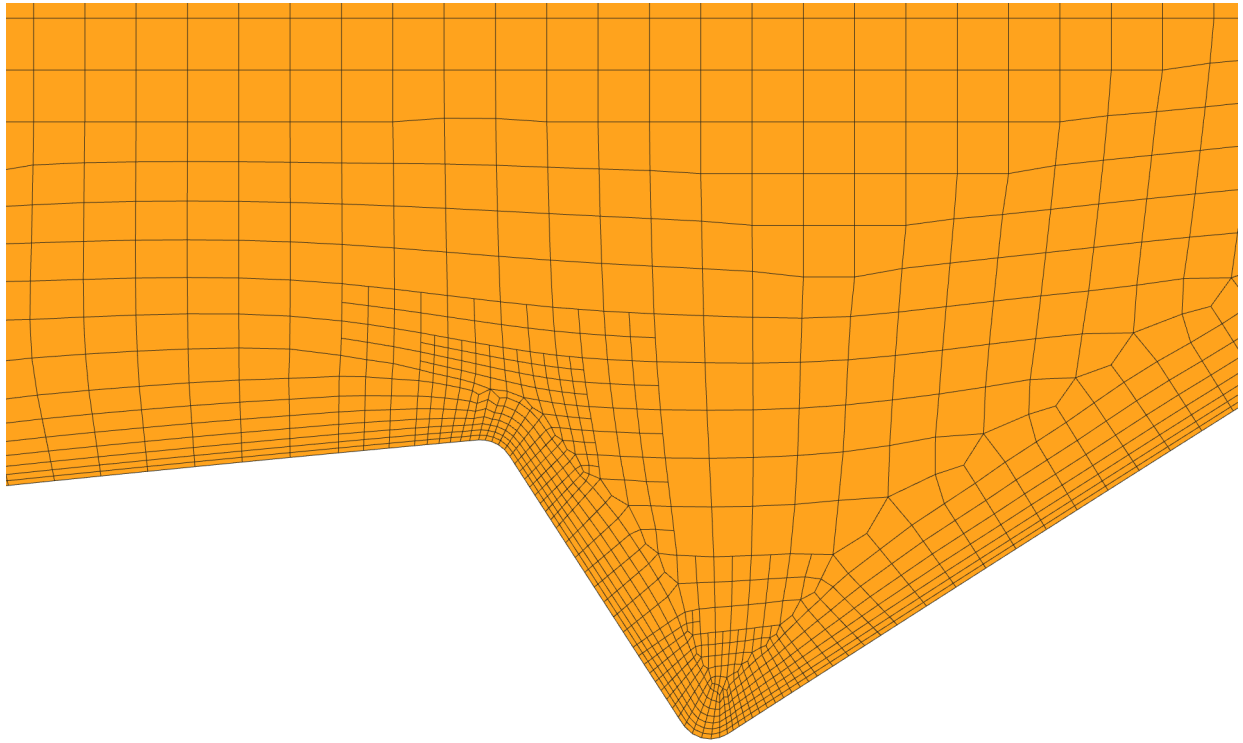
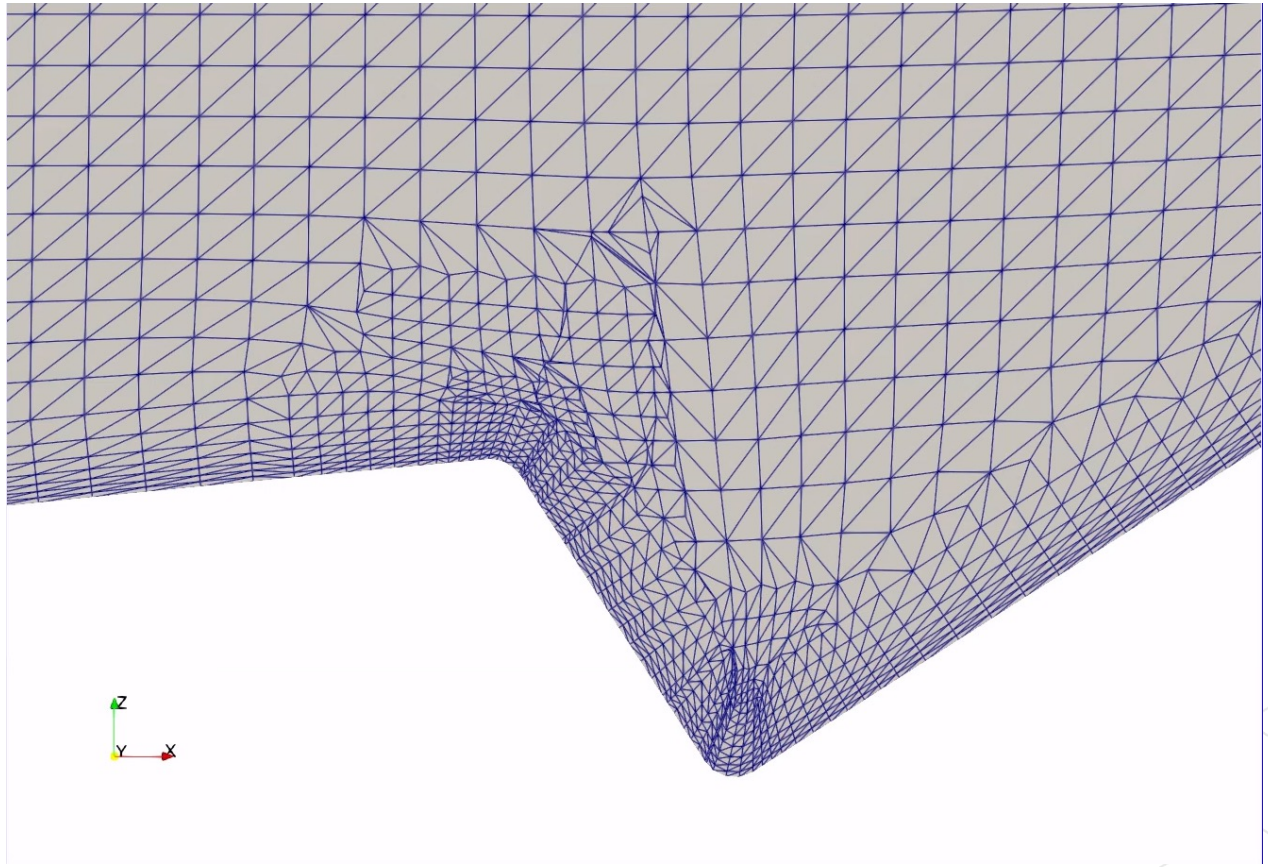
Case 2: DrivAer notchback with/out wheel deflector

