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INFORME Nº / *REPORT No.* CV23060122

INFORME DE VALIDACION DEL MÉTODO DE SIMULACIÓN DE DINÁMICA DE FLUIDOS COMPUTACIONAL (CFD) SEGÚN ANEXO V DEL REGLAMENTO (EU) 2022/1362, RELATIVO AL PROCEDIMIENTO PARA LA OBTENCIÓN DE DATOS DE RENDIMIENTO DE APENDICES AERODINÁMICOS MONTADOS EN REMOLQUES Y SEMIREMOLQUES PESADOS.

VALIDATION REPORT OF THE COMPUTATIONAL FLUID DYNAMICS (CFD) SIMULATION METHOD ACCORDING TO ANNEX V OF REGULATION (EU) 2022/1362, REGARDING THE PROCEDURE FOR THE PERFORMANCE DETERMINATION OF THE AERODYNAMIC DEVICES ASSEMBLED TO TRAILERS AND SEMITRAILERS.

Solicitante / *Applicant*	: IDIADA Automotive Technology, SA L'Albornar, PO Box 20 43710 Santa Oliva, Spain
Fabricante / *Manufacturer*	: N/A
Marca / *Make*	: N/A
Informe de metodología / *Methodology report*	: 22INN_TENDER_CFD_TRAILE_2023 05 09
Lugar y fecha de emisión del informe / *Place and date of issue*	: L'Albornar, Santa Oliva (Tarragona), 02/06/2023

CONCLUSIONES: El método de simulación de dinámica de fluidos computacional (CFD) presentado por IDIADA Automotive Technology, SA CUMPLE con las prescripciones aplicables para su validación según establece el Anexo V del Reglamento (UE) 2022/1362, cuya última modificación es el Reglamento (UE) 2022/1362.
CONCLUSIONS: The computational fluid dynamics (CFD) simulation method presented by IDIADA Automotive Technology, SA FULFILS with the applicable prescriptions for its validation as established in Annex V of Regulation (EU) 2022/1362, which is last amended by Regulation (EU) 2022/1362.

Realizado / *Performed by:*

Francesc Xavier Font Mila
INGENIERO DE HOMOLOGACIONES
HOMOLOGATION ENGINEER

V. Bº / *Revised by:*

Ignacio Lafuente Buil
JEFE DE DEPARTAMENTO
DEPARTMENT MANAGER

ANNEXO I AL INFORME DE VALIDACION / *ANNEX I TO THE VALIDATION REPORT*

1. GENERAL / *GENERAL*

1.1 Datos del solicitante e informe de metodología / *Applicant and Methodology document data*

1.1.1 Solicitante / *Applicant* : IDIADA Automotive Technology, SA
L'Albornar, PO Box 20
43710 Santa Oliva, Spain

1.1.2 Informe de metodología / Methodology report : 22INN_TENDER_CFD_TRAILE_2023 05 09

1.2 Referencias del modelo virtual / *References of the virtual model*

1.2.1 Nombre comercial del software y versión / *Commercial name and version of the software* : Simcenter STAR-CCM+ Version: 16.04.012

1.2.2 Fabricante del software / *Software producer* : SIEMENS Industry Software Inc

1.2.3 Datos de contacto del desarrollador de software / *Contact details of software developer* : 5800 Granite Pkwy 600
75024 Plano, Texas, United States

1.2.4 Identificación de los modelos CFD para la validación / : *CFD Models identification for validation*

Descripción *Description*	Referencia de archivo de modelo *Model file reference*
Base model at 0.0 degree of yaw	G5_BASE_ST1_Yaw00_SOLVED.sim
Base model at 3.0 degree of yaw	G5_BASE_ST1_Yaw03_SOLVED.sim
Base model at 6.0 degree of yaw	G5_BASE_ST1_Yaw06_SOLVED.sim
Tall Rear Flaps model at 0.0 degree of yaw	G5_BASE_TRF_Yaw00_SOLVED.sim
Tall Rear Flaps model at 3.0 degree of yaw	G5_BASE_TRF_Yaw03_SOLVED.sim
Tall Rear Flaps model at 6.0 degree of yaw	G5_BASE_TRF_Yaw06_SOLVED.sim
Long Side Covers model at 0.0 degree of yaw	G5_BASE_LSC_Yaw00_SOLVED.sim
Long Side Covers model at 3.0 degree of yaw	G5_BASE_LSC_Yaw03_SOLVED.sim
Long Side Covers model at 6.0 degree of yaw	G5_BASE_LSC_Yaw06_SOLVED.sim

2. VERIFICACIÓN DEL MODELO VIRTUAL / *VIRTUAL MODEL VERIFICATION*

La actividad de verificación consiste en comprobar que los modelos CFD están alineados con los requerimientos listados en el Annexo V del Reglamento (EU) 2022/1362. El siguiente listado muestra los conceptos de verificación de datos de entrada y de datos de salida de modelo. Los datos detallados de esta actividad de verificación se registran en la lista de verificación, que es un documento de trabajo utilizado por el ingeniero en simulación. /
The verification activity consists of verifying that the CFD models are aligned with the requirements listed in Annex V of Regulation (EU) 2022/1362. The following list shows the concepts of verification of input and output data of the model. The detailed data from this verification activity is recorded in the checklist, which is a working document used by the simulation engineer.

2.1. Verificación de datos de entrada / *INPUT data verification*

2.1.1. Geometría del vehículo / *Vehicle geometry*

Configuración BASE / *BASE configuration:*

Tractocamión genérico 4x2 descargado de:
Generic 4x2 tractor downloaded from:
https://code.europa.eu/vecto/vecto-cfd/-/blob/main/cfd_files/01_Tractor_4x2/

Semirremolque genérico ST1 descargado de:
Generic ST1 semi-trailer downloaded from:
https://code.europa.eu/vecto/vecto-cfd/-/blob/main/cfd_files/04_DA_ST1/

Configuración TRF / *TRF configuration:*

Tractocamión genérico 4x2 descargado de:
Generic 4x2 tractor downloaded from:
https://code.europa.eu/vecto/vecto-cfd/-/blob/main/cfd_files/01_Tractor_4x2/

Semirremolque genérico ST1 descargado de:
Generic ST1 semi-trailer downloaded from:
https://code.europa.eu/vecto/vecto-cfd/-/blob/main/cfd_files/04_DA_ST1/

Alerones traseros altos genéricos descargados de:
Generic tall rear flaps downloaded from:
https://code.europa.eu/vecto/vecto-cfd/-/tree/main/cfd_files/99_ST1_GenericAeroEnablers

Configuración LSC / *LSC configuration:*

Tractocamión genérico 4x2 descargado de:
Generic 4x2 tractor downloaded from:
https://code.europa.eu/vecto/vecto-cfd/-/blob/main/cfd_files/01_Tractor_4x2/

Semirremolque genérico ST1 descargado de:
Generic ST1 semi-trailer downloaded from:
https://code.europa.eu/vecto/vecto-cfd/-/blob/main/cfd_files/04_DA_ST1/

Cubiertas laterales largas genéricas descargadas de:
Generic long side covers downloaded from:
https://code.europa.eu/vecto/vecto-cfd/-/tree/main/cfd_files/99_ST1_GenericAeroEnablers

2.1.2. Otros parámetros geométricos / *Other geometry parameters*

CAMPO / *FIELD*	VALOR MÍNIMO / *MINIMUM VALUE*	CUMPLE / *FULFILS* NO CUMPLE / *DOES NOT FULFIL*
Rueda delantera de tractocamión Distancia vertical entre el eje de rotación y el suelo / *Tractor Front Wheel Rotation axis-to-Ground Vertical Distance*	527.00 mm	Si / *Yes* ~~No / *No*~~
Rueda trasera de semirremolque Distancia vertical entre el eje de rotación y el suelo / *Semi-trailer Rear Wheel Rotation axis-to-Ground Vertical Distance*	514.64 mm	Si / *Yes* ~~No / *No*~~
Longitud del dominio de simulación / *Length of the simulation domain*	≥ 145.00 m	Si / *Yes* ~~No / *No*~~
Anchura del dominio de simulación / *Width of the simulation domain*	≥ 75.00 m	Si / *Yes* ~~No / *No*~~
Altura del dominio de simulación / *Height of the simulation domain*	≥ 25.00 m	Si / *Yes* ~~No / *No*~~
Distancia de la entrada de aire al extremo delantero del vehículo / *Air Inlet to Vehicle Front End Distance*	≥ 25.00 m	Si / *Yes* ~~No / *No*~~
Distancia de la salida del aire al extremo trasero del vehículo / *Air Outlet to Vehicle Rear End Distance*	≥ 100.00 m	Si / *Yes* ~~No / *No*~~

2.1.3. Condiciones de contorno */ Boundary conditions*

CAMPO / *FIELD*	VALOR / *VALUE*	CUMPLE / *FULFILS* NO CUMPLE / *DOES NOT FULFIL*
Velocidad del vehículo/ *Vehicle velocity*	> 25.0 m/s	Si / *Yes* ~~No / *No*~~
Superficie frontal del vehículo/ *Vehicle Frontal Area*	> 10.047 m^2	Si / *Yes* ~~No / *No*~~
Coeficientes de resistencia del medio poroso Radiador / *Porous media resistance coefficients Radiator*	P_i = 120.00 kg/m^4 P_v = 450.00 kg/m^2s	Si / *Yes* ~~No / *No*~~
Coeficientes de resistencia del medio poroso Refrigerador del aire de sobrealimentación / *Porous media resistance coefficients Charge Aire Cooler*	P_i = 60.00 kg/m^4 P_v = 300.00 kg/m^2s	Si / *Yes* ~~No / *No*~~
Coeficientes de resistencia del medio poroso Condensador / *Porous media resistance coefficients Condenser*	P_i = 140.00 kg/m^4 P_v = 450.00 kg/m^2s	Si / *Yes* ~~No / *No*~~
Velocidad tangencial del suelo / *Floor tangential velocity*	-	Si / *Yes* ~~No / *No*~~
Ruedas giratorias / *Rotating wheels*	-	Si / *Yes*

		~~No / *No*~~
Viento cruzado procedente del lado izquierdo del vehículo / *Crosswind effects coming from the left-hand side of the vehicle*	-	Si / *Yes* ~~No / *No*~~

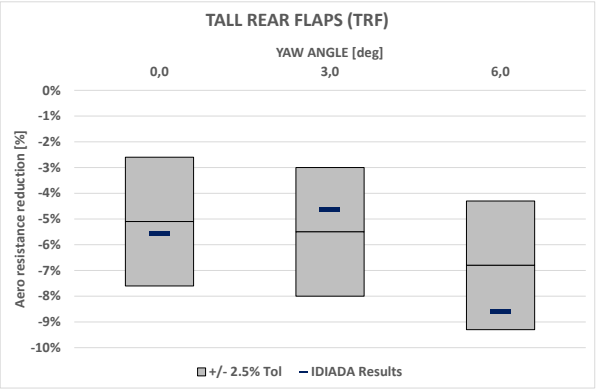
2.1.4. Discretización del dominio / *Domain discretization*

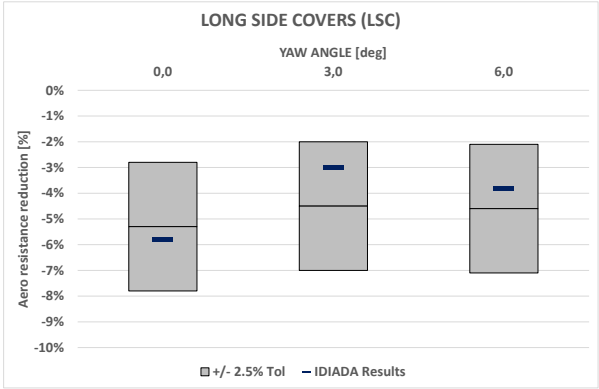
CAMPO / *FIELD*	**VALOR / *VALUE***	**CUMPLE / *FULFILS* NO CUMPLE / *DOES NOT FULFIL***
Recuento de celdas / *Mesh cell count*	≥ 60 millones de celdas / *≥ 60 million cells*	Si / *Yes* ~~No / *No*~~
Refinamiento de malla aplicado en áreas aerodinámicamente relevantes / *Mesh refinement applied to aerodynamic relevant areas*	-	Si / *Yes* ~~No / *No*~~

3. VERIFICACIÓN DEL MODELO VIRTUAL / *VIRTUAL MODEL VERIFICATION*

El método de simulación de dinámica de fluidos computacional (CFD) debe tener una exactitud correspondiente a Δ(CD×A) durante la validación en cada una de las seis comparaciones con respecto a los intervalos de referencia, de acuerdo con los límites establecidos en la Tabla 3 del Anexo V del Reglamento (UE) 2022/1362) / *The computational fluid dynamics (CFD) simulation method shall fulfil an accuracy for Δ(CD×A) during the validation for each of the six comparisons in accordance with the limits in Table 3 of Annex V of Regulation (EU) 2022/1362*:

Conjunto de simulación / *Simulation set*	**Ángulo de guiñada / *Yaw angle* β(º)**					
	0,0º		**3,0º**		**6,0º**	
	(C_D×A) (m^2)	**Δ(C_D×A) (%)**	**(C_D×A) (m^2)**	**Δ(C_D×A) (%)**	**(C_D×A) (m^2)**	**Δ(C_D×A) (%)**
BASE	4.16	-	4.35	-	5.02	-
TRF	3.93	-5.56 %	4.15	-4.62%	4.59	-8.60%
LSC	3.92	-5.80%	4.22	-3.00%	4.83	-3.80%





Todos los valores de decremento porcentual de C_D×A respecto a la configuración BASE quedan dentro de la tolerancia / *All percentage decrement values of C_D×A with respect to BASE configuration are within the tolerances:*

CUMPLE / *FULFILS*
~~NO CUMPLE / *DOES NOT FULFIL*~~

Datos adicionales para la validación del método CFD / *Adicional data for the CFD method Validation*

- **Métodos de condiciones estables / *Steady-state methods*:** APLICA / *APPLICABLE*
  ~~NO APLICA / *NOT APPLICABLE*~~
  - Datos brutos de la evolución de C_D (o C_D×A) frente a iteración (csv) / *Raw data of the evolution of C_D (o C_D×A) vs iteration (csv)* — Adjunto / *Attached*
  - Media de las últimas 400 iteraciones / *Average of the last 400 iteratios* — Adjunto / *Attached*
- **Métodos de condiciones transitorias / *Transient methods*:** ~~APLICA / *APPLICABLE*~~
  NO APLICA / *NOT APPLICABLE*
  - Datos brutos de la evolución de C_D (o C_D×A) frente a tiempo (csv) / *Raw data of the evolution of C_D (o C_D×A) vs time (csv)*
  - Media de los últimos 5 segundos / *Average of the last 5 seconds*
- **Sección del plano XY del dominio de simulación / *XY plane section intersecting the entire simulation domain*:**
  - Atravesando el punto de rotación de las ruedas del eje delantero del tractocamión / *Passing through the tractor front axle wheel rotation point* — Adjunto / *Attached*
  - Mostrando la magnitud de la velocidad del flujo del aire en una escala que va de 0 a 30 m/s y con una barra de color dividida, como mínimo, en 18 niveles de color / *Showing the airflow velocity magnitude in a scale going from 0 to 30 m/s and with a colour bar divided in, at least, 18 colour levels*
- **Sección del plano XY del dominio de simulación / *XY plane section intersecting the entire simulation domain*:**
  - Atravesando los retrovisores laterales del tractocamión / *Passing through the tractor side mirrors* — Adjunto / *Attached*
  - Mostrando la magnitud de la velocidad del flujo del aire en una escala que va de 0 a 30 m/s y con una barra de color dividida, como mínimo, en 18 niveles de color / *Showing the airflow velocity magnitude in a scale going from 0 to 30 m/s and with a colour bar divided in, at least, 18 colour levels*
- **Sección del plano YZ del dominio de simulación- / *YZ plane section intersecting the entire simulation domain*:**
  - Atravesando el punto de rotación de las ruedas del eje delantero del tractocamión / *Passing through the tractor front axle wheel* — Adjunto / *Attached*

rotation point

- Mostrando la magnitud de la velocidad del flujo del aire en una escala que va de 0 a 30 m/s y con una barra de color dividida, como mínimo, en 18 niveles de color / *Showing the airflow velocity magnitude in a scale going from 0 to 30 m/s and with a colour bar divided in, at least, 18 colour levels*

- **Sección del plano XZ del dominio de simulación / *XZ plane section intersecting the entire simulation domain*:**
  - Atravesando el centro del vehículo / *Passing through the centre of the vehicle*
  - Mostrando la magnitud de la velocidad del flujo del aire en una escala que va de 0 a 30 m/s y con una barra de color dividida, como mínimo, en 18 niveles de color / *Showing the airflow velocity magnitude in a scale going from 0 to 30 m/s and with a colour bar divided in, at least, 18 colour levels*

  Adjunto / *Attached*

- **Posición del sistema de coordenadas en relación con el vehículo / *Position of the coordinate system in relation to the vehicle*:**
  - El eje X debe estar orientado a lo largo de la dirección longitudinal del vehículo / *The X-axis shall be oriented along the longitudinal direction of the vehicle*
  - El eje Y debe estar orientado a lo largo de la anchura del vehículo / *The Y-axis shall be oriented along the width of the vehicle*
  - El eje Z debe estar orientado a lo largo de la altura del vehículo / *The Z-axis shall be oriented along the height of the vehicle*

  Adjunto / *Attached*

4. DOCUMENTOS DE REFERENCIA / *REFERENCE DOCUMENTS*

En la siguiente tabla se muestran los documentos de referencia utilizados para la validación de la metodología. /
The next table shows the reference documents used for the validation of the methodology.

Descripción / *Description*	Archivo de referencia / *Reference file*	Responsable del documento / *Document responsible*
Informe metodológico / *Methodology report*	22INN_TENDER_CFD_TRAILE _2023 05 09	Albert Gascón (IDIADA Automotive Technology, SA)
Geometrías genéricas / *Generic geometries*	Véase el apartado 2.1.1 / *See paragraph 2.1.1*	

Lugar del ensayo / *Place of test*: L'Albornar (Santa Oliva)
Fecha del ensayo / *Date of test*: 02/06/2023

Francesc Xavier Font Mila
INGENIERO DE HOMOLOGACIONES
HOMOLOGATION ENGINEER

DOCUMENTACIÓN TÉCNICA /
TECHNICAL DOCUMENTATION

CFD METHOD VALIDATION

(Semi-)Trialer Aerodynamic Add-ons

CV23060122

REPORT: 22INN_TENDER_CFD_TRAILE_2023-05-09

Mr ALBERT GASCÓN VALLBONA

IDIADA CFD Group Coordinator

9th May 2023

CONFIDENTIAL

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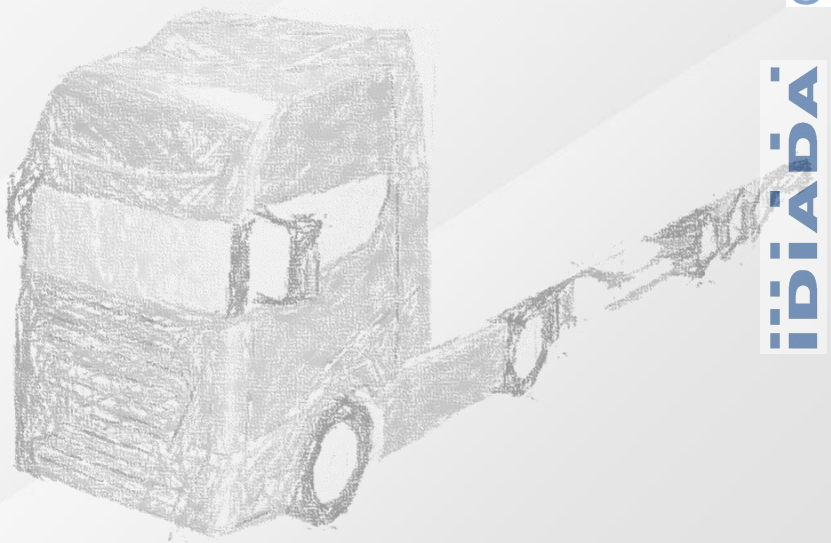

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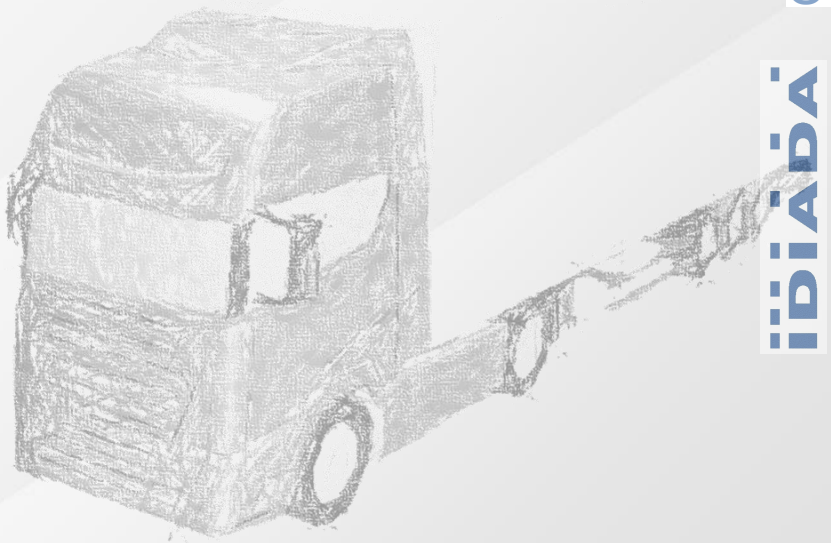

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CFD SOFTWARE

SIMCENTER STAR-CCM+

- Software name and version:

  Simcenter STAR-CCM+ v16.04.012

- Software vendor:

  SIEMENS Industry Software Inc

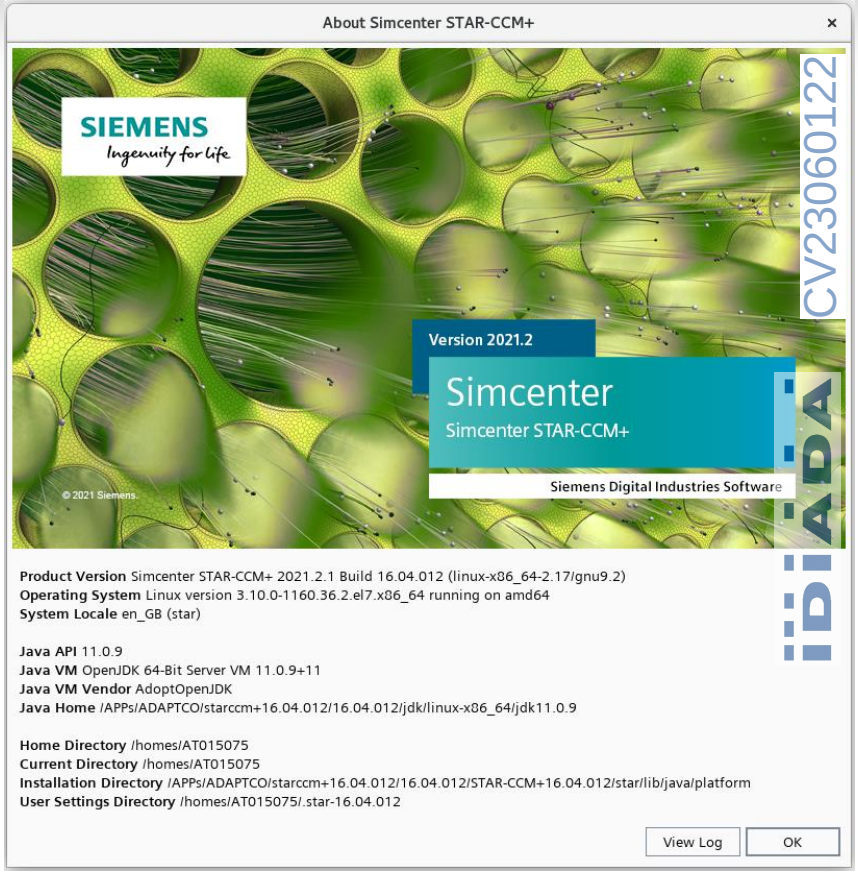
- Operating System:

  LINUX

- Software vendor contact details:

  5800 Granite Parkway 600

  75024 Plano, Texas, United States



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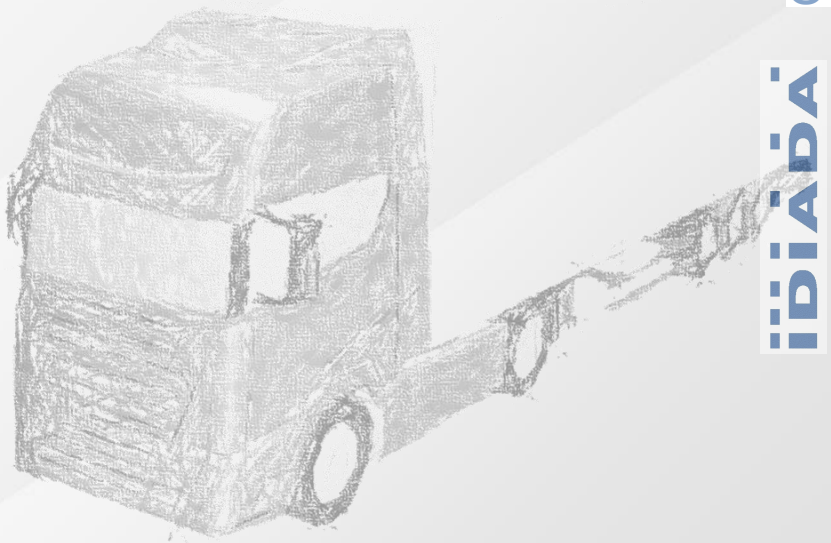

