# Quantifying Noise Factors: Sampling Length and Cross-Solver Analysis

AutoCFD5 | 8-9 October 2026 | Skoda Auto | Aerodynamics | V. Skarolek, O. Čavoj, P. Viochna, M. Ševčík

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**Skoda CFD methodology team**
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**Scope**
ACFD4 - results from 2 CFD codes, sensitivity to different noise factors
ACFD5 - 3 CFD codes, various models, data recorded at up to 1 kHz, extensive dataset

No differentiated effect of noise factors was observed in our ACFD4 work →
**ACFD5**: **Replicates are generated solely by perturbing dynamic viscosity** in the 6th significant digit ($\Delta\mu/\mu \sim 10^{-5}$)
$\mu$ = 1.81380E-05, 1.81381E-05, 1.81382E-05, … Pa·s

Perturbation considered physically negligible. Straightforward to set up consistently across different CFD solvers.

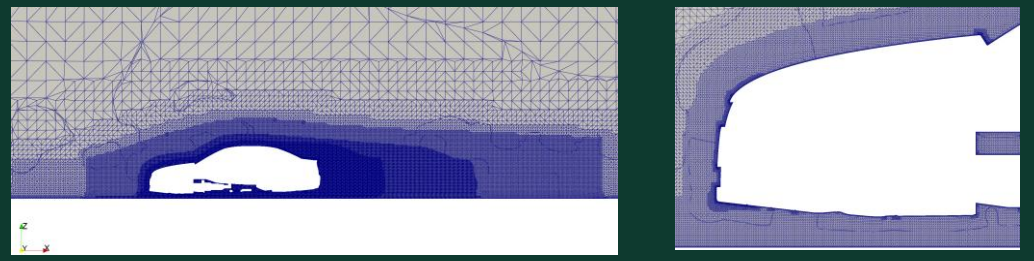
# STUDY SETUP

| SW | iconCFD 5.0.5 | StarCCM+ 21.02.007 | Volcano ScaLES 2026.07 |
|---|---|---|---|
| SW vendor | **ICON** | **Siemens** | **Volcano Platforms** |
| Mesh | ANSA (ACFD5) | ANSA (ACFD5) | STL (ACFD5) |
| Mesh type | Medium (123 M) | Medium (123 M) | Custom (168 M) |
| Solver type | FV | FV | H-O FD |
| Compressibility | Incompressible | Incompressible | Compressible |
| Hybrid model | **IDDES / DDES / ZDES*** | **IDDES / DDES / WMLES** | **WMLES** |
| Model | SA92 | SA92 / WALE | Dyn. Smag. |
| HW | CPU AMD EPYC 9654 | CPU AMD EPYC 9654 | GPU Nvidia L40S |
| HW count | 2128 cores | 3040 cores | 4 GPUs |
| Time step [s] | 2.5e-4 | 2.5e-4 | ~1e-6 |

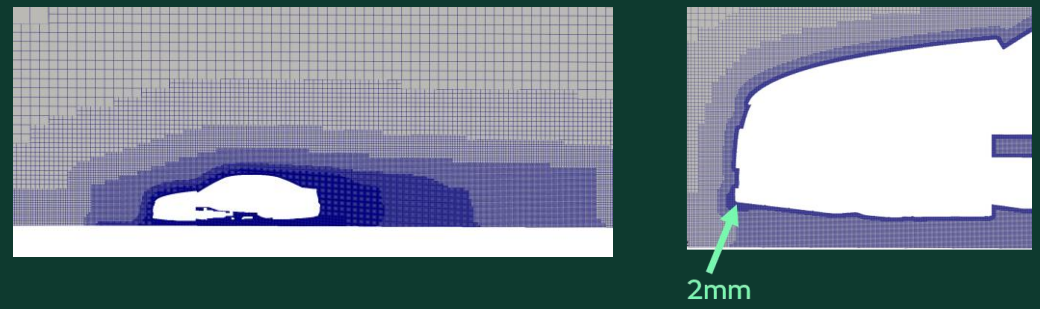
*ZDES: Constant-thickness shielding function (0.04 m)

| SW | Simulation initialization |
|---|---|
| iconCFD | RANS initialization, then 2.35 s of DES with a large dt, the first 2 s of the final time step run are discarded. |
| StarCCM+ | DES initialization, first 400 s with ramp-down from a large dt, the first 2 s of the final time step run are discarded. |
| Volcano ScaLES | Freestream initialization with zero velocity near the car (within 0.5 m), the first 2 s of the final time step run are discarded. |

**ACFD5 committee mesh (medium)**



**Custom mesh for Volcano ScaLES**



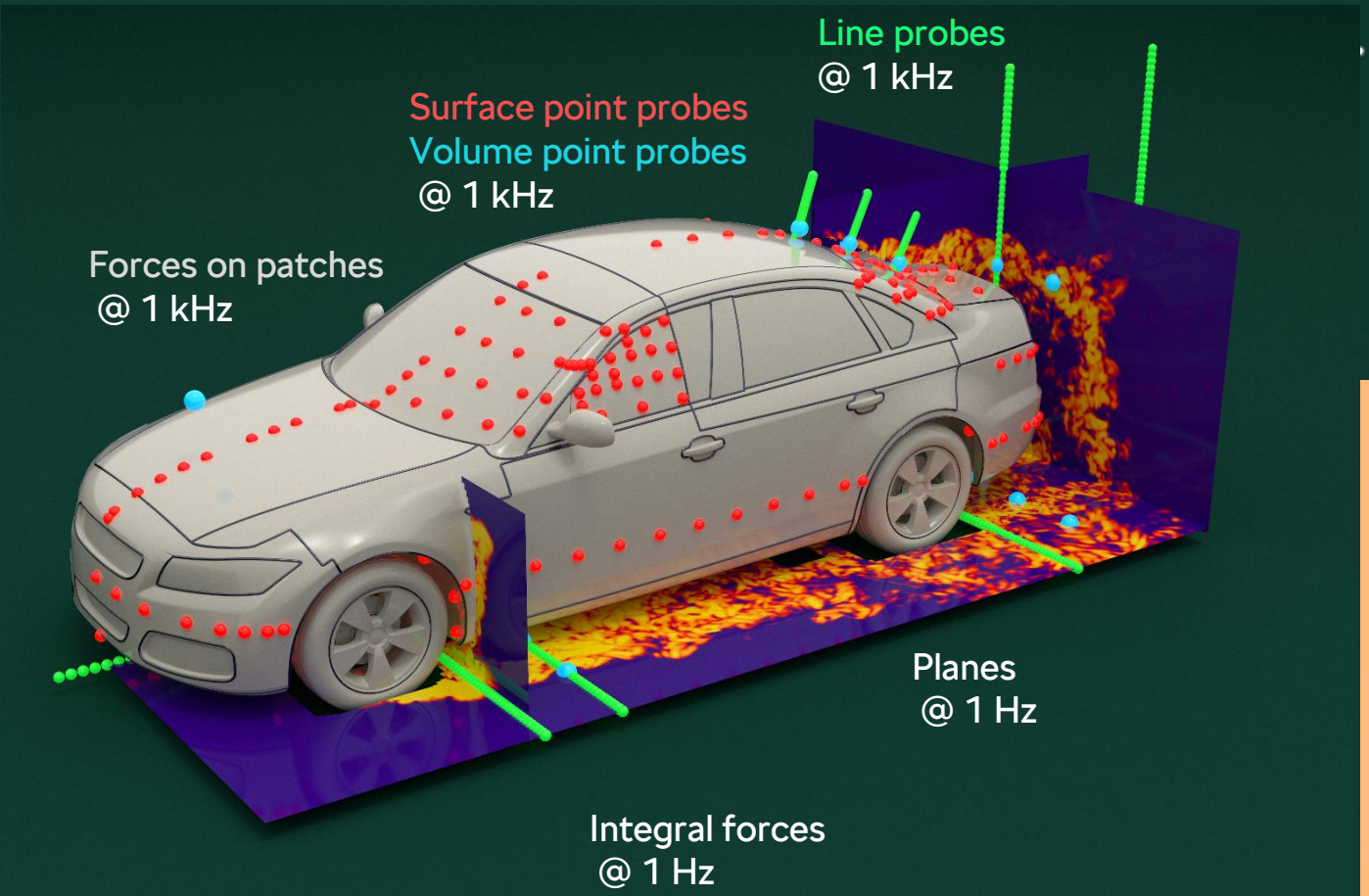

An effort to standardize the settings for the noise factors study.

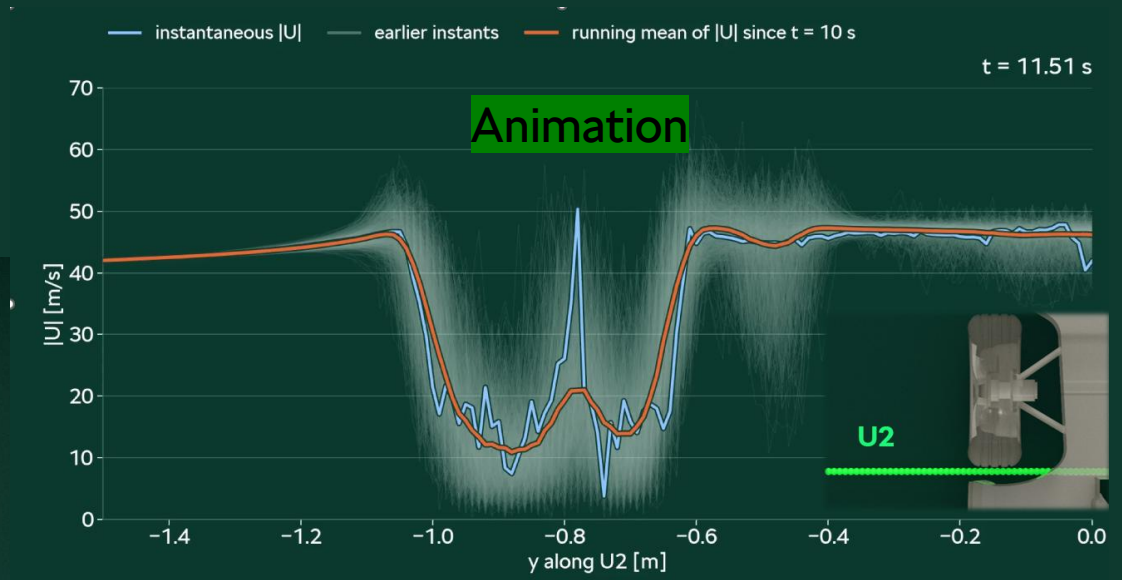
The setup aligns more closely with out-of-the-box settings in terms of accuracy.

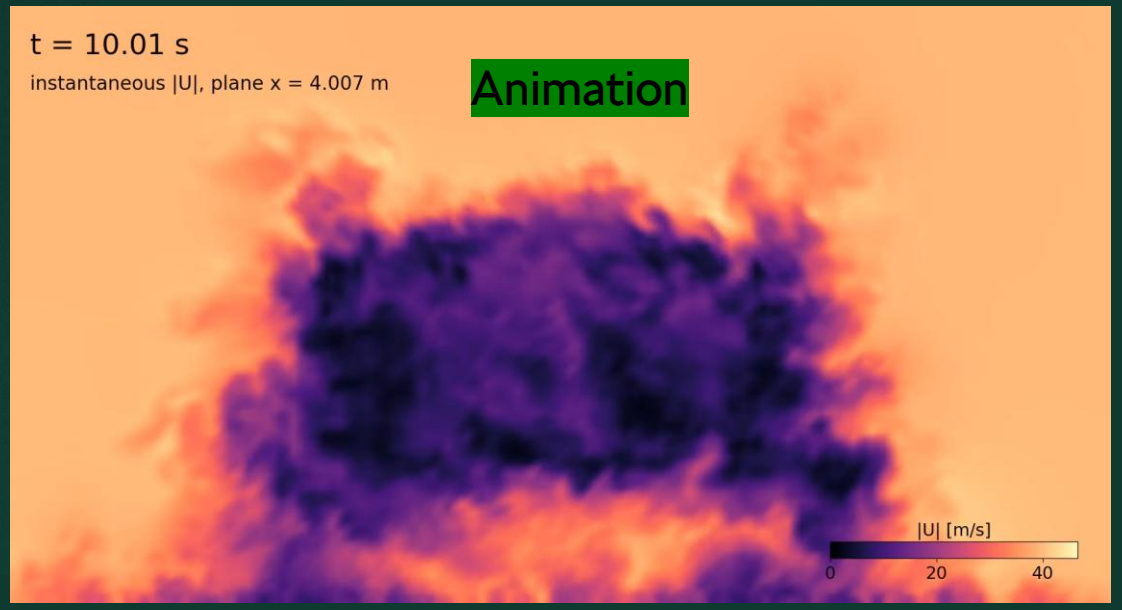


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## Data export


Line probes
@ 1 kHz
Surface point probes
Volume point probes
@ 1 kHz
Forces on patches
@ 1 kHz
Planes
@ 1 Hz
Integral forces
@ 1 Hz


instantaneous |U|
earlier instants
running mean of |U| since t = 10 s
t = 11.51 s
Animation
|U| [m/s]
y along U2 [m]
U2


t = 10.01 s
instantaneous |U|, plane x = 4.007 m
Animation
|U| [m/s]

# RESULTS OVERVIEW

| Model | Code | Long run | Replicates | Long run Mean Cd | Ensemble Mean Cd N=25 | Sample std. dev. of mean Cd across repeats | Sample std. dev. of mean Clr across repeats | \|Max-Min\| of replicate mean Cd | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | T=end | T= 10 s | T=10 s | T= 10 s | **T=10 s** | T=80 s |
| **SA-DDES** | iconCFD | **1x 100 s (2x)** | 25 x 10 s | 0.28037<br>0.28032 | 0.28036 | 0.56 ct | 0.94 ct | 1.88 ct | - |
| | StarCCM+ | 1x 60 s | 25 x 10 s | 0.29863 | 0.29918 | 0.55 ct | 1.69 ct | 2.03 ct | - |
| | StarCCM+ | - | **25 x 80 s** | - | 0.29920 (T= 80 s) | 0.18 ct (T= 80 s) | 0.55 ct (T= 80 s) | - | 0.82 ct |
| **SA-IDDES** | iconCFD | 1x 30 s | 25 x 10 s | 0.27757 | 0.27759 | 0.49 ct | 1.42 ct | 2.07 ct | - |
| | StarCCM+ | 1x 60 s | 25 x 10 s | 0.29734 | 0.29738 | 0.38 ct | **1.49 ct** | 1.41 ct | - |
| **SA-ZDES** | iconCFD | 1x 30 s | 25 x 10 s | 0.27600 | 0.27595 | **0.82 ct** | 1.27 ct | **3.29 ct** | - |
| **WMLES** | StarCCM+ | 1x 60 s | 25 x 10 s | 0.27625 | 0.27592 | **0.25 ct** | **0.55 ct** | **0.96 ct** | - |
| | Volcano | 1x 30 s | 25 x 10 s | 0.27190 | 0.27206 | **0.30 ct** | **2.30 ct** | **1.12 ct** | - |

slow convergence

■ best
■ worst

StarCCM+ front patches (bumper + lower / upper grille) account for most of the difference (~20 ct)
iconCFD SA-DDES shows strong separation on the rear window / trunk