Comparison of cadence and committee meshes



Cadence mesh



Committee mesh

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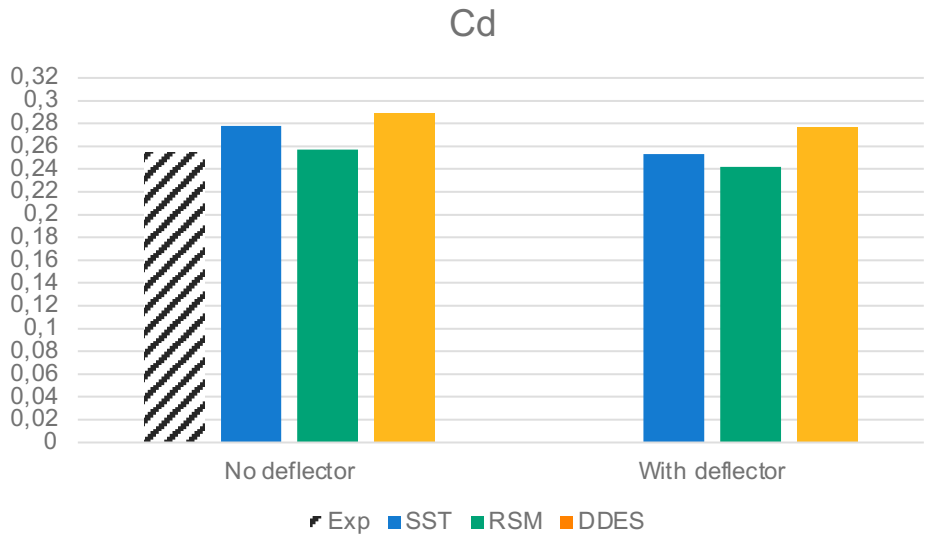
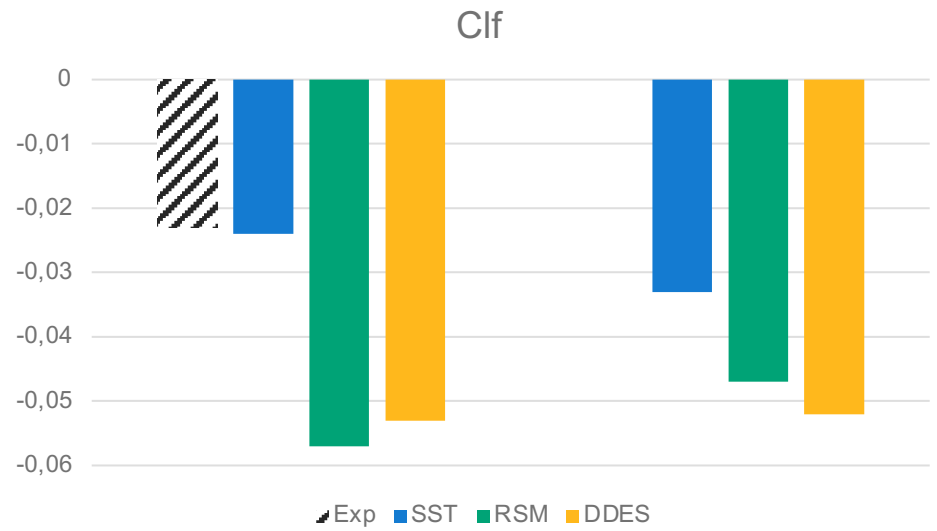
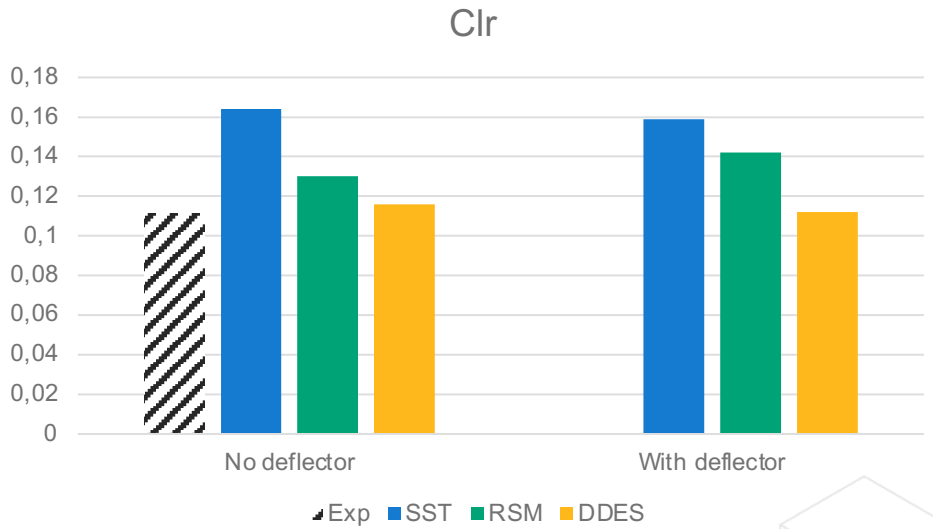
Case 2: DrivAer notchback with/out wheel deflector

Global forces

- RSM is closest to experimental value in drag and is also close to DDES and experimental values in rear lift
- Front lift predictions are further away from experiment







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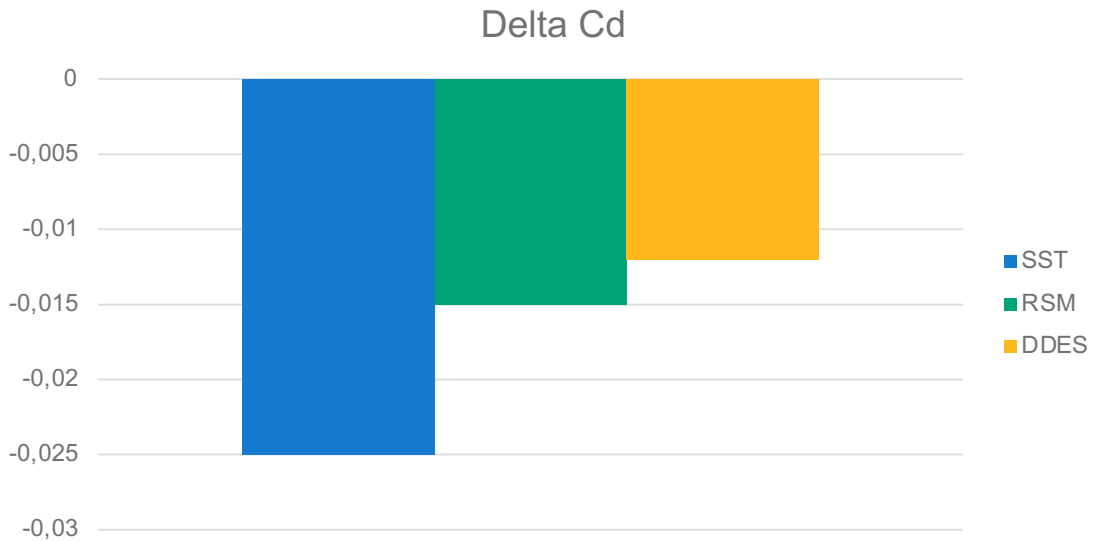
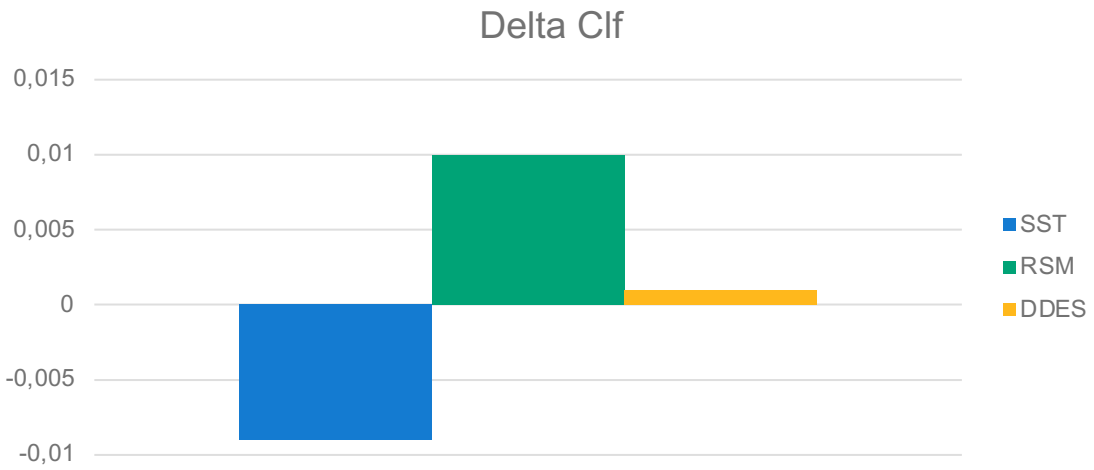
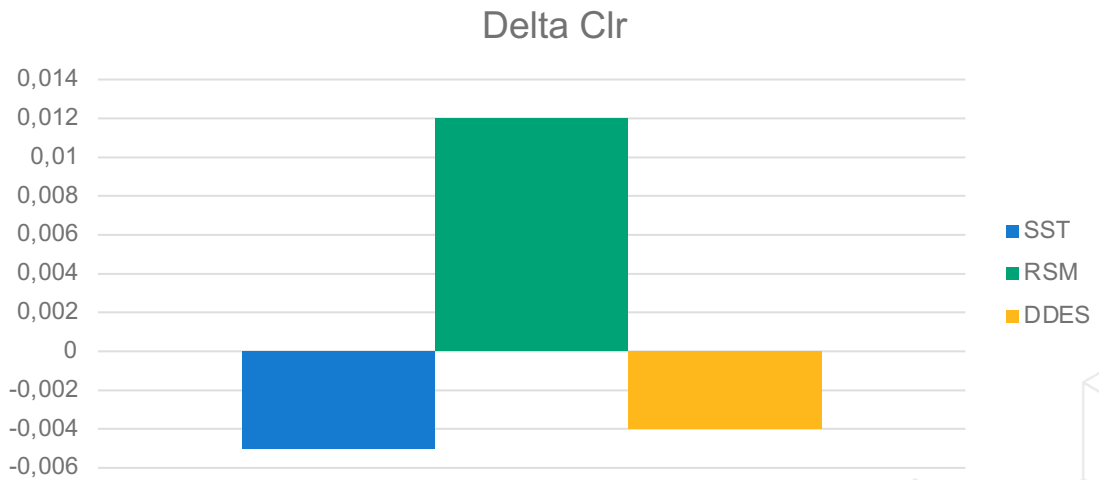
Case 2: DrivAer notchback with/out wheel deflector

Impact of the deflector on forces

- RSM predicts a smaller drag decrease from the deflector, closer to what the DDES predicts.
- Lift variation predictions are not perfectly consistent across the various models.







