

KREUZINGER MANHART TURBULENZ GMBH

Effect of LES model on the onset of separation

AutoCFD5 2026, Bologna

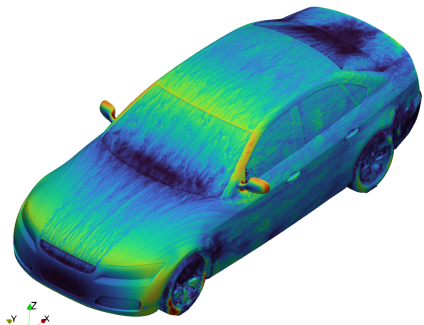
J. Kreuzinger, I. Kursakov, F. Schwertfirm

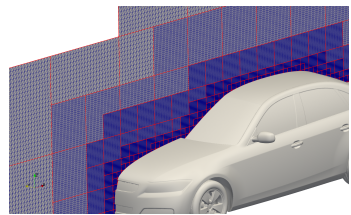
Contents

- Method MGLET Recap
  - FV, IB, Cartesian-octree
- Inspection of DrivAer results / Recap 2024
- Separation bubble
  - Test case
  - Analysis of coarse grid results
  - A-priori / a-posteriori test
  - Different LES models
- DrivAer Case 2b
  - Different LES models
- Conclusions and Outlook
- Appendix
  - Case 2a vs. Case 2b

Method MGLET Recap

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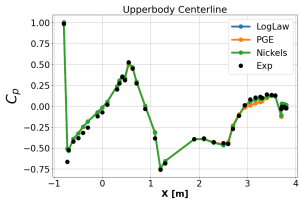
- Present Results with $\Delta x = 2mm$
- Boundary layer should be turbulent ($x_{crit} = 12.5cm$)

- 2nd Order FV, staggered arrangement, energy conserving discretization
- Block structured hierarchical Cartesian grids, cut cell immersed boundary, cubic cells
- WMLES prerequisite as grid adaption to boundary layers not possible
- Advantages: direct application of wall shear stress, no damping of turbulence due to aspect ratios

Inspection of DrivAer results / Recap 2024

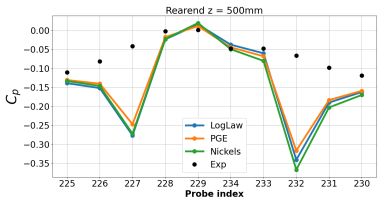
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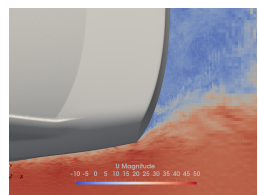
Overall good:



- Good correlation to measurement
- Including pressure gradient in the wall model shows only weak effects on time averaged forces, indicating equilibrium wall functions are sufficient.

Bad details:





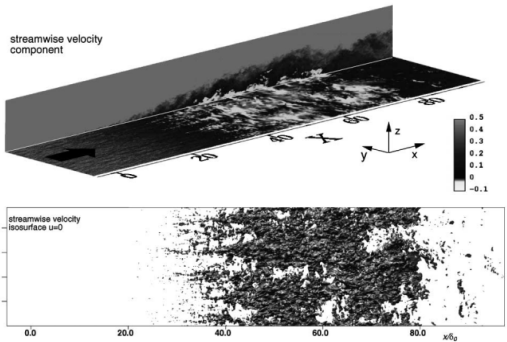
- Rear end (shown) and side window (not shown)
- Too late or missing separation

Separation bubble

Test case

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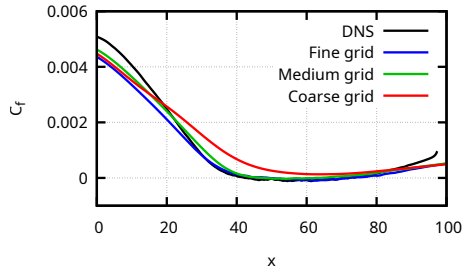
Reference



- DNS of turbulent boundary layer
- Separation due to the presence of a weak pressure gradient
- Moderate Reynolds number: (Re_θ=870)

  Manhart 2002[2]

LES grid study

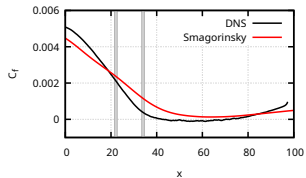


$\delta_{0.99,(x=0)} = 1.5$	Δx, Δy, Δz_{min}	No. cells
DNS	0.0354, 0.0218, 0.0048	130 mio.
LES Fine	0.0625	28 mio.
LES Medium	0.1250	7 mio.
LES Coarse	0.2500	3 mio.