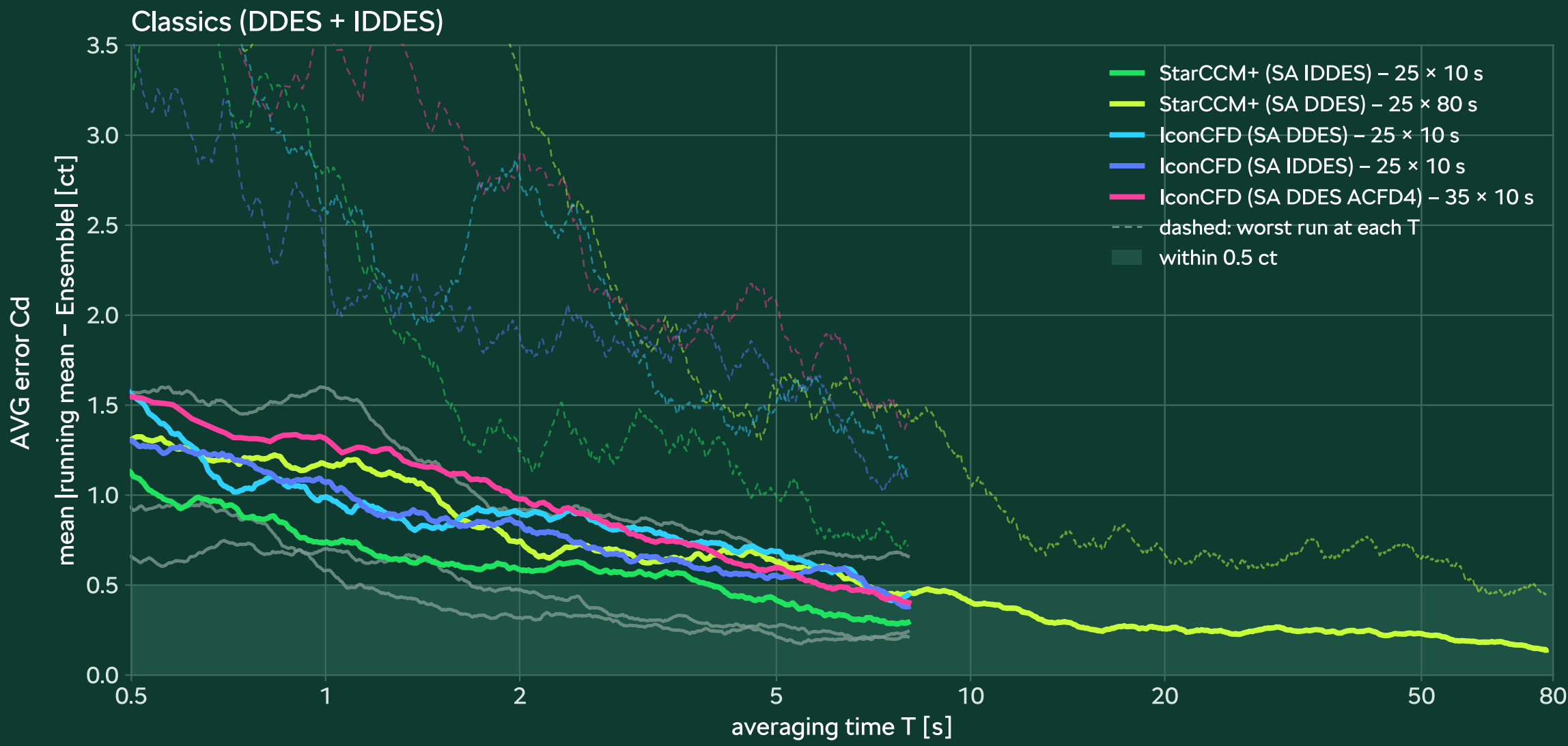
Both WMLES simulations show lower Cd scatter at T = 10 s than DES. Volcano WMLES exhibits the highest Clr scatter.

Both codes are sensitive to the hybrid RANS–LES formulation (DDES vs. IDDES).

Large code-to-code differences in flow field prediction between DES models.

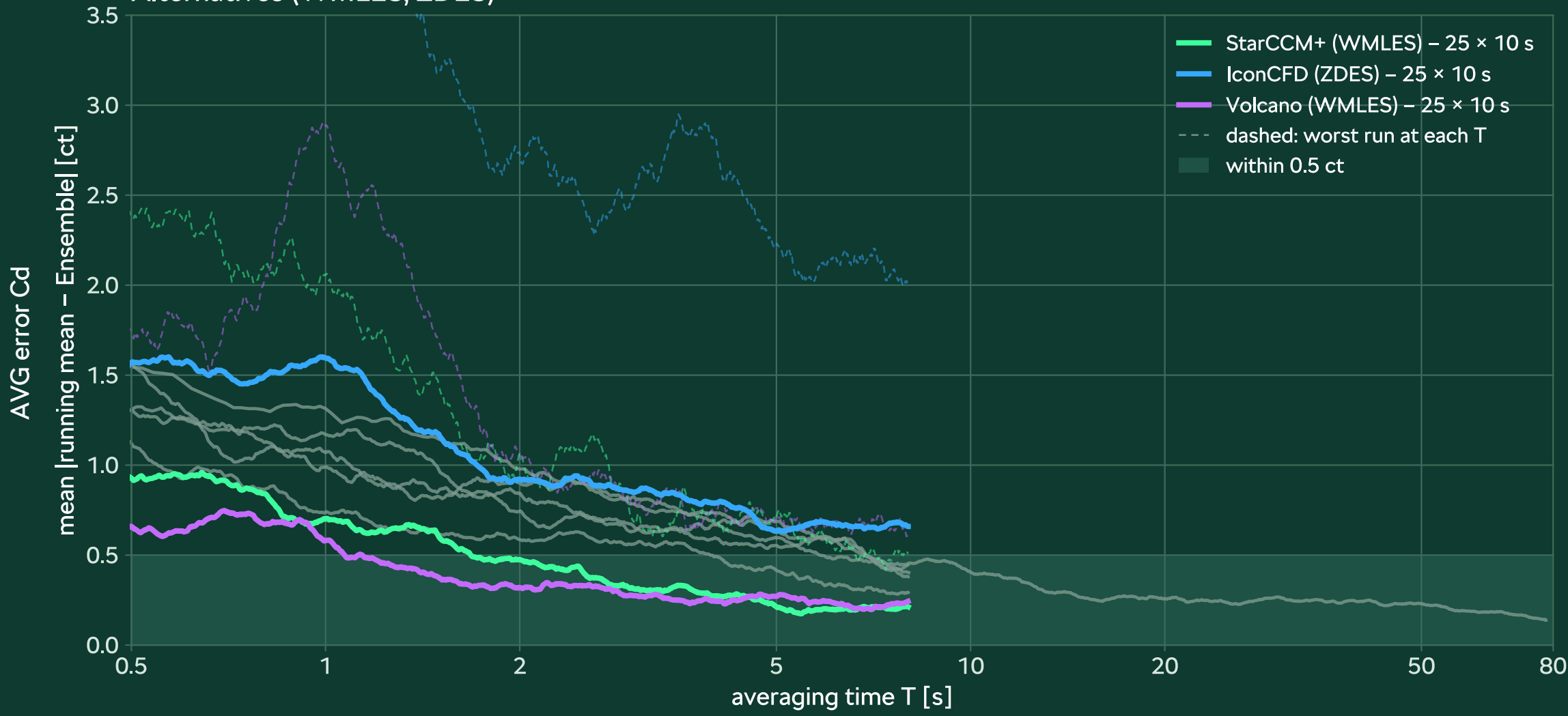


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On average, a single run is within 0.5 ct of its ensemble mean after **1–2 s of averaging with WMLES and 4–7 s with DDES/IDDES.**
With ZDES, the deviation is still 0.66 ct after 8 s of averaging.
In the same code (StarCCM+), WMLES reaches 0.5 ct 2.5–4× sooner than IDDES/DDES (1.7 s vs 4.0–6.8 s).

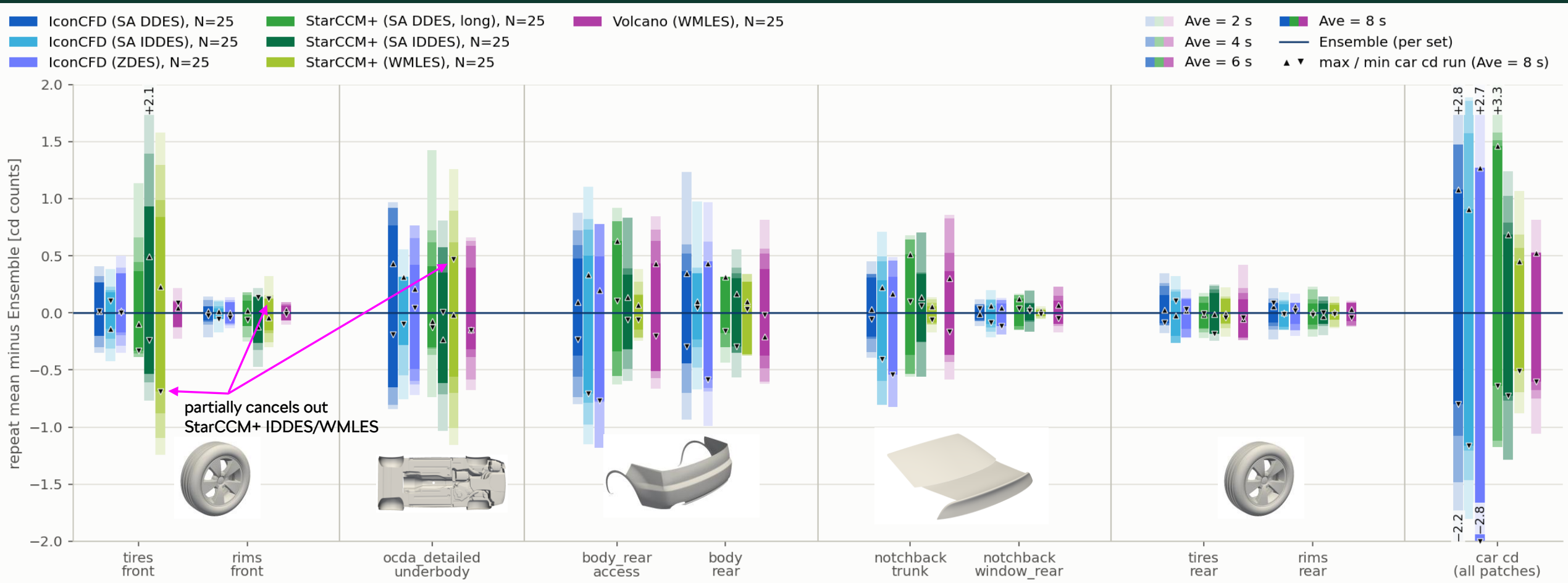
## Alternatives (WMLES, ZDES)




On average, a single run is within 0.5 ct of its ensemble mean after **1–2 s of averaging with WMLES and 4–7 s with DDES/IDDES.**
With ZDES, the deviation is still 0.66 ct after 8 s of averaging.
In the same code (StarCCM+), WMLES reaches 0.5 ct 2.5–4× sooner than IDDES/DDES (1.7 s vs 4.0–6.8 s).

# Where is the Cd scatter located on the car?

- 9 patches carry ~80–97 % of the car's Cd scatter in every code; the other 41 are quiet.
- Front tire scatter is partly cancelled by rims and underbody, e.g. StarCCM+ IDDES/WMLES.




The turbulence model, less the code, **sets the scatter size**, not its existence. Both WMLES setups show lower Cd scatter.

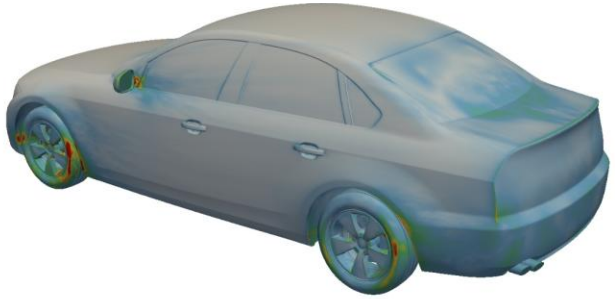
**Hypothesis for the model-dependent part**: resolved vs. modelled turbulence in the boundary layer and early shear layer.

# Where is the Cd scatter located on the car?

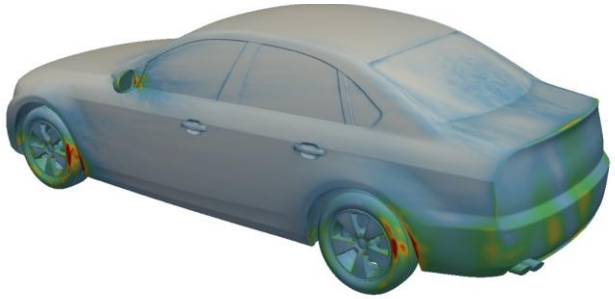
- An asymmetric pattern is visible on the vehicle rear for most variants.
- Patterns stay visible on the car even for very long runs of 50 s.
- Almost all run-to-run variation is pressure-related (see backup).

Scatter between repeats: sample standard deviation of time-averaged Cp over N runs at T= 10 s (colour scale 0–0.01)