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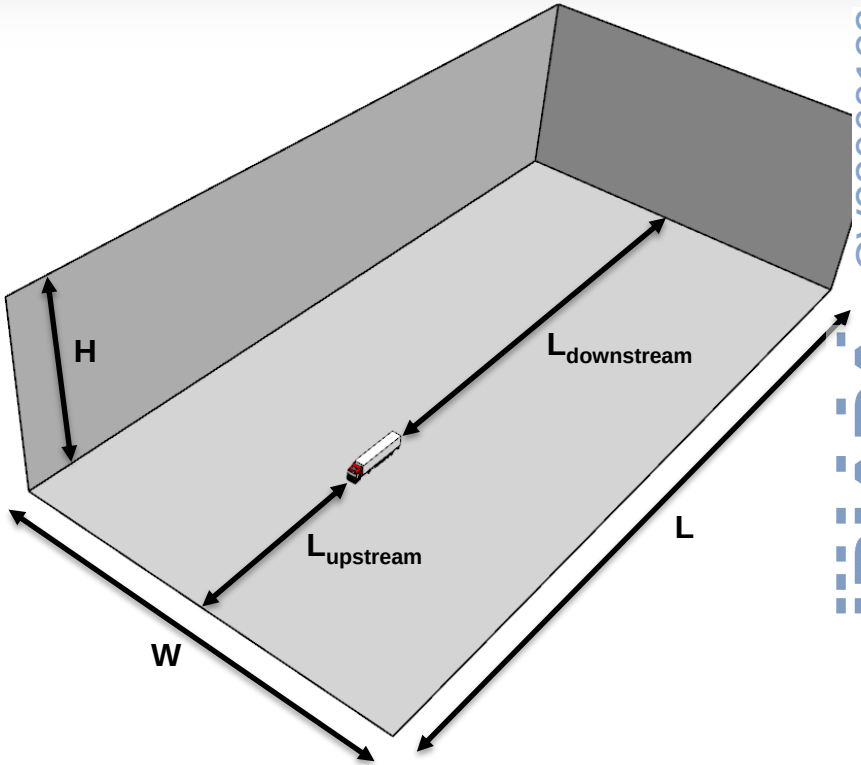
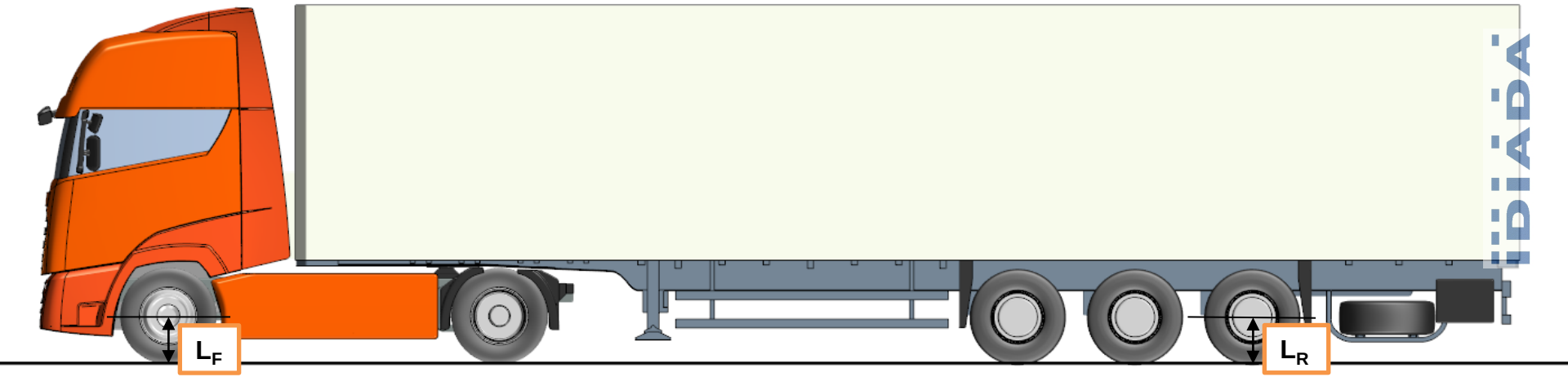
Simulation Domain & Vehicle Positioning

Air Domain

- Vehicle simulated under open road conditions rather than encapsulated within a particular wind tunnel.
- Domain is large enough so blockage effects can be neglected
  - L = 200.0 m
    - $L_{upstream} \approx 38.5$ m
    - $L_{downstream} \approx 145.0$ m
  - W = 100.0 m
  - H = 50.5 m
  - Vehicle Frontal Area = 10,047 m^2
    - Blockage ratio = 0,20%



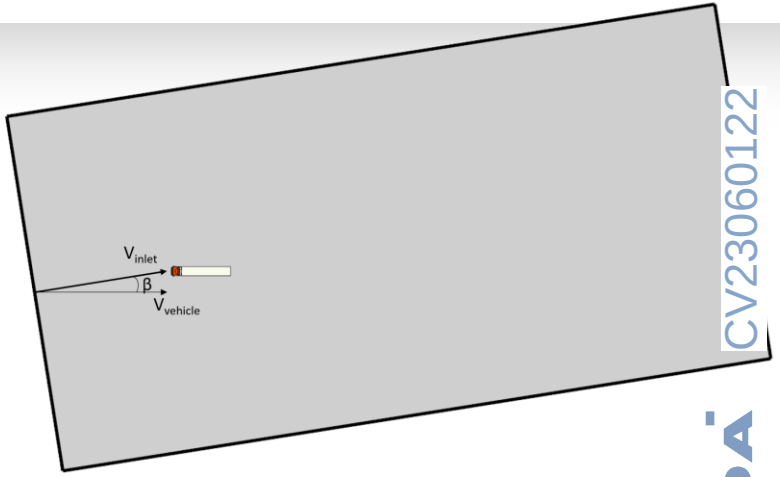
- L_F = 527,00 mm
- L_R = 514,64 mm



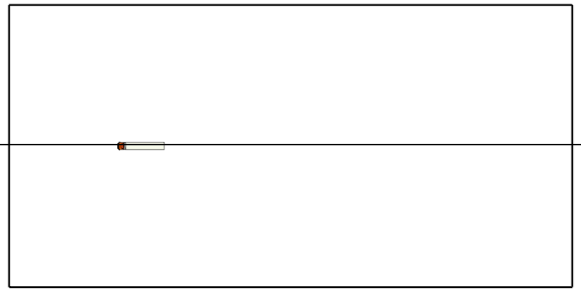
Simulation Domain & Vehicle Positioning

Crosswind Modelling

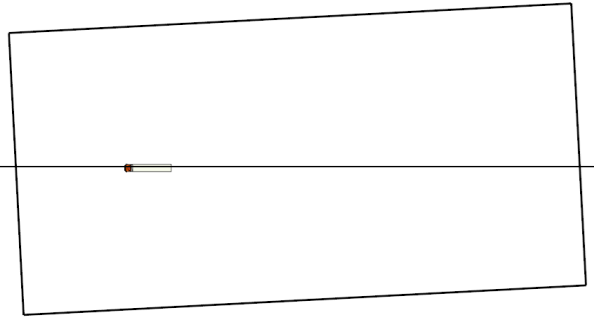
- Vehicle position is not modified
- Simulation domain is rotated accordingly
  - Crosswind coming from the left-hand side of the vehicle
  - Air velocity is always modeled perperdicular to the inlet



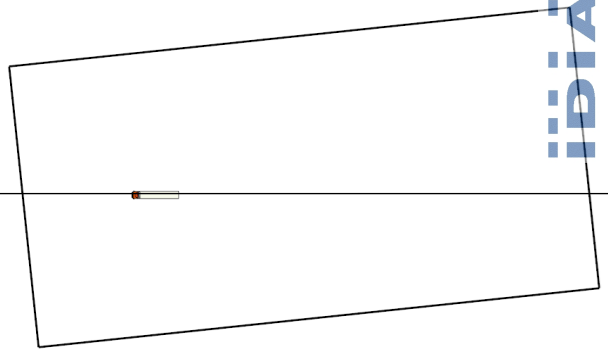
β = 0,0 deg



β = 3,0 deg



β = 6,0 deg



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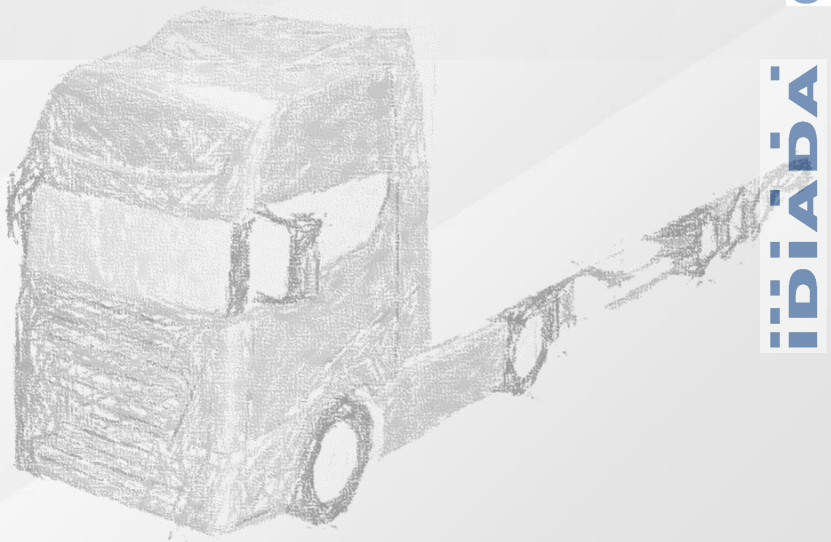
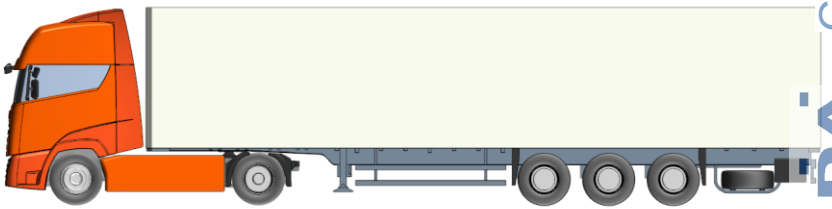


VEHICLE CONFIGURATIONS

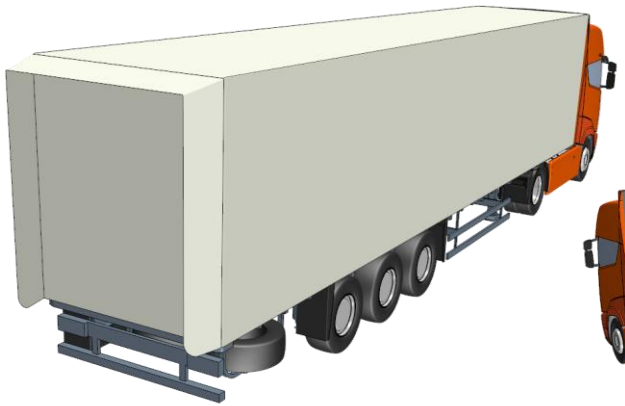
BASELINE (BASE)

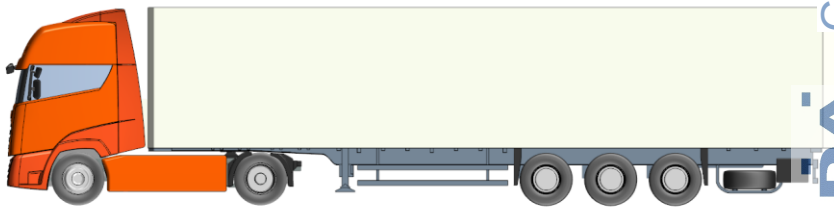
- Tractor source: *https://code.europa.eu/vecto/vecto-cfd/-/blob/main/cfd_files/01_Tractor_4x2/*
- Semitrailer source: *https://code.europa.eu/vecto/vecto-cfd/-/blob/main/cfd_files/04_DA_ST1/*



VEHICLE CONFIGURATIONS
TALL REAR FLAPS (TRF)

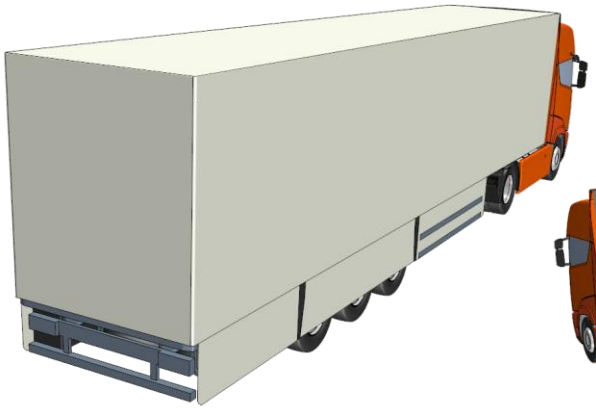
- Tractor source: *https://code.europa.eu/vecto/vecto-cfd/-/blob/main/cfd_files/01_Tractor_4x2/*
- Semitrailer source: *https://code.europa.eu/vecto/vecto-cfd/-/blob/main/cfd_files/04_DA_ST1/*
- TRF source: *https://code.europa.eu/vecto/vecto-cfd/-/tree/main/cfd_files/99_ST1_GenericAeroEnablers*

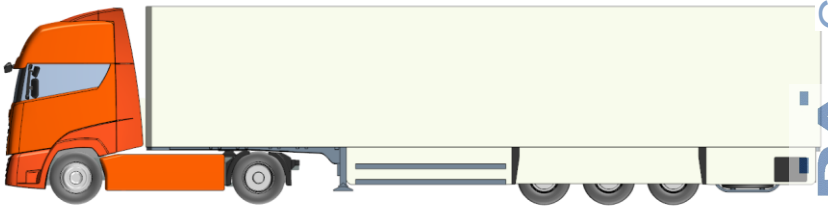




VEHICLE CONFIGURATIONS
LONG SIDE COVERS (LSC)

- Tractor source: *https://code.europa.eu/vecto/vecto-cfd/-/blob/main/cfd_files/01_Tractor_4x2/*
- Semitrailer source: *https://code.europa.eu/vecto/vecto-cfd/-/blob/main/cfd_files/04_DA_ST1/*
- LSC source: *https://code.europa.eu/vecto/vecto-cfd/-/tree/main/cfd_files/99_ST1_GenericAeroEnablers*





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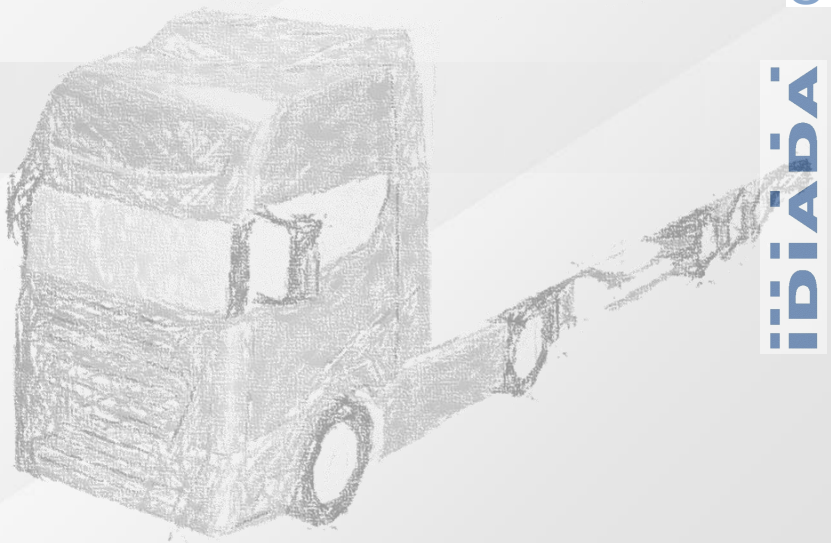

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MESH SETTINGS

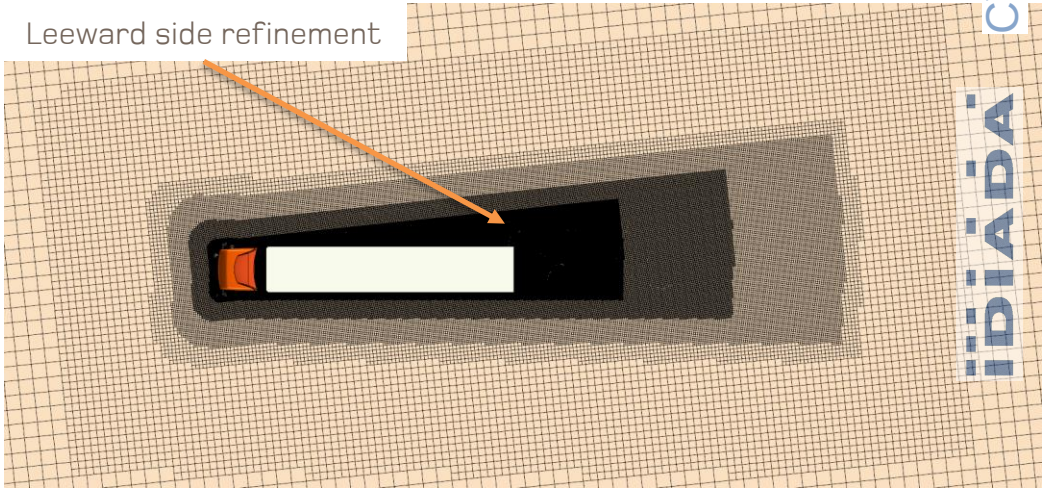
GENERAL MESH SETTINGS

- The cell count is between 100 and 122 million cells (depending on the load case).

  Cell count increases with the yaw angle due to the mesh refinement in the leeward side of the vehicle.

Cell count (in million):

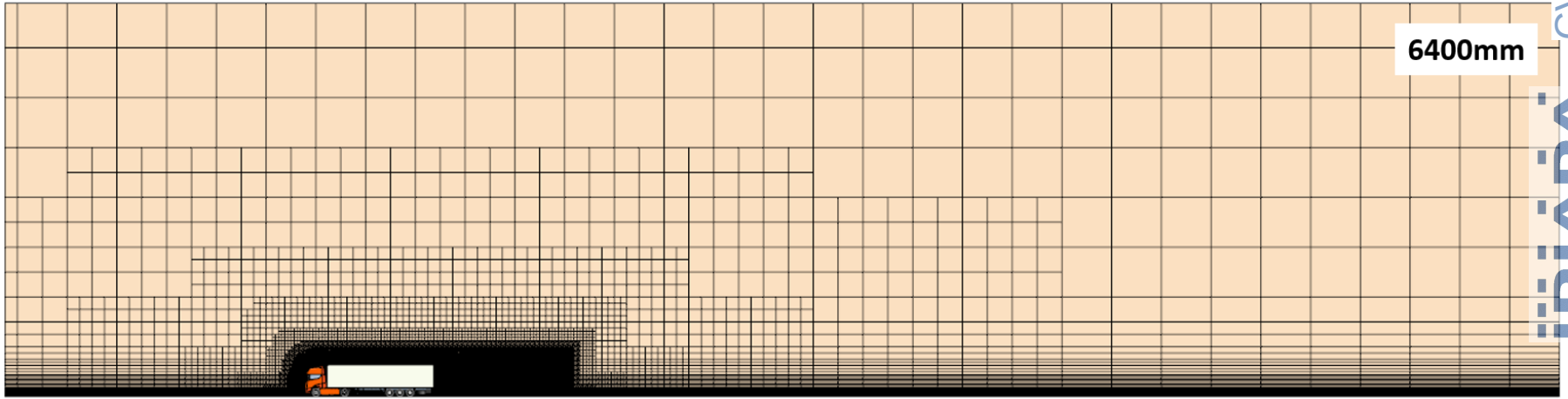
	BASE	TRF	LSC
Yaw = 0,0 deg	104,6	106,3	110,3
Yaw = 3,0 deg	110,5	112,1	116,1
Yaw = 6,0 deg	115,2	116,8	121,0



MESH SETTINGS

GENERAL MESH SETTINGS

- A cell size between 5 and 25mm is used in close vicinity to the vehicle and steadily growing the size as the cells mov away towards to domain limits.



Mesh detail in Y mid section

MESH SETTINGS

GENERAL MESH SETTINGS

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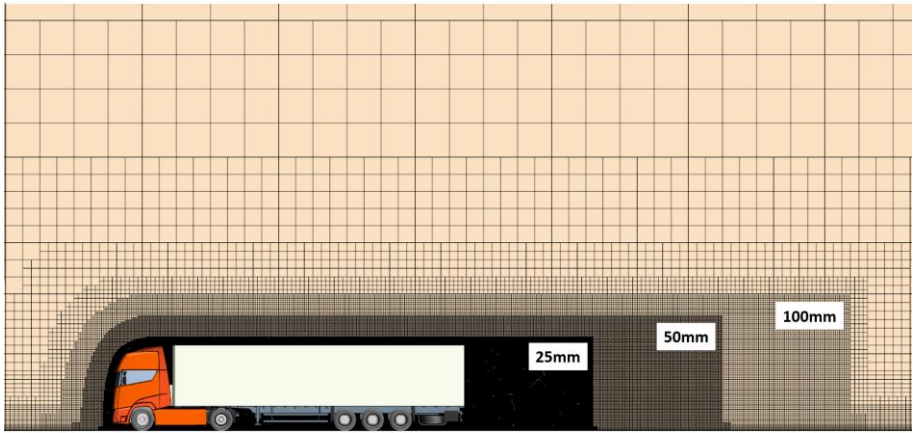
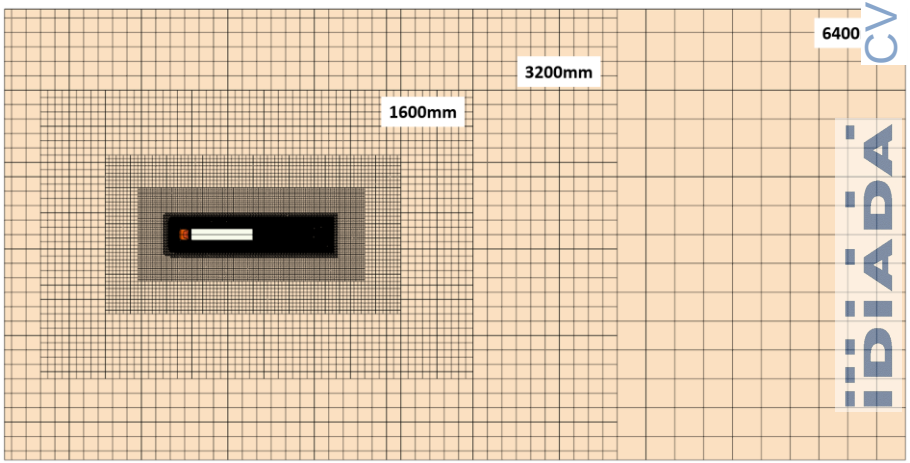


Mesh detail in Y mid section



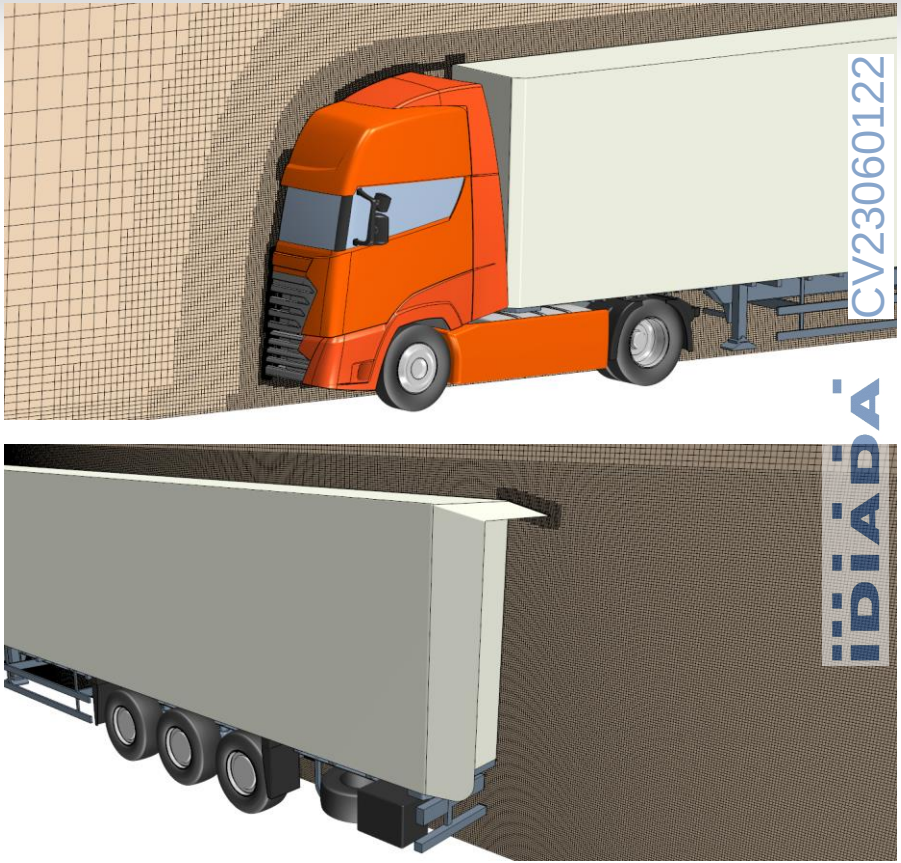
Mesh detail in Z section (across tractor front axle)

Mesh Settings

General Mesh Settings

- Mesh refinement is applied to aerodynamic relevant areas, such as:

  - Rear view mirrors
  - Tractor-trailer gap deflectors
  - A-pillars
  - Vehicle rear wake (including TRF system)
  - Cooling airflow intake grille
  - Tyres contact patch



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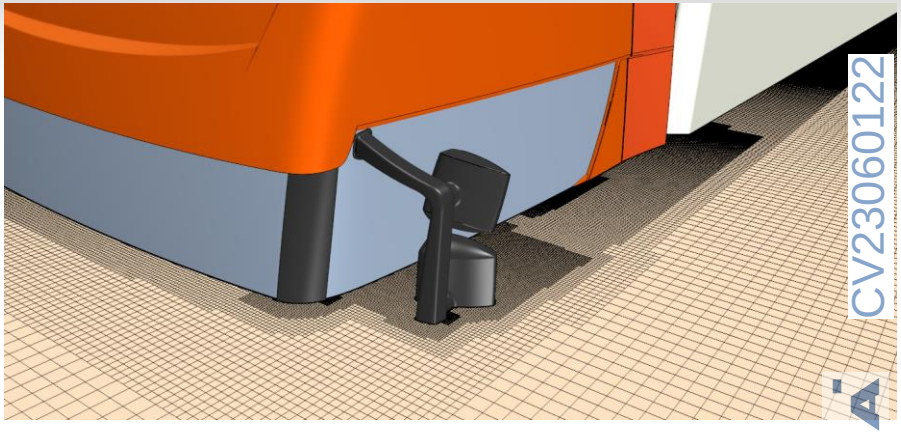