- Coarse grid: no separation

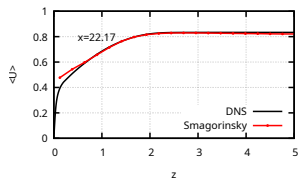
Separation bubble

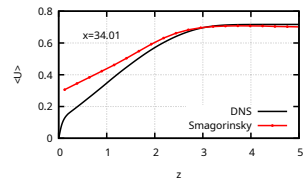
Analysis of coarse grid results

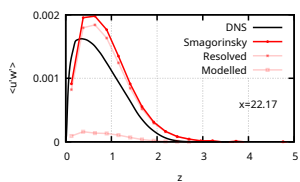


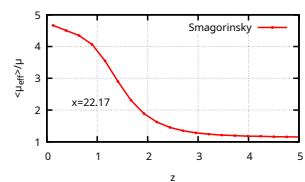
1. C_f is too high.
2. ... because U close to the wall is too high ...
   (Wall models can not help.)
3. ... because momentum transport towards the wall is too high ...
4. *Hypothesis:*
   ... because turbulence is too high, since turbulent viscosity is too low.

$\Rightarrow$ *Problem: LES model*









Separation bubble

A-priori / a-posteriori test

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A-priori

"In LES, a primary function of the residual-stress model is to remove energy from the resolved scales at the appropriate rate, this being $P_r = \tau_{ij}^r \overline{S_{ij}}$*"* (Pope[1])

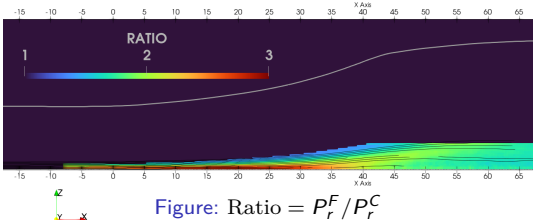
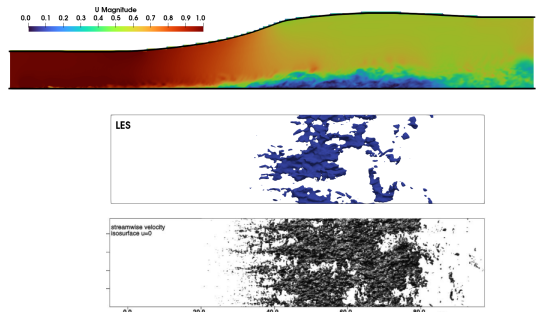


Figure: $\text{Ratio} = P_r^F / P_r^C$

- Fine grid LES P_r^F (considered as ground truth) compared to P_r^C computed from filtered velocity field. $\Delta x^C = 4\Delta x^F$
- Ratio > 1 throughout the BL
- Convective / non equilibrium effect

A-posteriori

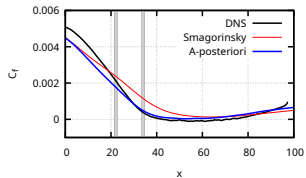
- 2D-field of $\sqrt{\text{Ratio}}$ used to scale Model constant since $P_r \sim C_m^2$



- Separation also using coarse grid

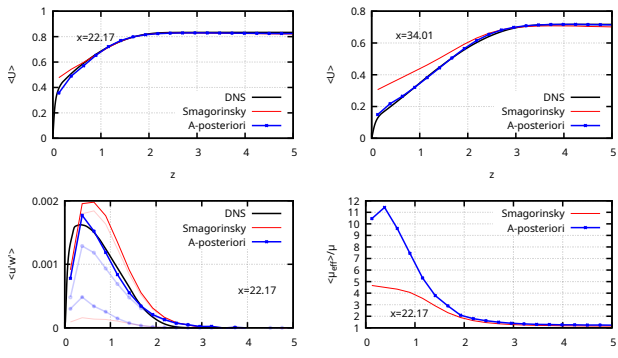
Separation bubble

A-posteriori test



1. C_f is ok ...
2. ... because U profile fits ...
3. ... because momentum transport towards the wall fits ...
4. *... because turbulent viscosity dissipates sufficient kinetic energy.*