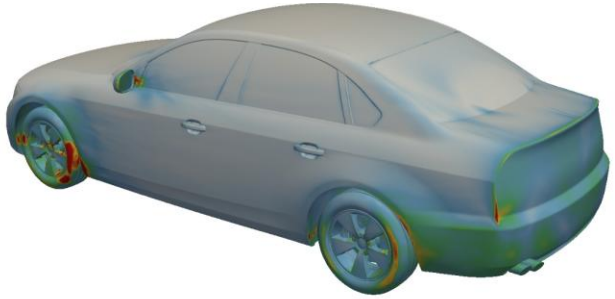
iconCFD SA-DDES
N=25 T=10s



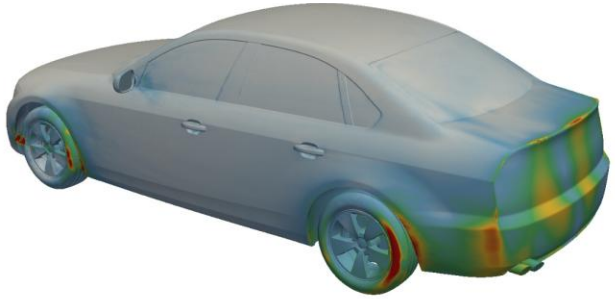
iconCFD SA-IDDES
N=25 T=10s



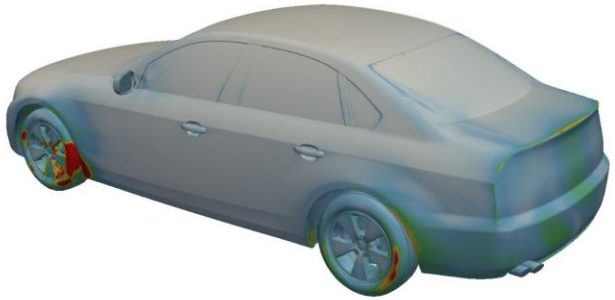
iconCFD SA-ZDES
N=25 T=10s



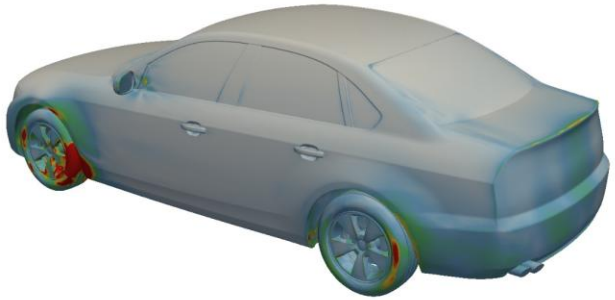
Volcano WMLES Dyn.Smag.
N=25 T=10s



StarCCM+ SA-DDES
N=25 T=10s



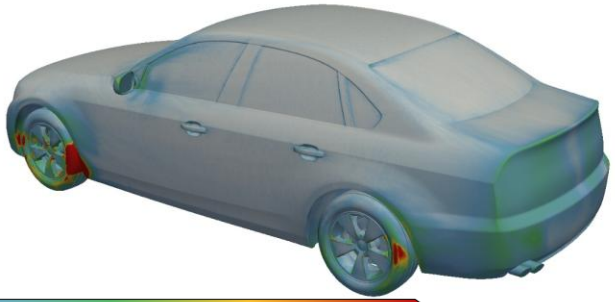
StarCCM+ SA-IDDES
N=25 T=10s

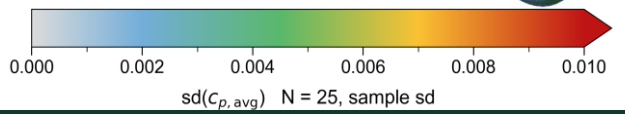


StarCCM+ SA-DDES
N=25 **T=50s**



StarCCM+ WMLES WALE
N=25 T=10s



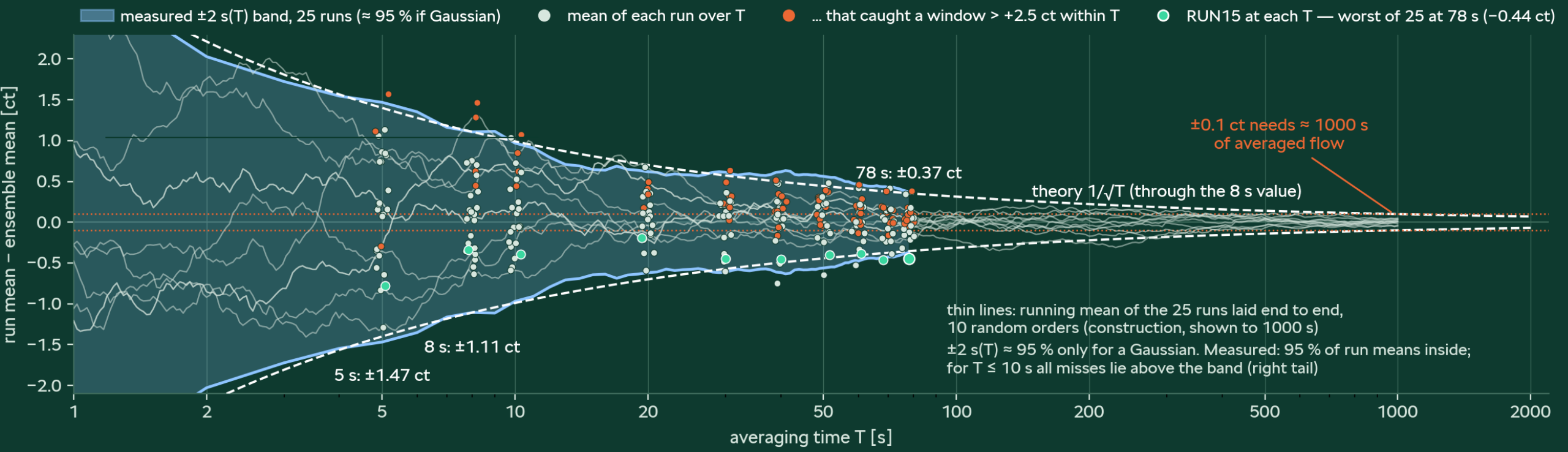



Shows where Cp varies, not how much Cd varies – anti-correlated regions cancel out.

# How long does a simulation need to be for a given precision?

**25 × 80 s StarCCM+ SA-DDES**:

- 8 s windows within one long run vary like 8 s means of separate repeats (variance ratio 0.98).
- Scatter of run means ~ 1/√T: flatter between 15 and 50 s; back on the line at 78 s.
- Precision depends on total averaged time, not on how it is split (pieces ≥ 8 s): 1 × 80 s ≈ 10 × 8 s.




Full convergence (±0.1 ct) requires ≈ 1000 s of averaging → unrealistic for industrial use.

DrivAer is less sensitive than modern hatchbacks and SUVs → production cars likely need even longer.

Shown for a model with mid-range scatter. WMLES appears to converge faster.

# How does the scatter in the flow field decrease with run length?

## 25 × 80 s StarCCM+ SA-DDES

Mean Cd max-min

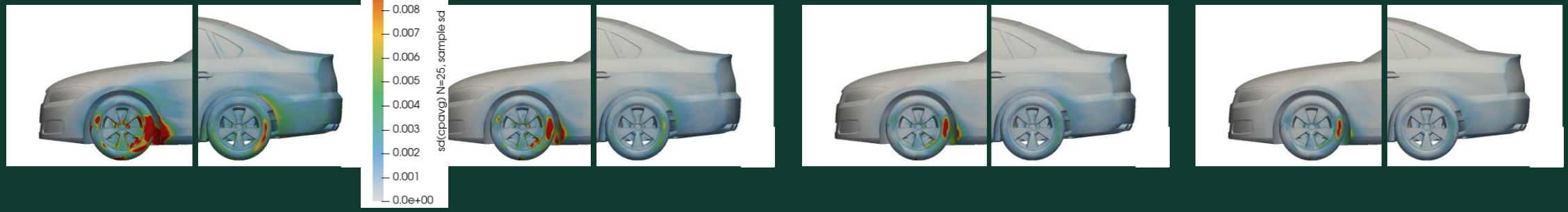
**T = 10 s**
2.1 ct

**T = 30 s**
1.16 ct

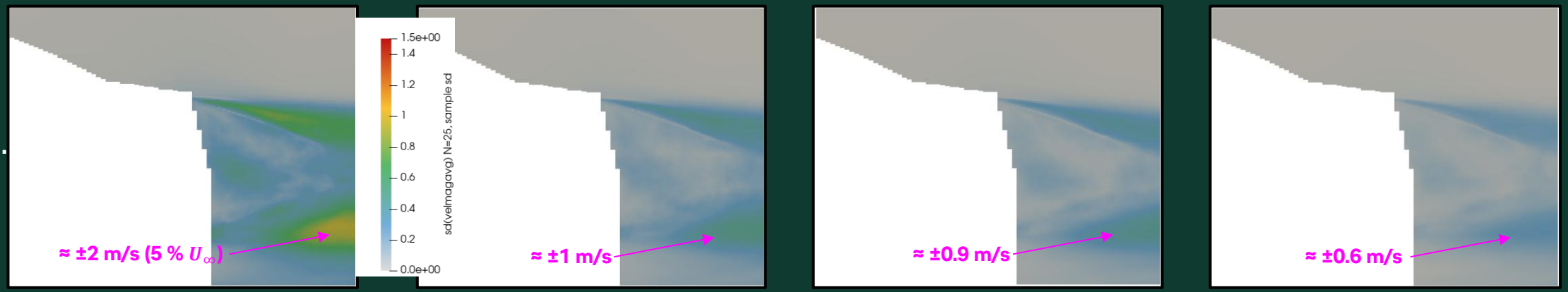
**T = 50 s**
1.14 ct

**T = 80 s**
0.82 ct

st.dev.
Mean Cp




st.dev.
Mean Vel.mag.
Y0




Scatter decreases with simulated time, but slowly: ≈ 1/√T, so halving it takes 4× longer averaging.

After 8 s of averaging, the mean wake field differs between runs by up to ±2 m/s locally.



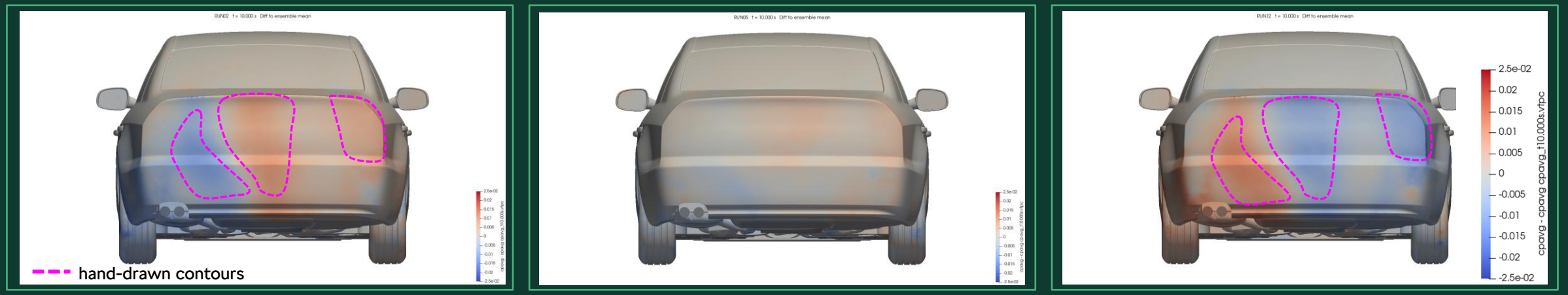
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# Can we visualize the final spread between runs on the car?

- Each run's deviation from the ensemble mean at T = 10 s after 8 s of averaging.
- Visible differences are approximately ±0.025 in Cp on the surface or range from −3 to +3 m/s in velocity in the wake.

Time-averaged Cp of each run minus the ensemble mean, both at T = 10 s (colour scale ±0.025)

**Volcano WMLES**




25 simulations



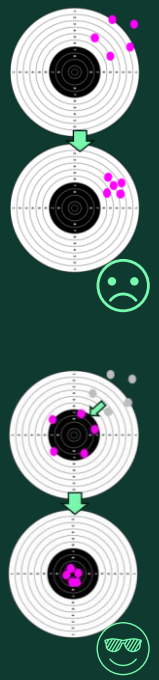
Three states are distinguishable in all codes and models.

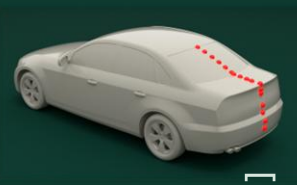


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# How does the spread look locally?

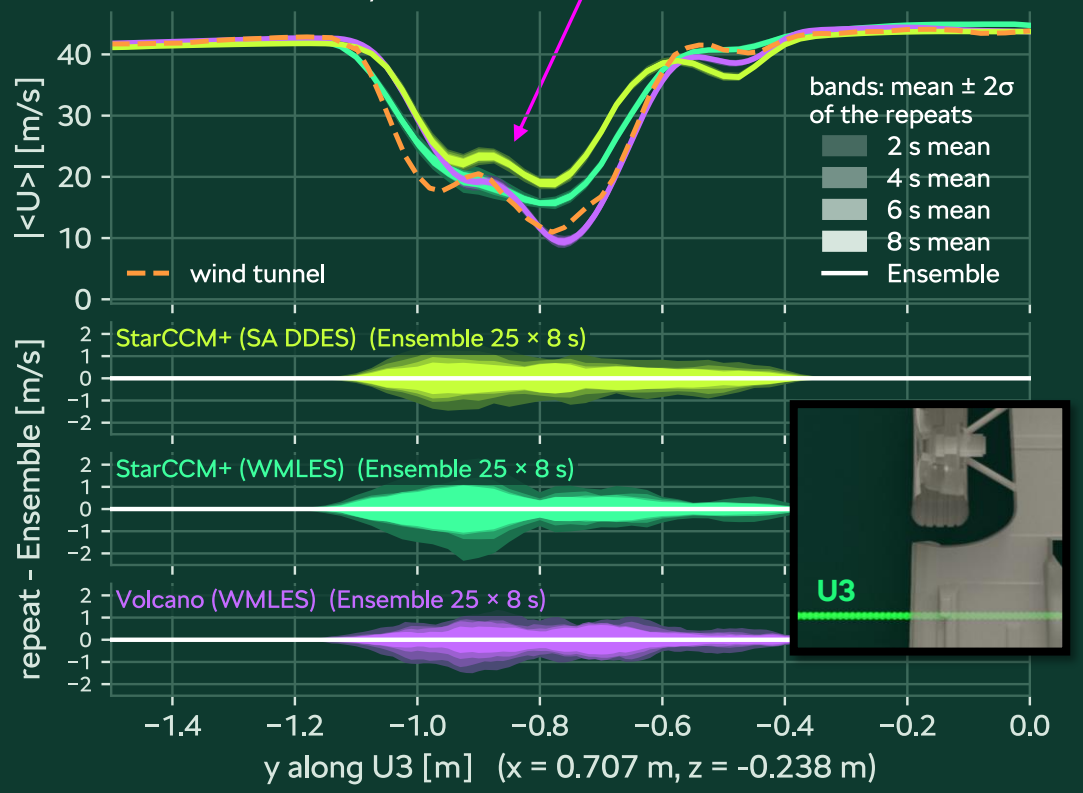
- Longer averaging buys precision, not accuracy.
- A 2 s mean already shows where the profile lands.
- Local profiles are usable very early in the simulation.
- 1-count global spread ~ small local differences.