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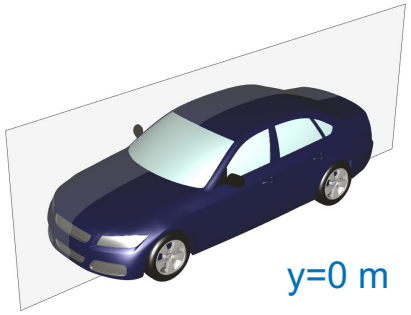
Case 2: DrivAer notchback without wheel deflector

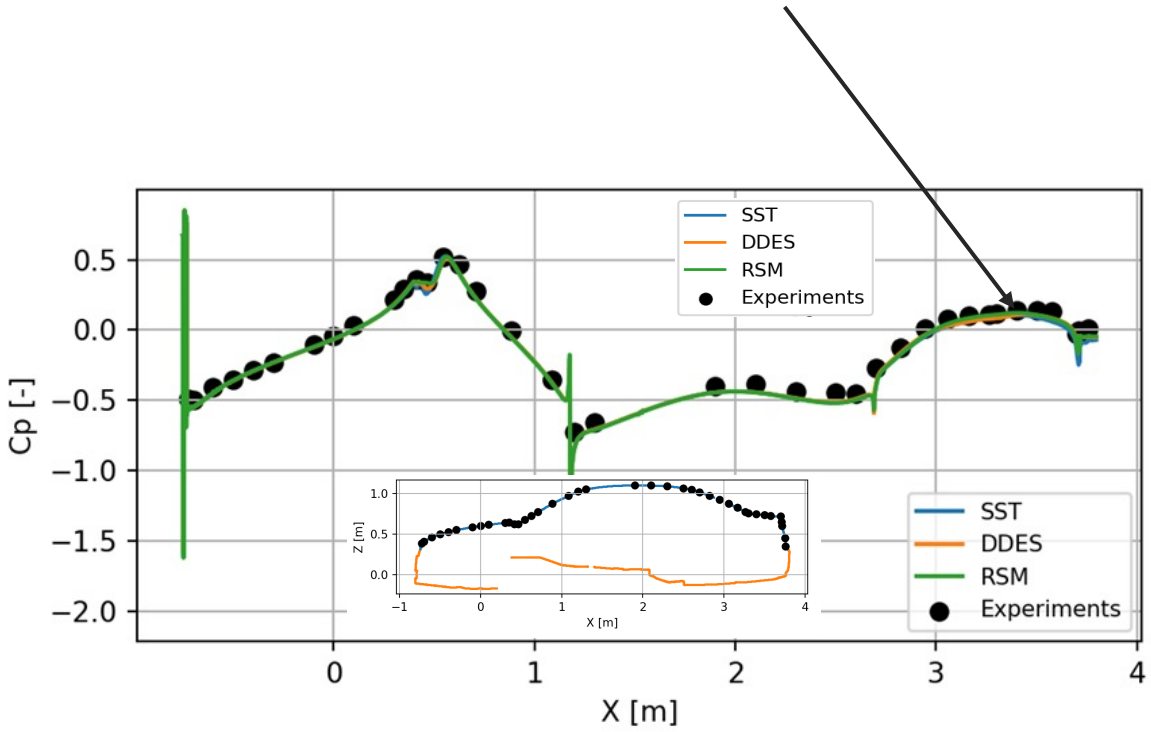
Pressure coefficient Cp at y=0 m

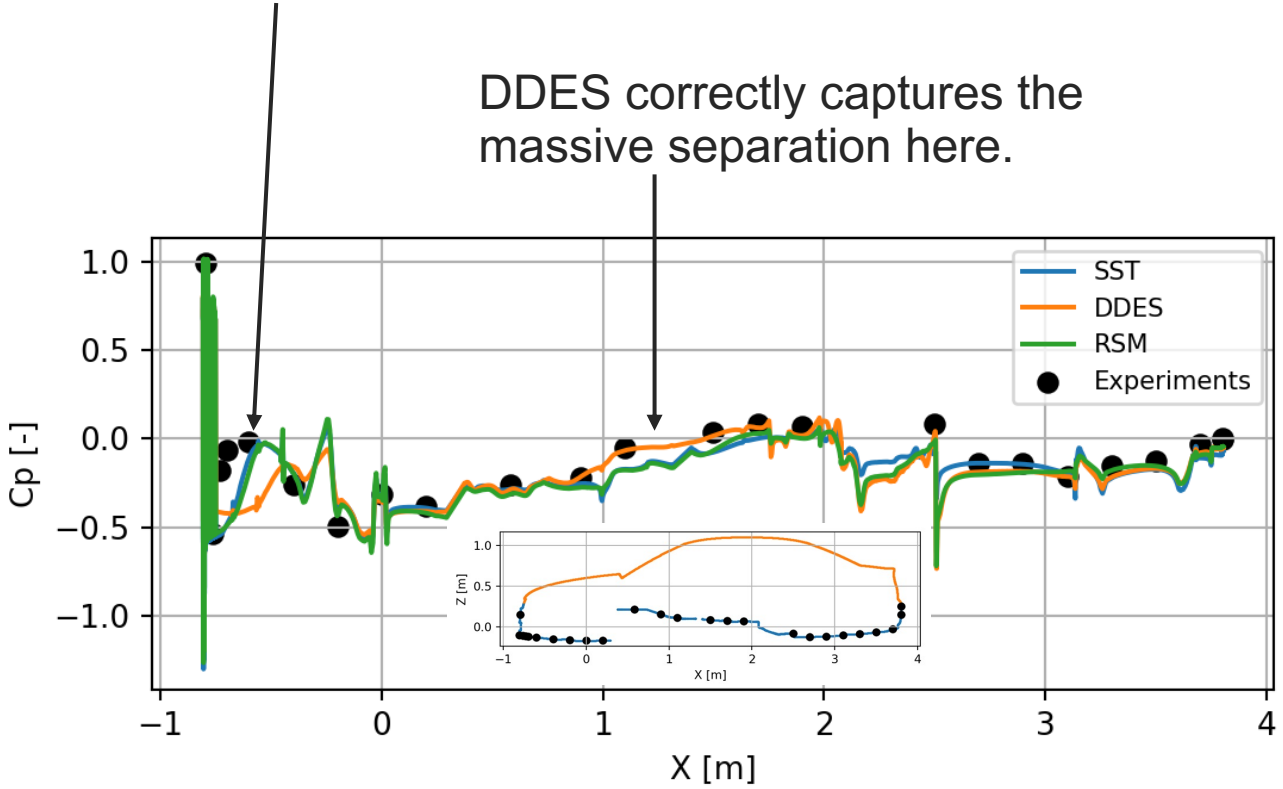


None perfectly captures the behavior above the trunk, although DDES and RSM come a bit closer to experiment.

No model correctly capture the flow separation around the front bumper lip, maybe missing refinement here.

DDES correctly captures the massive separation here.