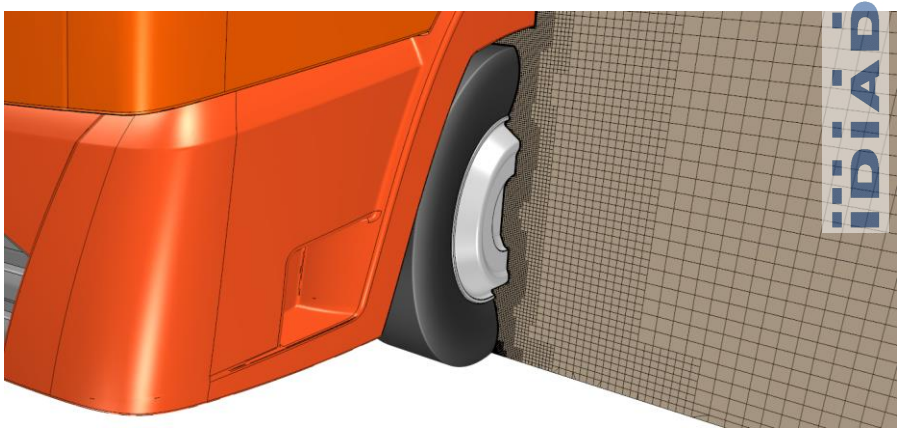

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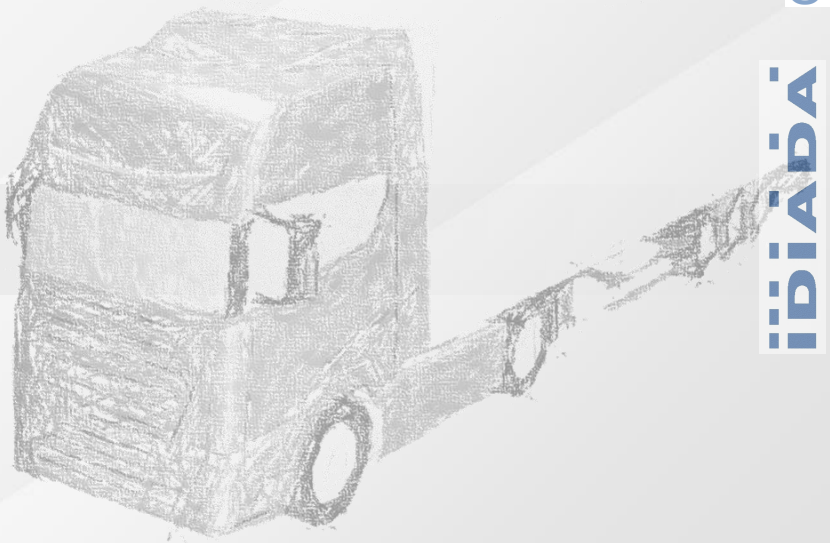

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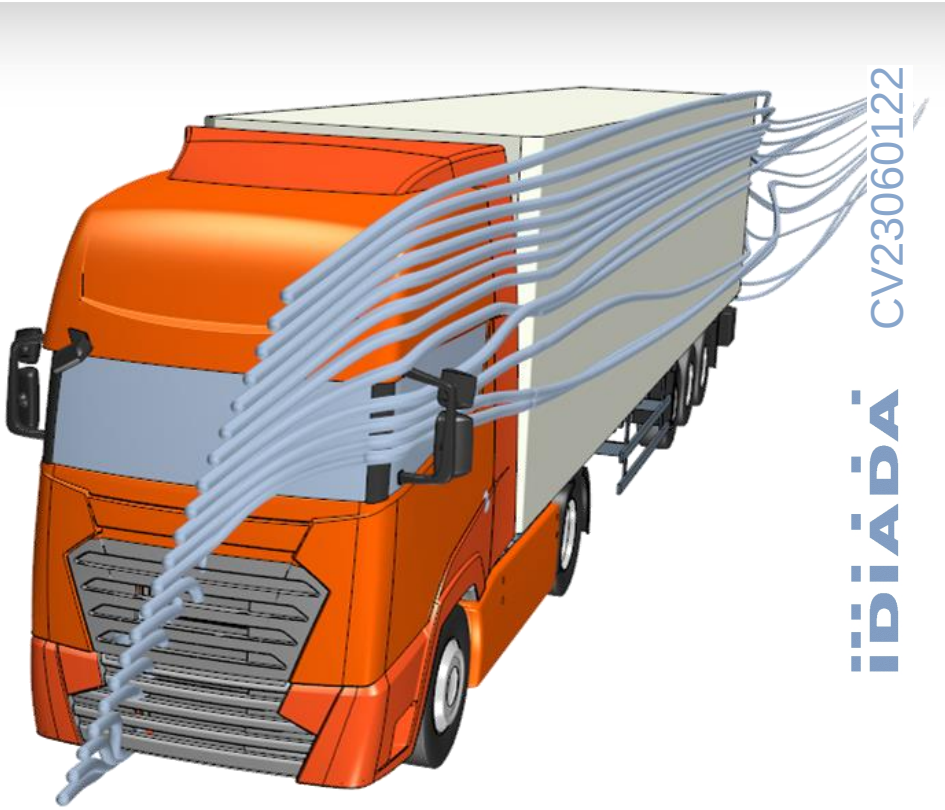
PHYSICS SETTINGS & BOUNDARY CONDITIONS

GENERAL PHYSICS SETTINGS

- Space:
  - Three Dimensional
- Time:
  - Steady-State
- Material:
  - Gas (air)
    - Constant Density = 1,18415 kg/m^3
- Turbulence Model:
  - RANS K-Omega SST (Menter)
    - All Y+ Wall Treatment



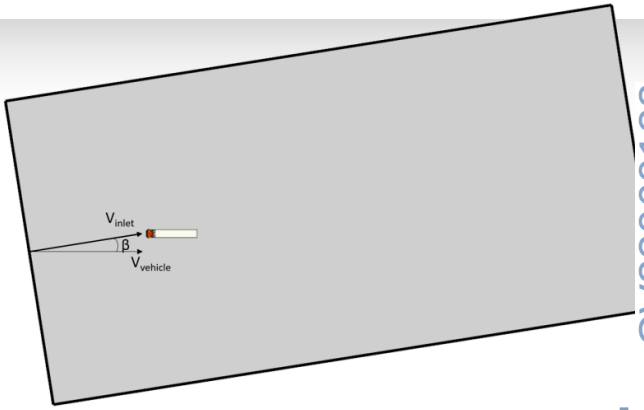
GENERAL BOUNDARY CONDITIONS

- Vehicle Speed = 25,0 m/s (= 90,0 km/h)
  - Air inlet velocity depends on the yaw angle:

Yaw angle [deg]	0,0	3,0	6,0
$v_{vehicle}$ [m/s]	25,0	25,0	25,0
v_{inlet} [m/s]	25,000	25,034	25,138

- The floor of the domain is modelled with a tangential velocity of 25,0 m/s in the vehicle advancing opposite direction.
- Vehicle wheels are also modelled with a tangential velocity to account for their rotation based on the wheel radius:

Wheels	Radius [m]	Vehicle Velocity [m/s]	Wheel Angular Velocity [rad/s]
Tractor	0,538	25,0	46,468
Semitrailer	0,539	25,0	46,382



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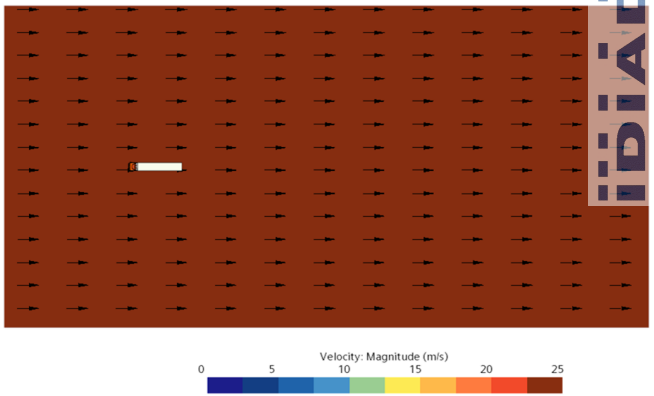
Velocity vectors in the ground domain:



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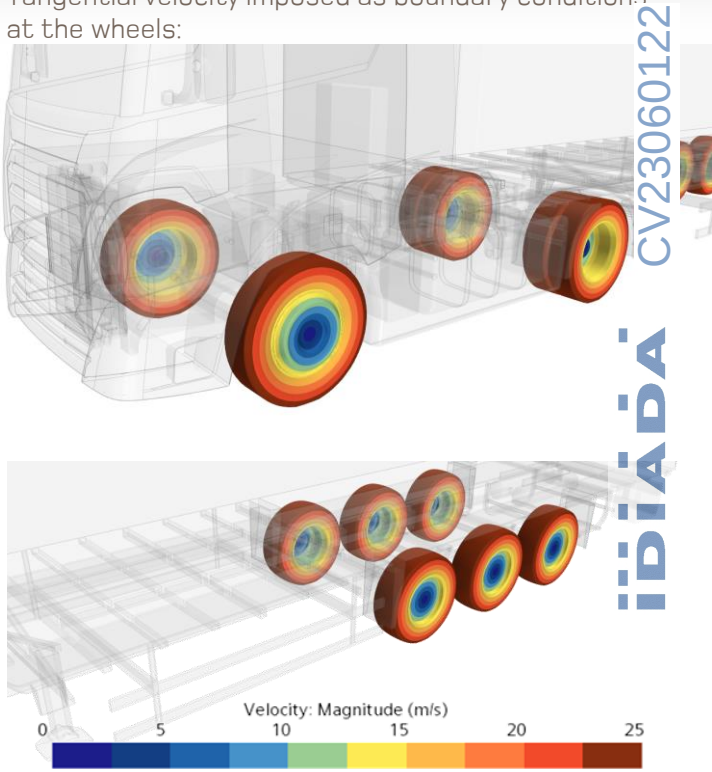
Wheels	Radius [m]	Vehicle Velocity [m/s]	Wheel Angular Velocity [rad/s]
Tractor	0,538	25,0	46,468
Semitrailer	0,539	25,0	46,382

Tangential velocity imposed as boundary conditions at the wheels:

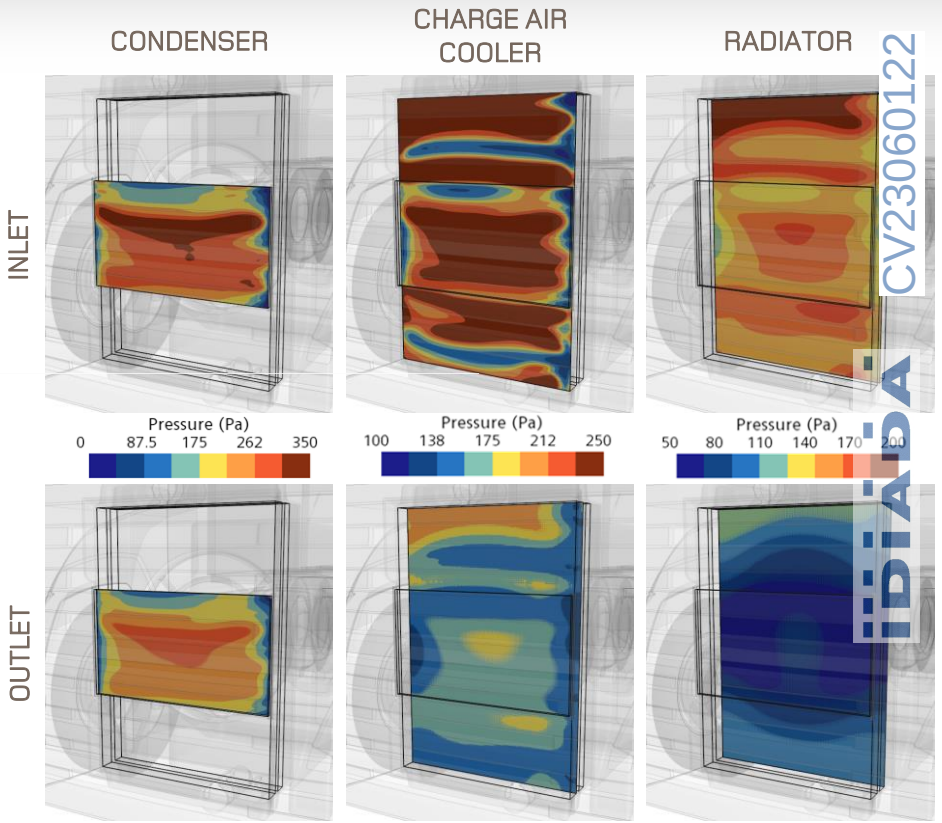


PHYSICS SETTINGS & BOUNDARY CONDITIONS

GENERAL BOUNDARY CONDITIONS

- The pressure losses across the different heat exchangers conforming the cooling pack (condenser, charge air cooler and radiator) have been characterized with the Darcy-Forchheimer model with the following viscous and inertial resistance coefficients:

Coefficient	Heat Exchanger		
	Condenser	Charge Air Cooler	Radiator
Intertial Resistance P_i [kg/m^4]	140,00	60,00	120,00
Viscous Resistance P_v [kg/m^{3}s]	450,00	300,00	450,00



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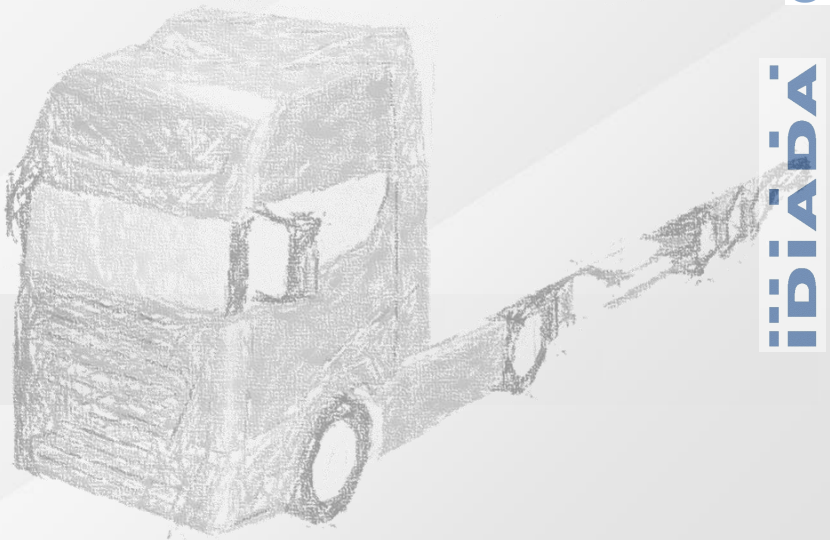

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RESULTS

AIR DRAG VALUES

- C_DxA[m^2] values predicted by CFD (average of the last 400 iterations):

Simulation Set	Yaw Angle – β [deg]		
	0,0	3,0	6,0
BASE	4,16	4,35	5,02
TRF	3,93	4,15	4,59
LSC	3,92	4,22	4,83

- Standard deviation (σ) of C_DxA[m^2] of the last 400 iterations, calculated as $\sigma = \sqrt{\frac{\sum(c_D \cdot A - \overline{c_D \cdot A})^2}{400}}$

Simulation Set	Yaw Angle – β [deg]		
	0,0	3,0	6,0
BASE	0,00077	0,00189	0,00192
TRF	0,00130	0,00129	0,00201
LSC	0,00064	0,00269	0,00085

C_DxA [m^2] vs iteration data available in Annex X

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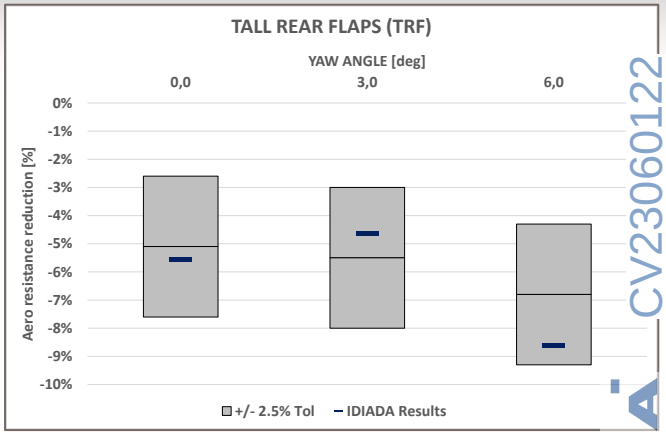
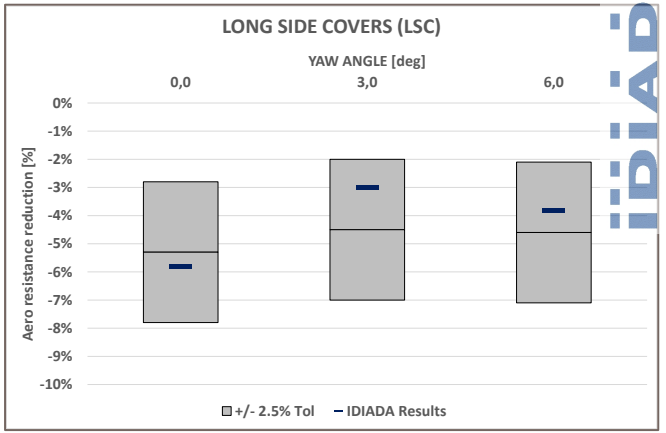
- The aerodynamic effect of the tall rear flaps (TRF) and the long side covers (LSC) is expressed, in percentage reduction, as follows:

$$Aero\ Device\ Effect\ (\%) = \frac{c_D \cdot A^{AeroDevice} - c_D \cdot A^{Base}}{c_D \cdot A^{Base}} x\ 100$$

Simulation Set	Yaw Angle – β [deg]		
	0,0	3,0	6,0
TRF	-5,56%	-4,62%	-8,60%
LSC	-5,80%	-3,00%	-3,80%

- All values fall well within the required ±2,5% accuracy specified in the regulation.





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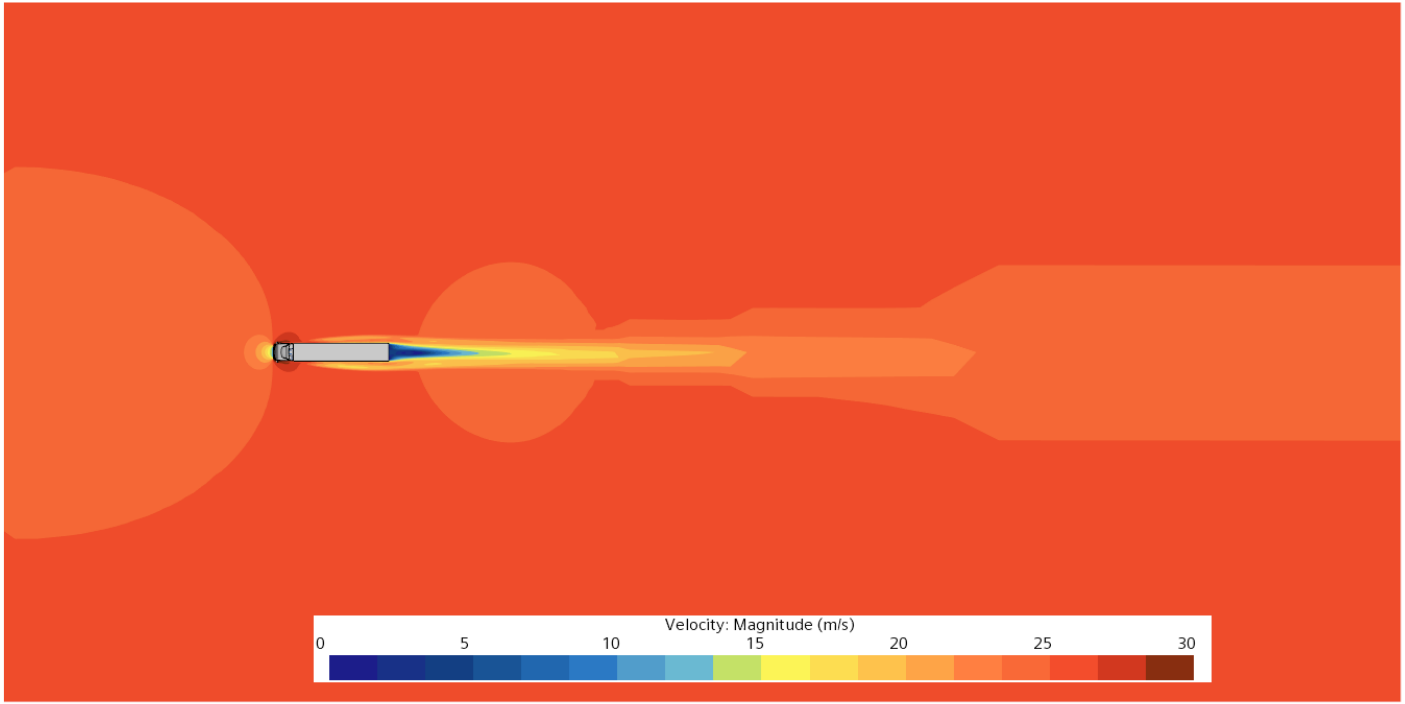
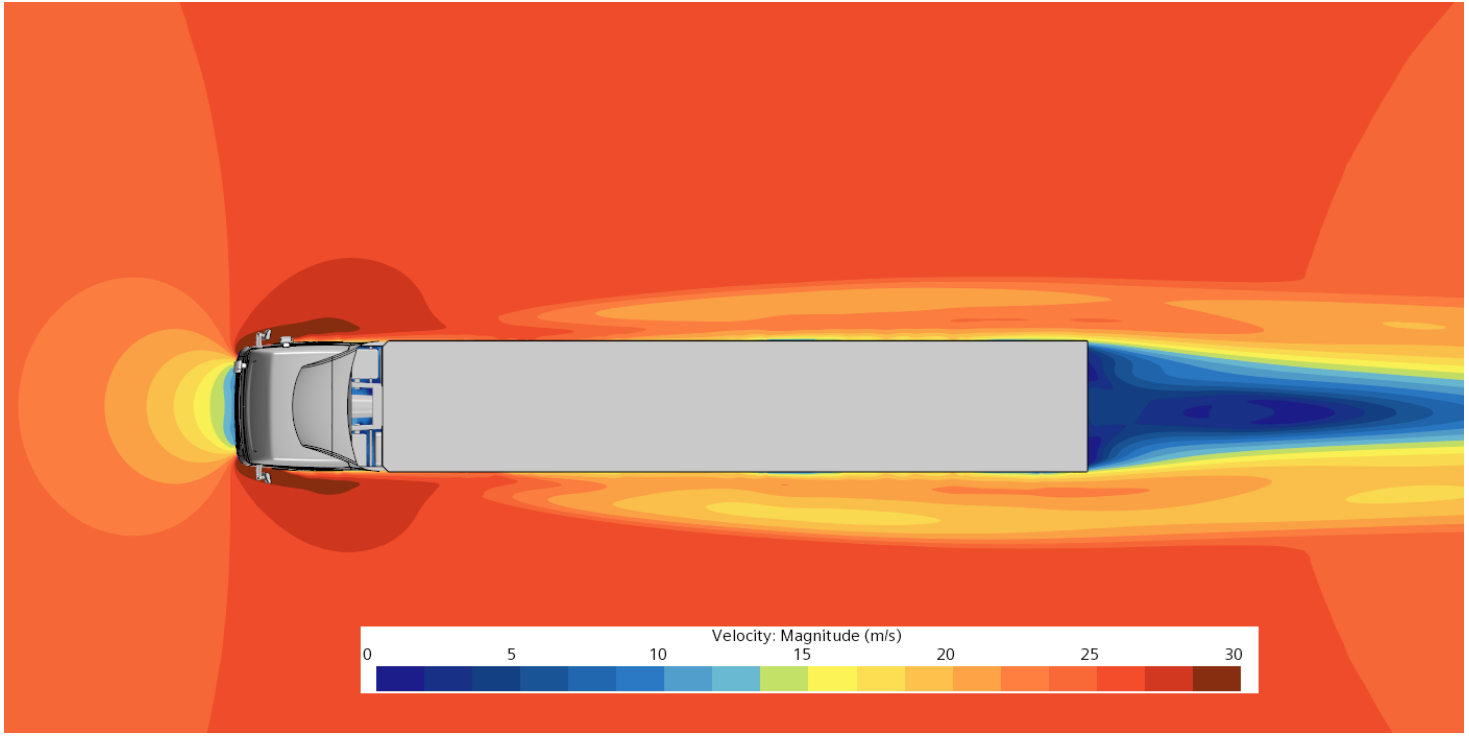
ANNEX I

BASE AT 0,0 DEG OF YAW

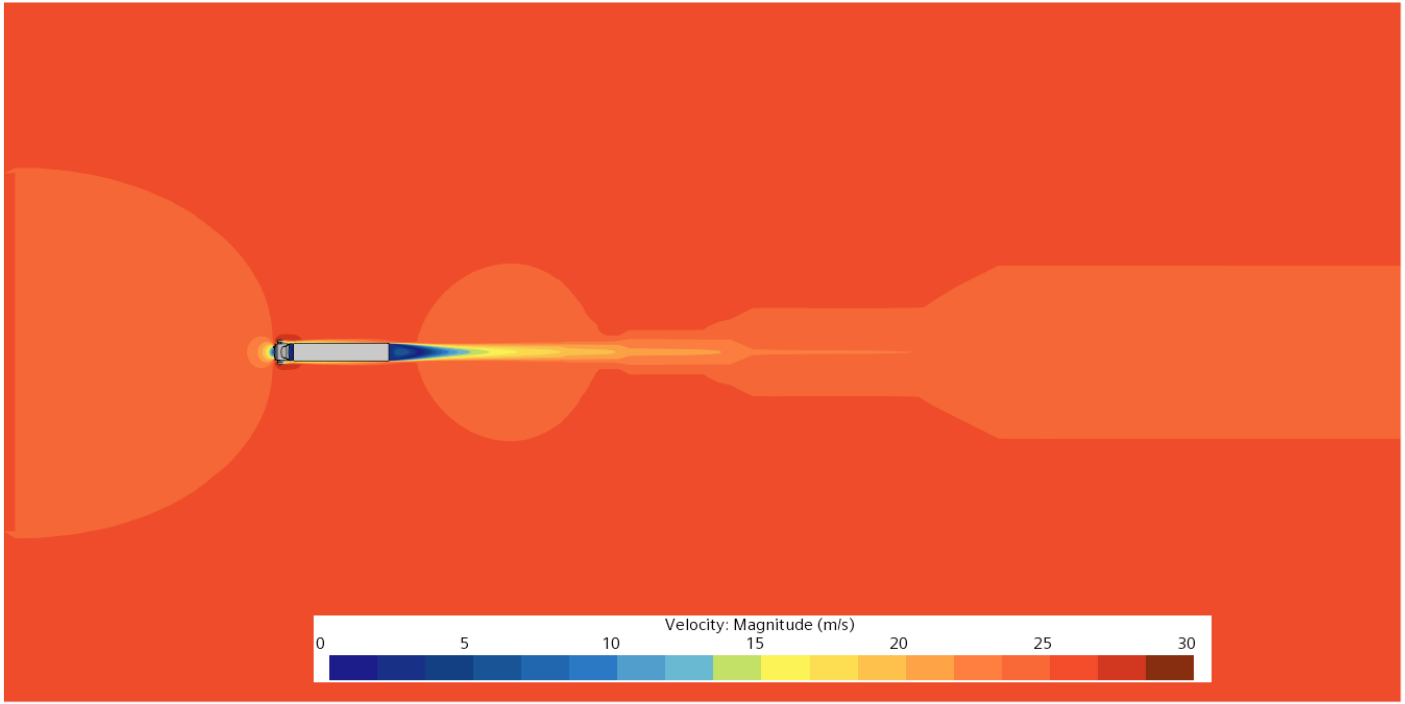
- BASE at 0,0deg. XY plane through the tractor front axle. Entire domain