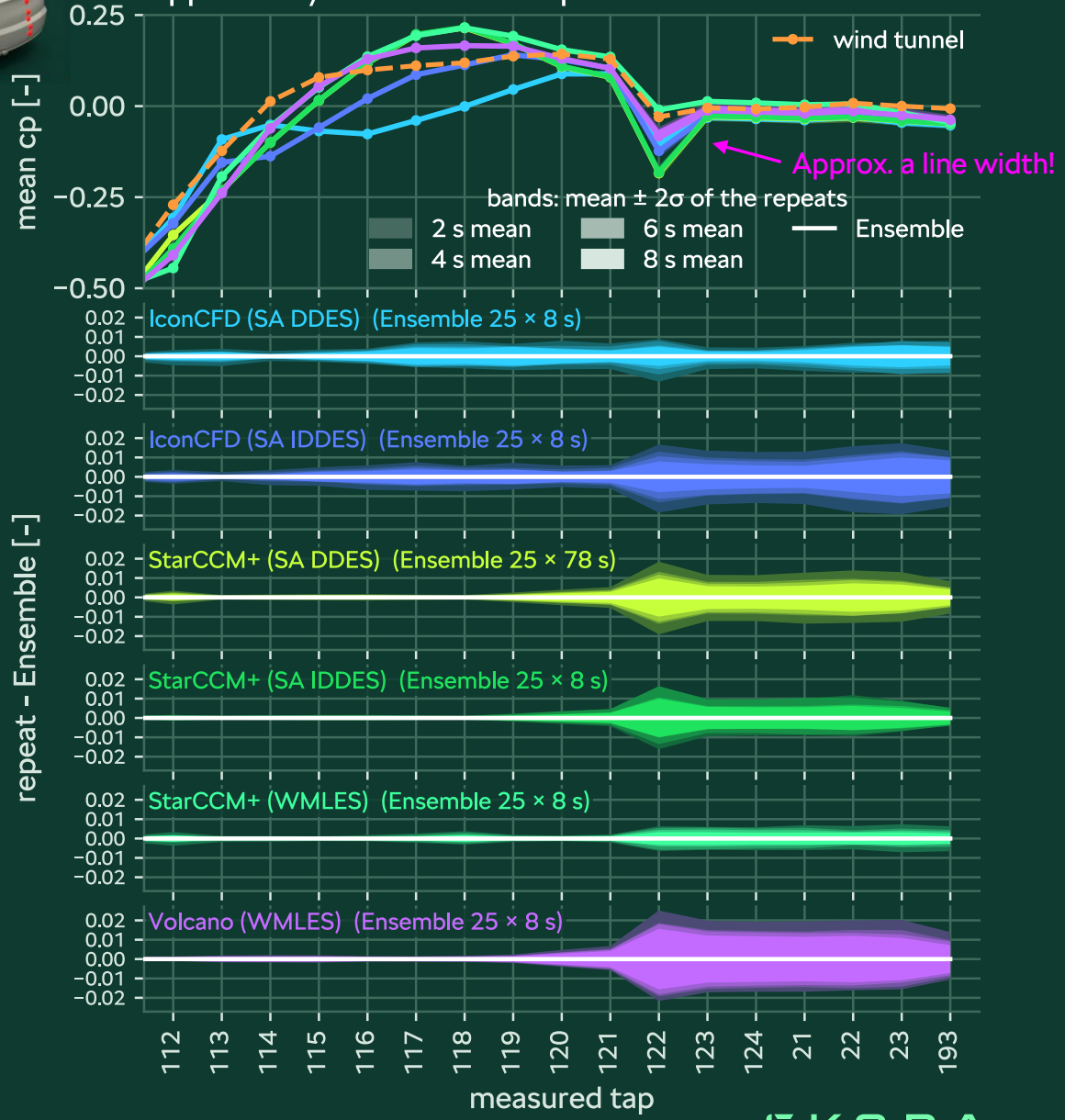


Accuracy changes little with averaging time

U3 under the car, behind the front wheels




Upper-body centerline: rear part






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# CONCLUSIONS

## Key takeaways

- Both WMLES show lower **Cd scatter** than DES, but not lower **Clr scatter**.
- In the same code (StarCCM+), WMLES reaches 0.5 ct spread **2.5–4× sooner** than DES.
- Full convergence (±0.1 ct) in SA-DDES requires ≈ 1000 s of averaging → unrealistic for industrial use.
- A practical band of ±1 / ±0.5 ct requires ≈ 10 / 60 s → still several times the typical averaging time.
- 9 out of 50 patches carry ~80–97 % of the car's Cd scatter in every code.
- Longer averaging buys precision, not accuracy → local profiles are usable very early.

## Recommendations for the next TFGs

- Confirm the WMLES behaviour across codes/geometries and identify the underlying mechanism.
- Extend the study to turbulence models beyond SA (e.g., k-ω SST-based DDES/IDDES).
- Explore whether ML models can predict the Cd scatter itself, not only the mean value. A ±1 ct Cd scatter sets a lower bound on the accuracy achievable by ML models trained on such data.

## Recommendations for the next benchmark

- Unsteady experimental data, sampled at ≥ 10–100 Hz.
- Left/right symmetric pressure taps, especially on the rear end, rear window and around the wheels.
- Finer patch split with left/right variants, groupable into logical assemblies.
- Extended result export: force time histories per patch, not only integral Cd.

# BACKUP

# The variation lies in the pressure, not the friction

- The analysis is based on available data from iconCFD and Volcano.
- Almost all run-to-run variation is pressure-related.

Std dev = the sample standard deviation (Cd means across realizations)

| Configuration | **N repeats** | Std dev @ T = 10 s **Cd** [ct] | Std dev @ T = 10 s **Cd_p** [ct] | Std dev @ T = 10 s **Cd_v** [ct] |
|---|---|---|---|---|
| iconCFD SA-DDES | 25 | 0.557 | 0.562 | 0.015 |
| iconCFD SA-IDDES | 25 | 0.493 | 0.501 | 0.015 |
| iconCFD ZDES | 25 | 0.817 | 0.825 | 0.016 |
| Volcano WMLES | 25 | 0.302 | 0.307 | 0.017 |

Cd_p – pressure part
Cd_v – viscous part

# Can we visualize variation in Cp on the car surface?

Cp field at T = 10 s, N=25 → Ensemble Cp field → Diff fields from Ensemble at T = 10 s → Standard deviation of ΔCp at T = 10 s



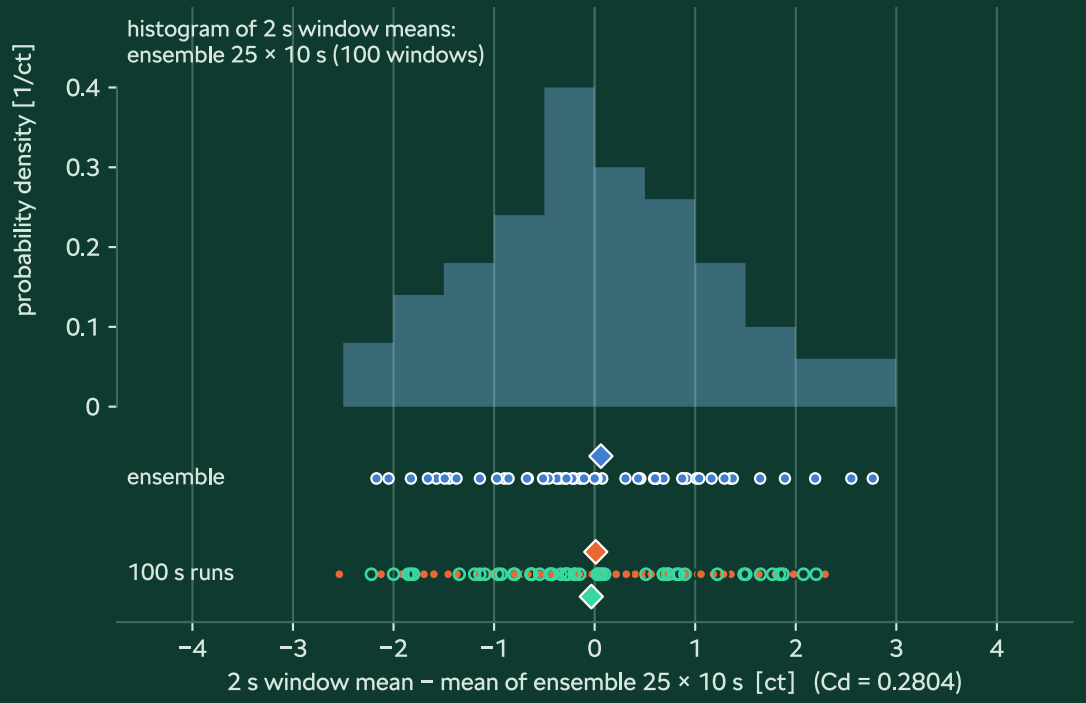


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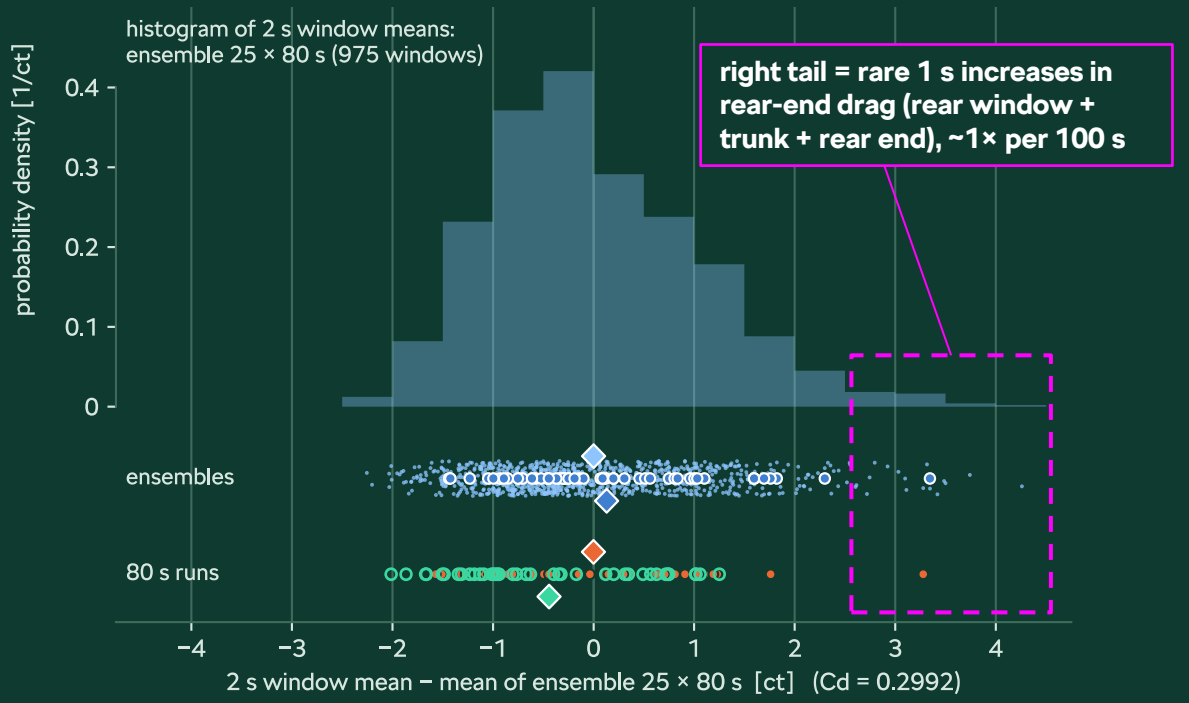
# Does one long run produce the same distribution as many shorter runs?

- Raw Cd from T = 2 s averaged over disjoint 2 s windows [2–4 s, 4–6 s, ...], one of many possible cuts.
- Gaussian-like distribution of 2 s means; StarCCM+ adds a right tail.

## IconCFD SA-DDES 25 × 10 s




## StarCCM+ SA-DDES 25 × 80 s




- histogram, ensemble 25 × 10 s (100 windows)
- Ensemble 25 × 6 s, 50 windows
- 1 long run, 100 s run #1, 49 windows
- 1 long run, 100 s run #2, 49 windows
- mean of the whole sample

- histogram, ensemble 25 × 80 s (975 windows)
- Ensemble 25 × 80 s, 975 windows
- Ensemble 25 × 6 s, 50 windows
- 1 long run, typical of 25 (RUN07), 39 windows
- 1 long run, worst of 25 (RUN15), 39 windows
- mean of the whole sample

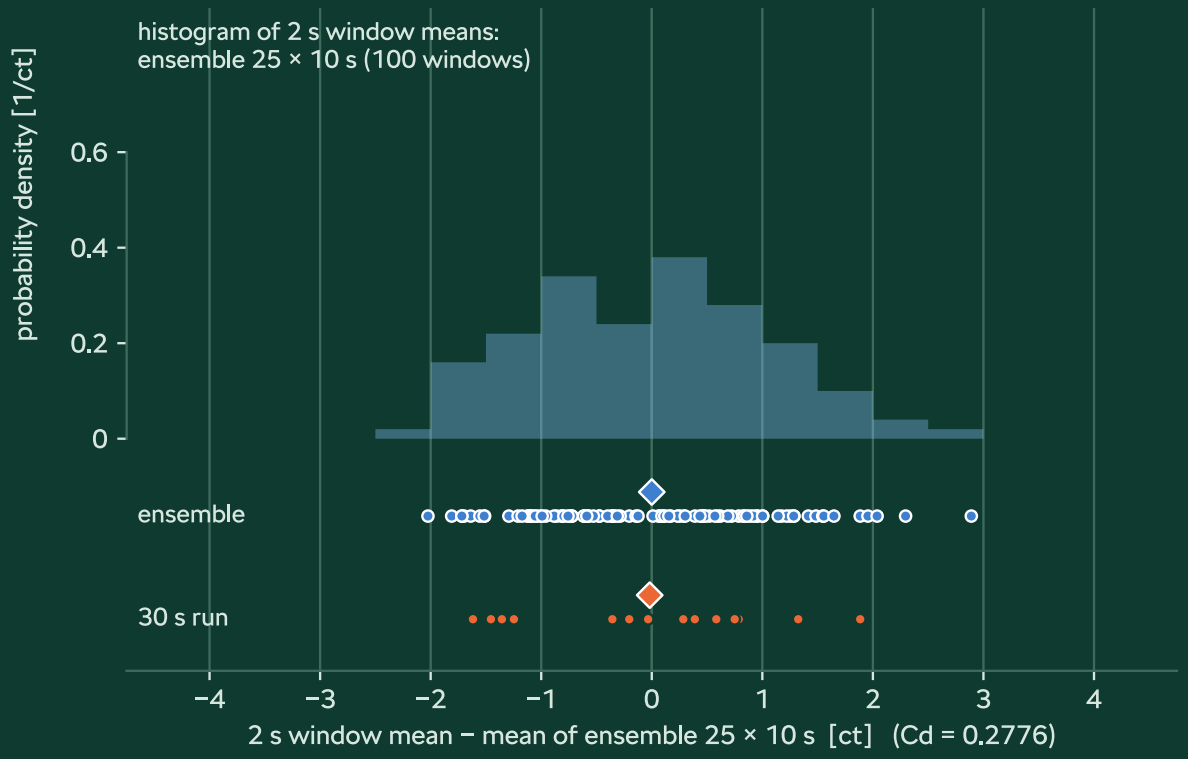


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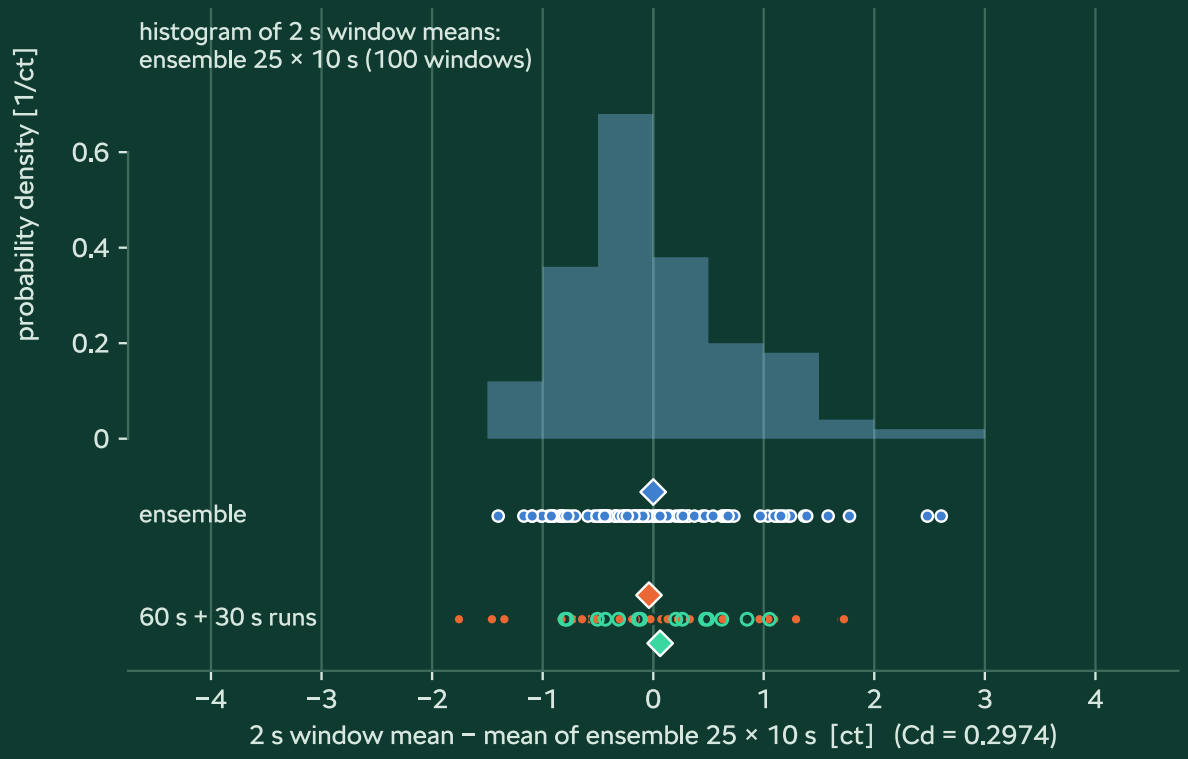
# Does one long run produce the same distribution as many shorter runs?