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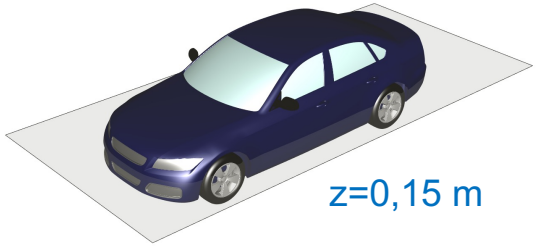
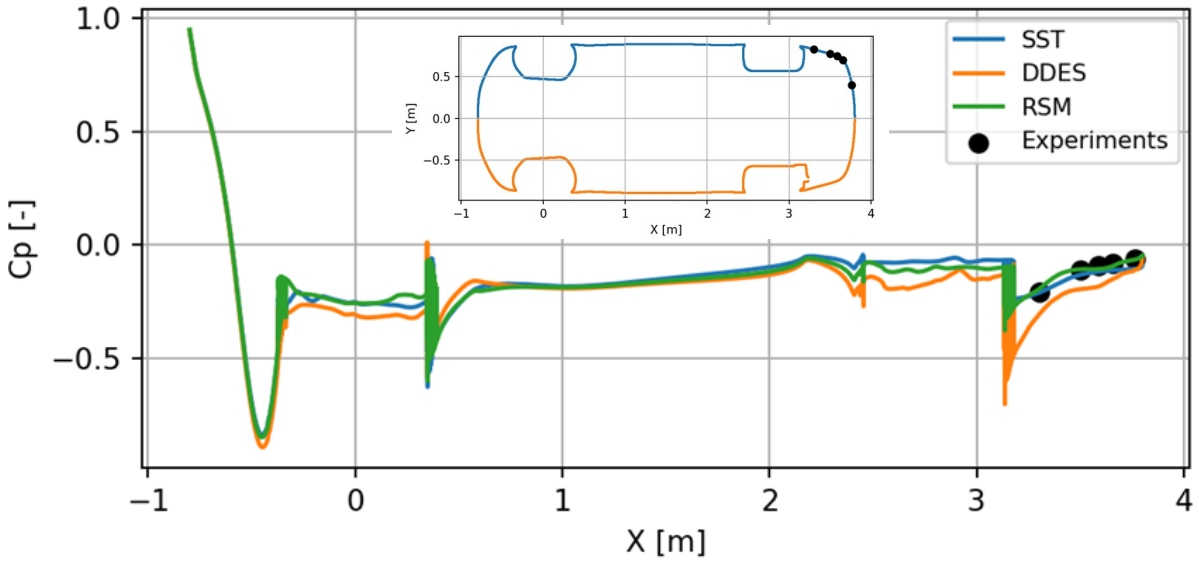
Case 2: DrivAer notchback without wheel deflector

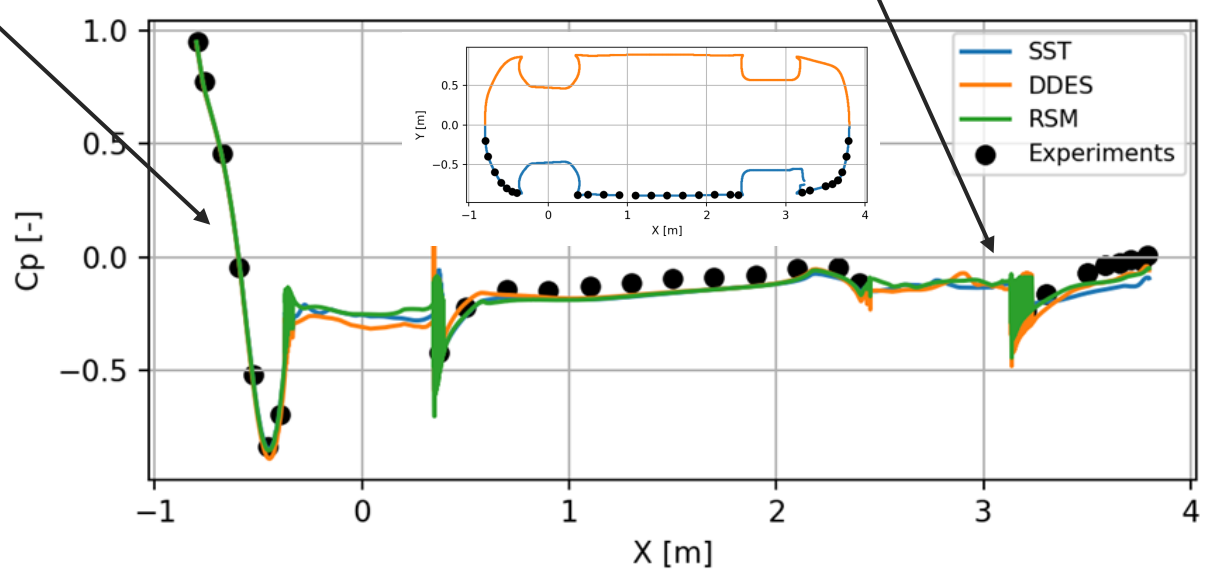
Pressure coefficient Cp at z=0.15 m



All models correctly predict the corner flow of the front bumper

RSM better predicts the corner flow of the rear bumper on both sides





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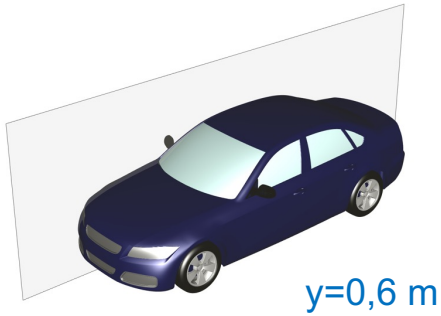
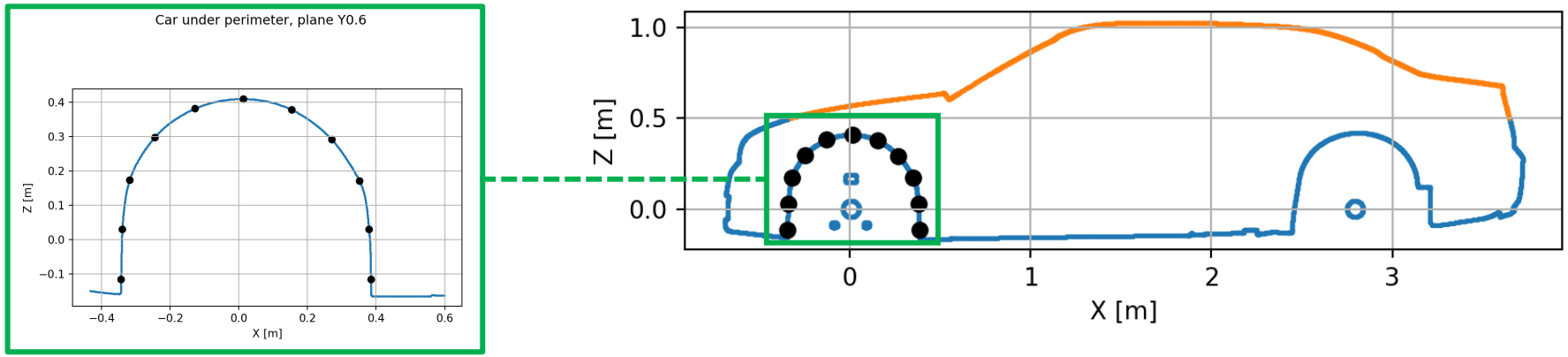
Case 2: DrivAer notchback with/out wheel deflector