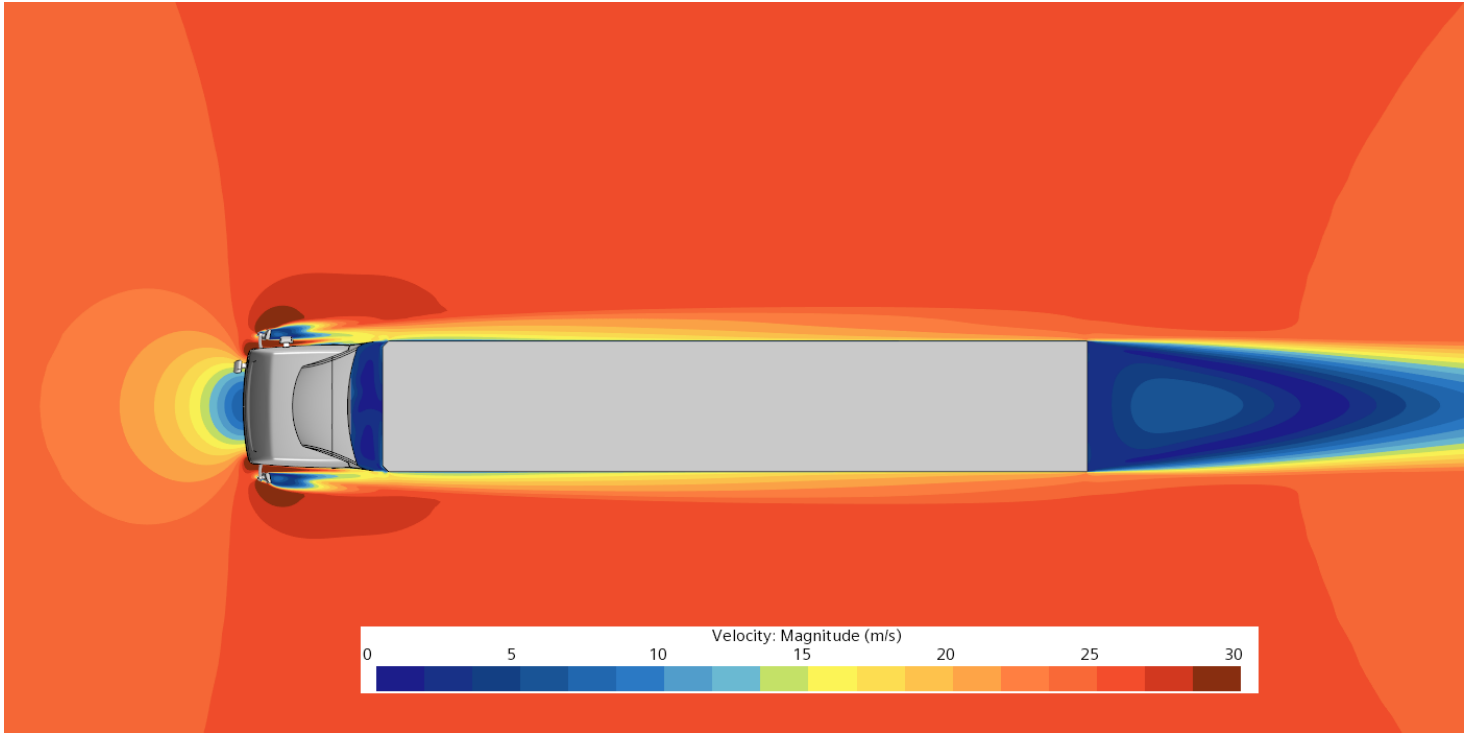
- BASE at 0,0deg. XY plane through the tractor front axle. Vehicle detail



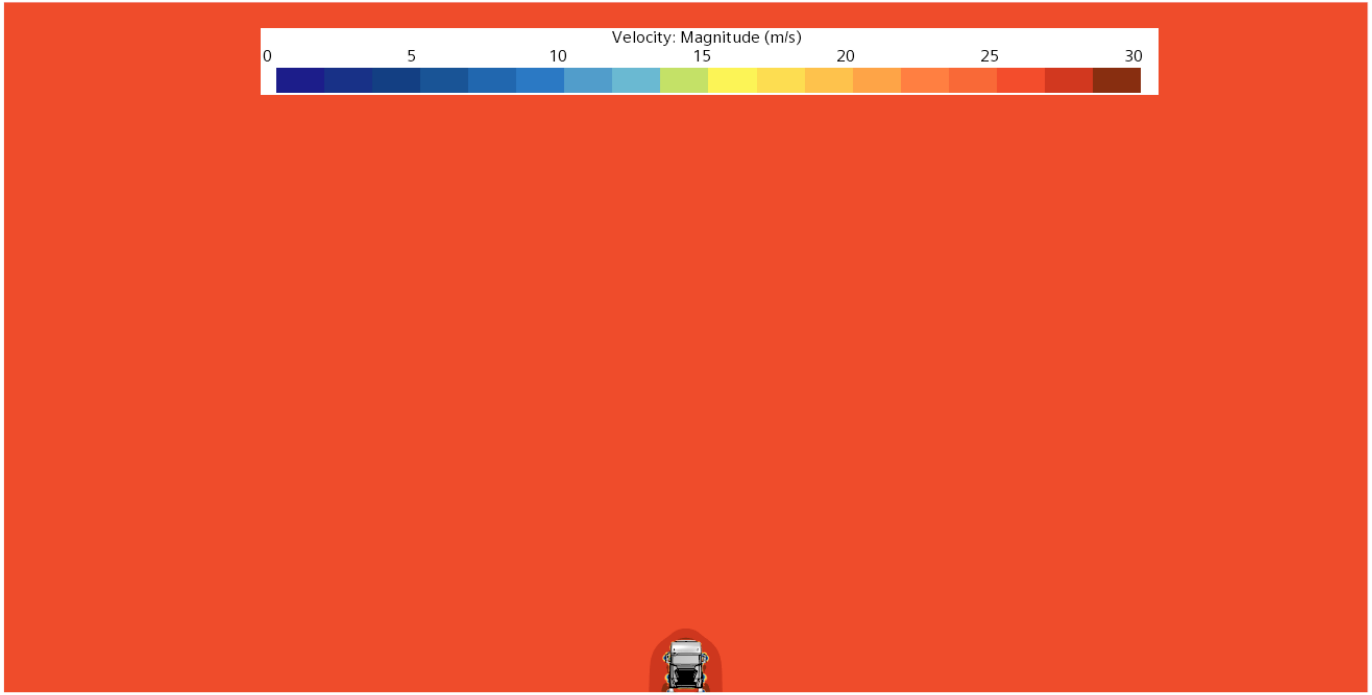
- BASE at 0,0deg. XY plane through the tractor side mirrors. Entire domain



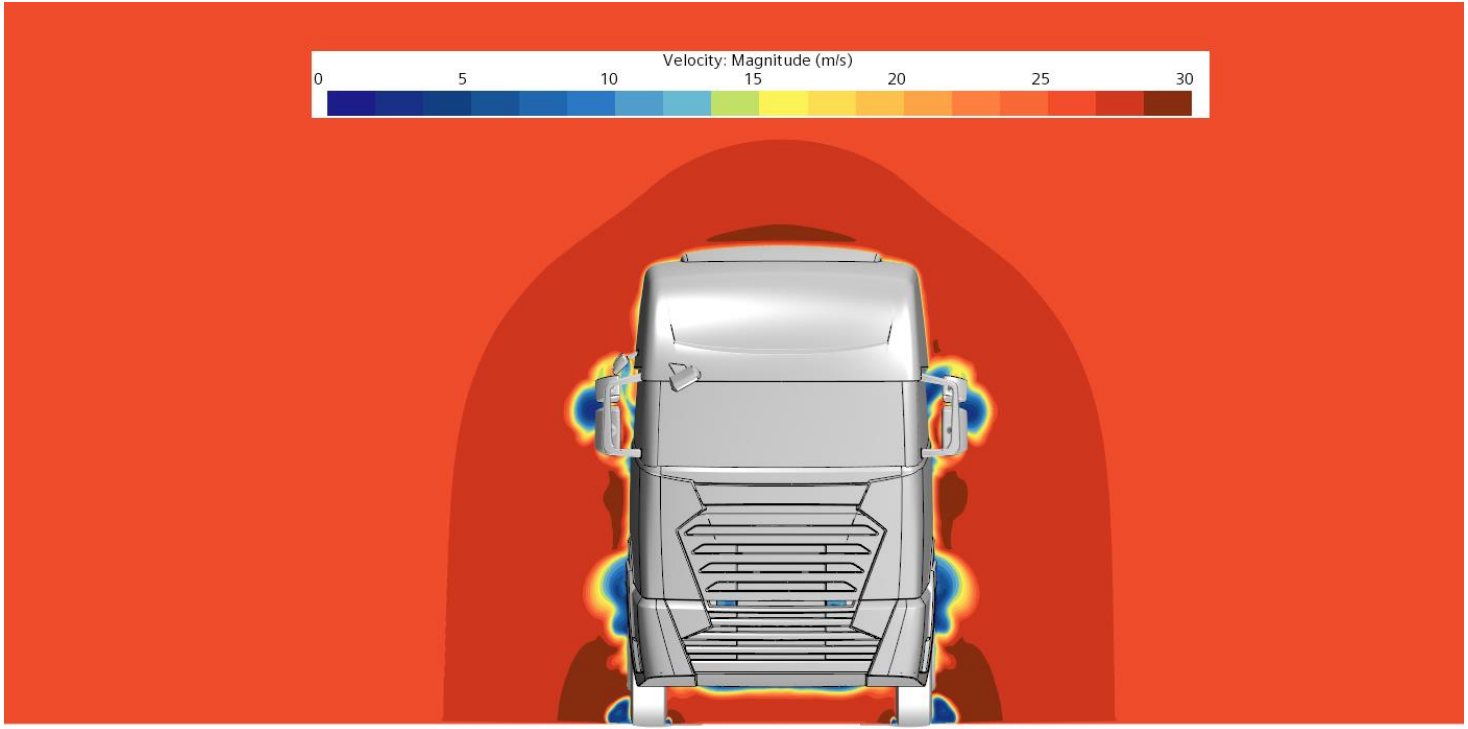
- BASE at 0,0deg. XY plane through the tractor side mirrors. Vehicle detail



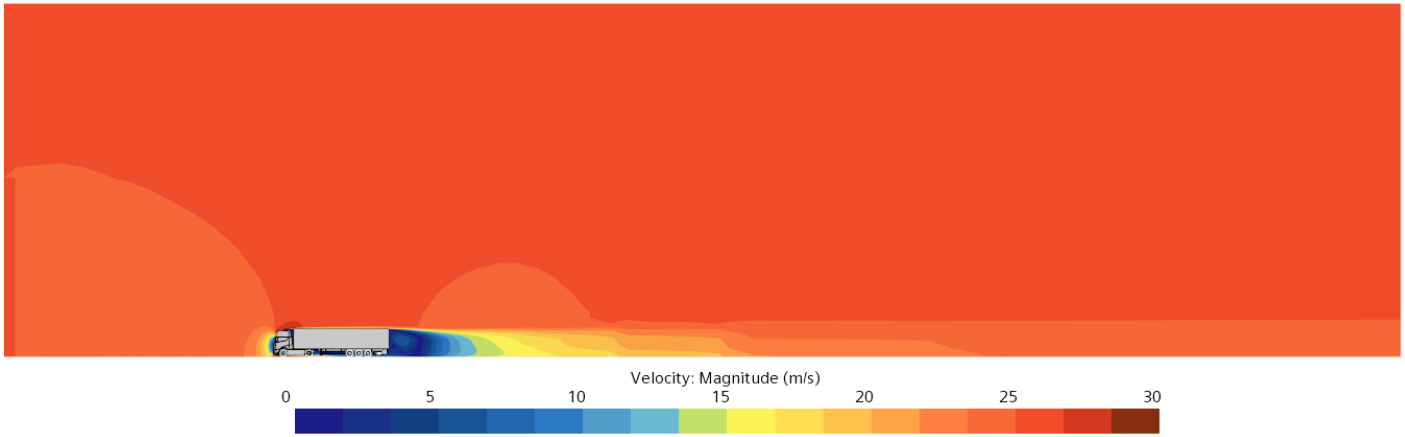
- BASE at 0,0deg. YZ plane through the tractor front axle. Entire domain



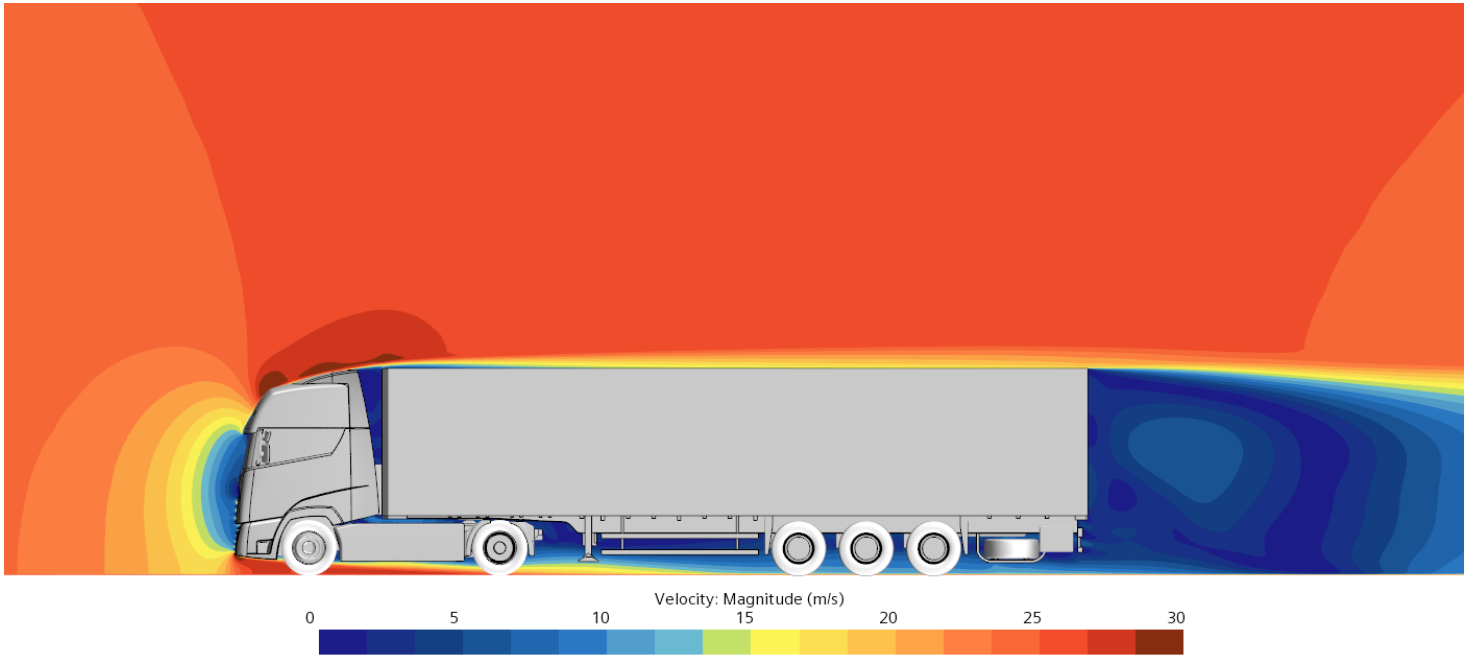
- BASE at 0,0deg. YZ plane through the tractor front axle. Vehicle detail



- BASE at 0,0deg. XZ plane through the centre of the vehicle. Entire domain



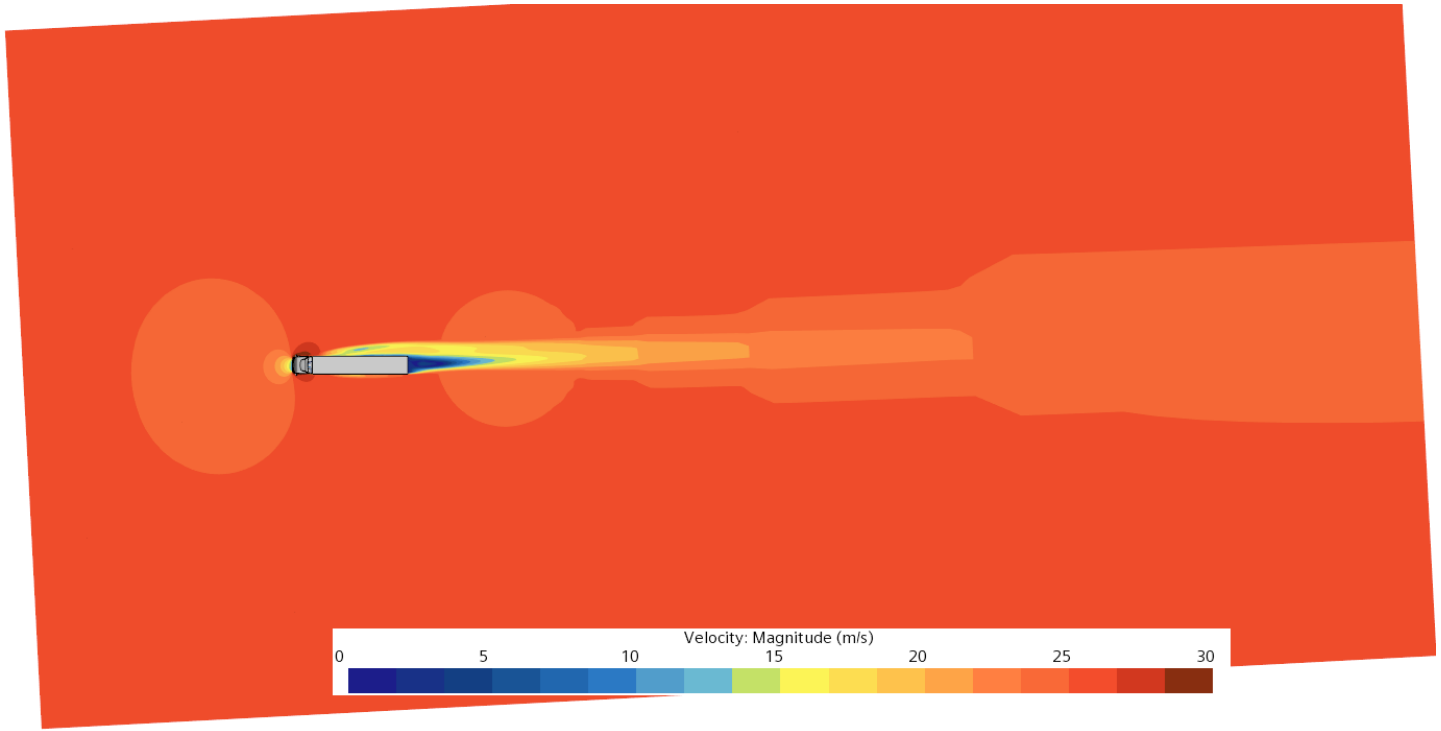
- BASE at 0,0deg. XZ plane through the centre of the vehicle. Vehicle detail



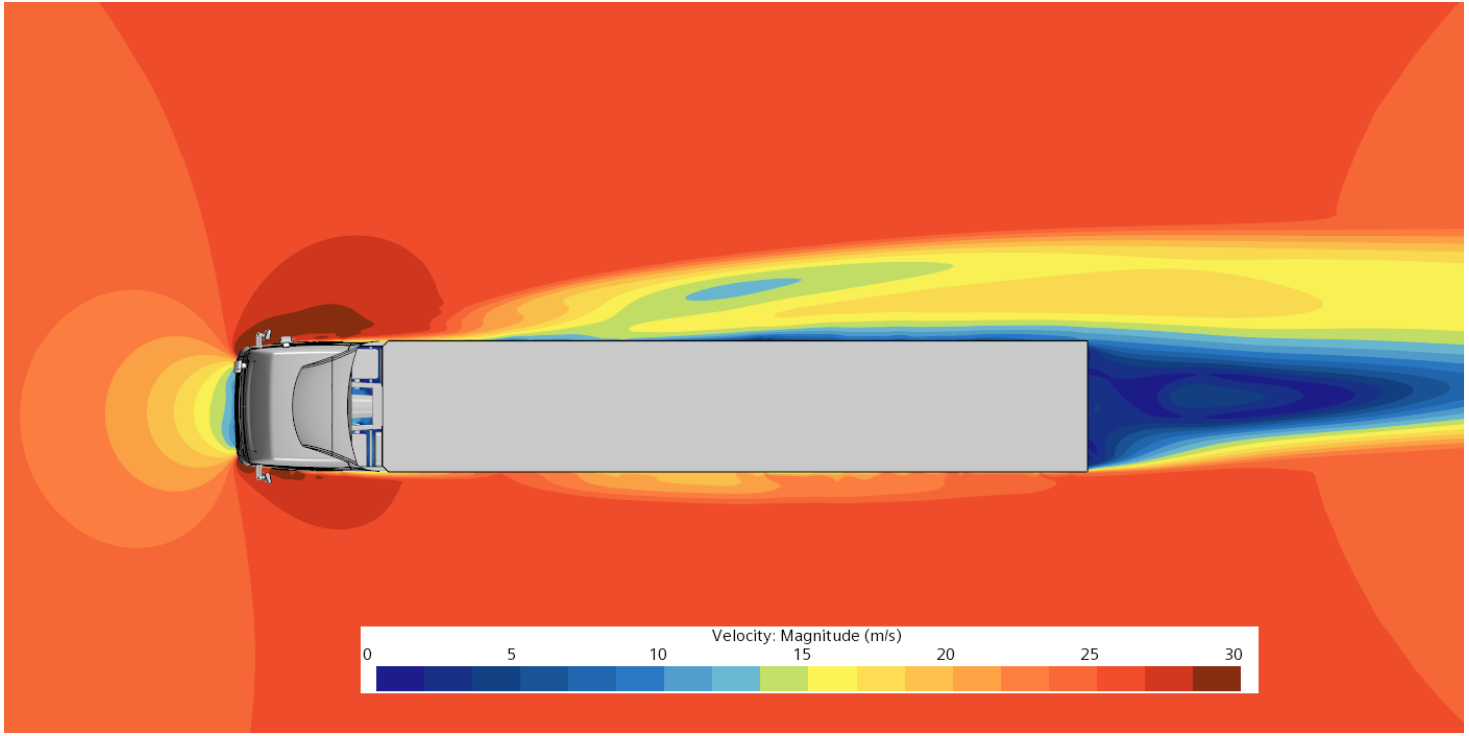
ANNEX II

BASE AT 3,0 DEG OF YAW

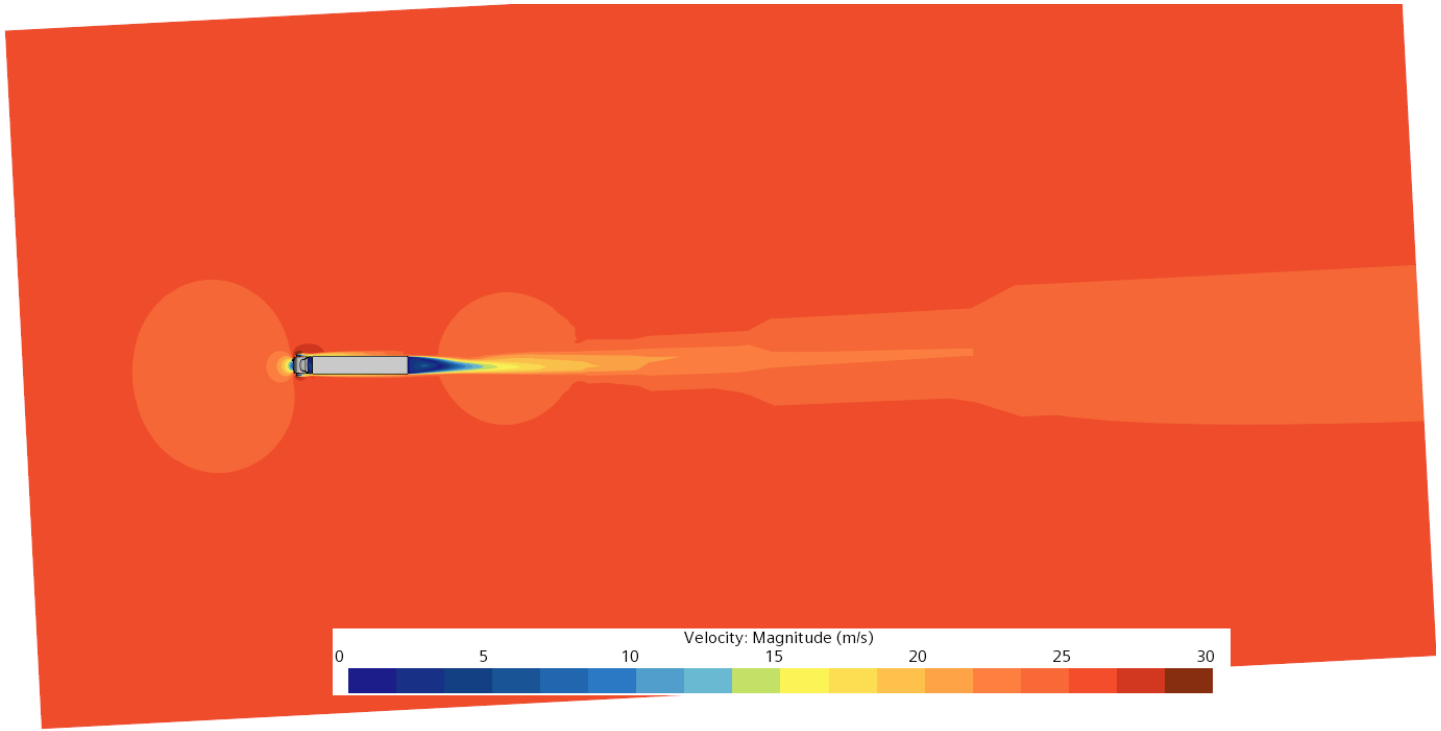
- BASE at 3,0deg. XY plane through the tractor front axle. Entire domain