- Raw Cd from T = 2 s averaged over disjoint 2 s windows [2–4 s, 4–6 s, ...], one of many possible cuts.
- Gaussian-like distribution of 2 s means; smaller sample set; iconCFD also has a right tail.

## IconCFD SA-IDDES 25 × 10 s




## StarCCM+ SA-IDDES 25 × 10 s




histogram, ensemble 25 × 10 s (100 windows)
Ensemble 25 × 10 s, 100 windows (the full set)
1 long run, 30 s reference, 14 windows
mean of the whole sample

histogram, ensemble 25 × 10 s (100 windows)
Ensemble 25 × 10 s, 100 windows (the full set)
1 long run, 60 s reference, 29 windows
1 long run, 30 s reference, 14 windows
mean of the whole sample

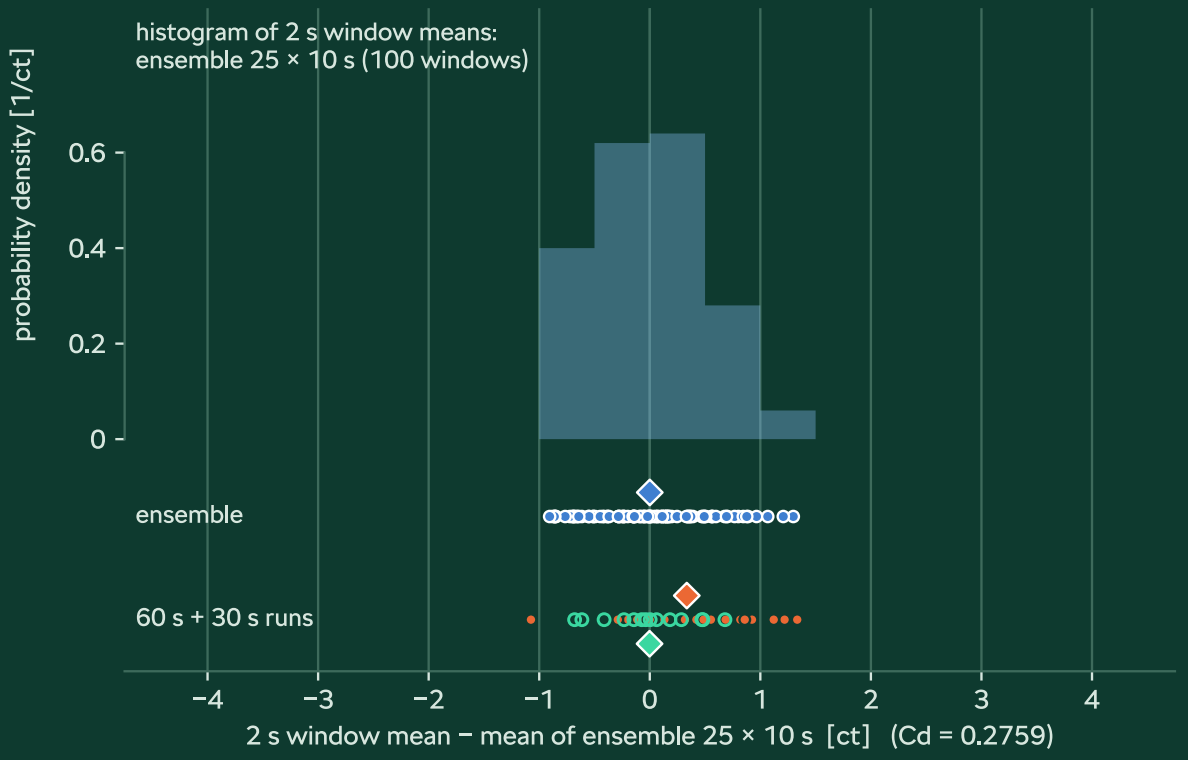


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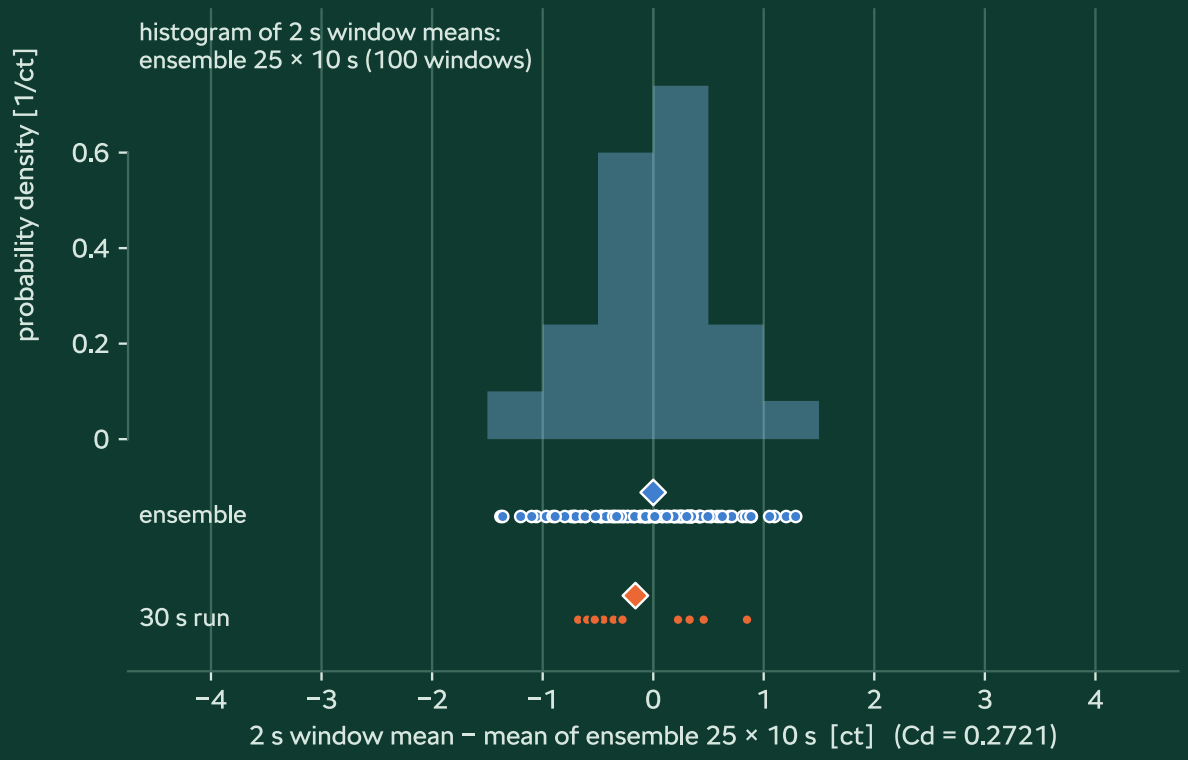
# Does one long run produce the same distribution as many shorter runs?

- Raw Cd from T = 2 s averaged over disjoint 2 s windows [2–4 s, 4–6 s, ...], one of many possible cuts.
- Gaussian-like distribution of 2 s means; smaller sample set; both WMLES simulations show no positive or negative outliers.

## StarCCM+ WMLES 25 × 10 s




## Volcano WMLES 25 × 10 s




histogram, ensemble 25 × 10 s (100 windows)
Ensemble 25 × 10 s, 100 windows (the full set)
1 long run, 60 s reference, 29 windows
1 long run, 30 s reference, 14 windows
mean of the whole sample

histogram, ensemble 25 × 10 s (100 windows)
Ensemble 25 × 10 s, 100 windows (the full set)
1 long run, 30 s reference, 14 windows
mean of the whole sample

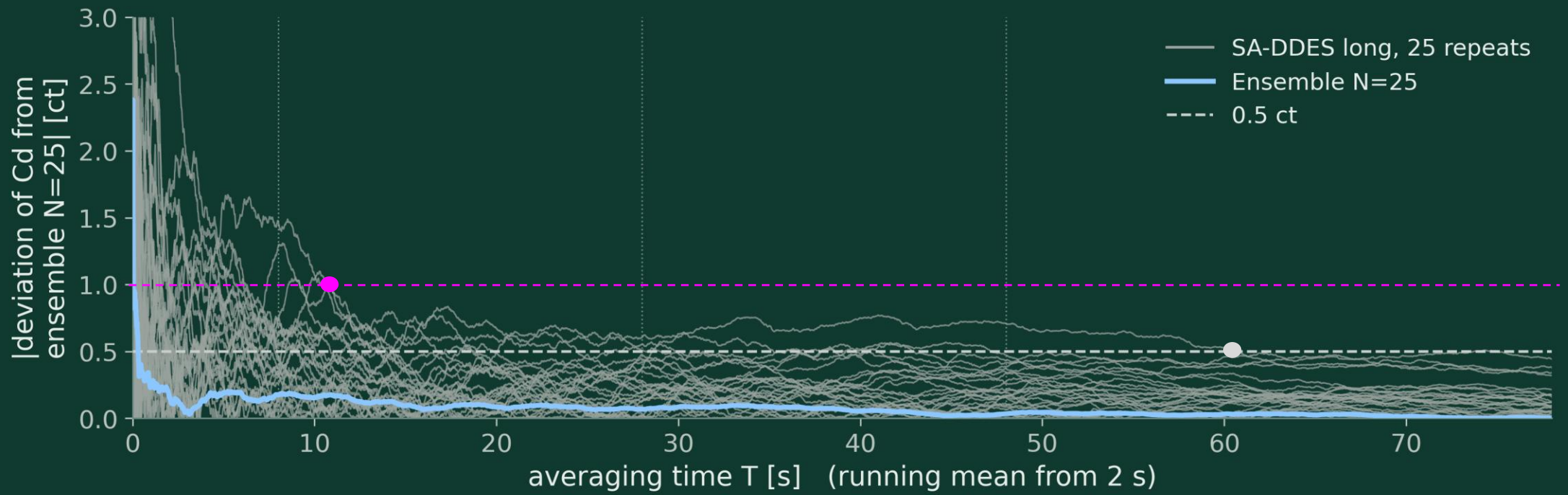


ŠKODA

## How does the spread of Cd change with run length?

- 25 × 80 s StarCCM+ SA-DDES:
- A band of ±1 ct requires approximately 10 s; a band of ±0.5 ct requires approximately 60 s.

| | T=10s | T=30s | T=50s | T=80s |
|---|---|---|---|---|
| Cd min-max [ct] | 2.1 ct | 1.16 ct | 1.14 ct | 0.82 ct |
| Std dev [ct] | 0.554 | 0.305 | 0.289 | 0.185 |

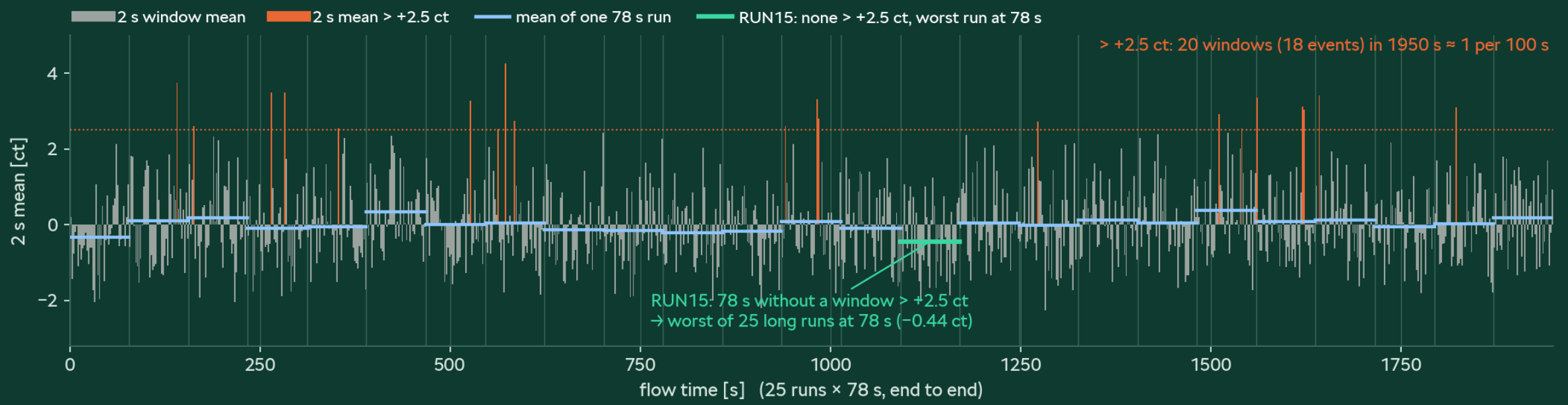





ŠKODA

# How does the spread of Cd change with run length?

- 25 × 80 s StarCCM+ SA-DDES:
- Shown as one synthetic signal assembled from 25 runs of 80 s each.
- Some long 80 s runs are calmer and free of extremes.
- Their means can lie toward one side of the distribution.
- Even an additional 80 s run may be too short to capture the full variability.






ŠKODA

## Where is the Cd scatter located on the car?

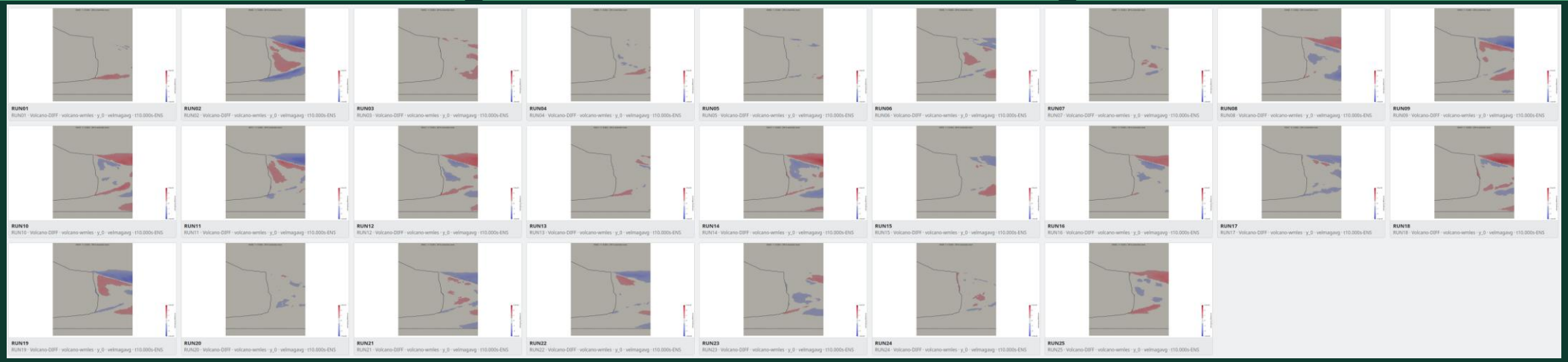
- Difference from the reference at T = 10 s (8 s average).
- Visible differences are approximately ±0.025 in Cp on the surface or range from −3 to +3 m/s in velocity in the wake.
- Three states are distinguishable

## Time-averaged velocity magnitude of each run minus the ensemble mean, both at T = 10 s (colour scale ±3 m/s)

**Volcano WMLES**




25 simulations



**Hand-drawn contours**



ŠKODA

## Where is the Cd scatter located on the car?

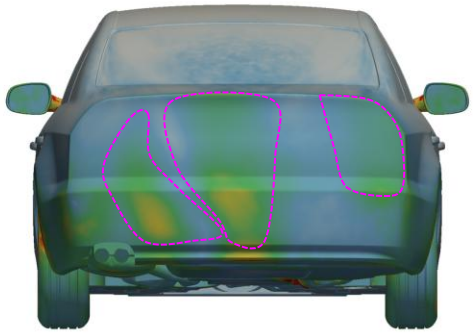
- An asymmetric pattern is visible at the rear of the vehicle in most variants.
- Discrepancy for iconCFD SA-DDES, likely due to distinct separation on the window, noticeable in $R_{1,2,3}$ profiles.
- Patterns stay visible on the car even for very long runs of 50 s.