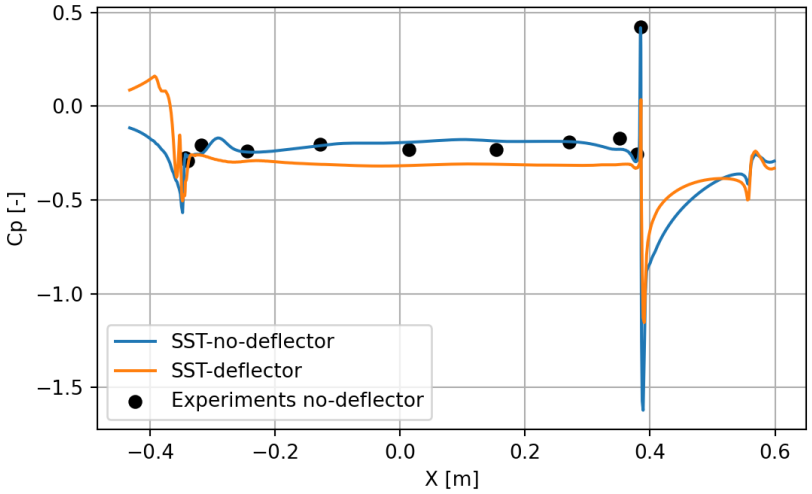
Pressure coefficient Cp at y=0.6 m



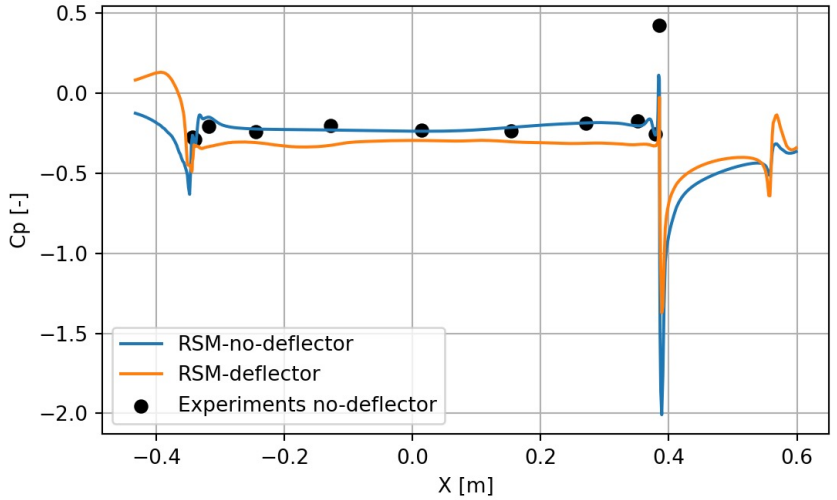
y=0,6 m



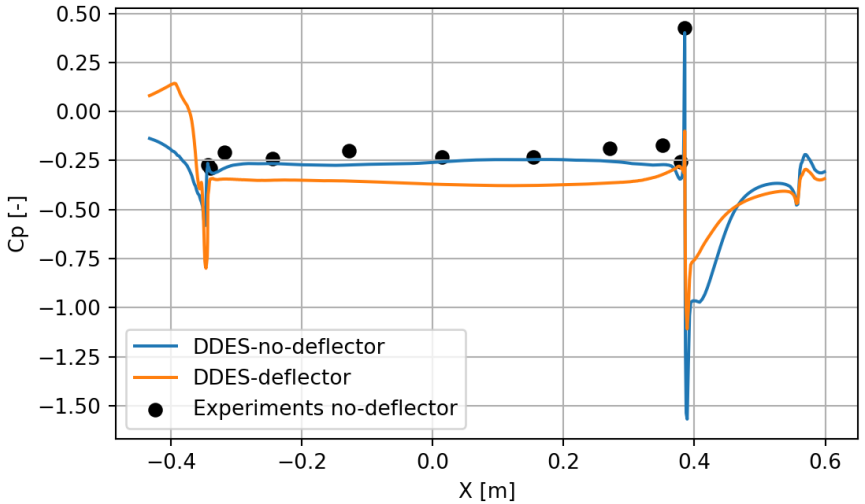
RANS SST



RSM



DDES-SST



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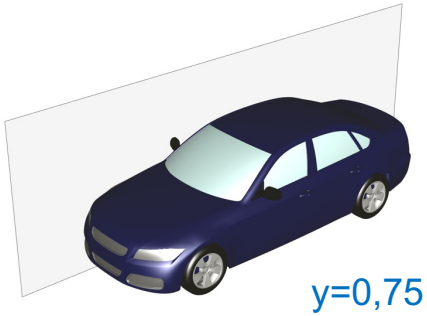
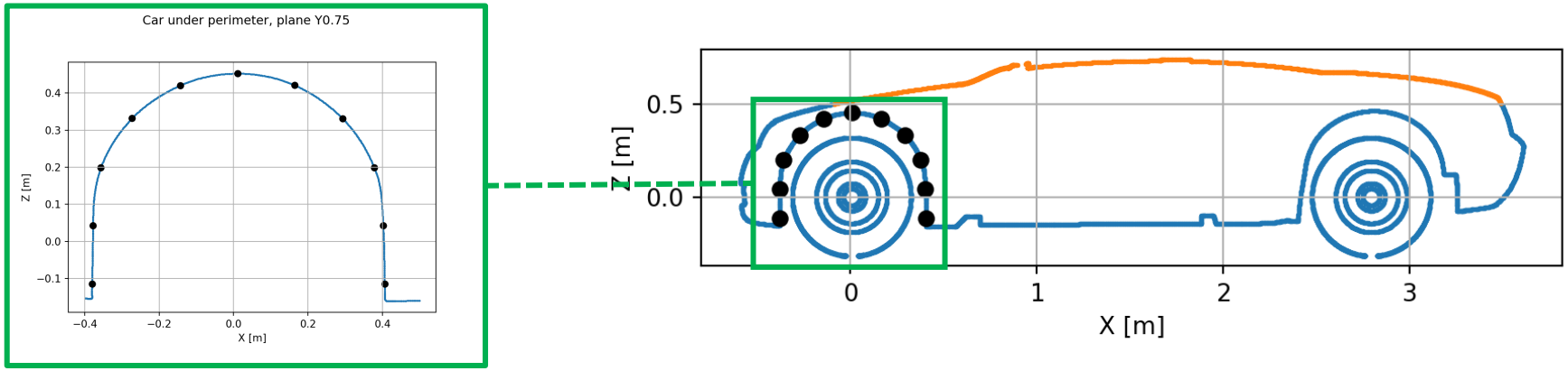
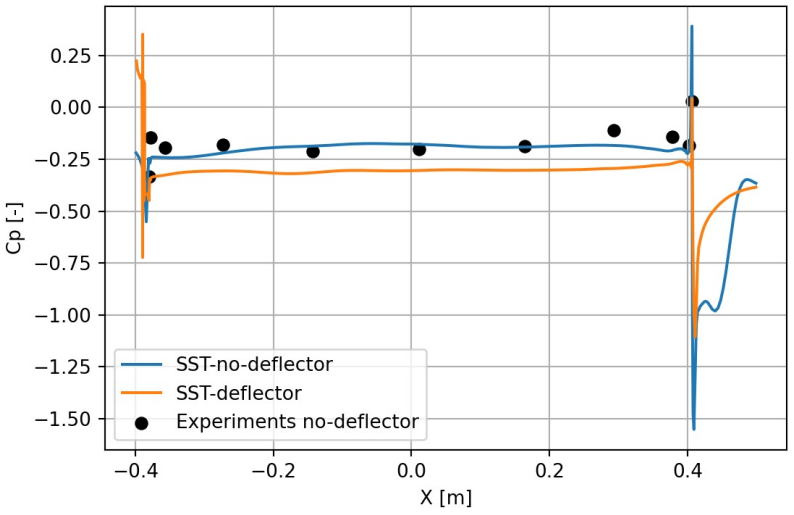
Case 2: DrivAer notchback with/out wheel deflector