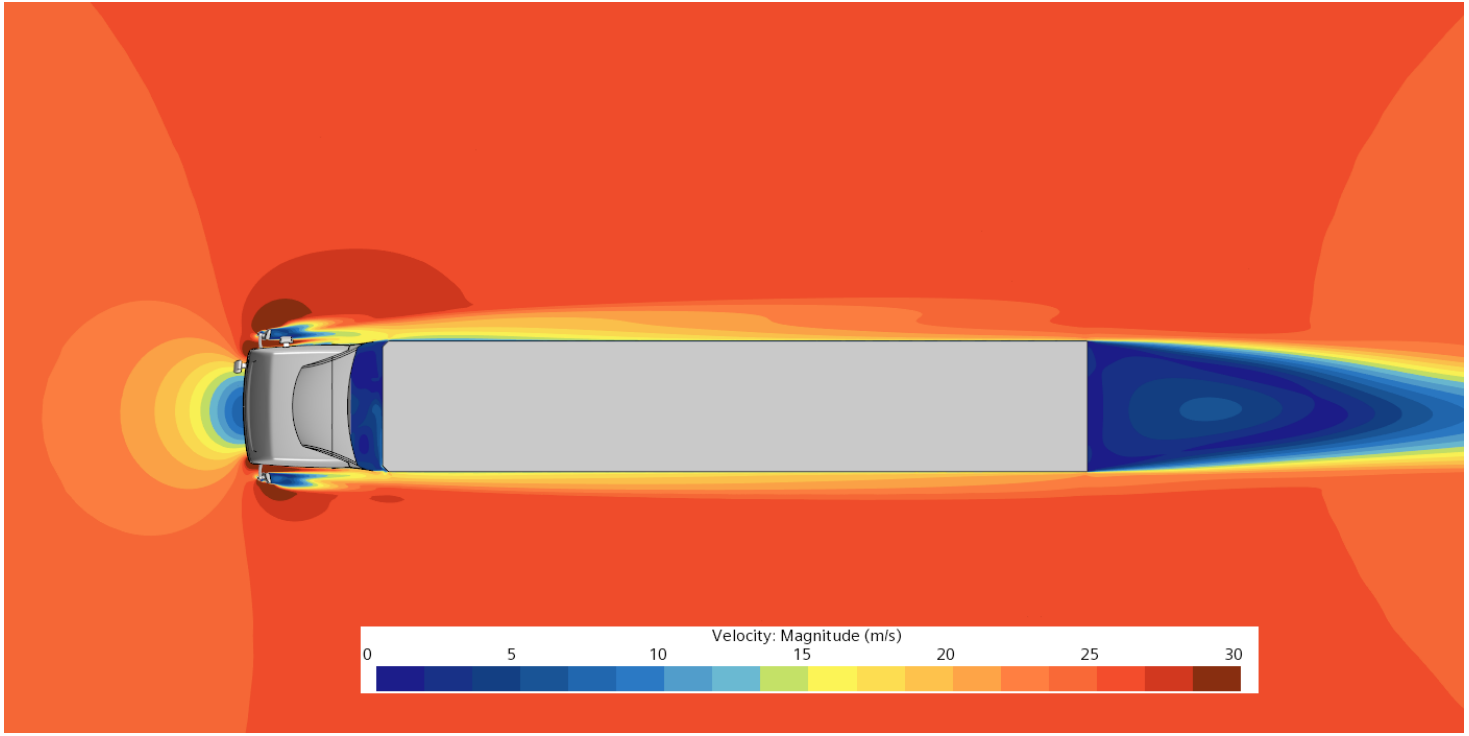
- BASE at 3,0deg. XY plane through the tractor front axle. Vehicle detail



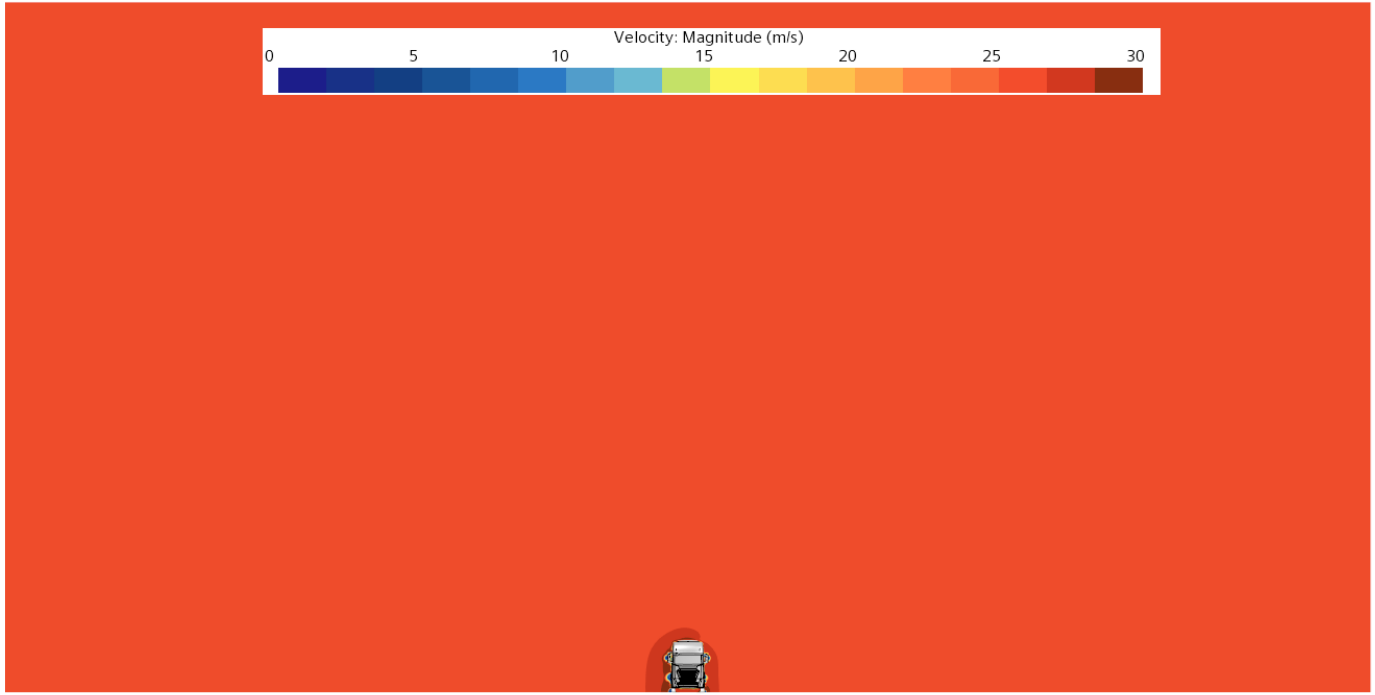
- BASE at 3,0deg. XY plane through the tractor side mirrors. Entire domain



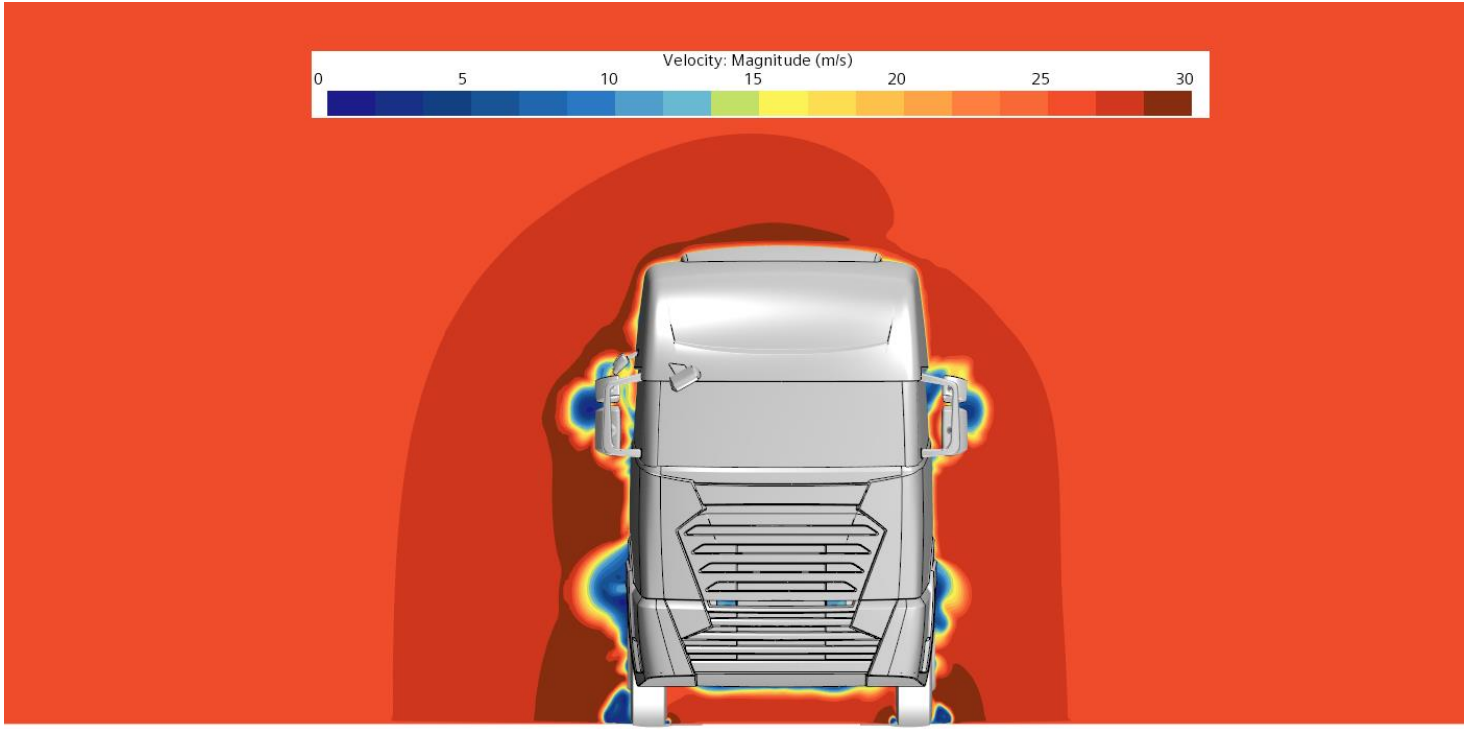
- BASE at 3,0deg. XY plane through the tractor side mirrors. Vehicle detail



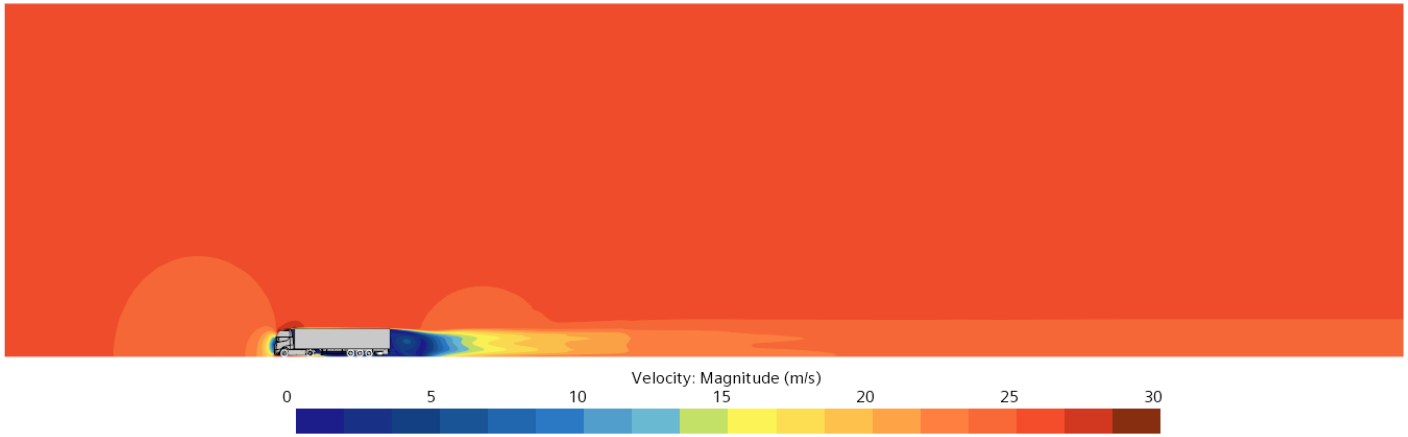
- BASE at 3,0deg. YZ plane through the tractor front axle. Entire domain



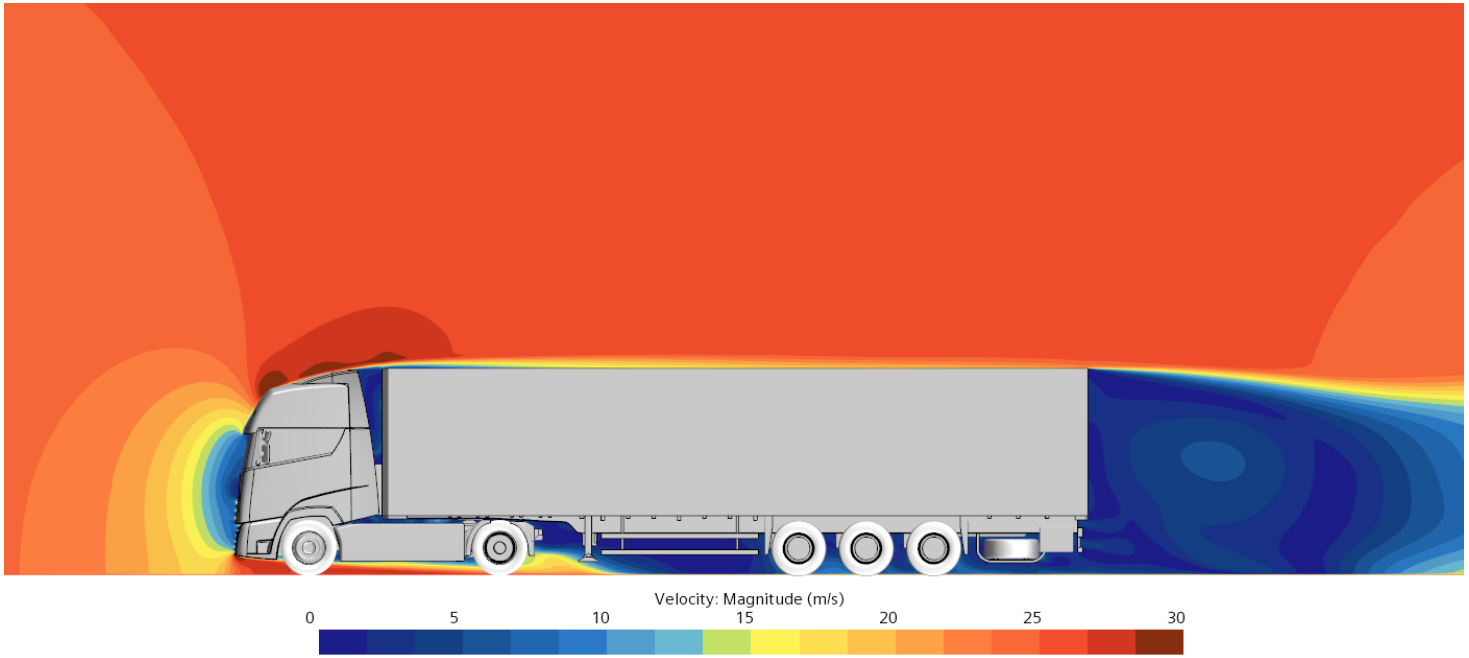
- BASE at 3,0deg. YZ plane through the tractor front axle. Vehicle detail



- BASE at 3,0deg. XZ plane through the centre of the vehicle. Entire domain



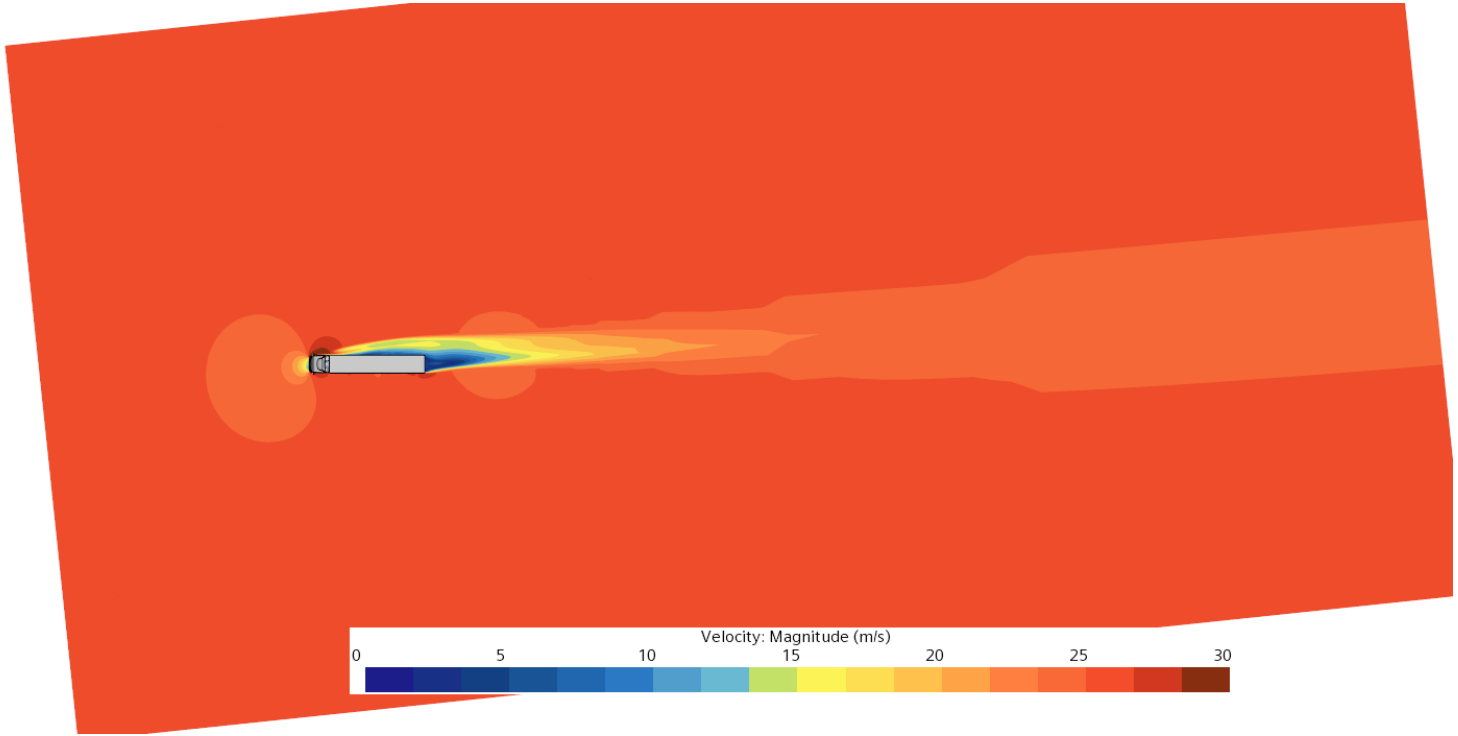
- BASE at 3,0deg. XZ plane through the centre of the vehicle. Vehicle detail



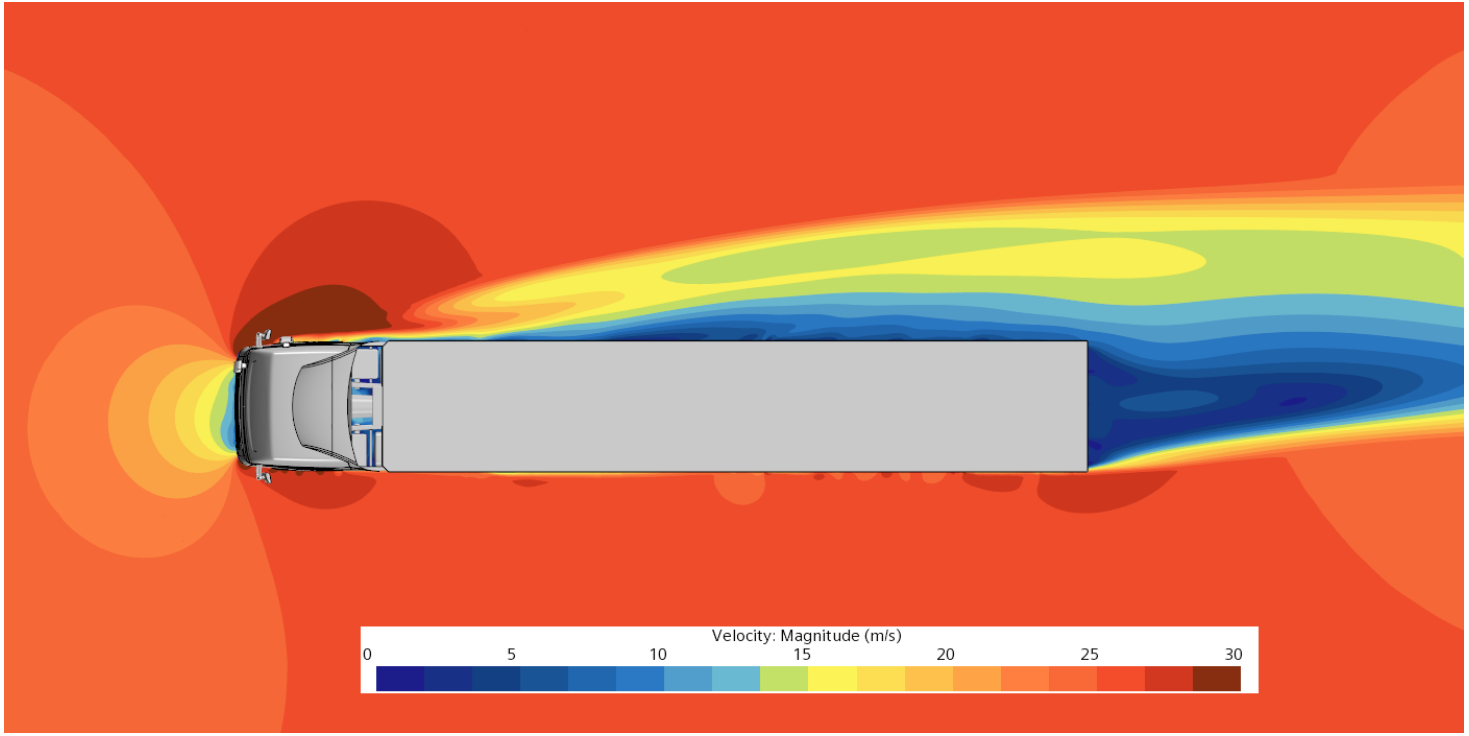
ANNEX III

BASE AT 6,0 DEG OF YAW

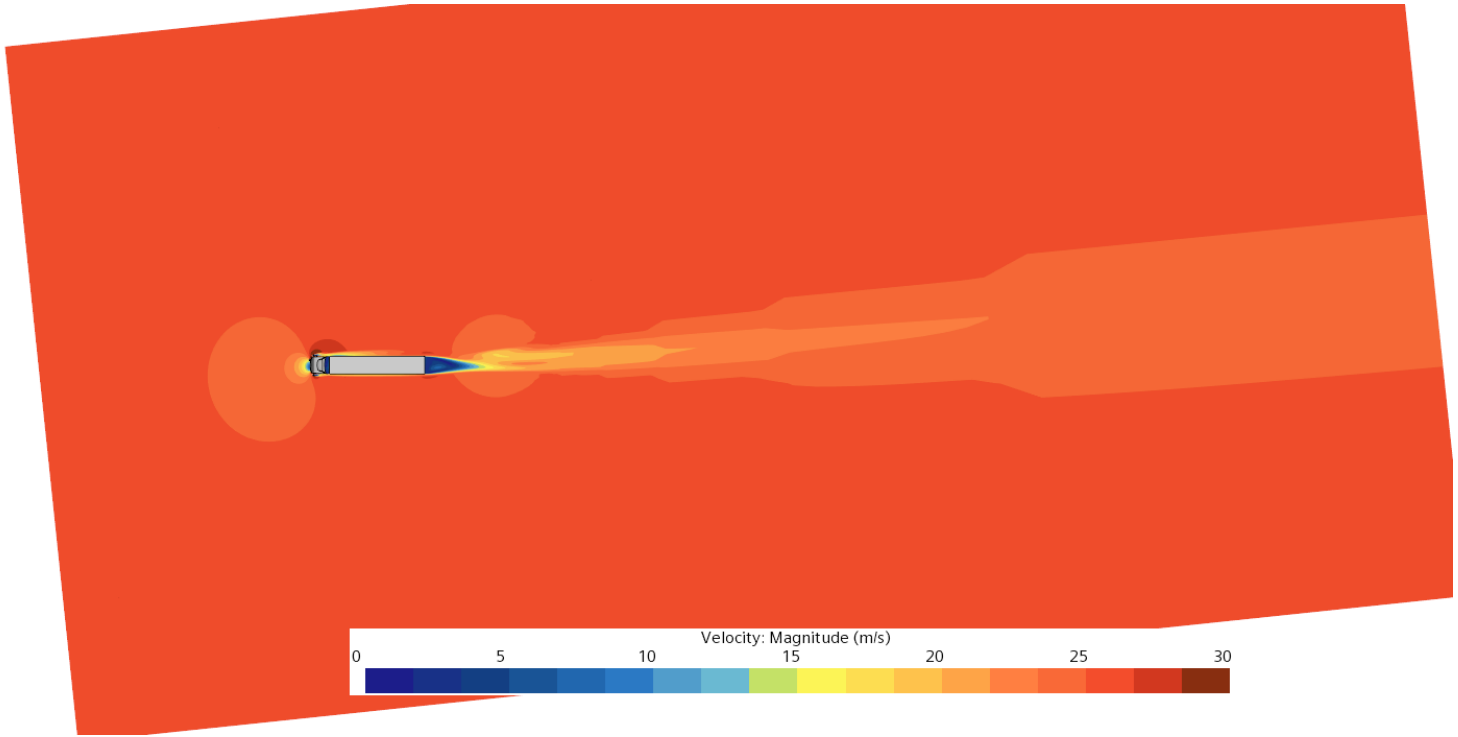
- BASE at 6,0deg. XY plane through the tractor front axle. Entire domain