## Scatter between repeats: sample standard deviation of time-averaged Cp over N runs at T = 10 s (colour scale 0–0.01)

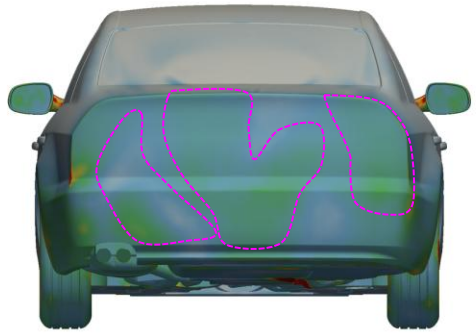
**iconCFD SA-DDES, N=25, T=10s**



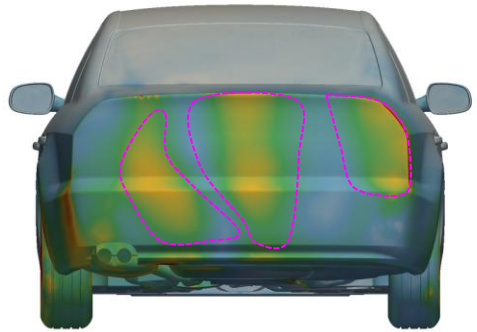
**iconCFD SA-IDDES, N=25, T=10s**

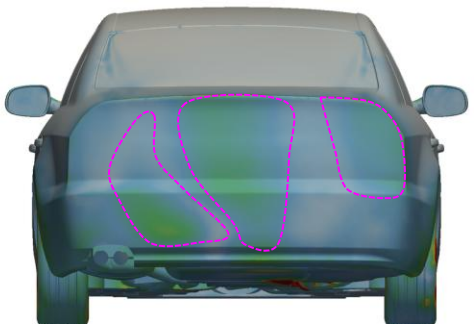


**iconCFD SA-ZDES, N=25, T=10s**

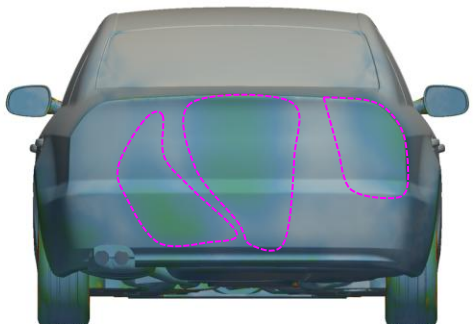


**Volcano WMLES Dyn. Smag. N=25, T=10s**

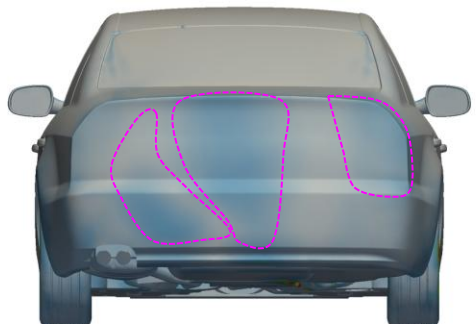


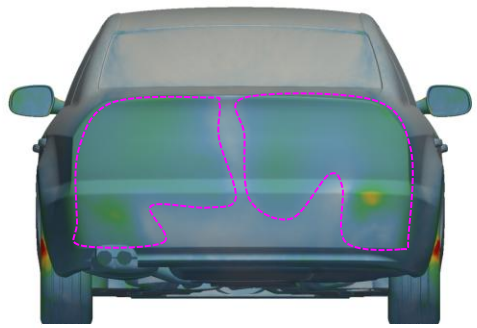
**StarCCM+ SA-DDES, N=25, T=10s**



**StarCCM+ SA-IDDES, N=25, T=10s**



**StarCCM+ SA-DDES, N=25, T=50s**



**StarCCM+ WMLES WALE, N=25, T=10s**

**Hand-drawn contours**



ŠKODA

## Where is the Cd scatter located on the car?

- The scatter is visible around the front tires and wheel arches, as well as the rear tires.
- Variability is also visible behind the mirrors, though to a lesser extent (iconCFD and StarCCM+ WMLES sets).
- Variability decreases as the averaging time increases (10 s vs. 50 s).

## Scatter between repeats: sample standard deviation of time-averaged Cp over N runs at T= 10 s (colour scale 0–0.01)

**iconCFD SA-DDES, N=25, T=10s**



**iconCFD SA-IDDES, N=25, T=10s**



**iconCFD SA-ZDES, N=25, T=10s**



**Volcano WMLES Dyn. Smag., N=25, T=10s**





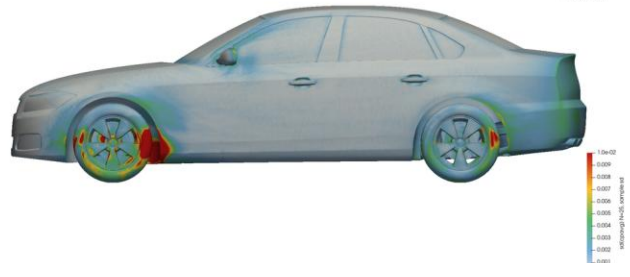

**StarCCM+ SA-DDES, N=25, T=10s**



**StarCCM+ SA-IDDES, N=25, T=10s**



**StarCCM+ SA-DDES, N=25, T=50s**



**StarCCM+ WMLES WALE, N=25, T=10s**

**Hand-drawn contours**



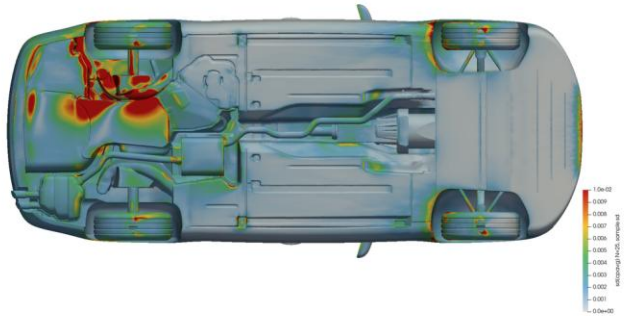
ŠKODA

## Where is the Cd scatter located on the car?

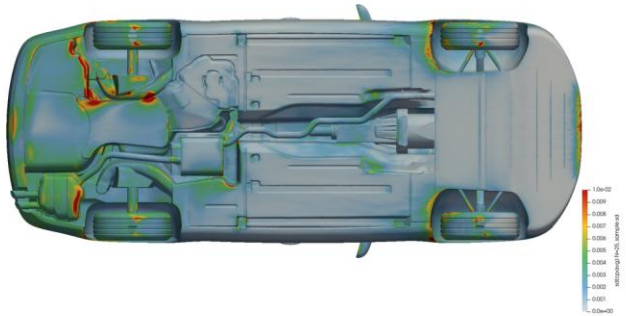
- Similarity of regions between the SW for SA-DDES and SA-IDDES in the rear section of the vehicle.
- Visible region in the wheel pad area, high-gradient region, impact of wheel pads to be analyzed.
- Differences on the front lip between SW as well as between models.

## Scatter between repeats: sample standard deviation of time-averaged Cp over N runs at T= 10 s (colour scale 0–0.01)

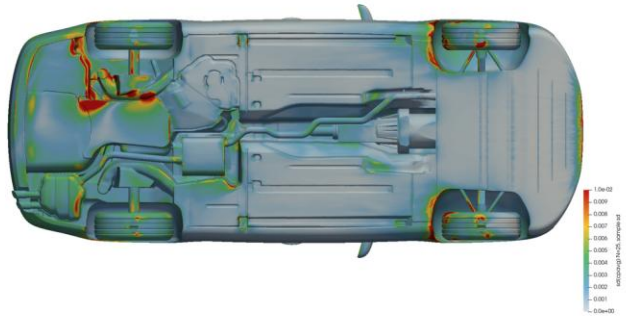
**iconCFD SA-DDES, N=25, T=10s**



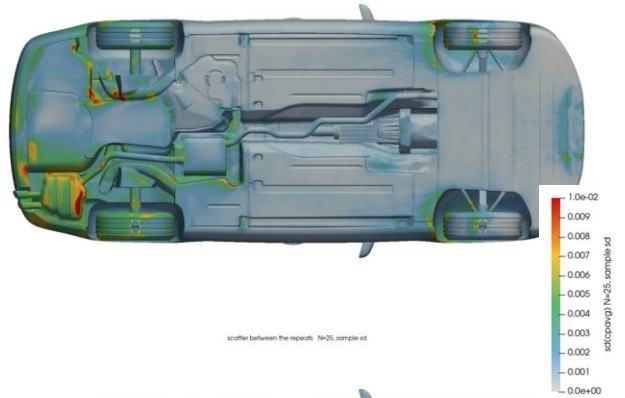
**iconCFD SA-IDDES, N=25, T=10s**

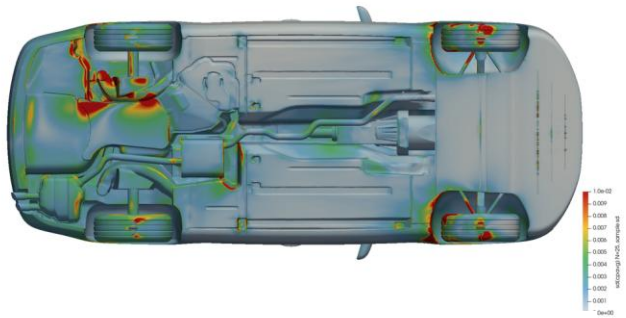


**iconCFD SA-ZDES, N=25, T=10s**

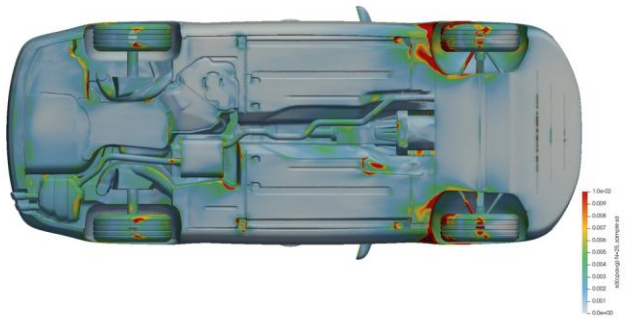


**Volcano WMLES Dyn. Smag., N=25, T=10s**

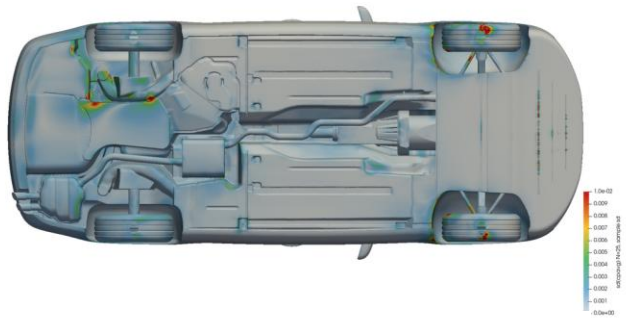


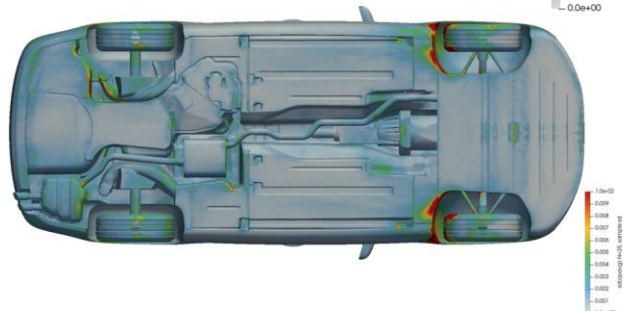
**StarCCM+ SA-DDES, N=25, T=10s**



**StarCCM+ SA-IDDES, N=25, T=10s**



**StarCCM+ SA-DDES, N=25, T=50s**



**StarCCM+ WMLES WALE, N=25, T=10s**

**Hand-drawn contours**



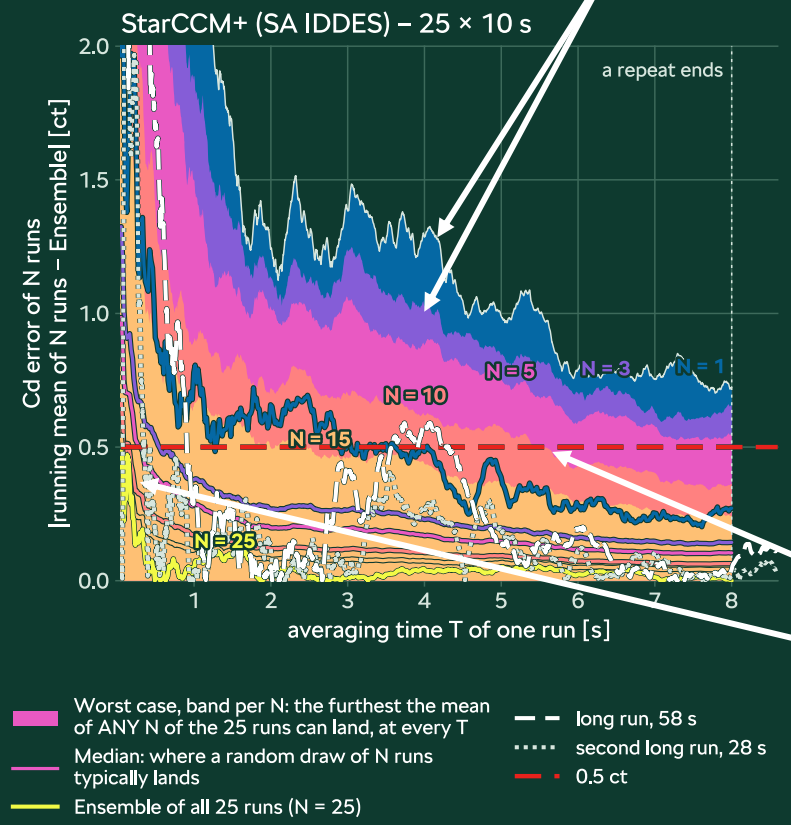
ŠKODA

# How Can the Ensemble Method Help?

- The N = 25 ensemble serves as the reference, so the N = 25 curve converges to itself at T_end by construction.
- The curves show the medians for subsets of runs drawn from the N = 25 set. For each subset size, half of the selections fall below the curve and half above.