⇒ **LES model can be the solution. Eddy viscosity seems to work.** *You just have to run a four times finer resolved simulation in advance . . .*



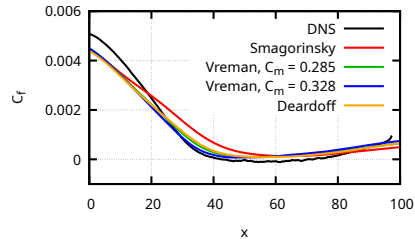
Separation bubble

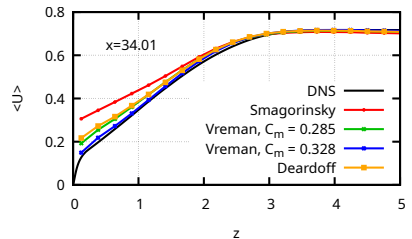
Different LES models

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- Coarse grid
- LES models:
  - Smagorinsky, our baseline
  - Vreman, our more modern choice
  - Vreman with increased constant, motivated by a-priori analysis
  - Deardorff[3], a non equilibrium model based on transport equation for subgrid scale energy

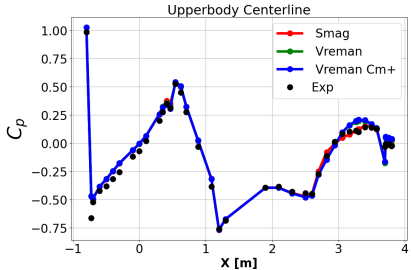
- Vreman and Deardorff perform similar
- Best result: Vreman increased constant
  At least until the onset of separation.

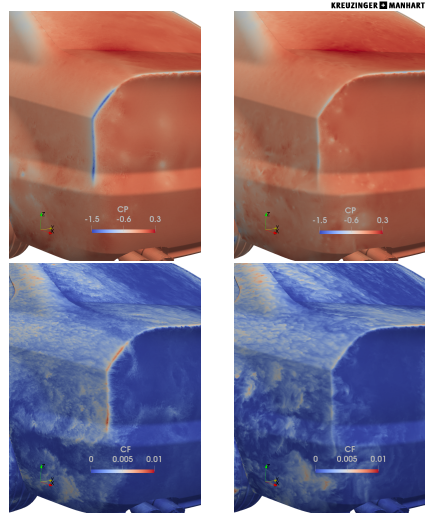




DrivAer Case 2b

Different LES models





Smagorinsky **Vreman** C_m+

Conclusions and Outlook

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- We have now a relevant and compact test case for LES development.
- Eddy viscosity models seem to be sufficient.
- LES model matters, but just tuning existing ones seems not sufficient.
- We continue researching on LES modeling.

Appendix

Case 2a vs. Case 2b

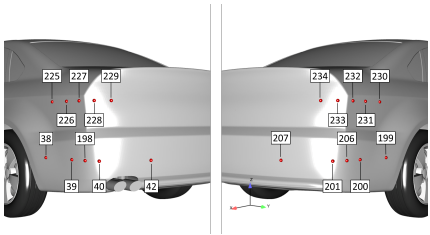


Figure: Probe positions

- Cases 2a and 2b differ only by the front wheel air deflector.
- This difference is not expected to change substantially the boundary layer at the upper part of the rear end.
- For Case 2a the measurement shows a low pressure at the right rear edge, comparable to the simulation data.
- The probe at the rear edge seems to be very sensitive.

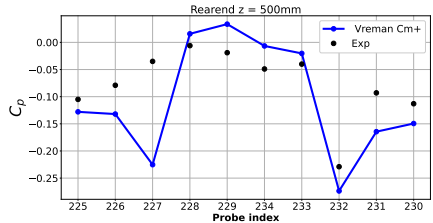


Figure: Case 2a

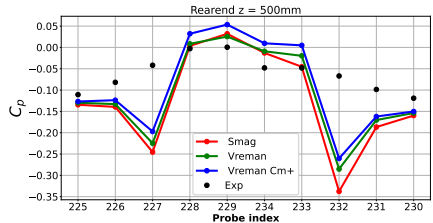


Figure: Case 2b

Literature

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