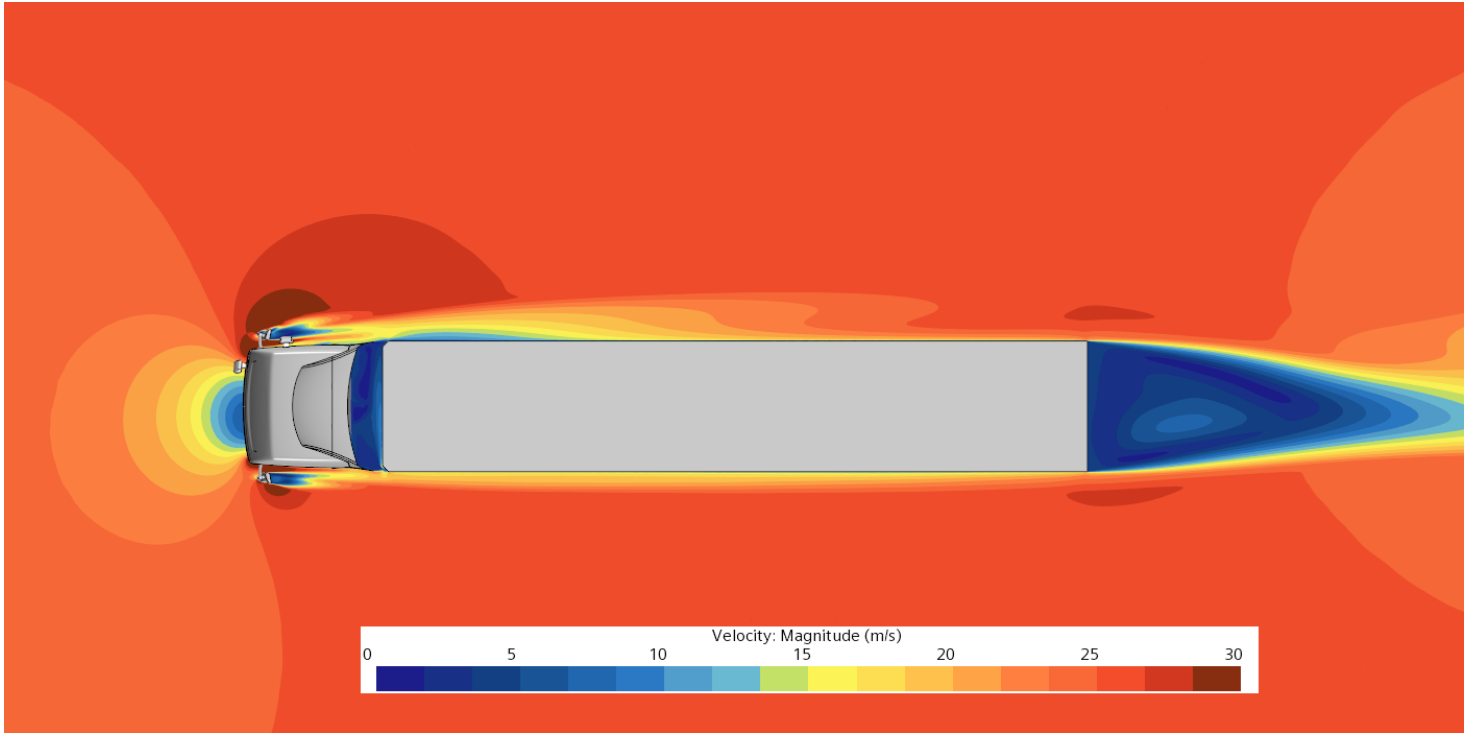
- BASE at 6,0deg. XY plane through the tractor front axle. Vehicle detail



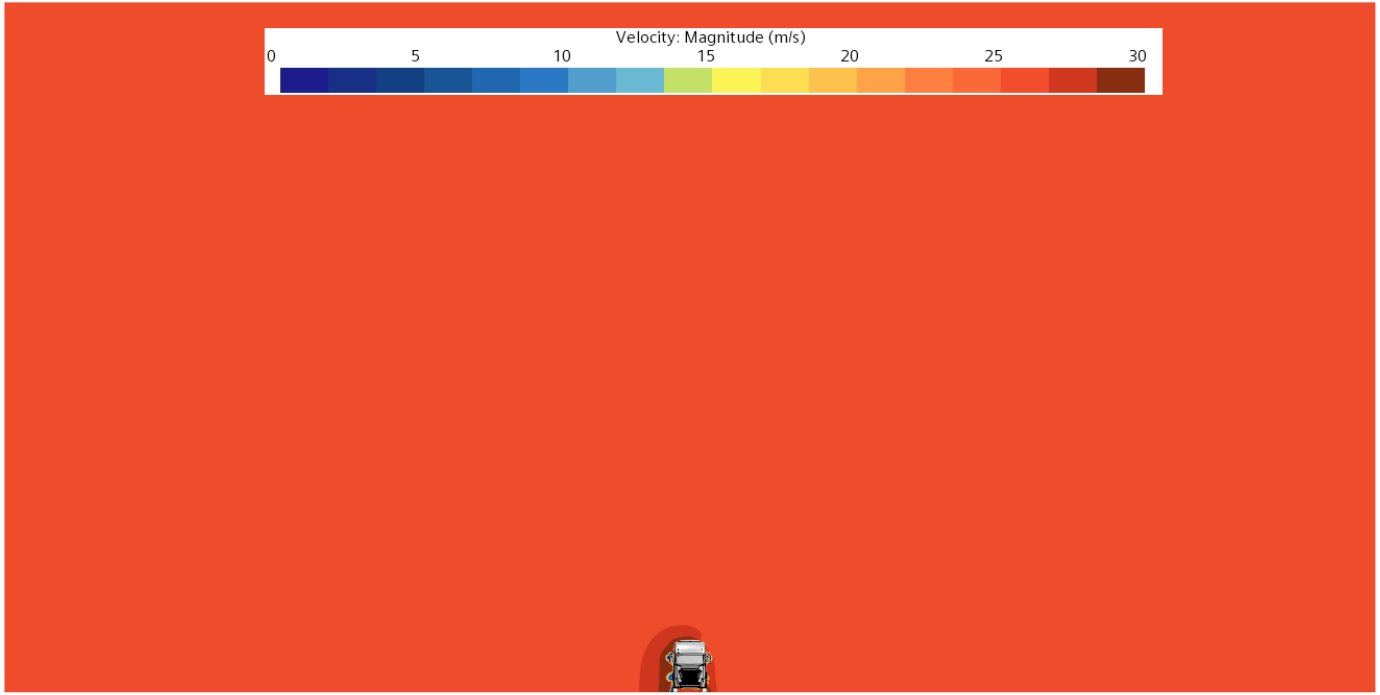
- BASE at 6,0deg. XY plane through the tractor side mirrors. Entire domain



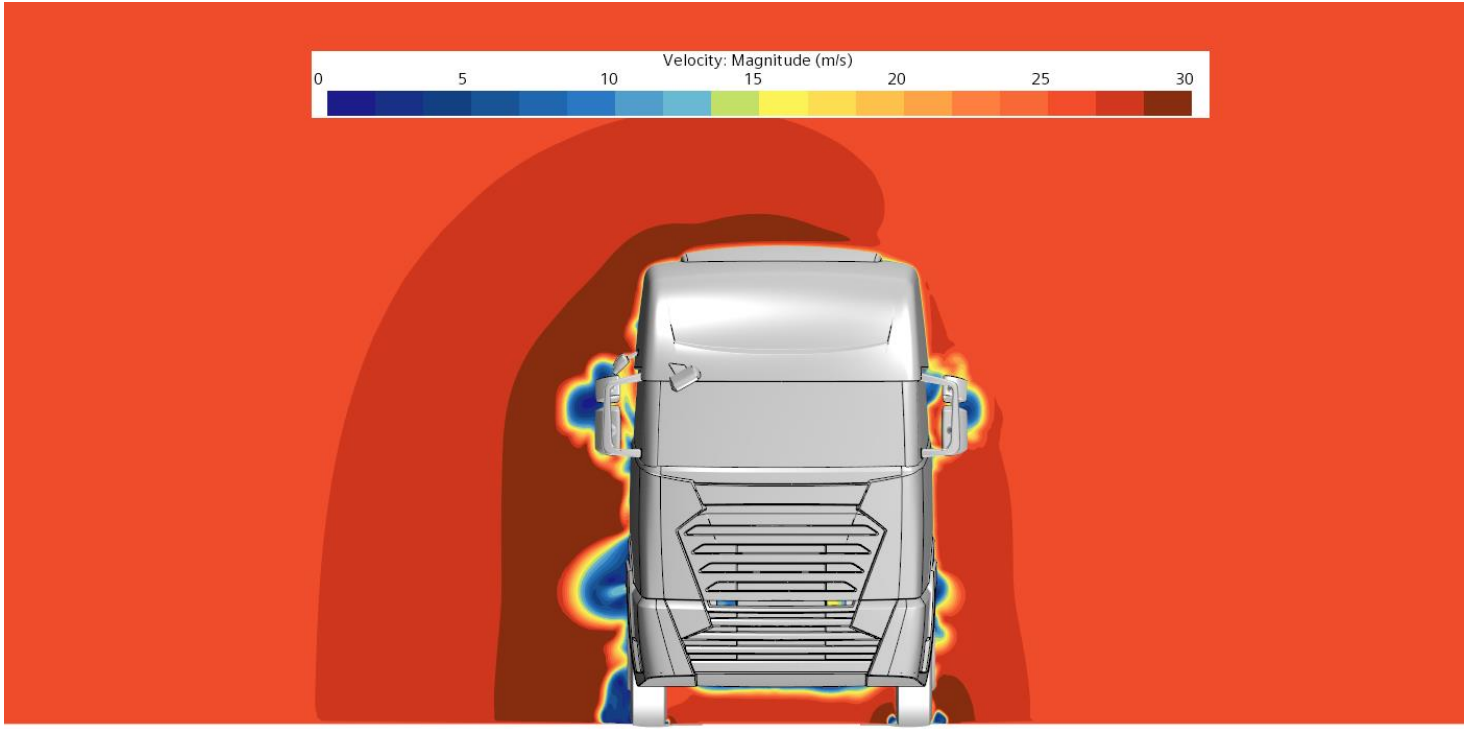
- BASE at 6,0deg. XY plane through the tractor side mirrors. Vehicle detail



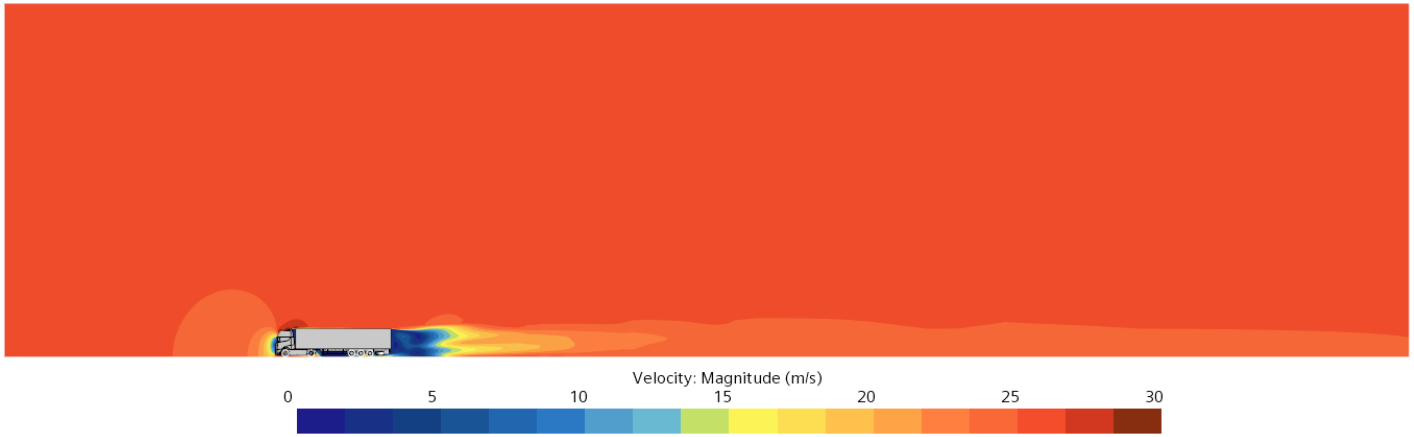
- BASE at 6,0deg. YZ plane through the tractor front axle. Entire domain



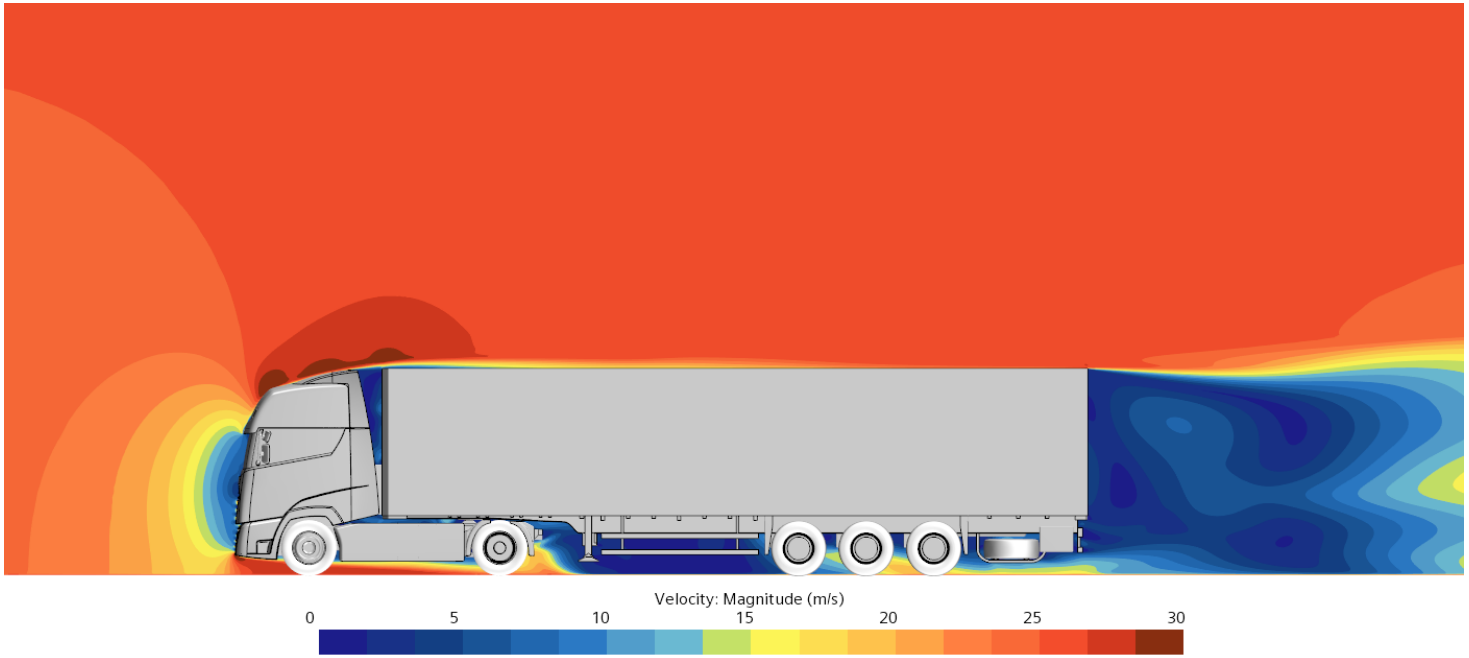
- BASE at 6,0deg. YZ plane through the tractor front axle. Vehicle detail



- BASE at 6,0deg. XZ plane through the centre of the vehicle. Entire domain



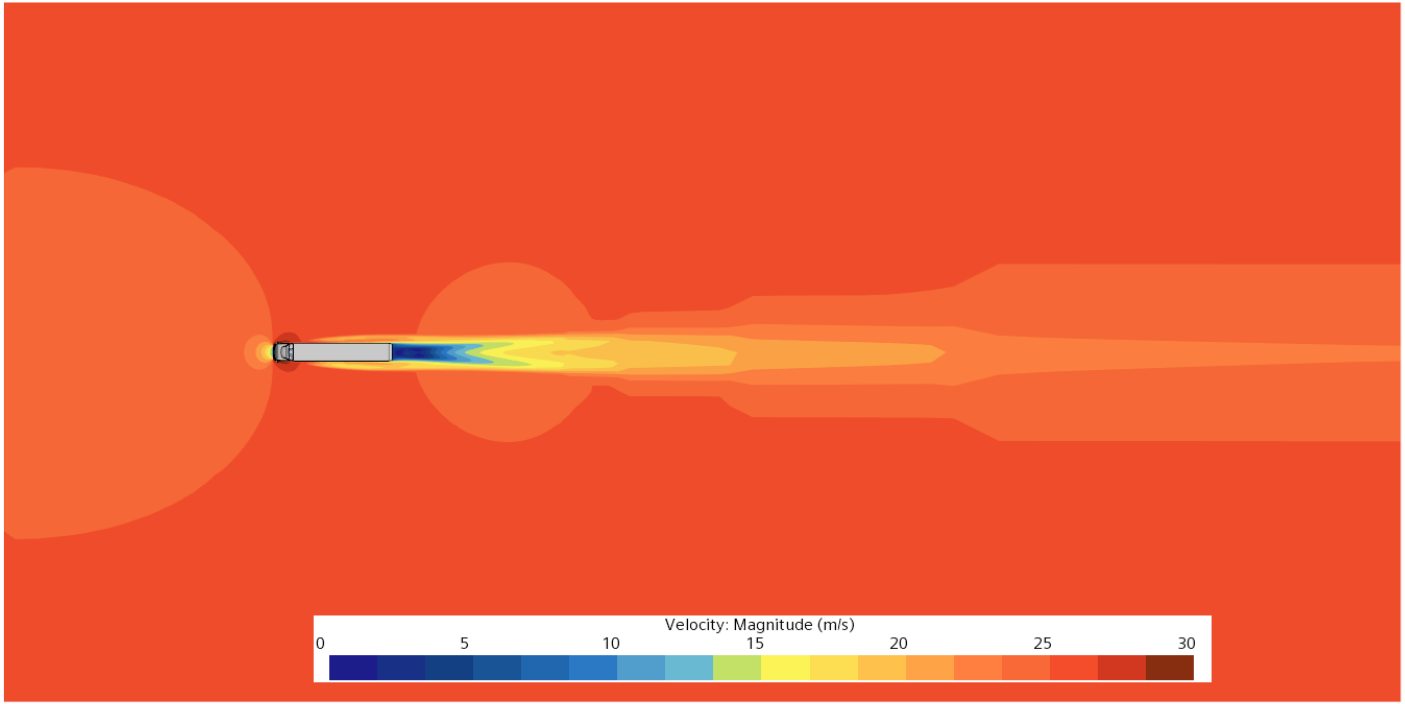
- BASE at 6,0deg. XZ plane through the centre of the vehicle. Vehicle detail



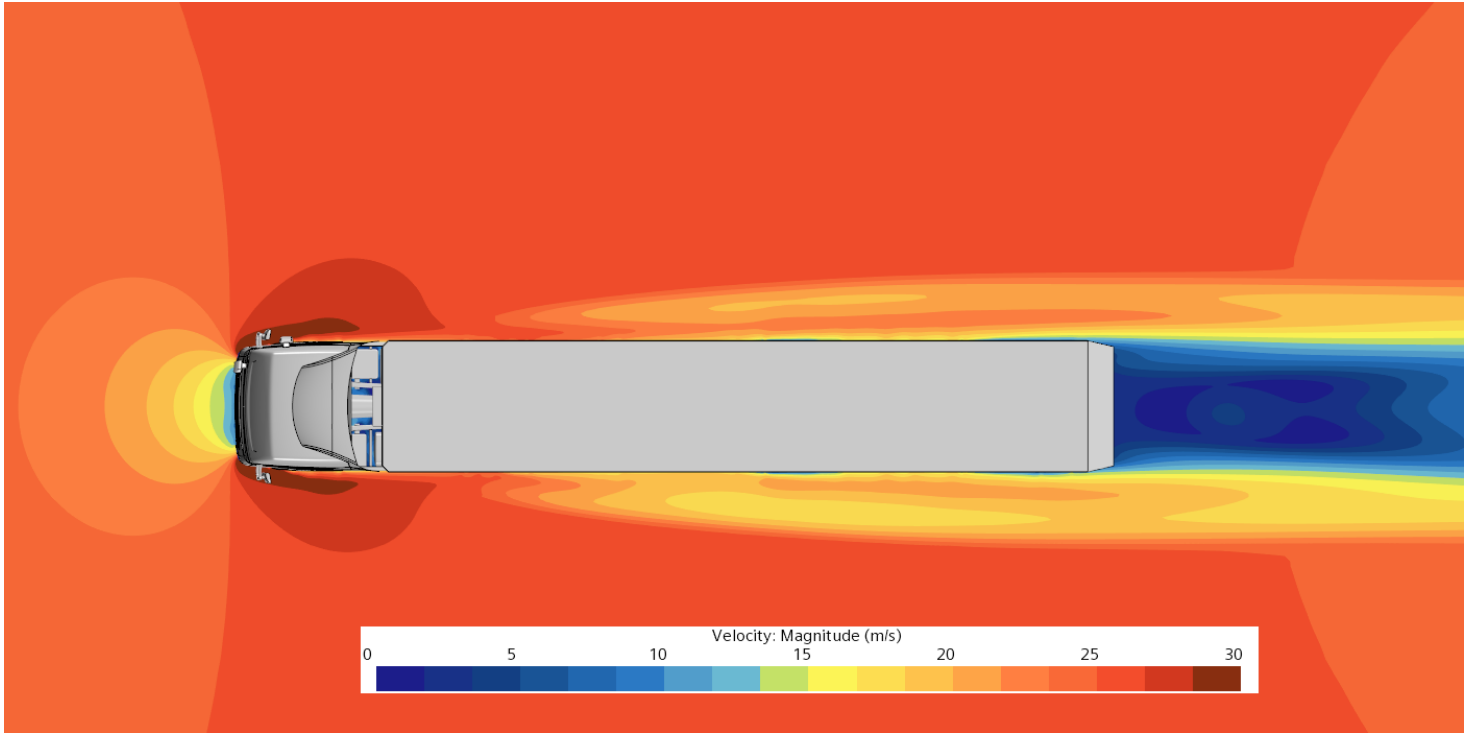
ANNEX IV

TRF AT 0,0 DEG OF YAW

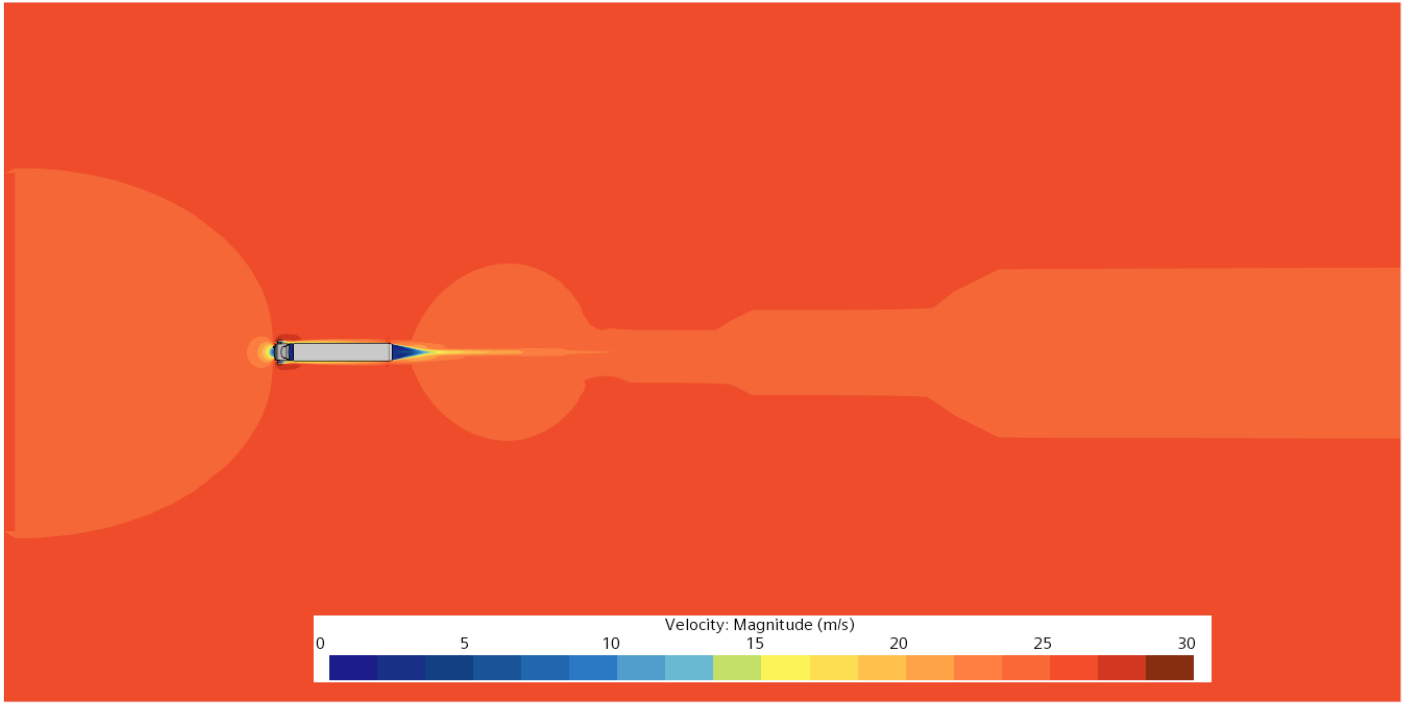
- TRF at 0,0deg. XY plane through the tractor front axle. Entire domain



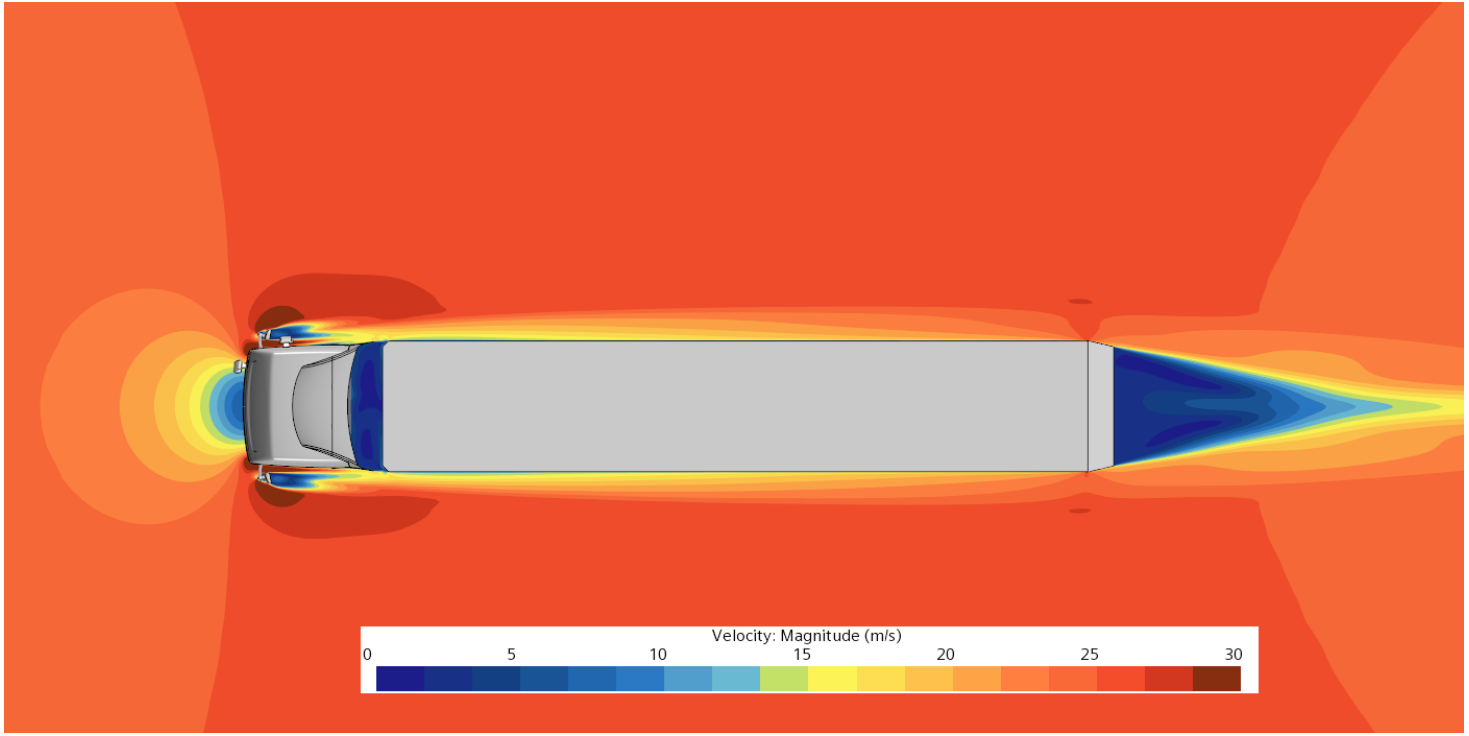
- TRF at 0,0deg. XY plane through the tractor front axle. Vehicle detail