Worst-case bands are exact over all combinations (the mean of the N most extreme runs at every T).

How to read the graph




| N (runs averaged) | Possible combinations C(25, N) | Combinations used for the median | Method |
|---|---|---|---|
| 1 | 25 | 25 | all |
| 3 | 2,300 | 2,300 | all |
| 5 | 53,130 | 53,130 | all |
| 10 | 3,268,760 | 300,000 (9.2 %) | random sample* |
| 15 | 3,268,760 | 300,000 (9.2 %) | random sample* |
| 25 | 1 | 1 | the ensemble itself (drawn as a line) |

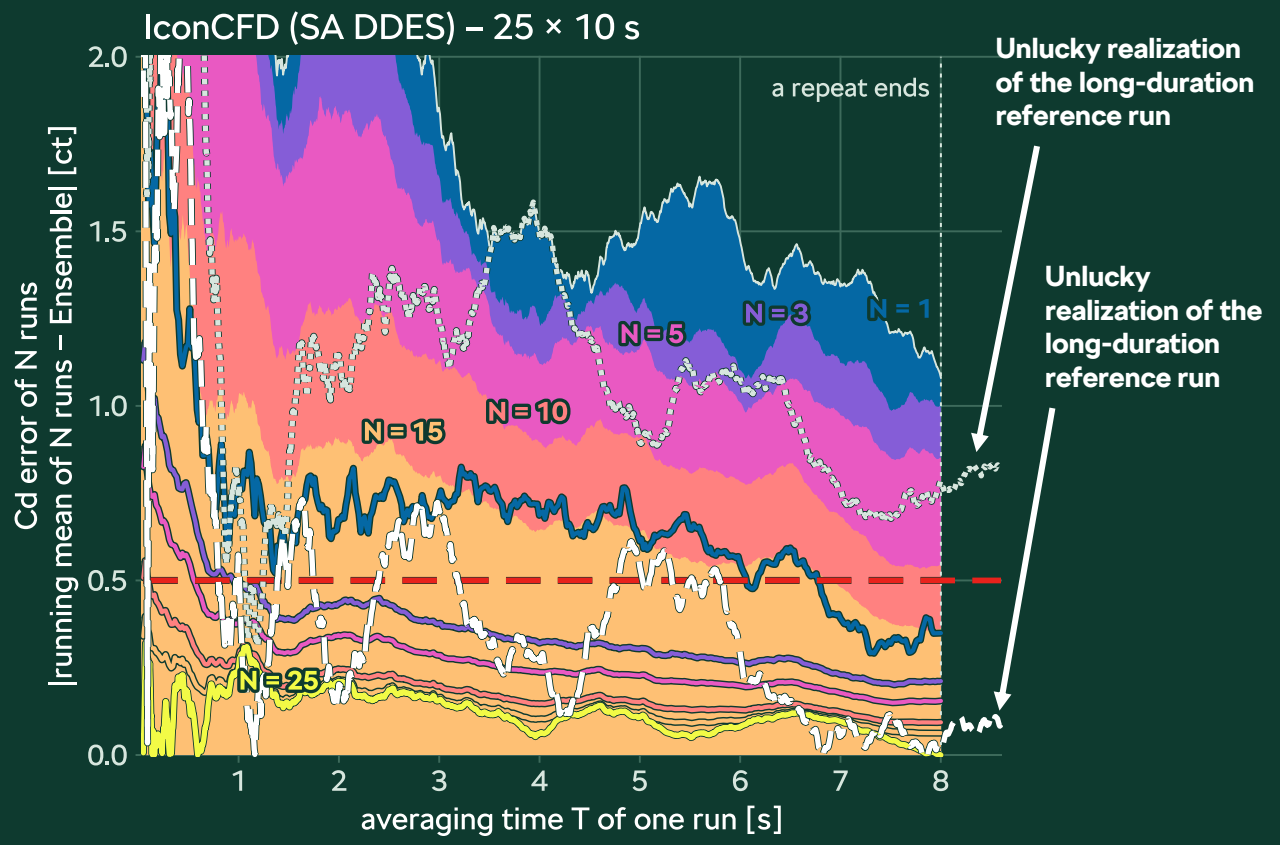
*Sampled medians (N = 10, 15) change by less than 0.01 ct with a different random seed.

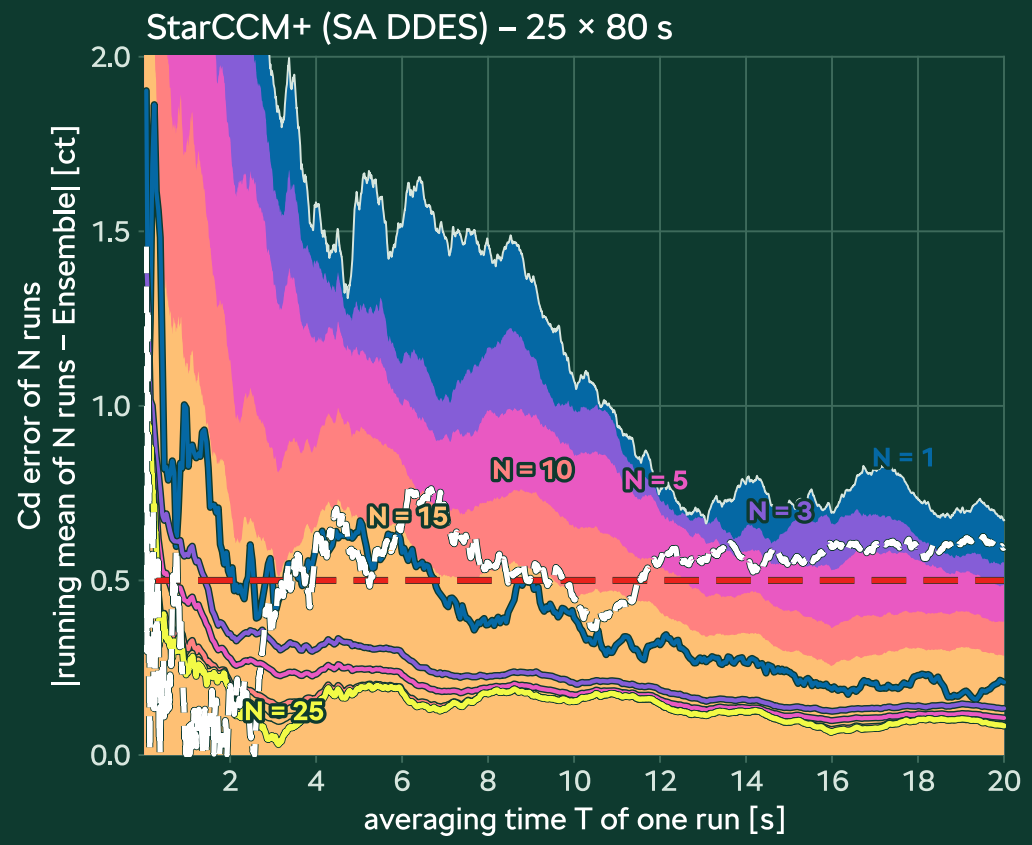
Worst-case N = 10 ensemble: crosses the 0.5 ct threshold at 5.8 s (∑**10x5.8s Avg**). Your unlucky day, but a rare one.

Half of all N = 10 combinations drawn from the 25 replicas cross the 0.5 ct threshold earlier (average of 10 runs < 1 s).

# How Can the Ensemble Method Help?

- The N = 25 ensemble serves as the reference, so the N = 25 curve converges to itself at T_end by construction.
- The curves show the medians for subsets of runs drawn from the N = 25 set. For each subset size, half of the selections fall below the curve and half above.




Worst case, band per N: the furthest the mean of ANY N of the 25 runs can land, at every T
Median: where a random draw of N runs typically lands
Ensemble of all 25 runs (N = 25)
long run, 98 s
second long run, 98 s
0.5 ct

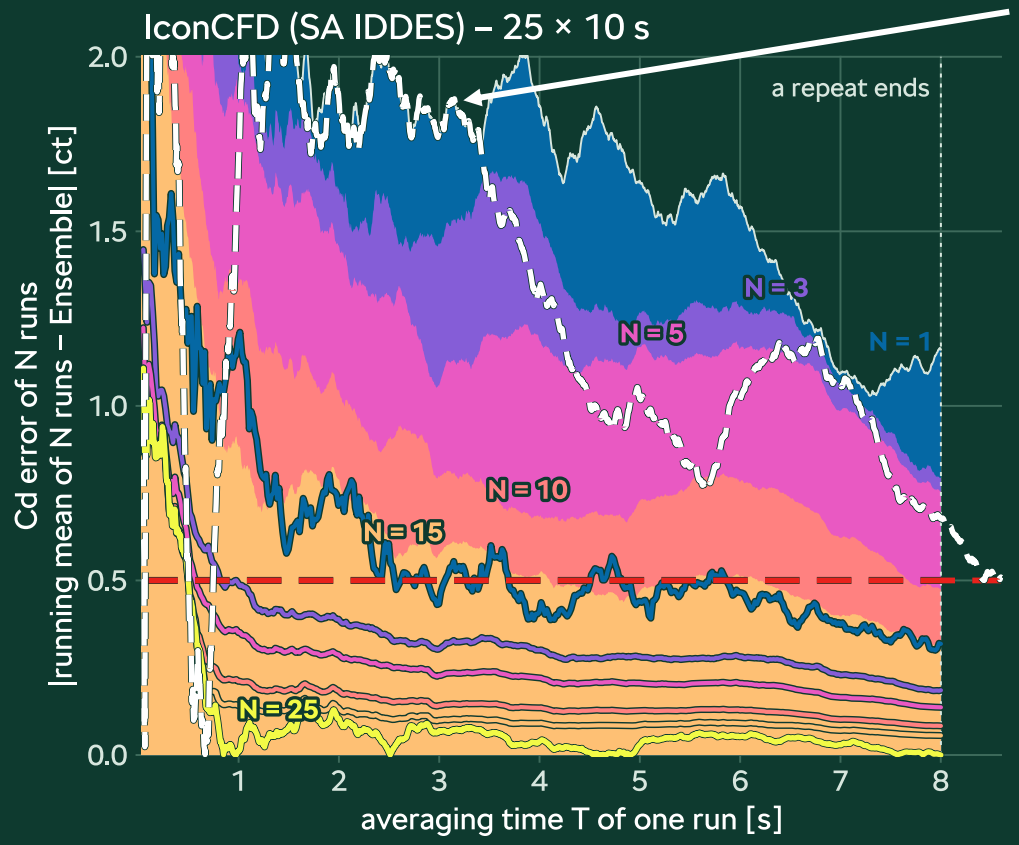
Worst case, band per N: the furthest the mean of ANY N of the 25 runs can land, at every T
Median: where a random draw of N runs typically lands
Ensemble of all 25 runs (N = 25)
long run, 58 s
0.5 ct



ŠKODA

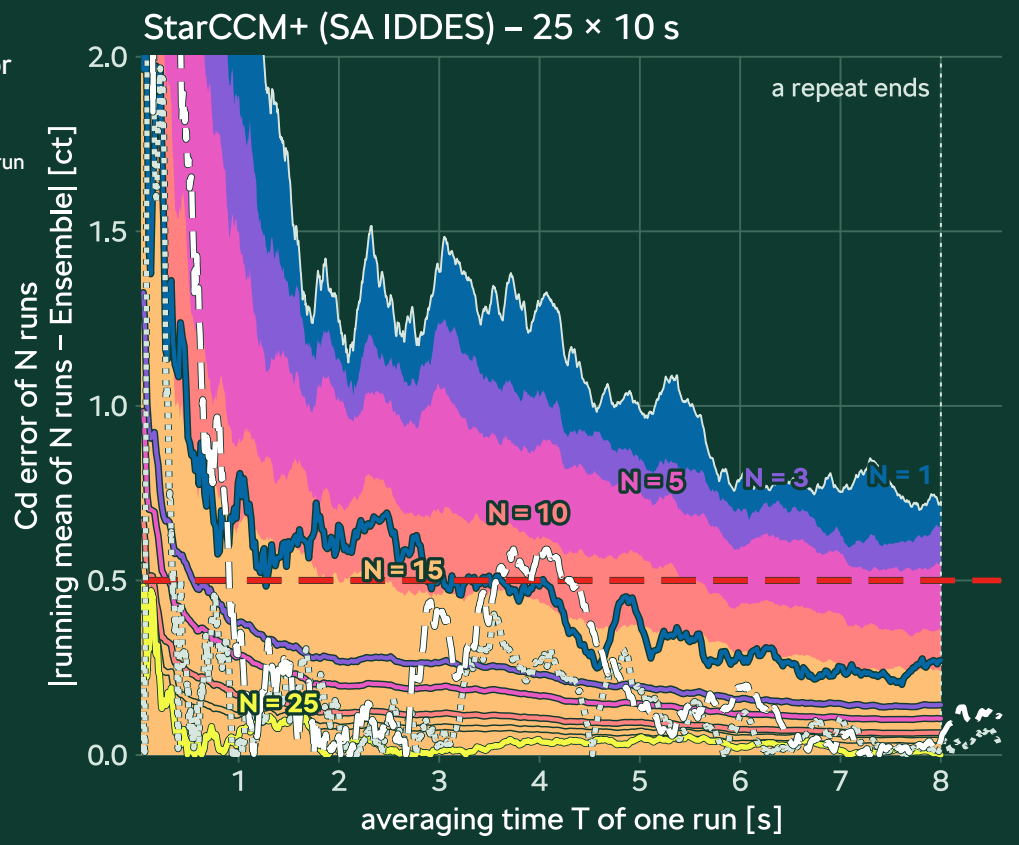
# How Can the Ensemble Method Help?

- The N = 25 ensemble serves as the reference, so the N = 25 curve converges to itself at T_end by construction.
- The curves show the medians for subsets of runs drawn from the N = 25 set. For each subset size, half of the selections fall below the curve and half above.




The long-duration run envelopes the worst-case runs for N = 1.

Here, the long-duration run uses the BCs of one run from the N = 25 set (an extension of that run in time).