Pressure coefficient Cp at y=0.75 m

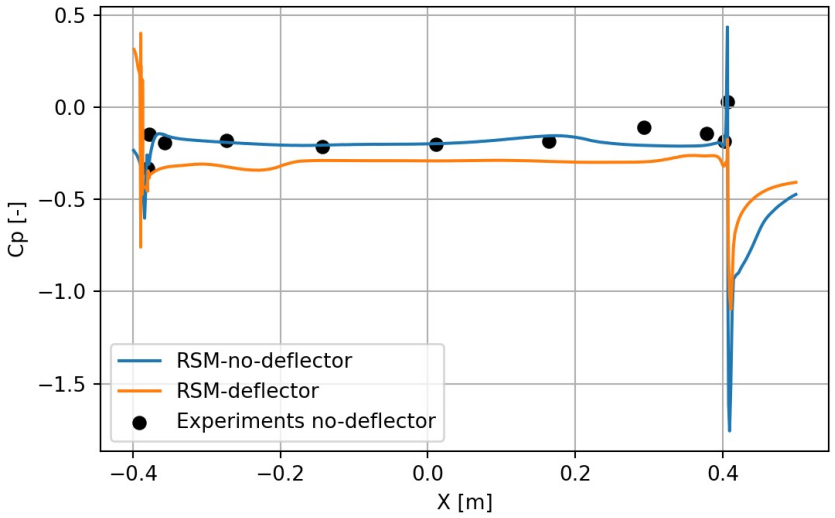




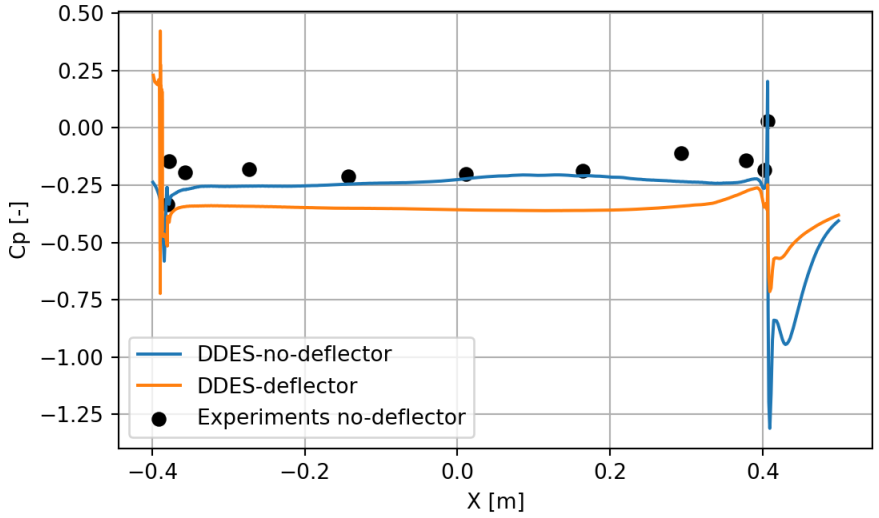
RANS SST



RSM



DDES-SST



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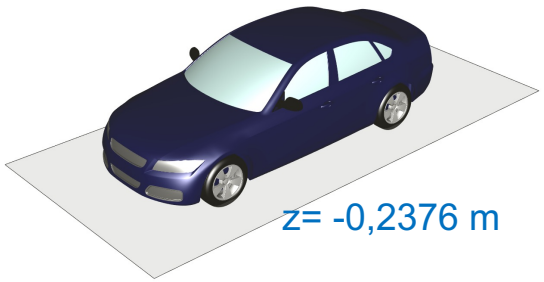
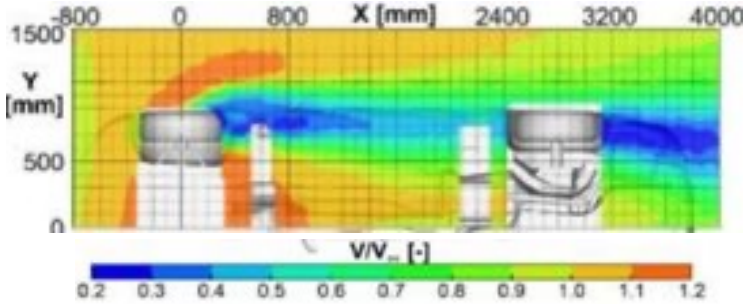
Case 2: DrivAer notchback with/out wheel deflector

Normalized velocity magnitude V/V_{inf} at z=-0.2376 m

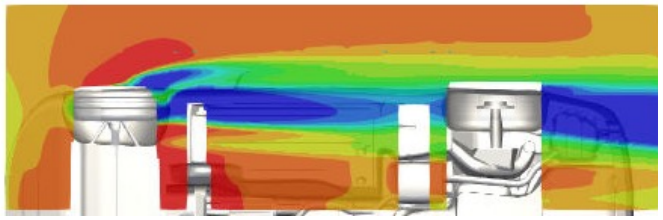


Exp (Hupertz et al. 2021) nD

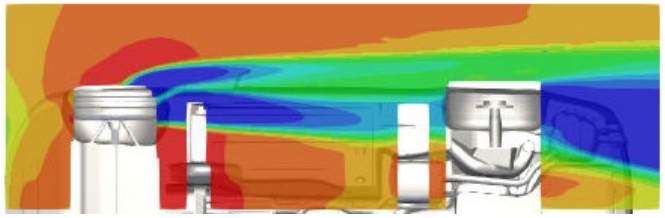


Front wheel wake is deflected outboard, generating a more energetic underbody flow.

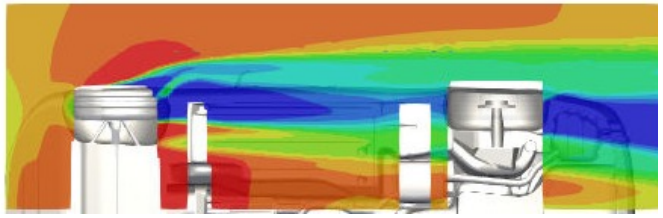
RANS – SST (nD)



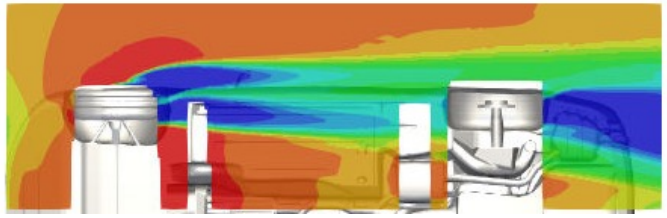
RANS – SST (wD)



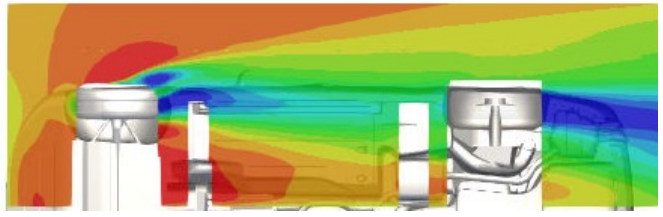
RANS – RSM (nD)



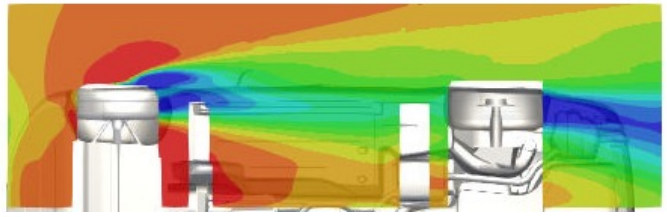
RANS – RSM (wD)

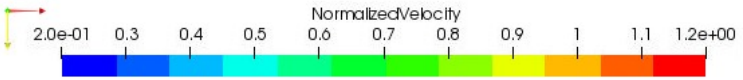


DDES – SST (nD)



DDES – SST (wD)





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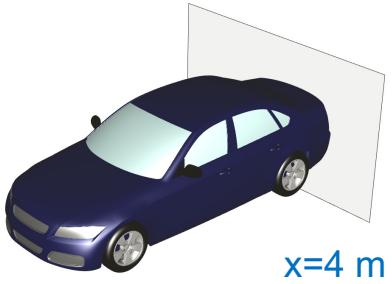
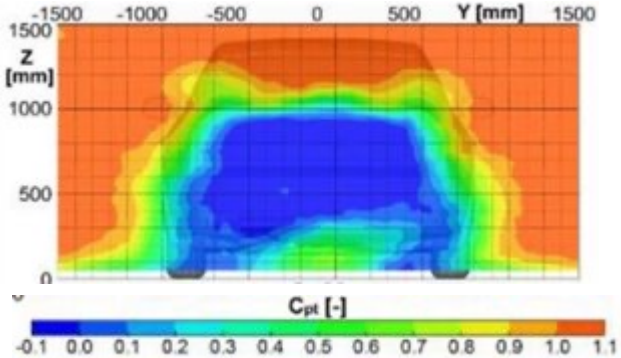
Case 2: DrivAer notchback with/out wheel deflector

Total pressure coefficient C_{pt} in the wake at x=4 m

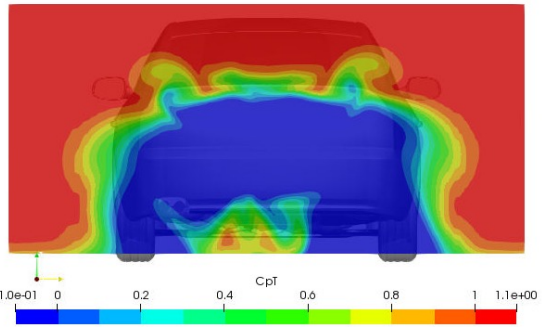


RSM offers a good intermediary, bringing steady-state results closer to DDES accuracy.