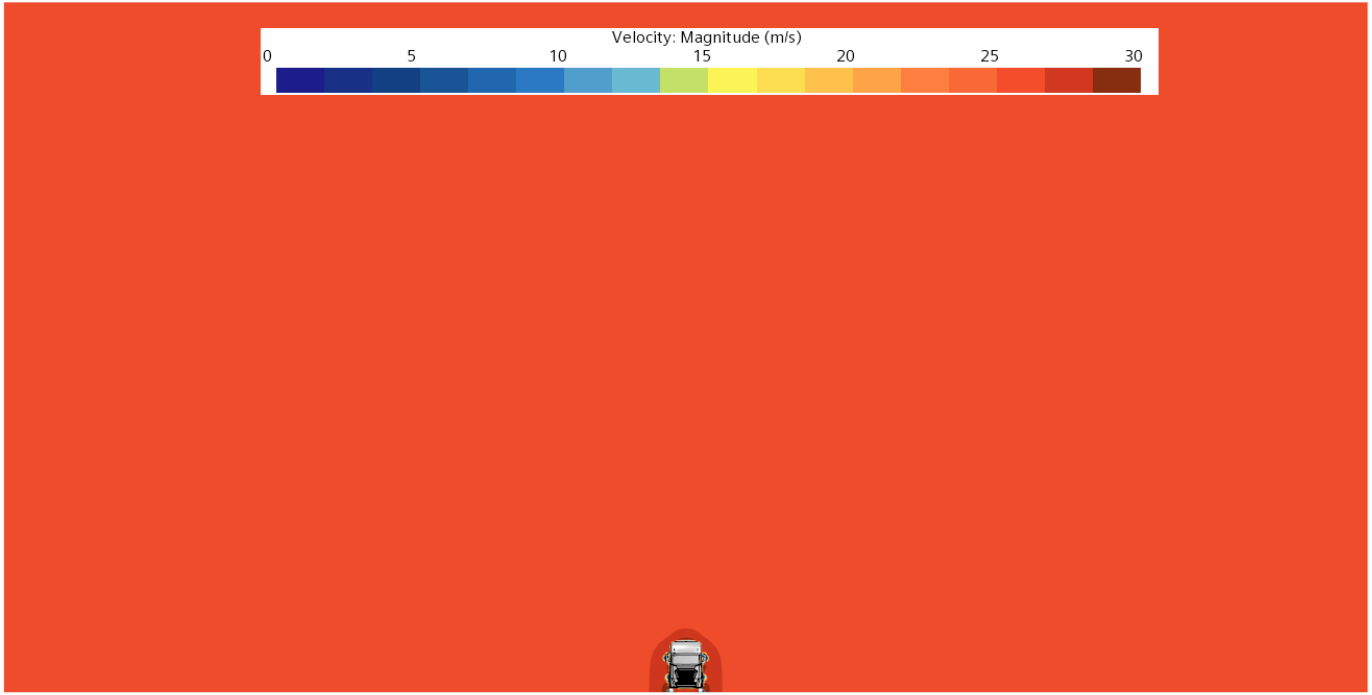
- TRF at 0,0deg. XY plane through the tractor side mirrors. Entire domain



- TRF at 0,0deg. XY plane through the tractor side mirrors. Vehicle detail



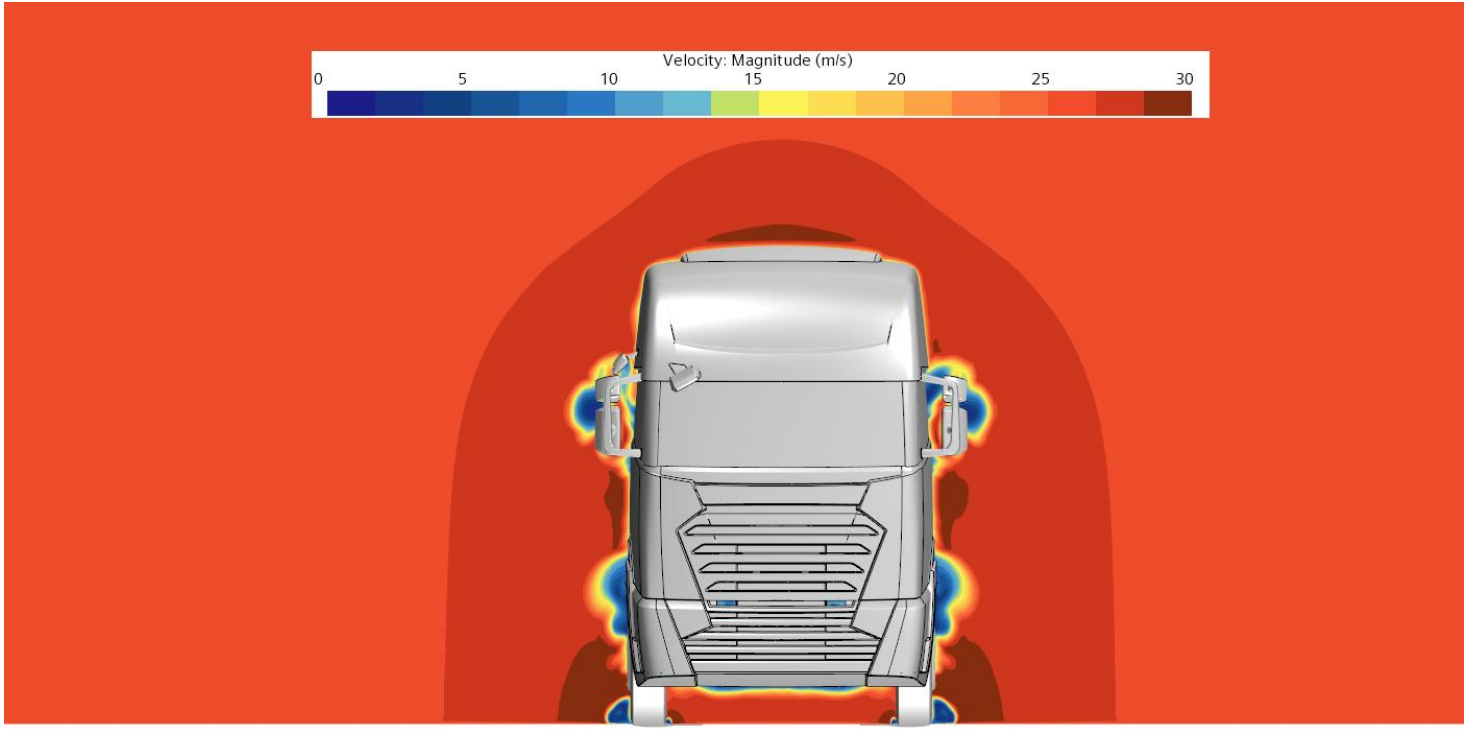
- TRF at 0,0deg. YZ plane through the tractor front axle. Entire domain



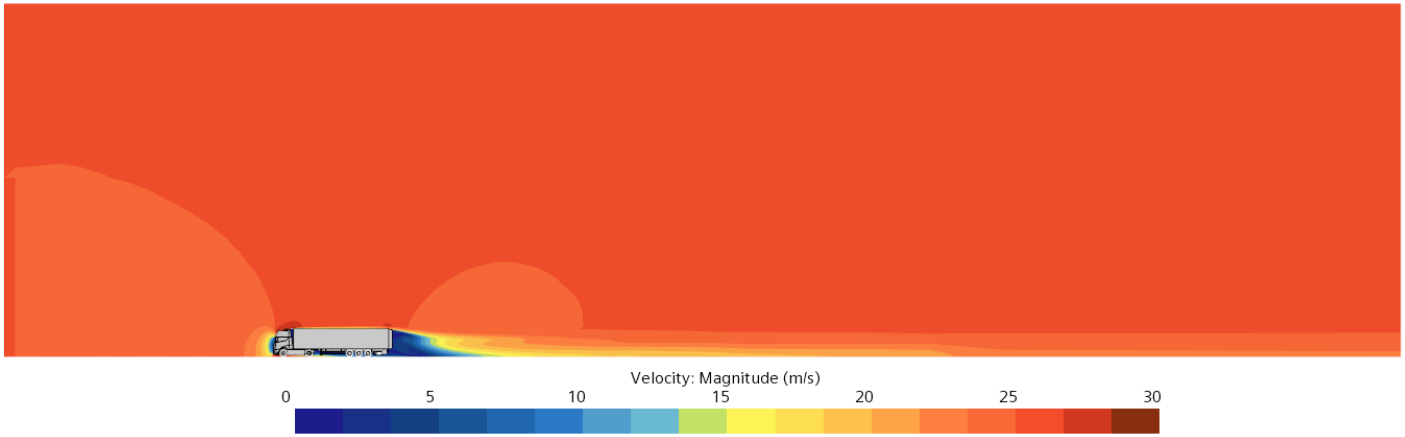
RESULTS

POST-PROCESSING IMAGES

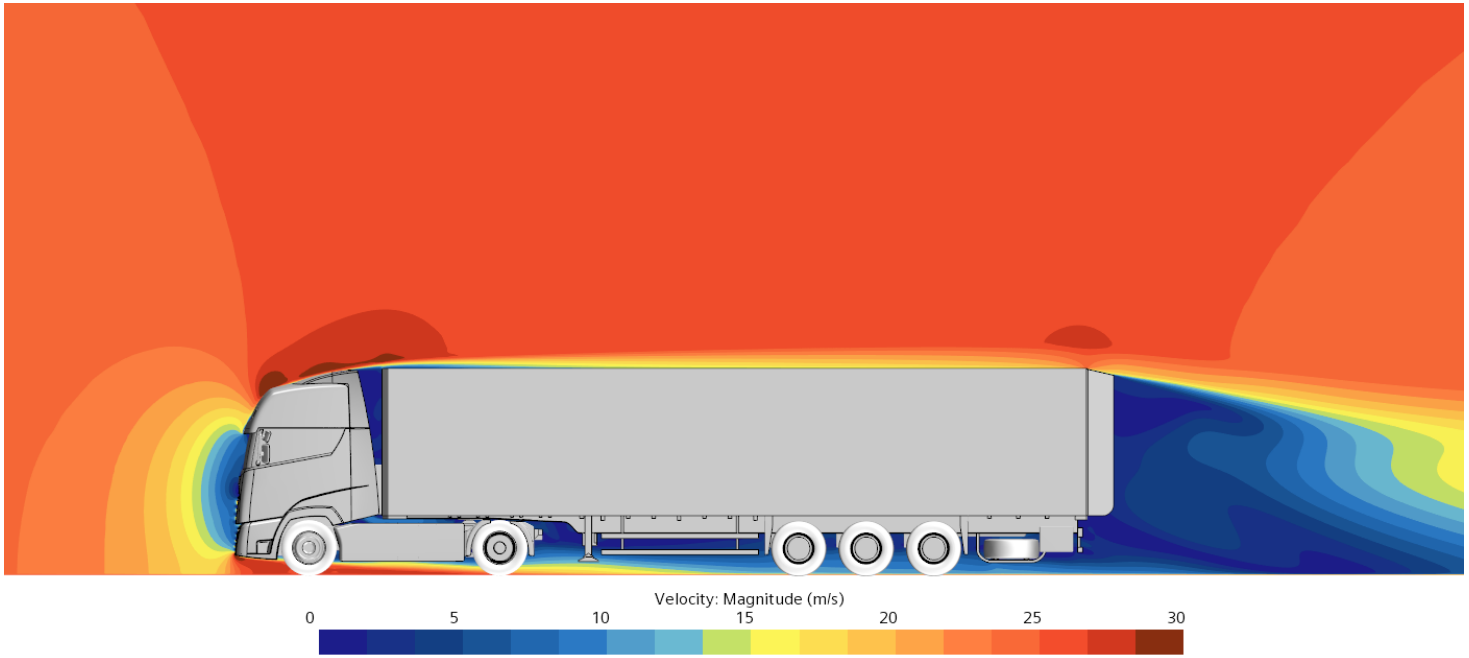
- TRF at 0,0deg. YZ plane through the tractor front axle. Vehicle detail



- TRF at 0,0deg. XZ plane through the centre of the vehicle. Entire domain



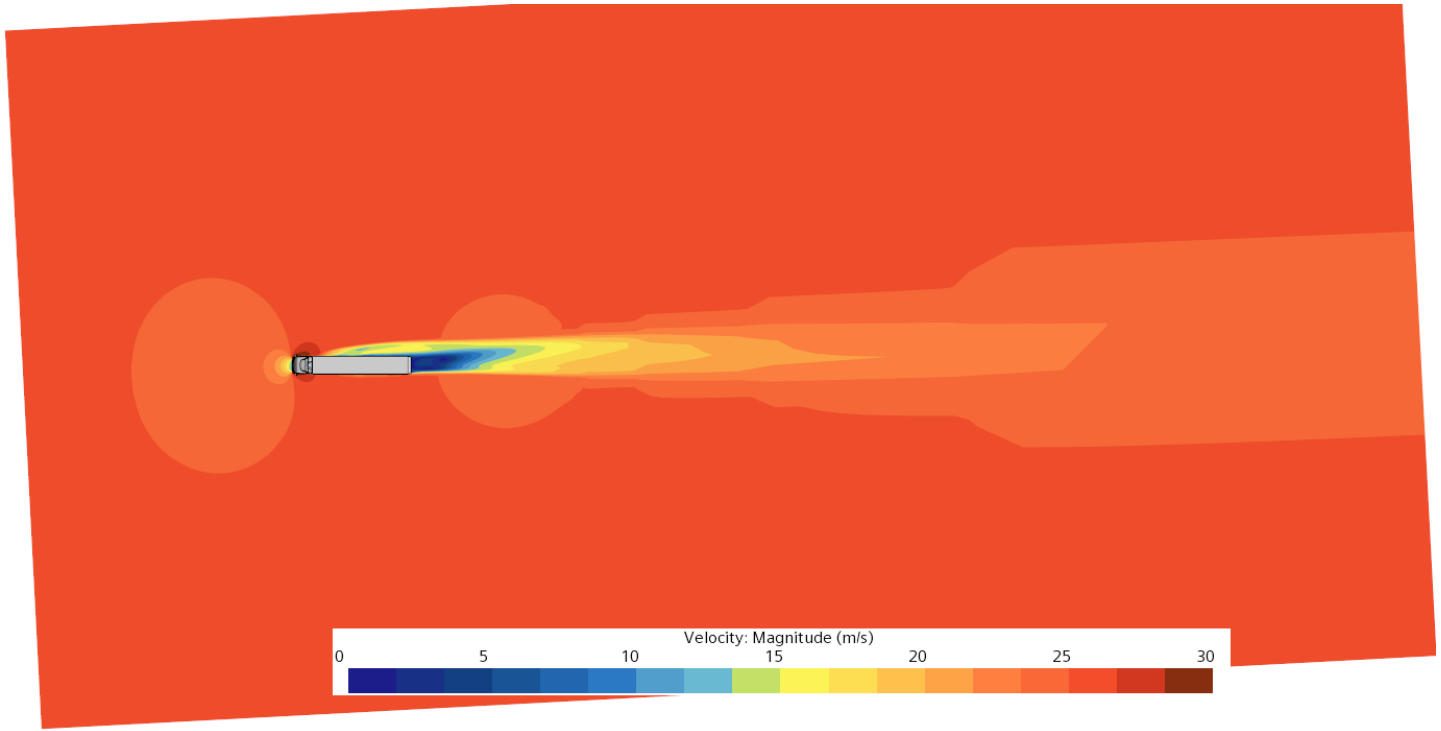
- TRF at 0,0deg. XZ plane through the centre of the vehicle. Vehicle detail



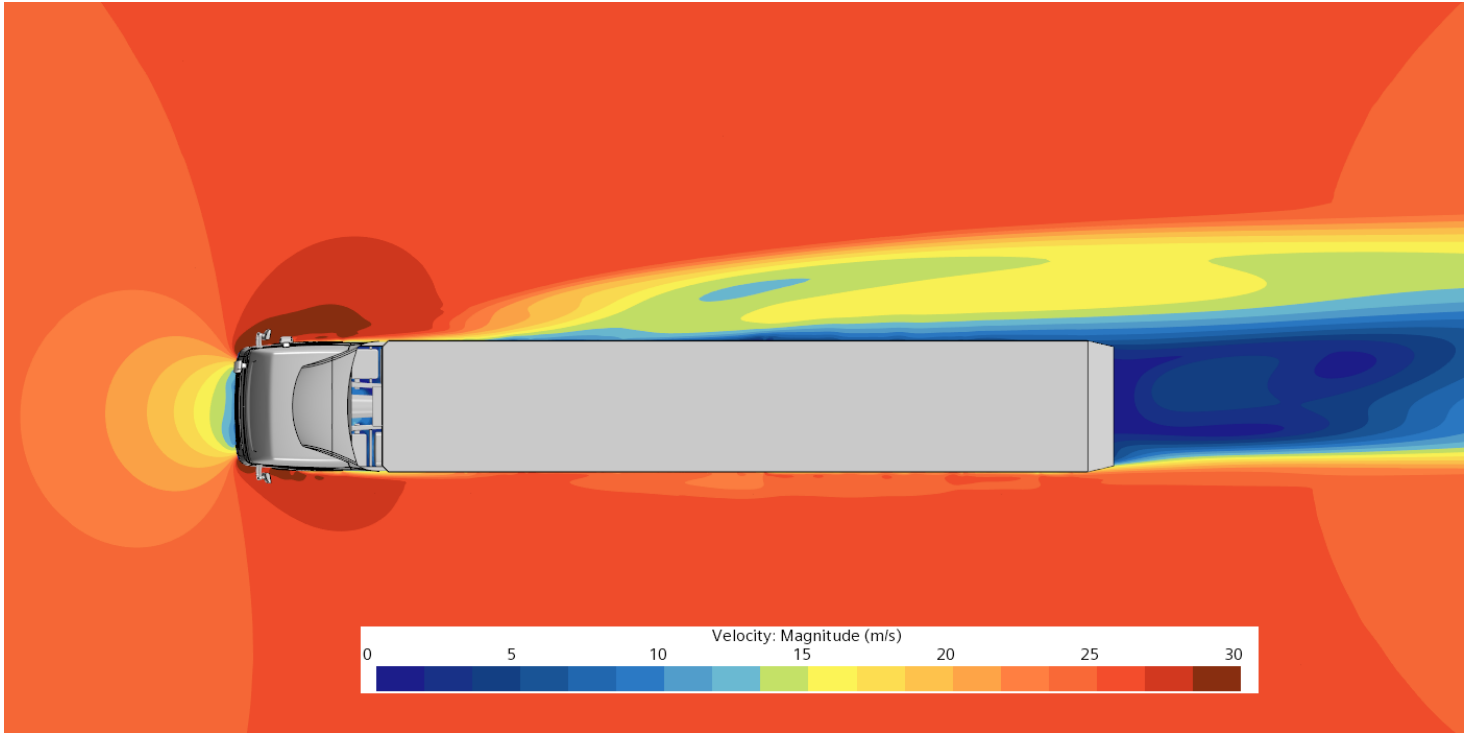
ANNEX V

TRF AT 3,0 DEG OF YAW

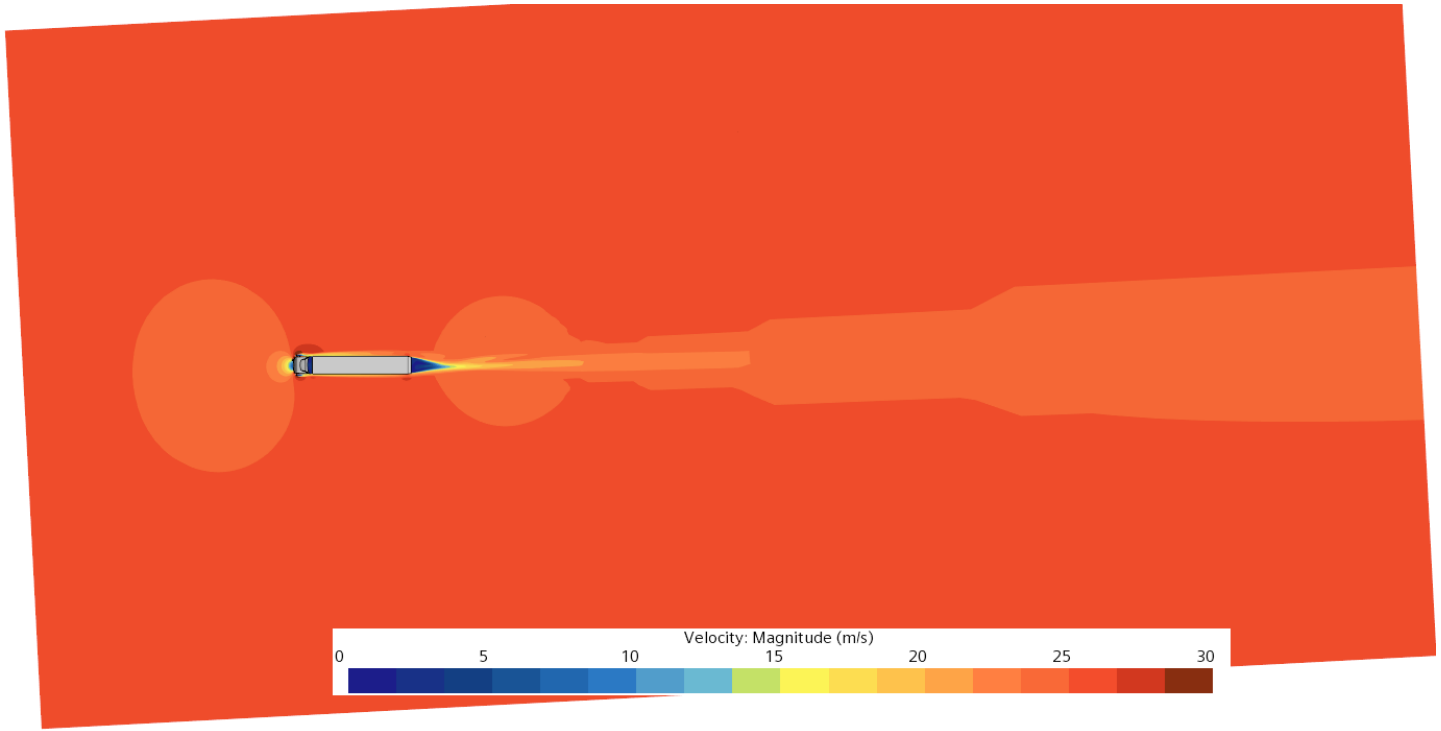
- TRF at 3,0deg. XY plane through the tractor front axle. Entire domain



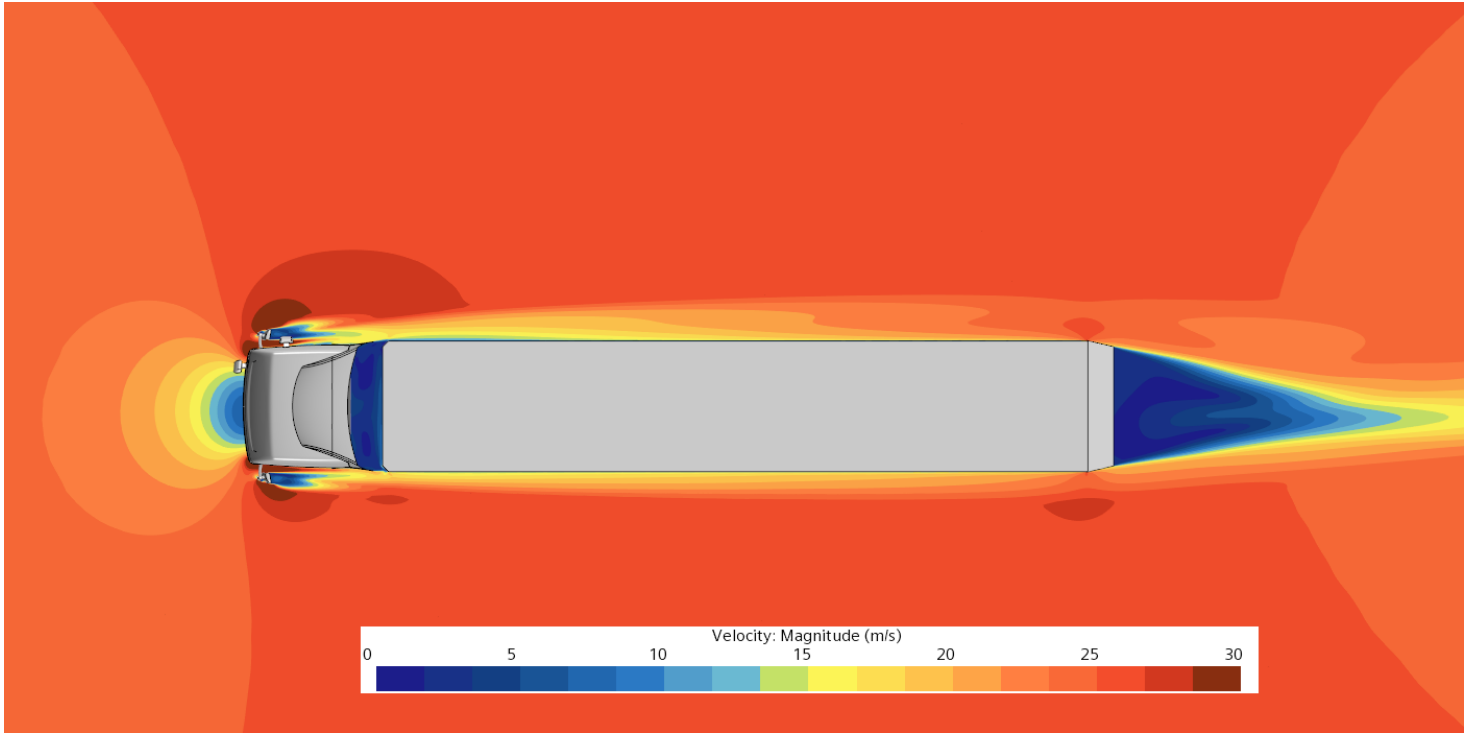
- TRF at 3,0deg. XY plane through the tractor front axle. Vehicle detail