Worst case, band per N: the furthest the mean of ANY N of the 25 runs can land, at every T

Median: where a random draw of N runs typically lands

Ensemble of all 25 runs (N = 25)

long run, 28 s

0.5 ct

Worst case, band per N: the furthest the mean of ANY N of the 25 runs can land, at every T

Median: where a random draw of N runs typically lands

Ensemble of all 25 runs (N = 25)

long run, 58 s

second long run, 28 s

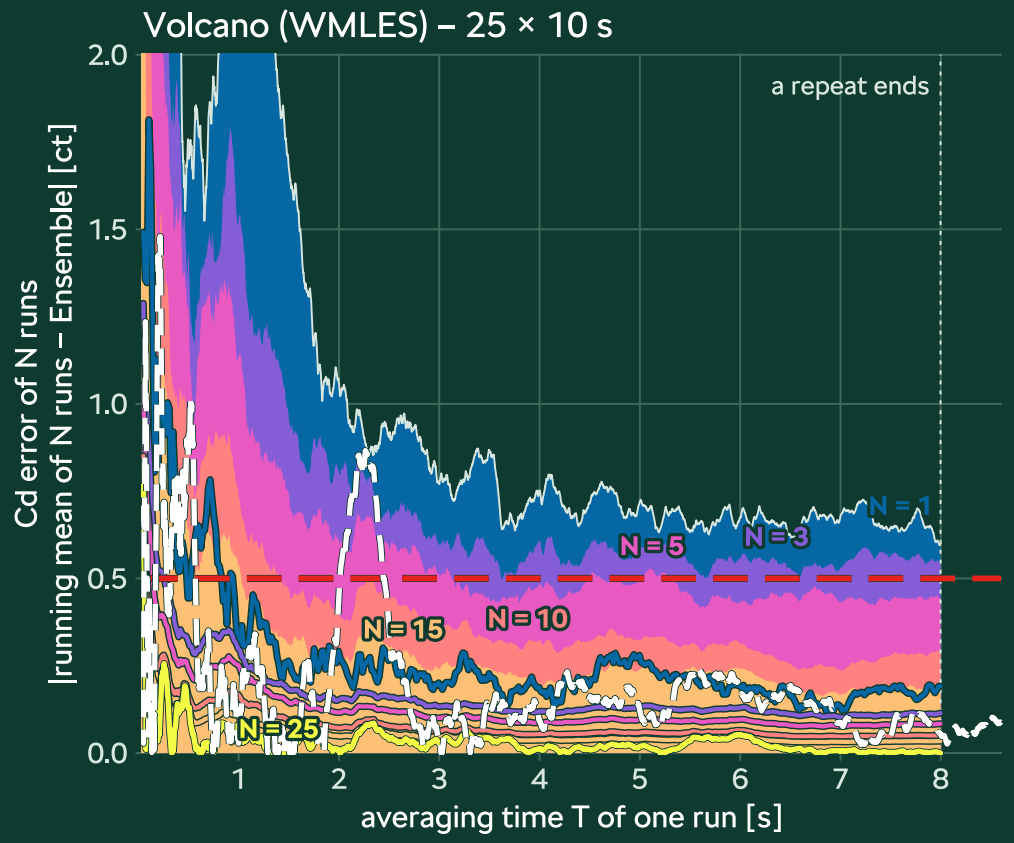
0.5 ct

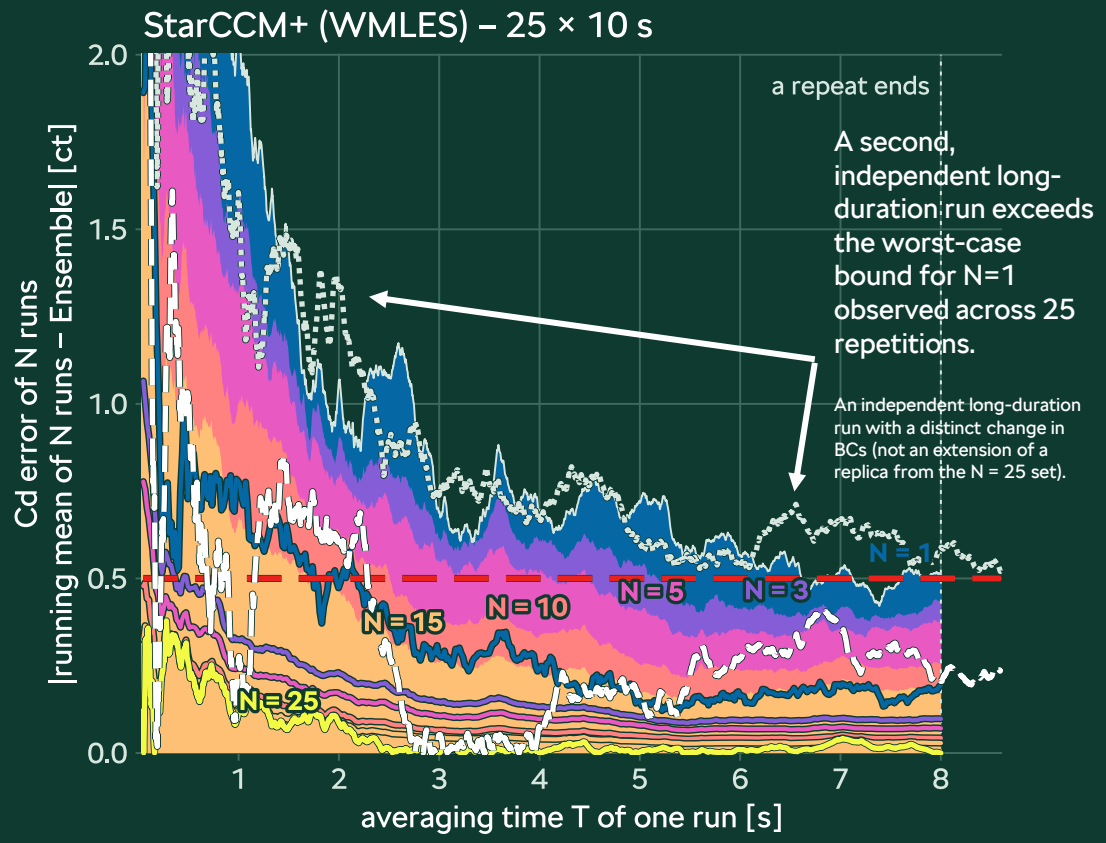


ŠKODA

# How Can the Ensemble Method Help?

- The N = 25 ensemble serves as the reference, so the N = 25 curve converges to itself at T_end by construction.
- The curves show the medians for subsets of runs drawn from the N = 25 set. For each subset size, half of the selections fall below the curve and half above.




Worst case, band per N: the furthest the mean of ANY N of the 25 runs can land, at every T
Median: where a random draw of N runs typically lands
Ensemble of all 25 runs (N = 25)
long run, 28 s
0.5 ct

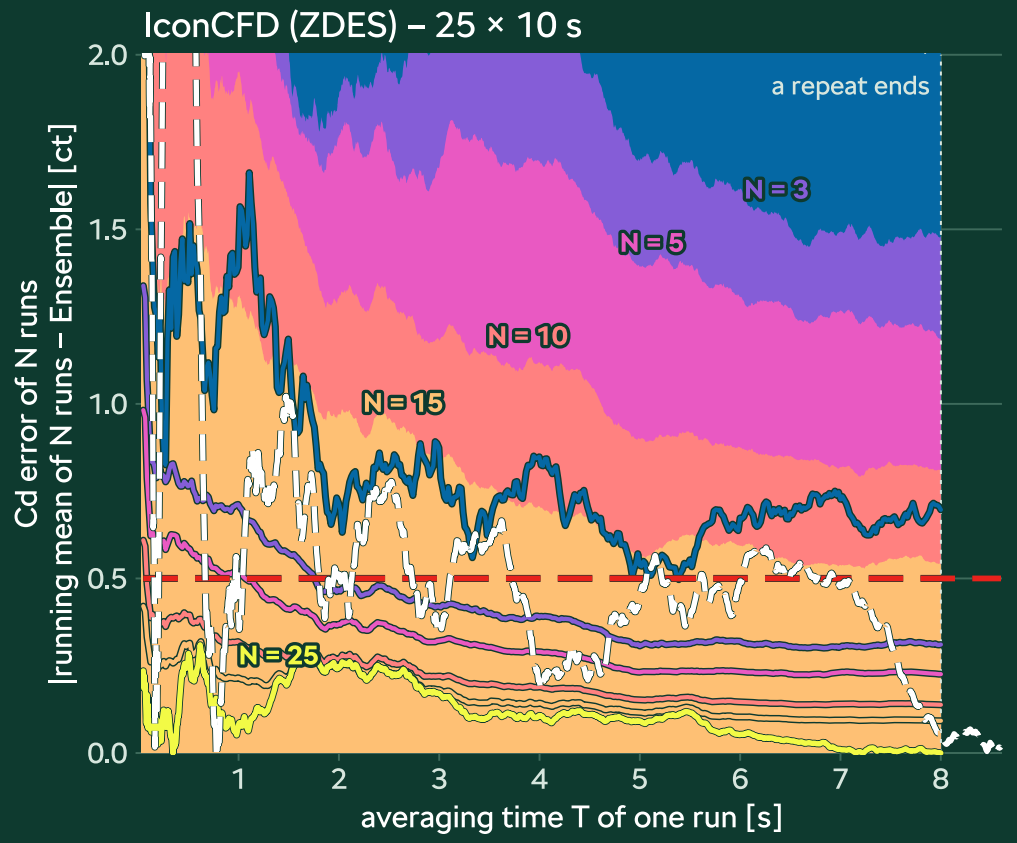
Worst case, band per N: the furthest the mean of ANY N of the 25 runs can land, at every T
Median: where a random draw of N runs typically lands
Ensemble of all 25 runs (N = 25)
long run, 28 s
second long run, 58 s
0.5 ct

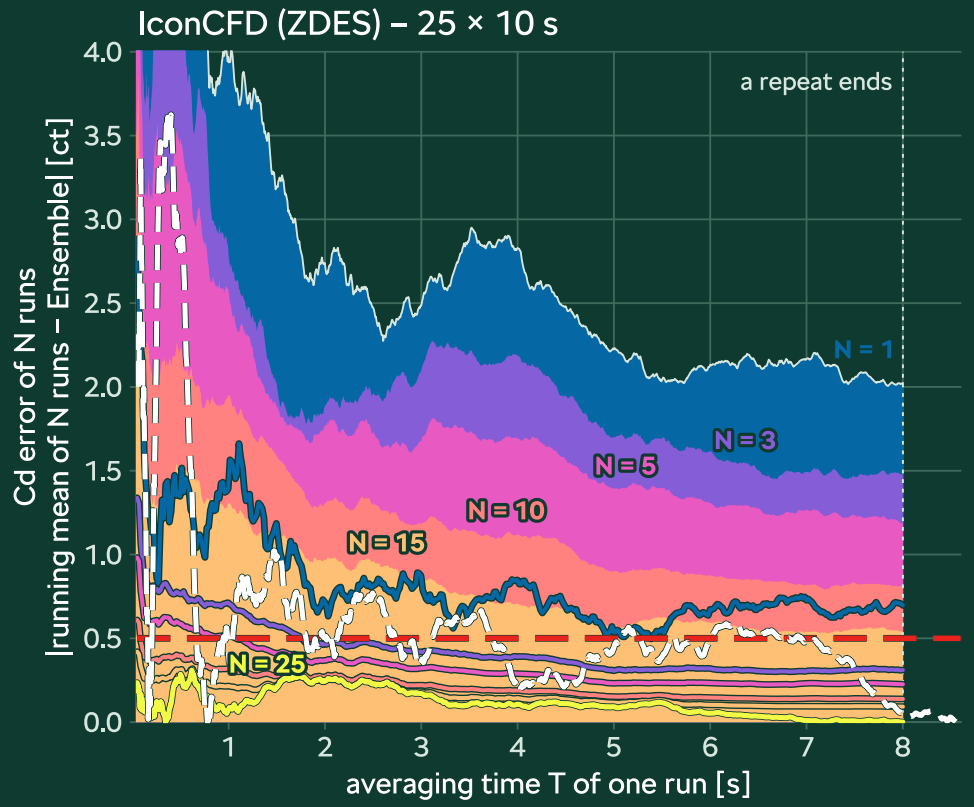


ŠKODA

# How Can the Ensemble Method Help?

- The N = 25 ensemble serves as the reference, so the N = 25 curve converges to itself at T_end by construction.
- The curves show the medians for subsets of runs drawn from the N = 25 set. For each subset size, half of the selections fall below the curve and half above.




Worst case, band per N: the furthest the mean of ANY N of the 25 runs can land, at every T

Median: where a random draw of N runs typically lands

Ensemble of all 25 runs (N = 25)

long run, 28 s

0.5 ct

Worst case, band per N: the furthest the mean of ANY N of the 25 runs can land, at every T

Median: where a random draw of N runs typically lands

Ensemble of all 25 runs (N = 25)

long run, 28 s

0.5 ct

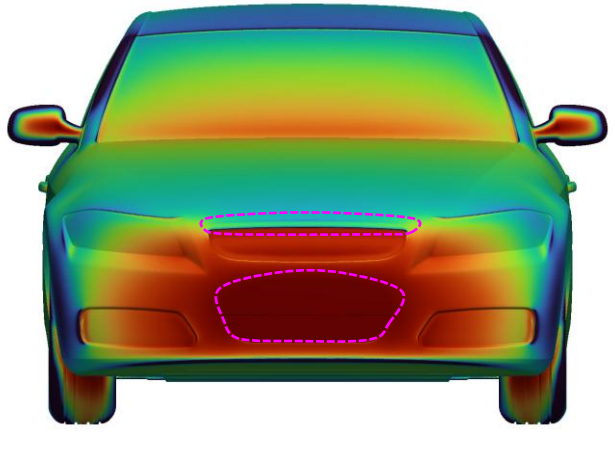


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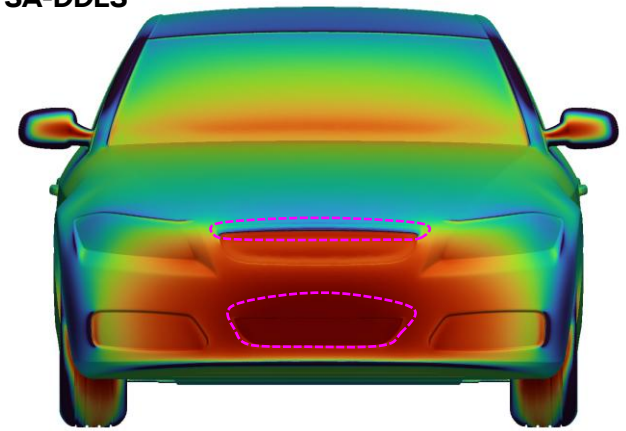
# Where StarCCM+ overpredicts Cd

- Front patches (bumper + lower/upper grille) account for most of the difference (~20 ct).
- The boundary conditions ahead of the vehicle are comparable between the software versions.
- The origin is currently unknown and will be analyzed after the workshop.

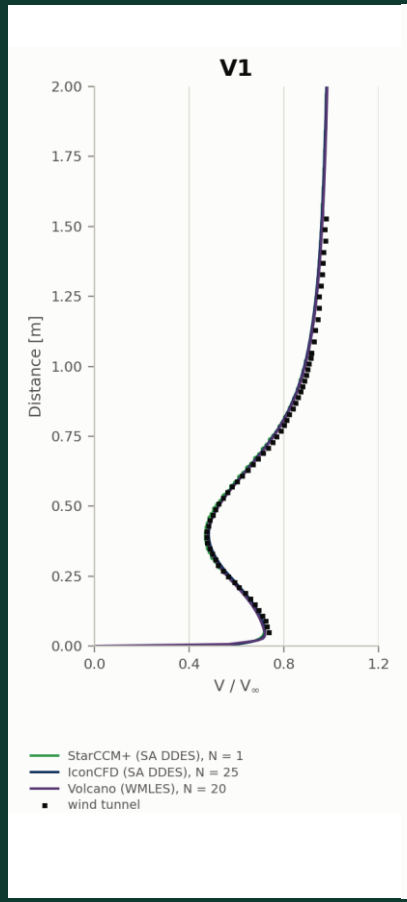
**StarCCM+ SA-DDES**



**iconCFD SA-DDES**



**Hand-drawn contours**




**Body_fascia_1**