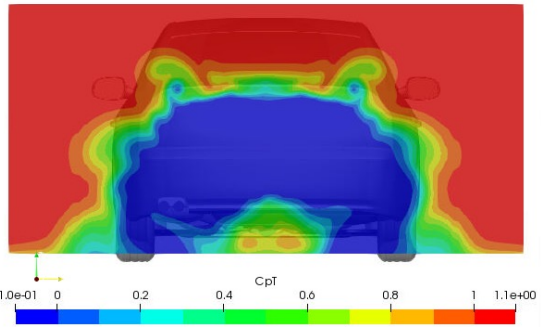
Exp (Hupertz et al. 2021) nD



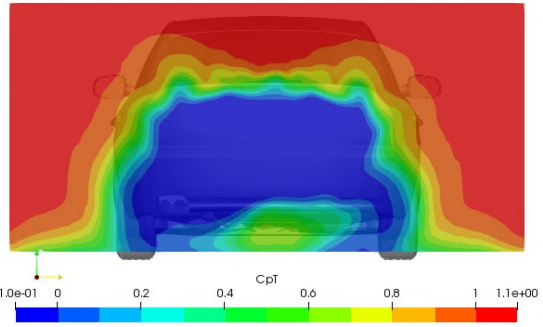
RANS – SST (nD)



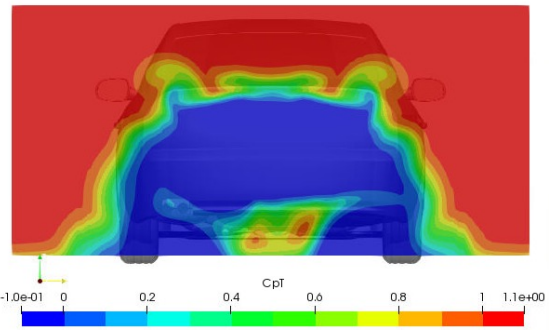
RANS – RSM (nD)



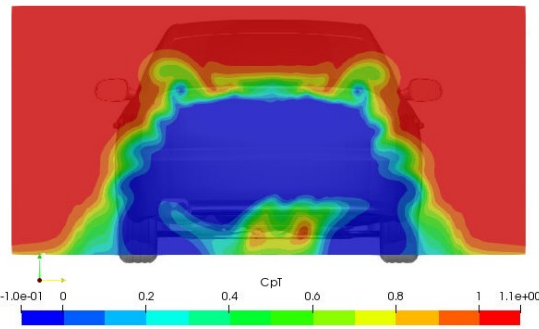
DDES – SST (nD)



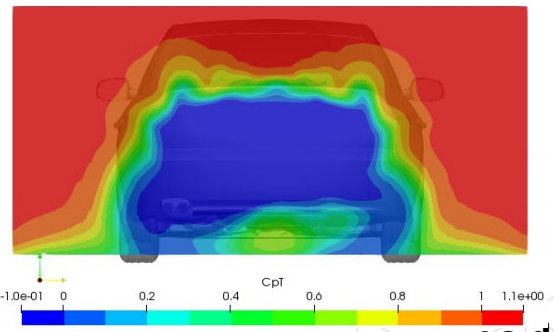
RANS – SST (wD)



RANS – RSM (wD)



DDES – SST (wD)



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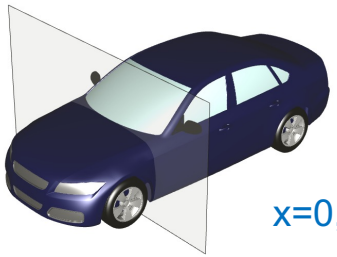
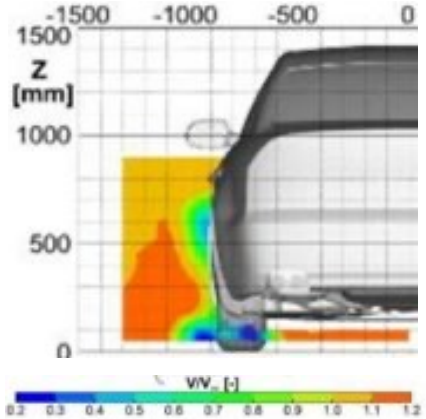
Case 2: DrivAer notchback with/out wheel deflector

Normalized velocity magnitude V/V_{inf} at x=0.4 m



Exp (Hupertz et al. 2021) nD



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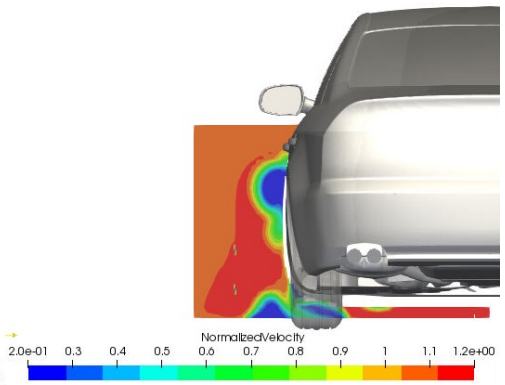
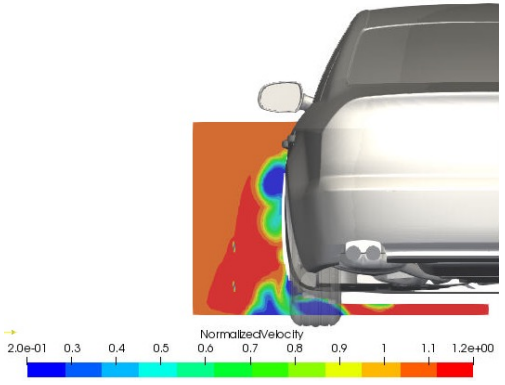
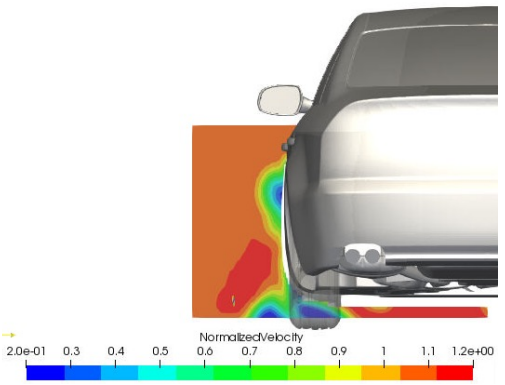


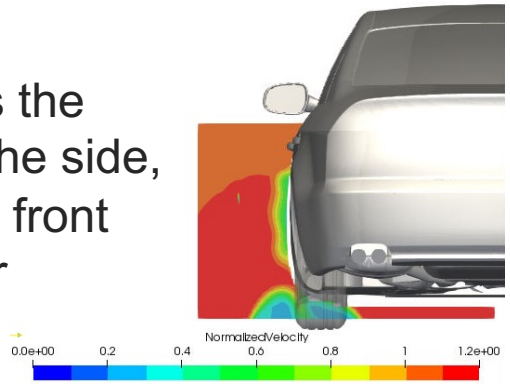
RANS – RSM (nD)



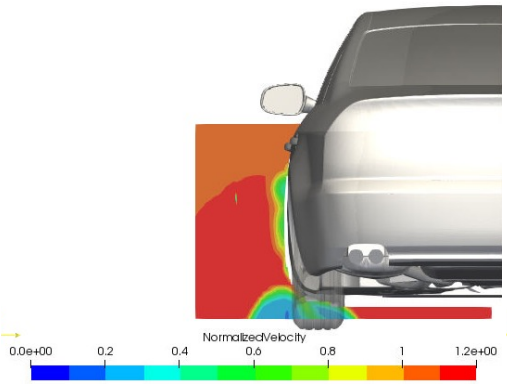
DDES – SST (nD)



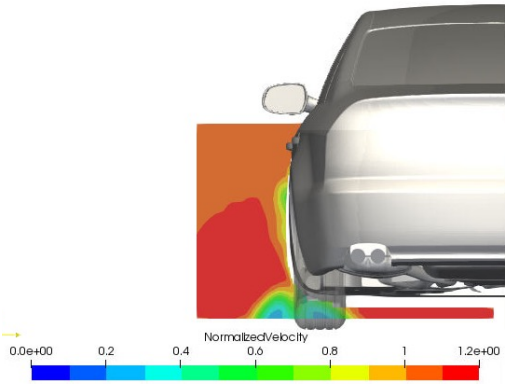
RANS – SST (wD)



RANS – RSM (wD)



DDES – SST (wD)



Wheel deflector pushes the flow downward and to the side, reducing losses around front wheel and front bumper

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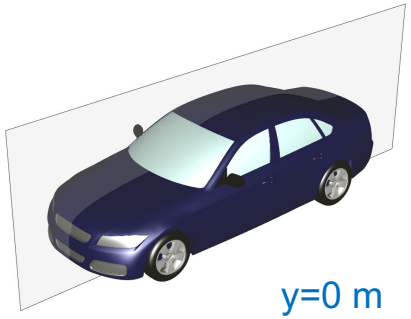
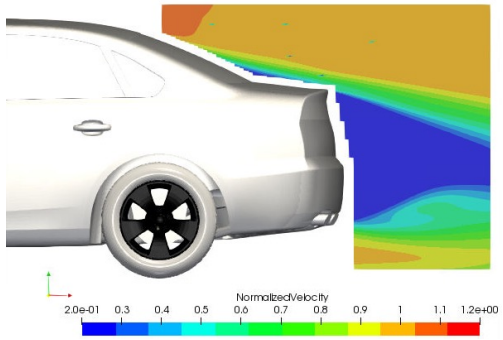
Case 2: DrivAer notchback with/out wheel deflector

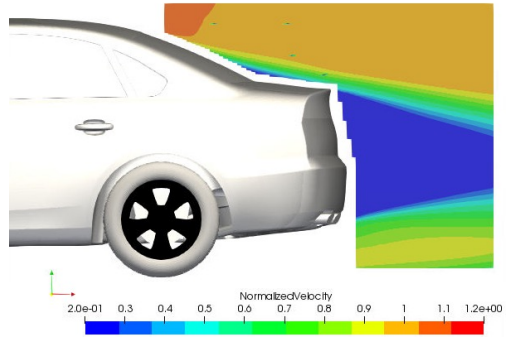
Normalized velocity magnitude V/V_{inf} at y=0 m



y=0 m

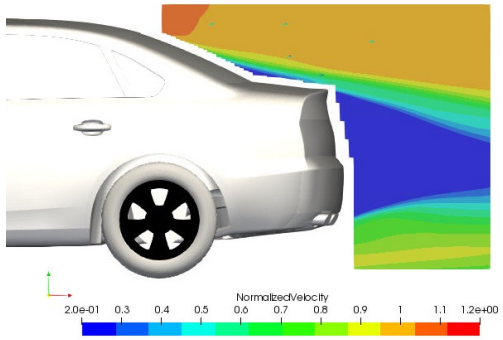
RANS – SST (nD)

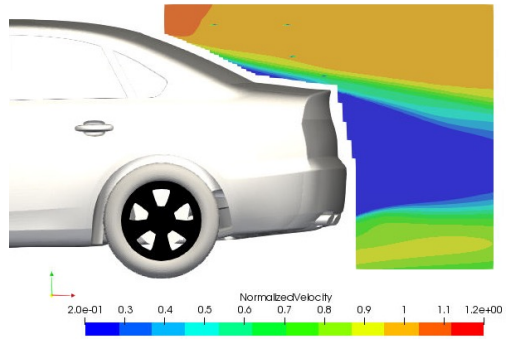




RANS – SST (wD)

RANS – RSM (nD)

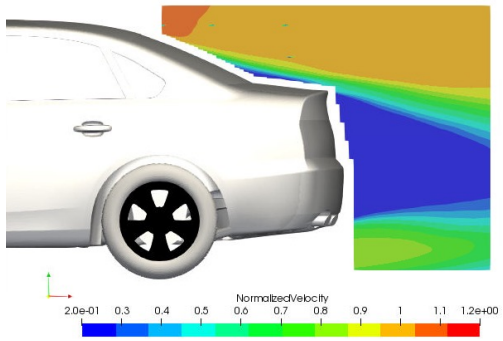


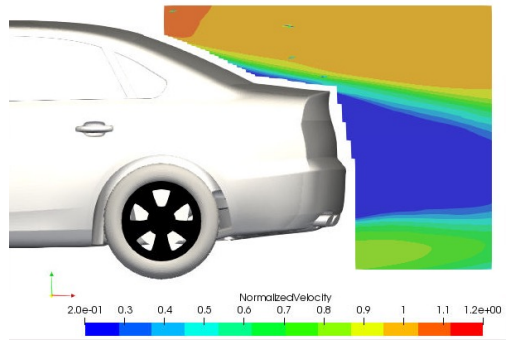


RANS – RSM (wD)

RSM and DDES predict significantly less updraft from the underbody flow than SST.

DDES – SST (nD)





DDES – SST (wD)

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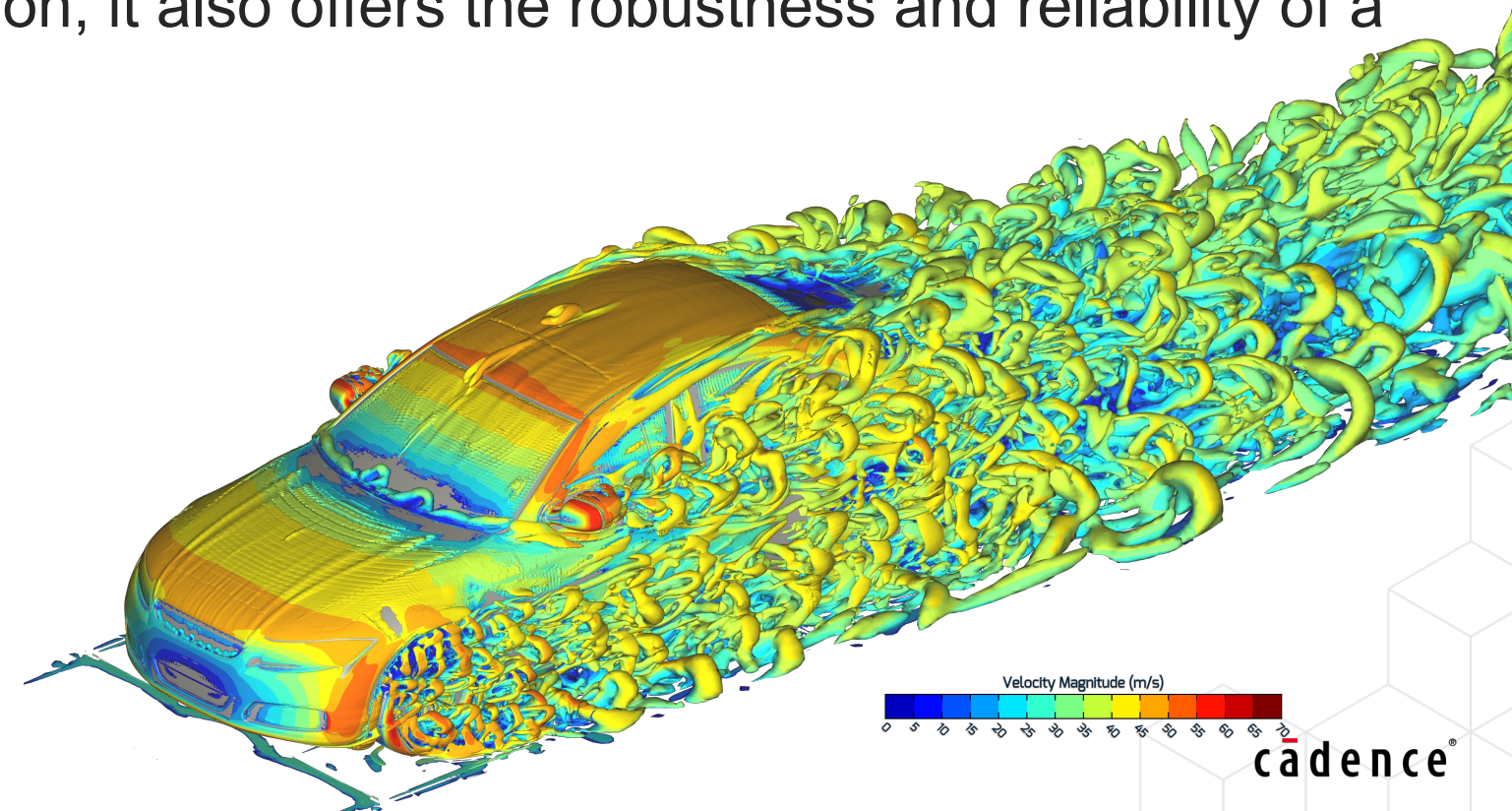
Conclusions

- Windsor body predictions underpredicted drag, possible links with pressure gradient correction in the wall models
- DrivAer results showed good behavior of the RSM model, offering a good tradeoff between the accuracy of DDES and the speed of RANS.
- In a fully coupled implementation, it also offers the robustness and reliability of a fully implicit solver.



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