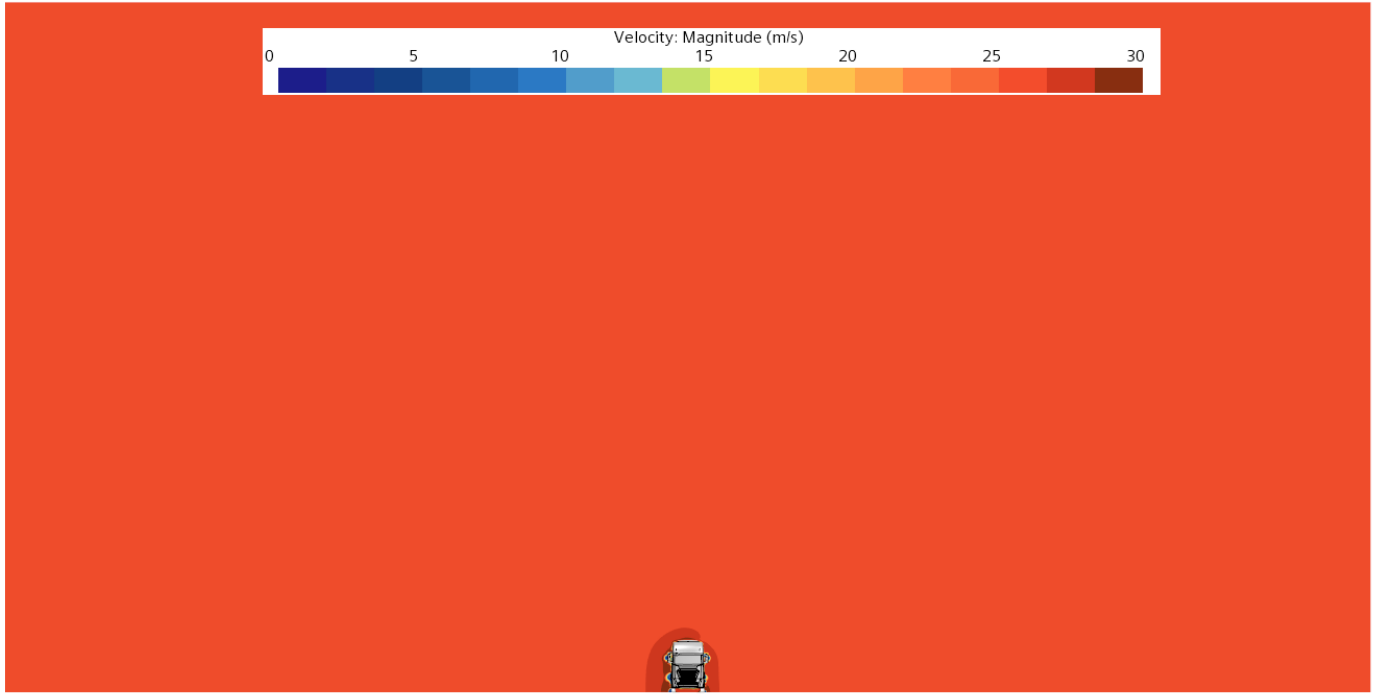
- TRF at 3,0deg. XY plane through the tractor side mirrors. Entire domain



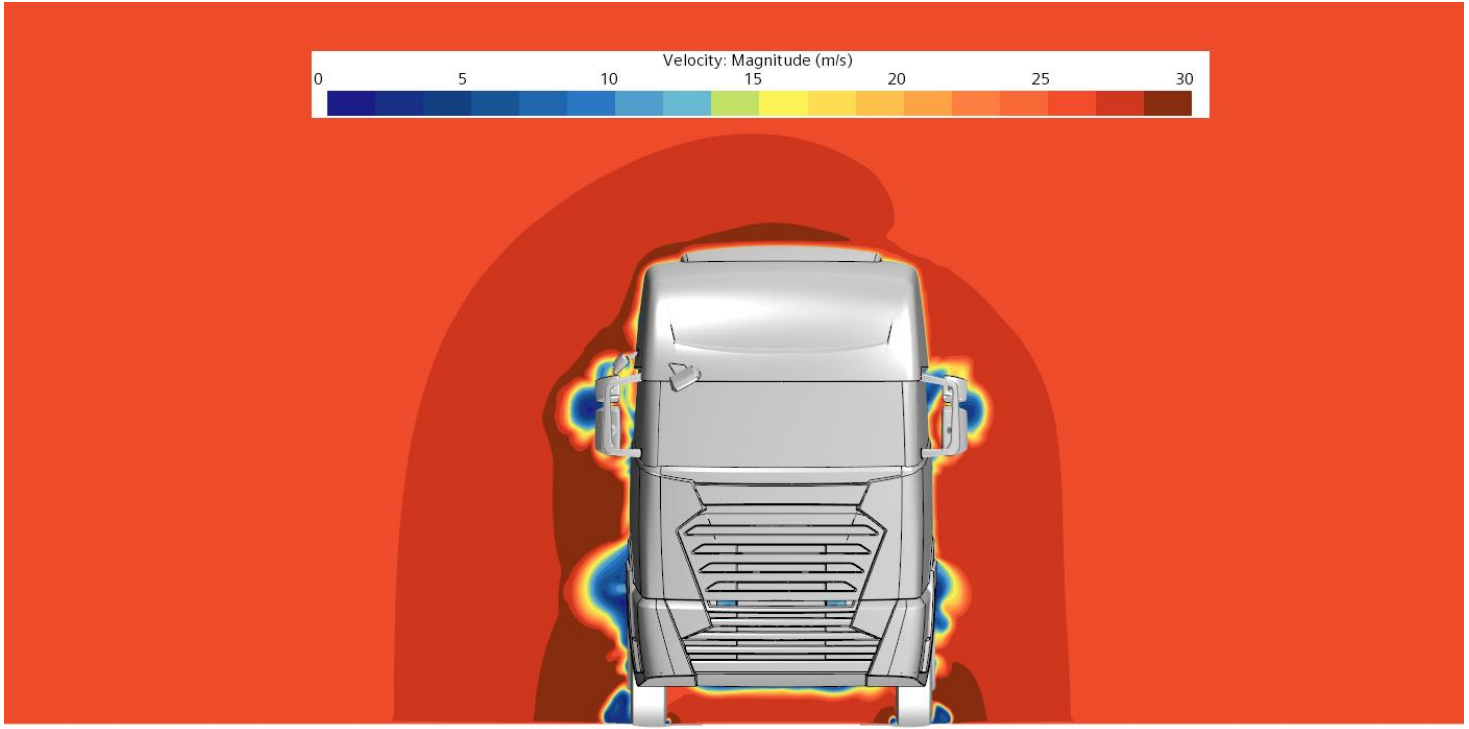
- TRF at 3,0deg. XY plane through the tractor side mirrors. Vehicle detail



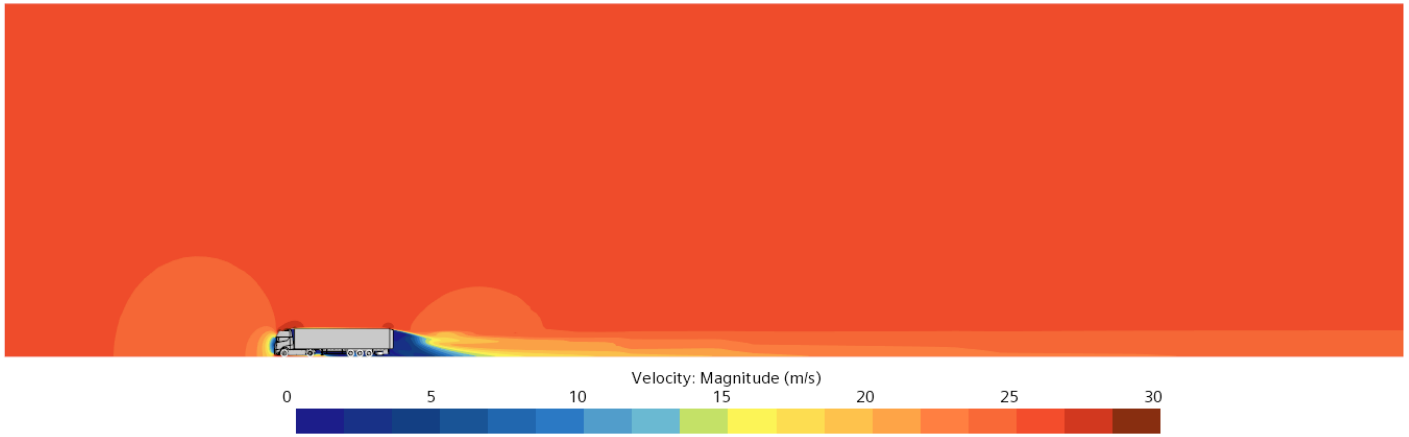
- TRF at 3,0deg. YZ plane through the tractor front axle. Entire domain



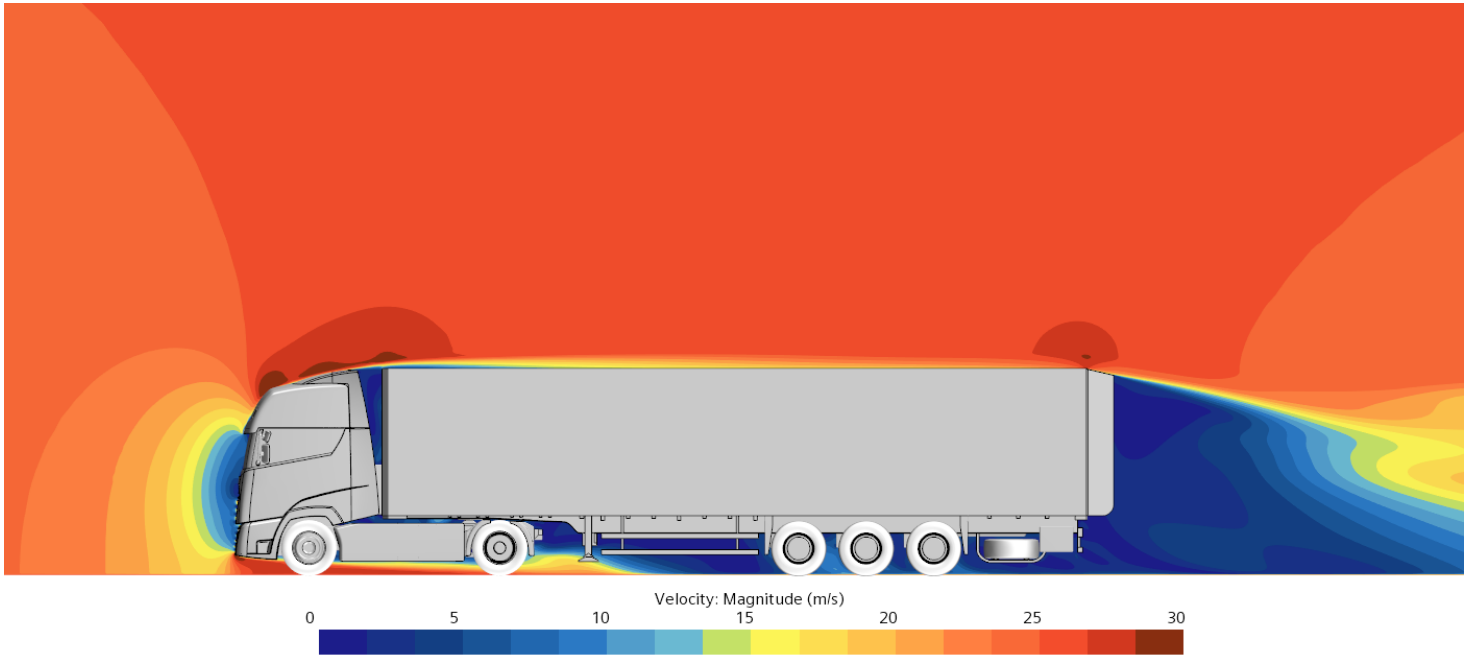
- TRF at 3,0deg. YZ plane through the tractor front axle. Vehicle detail



- TRF at 3,0deg. XZ plane through the centre of the vehicle. Entire domain



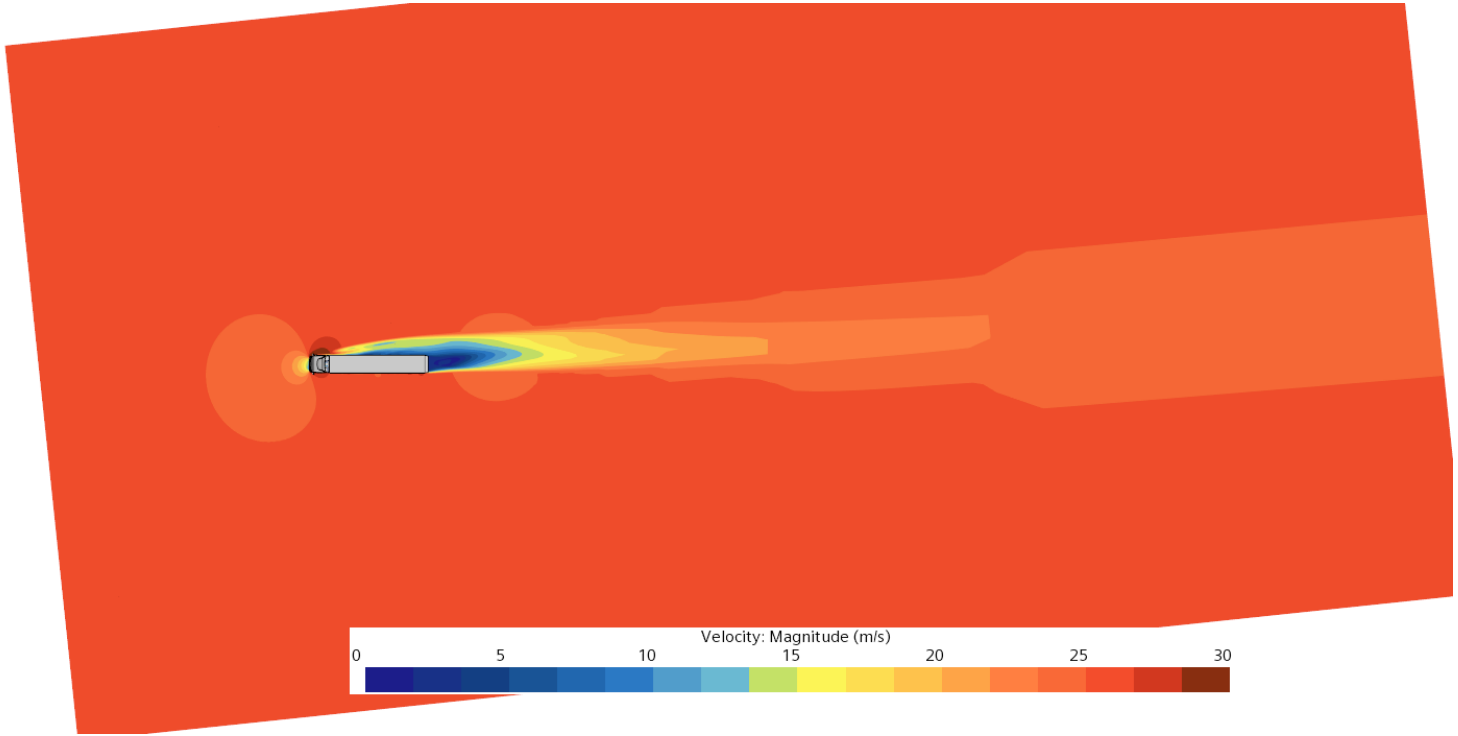
- TRF at 3,0deg. XZ plane through the centre of the vehicle. Vehicle detail



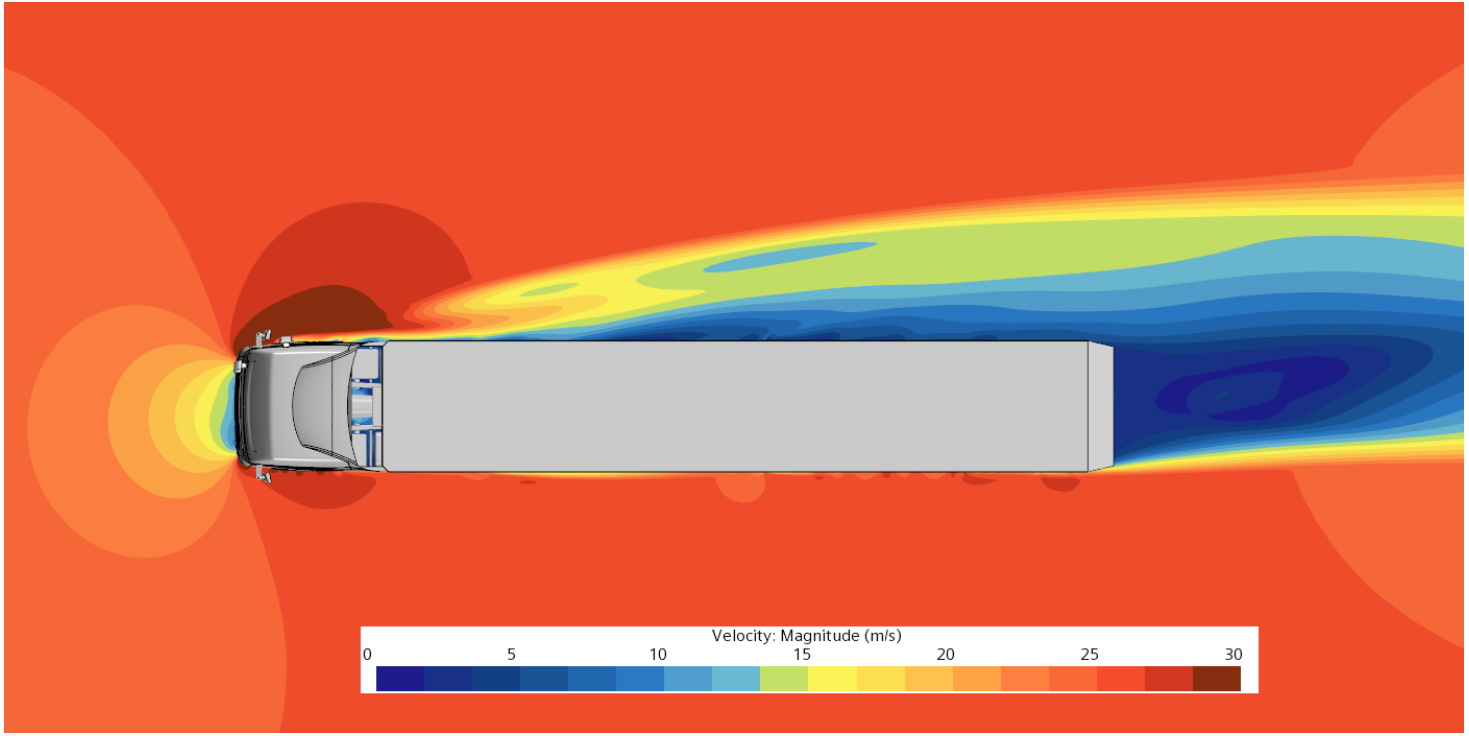
ANNEX VI

TRF AT 6,0 DEG OF YAW

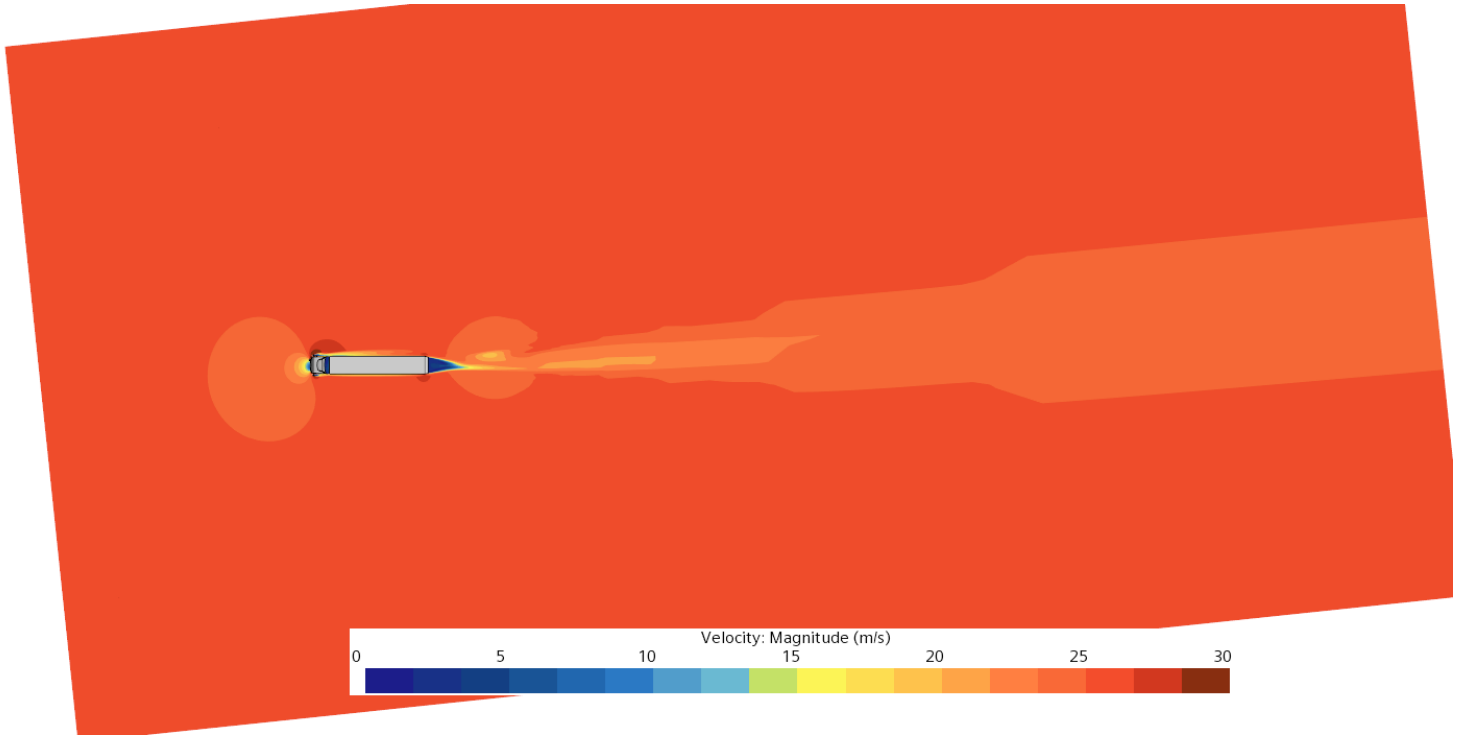
- TRF at 6,0deg. XY plane through the tractor front axle. Entire domain



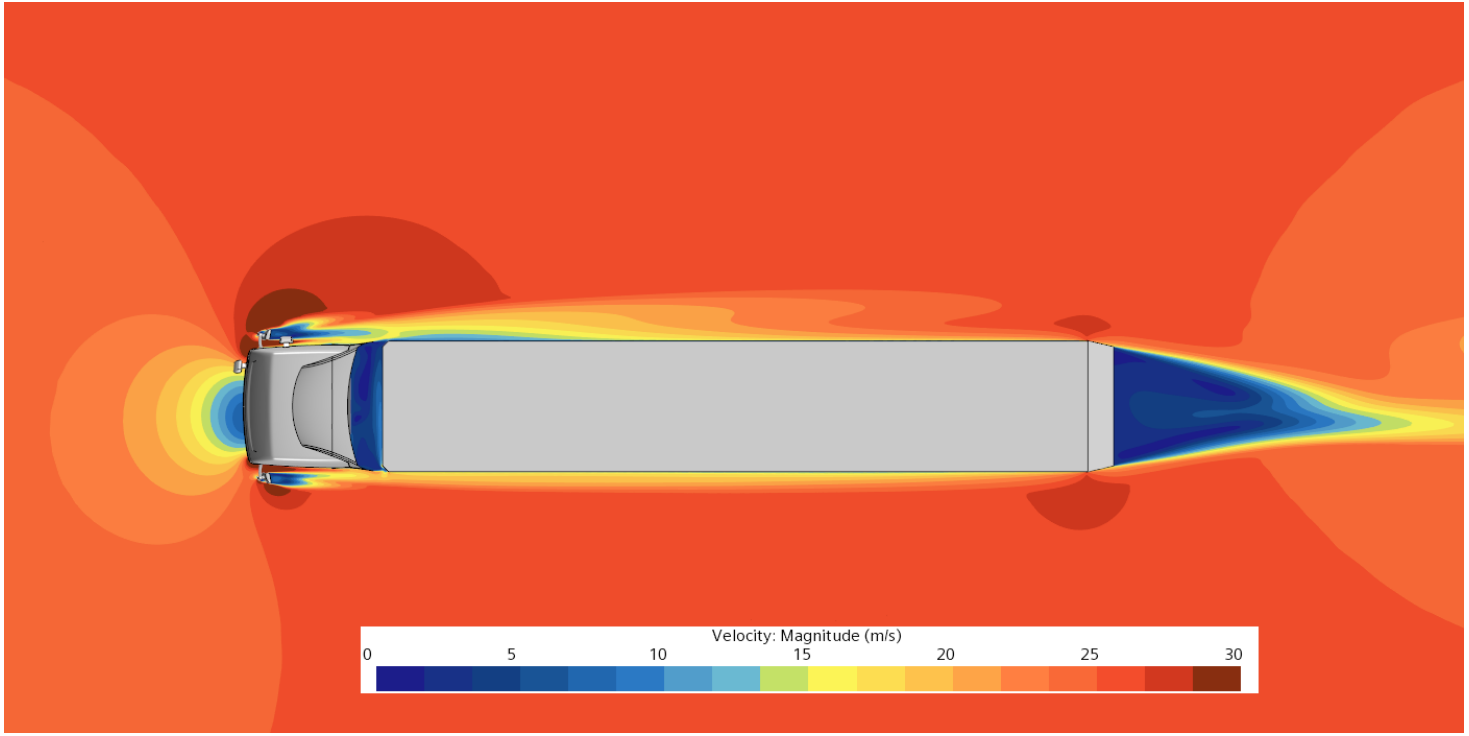
- TRF at 6,0deg. XY plane through the tractor front axle. Vehicle detail



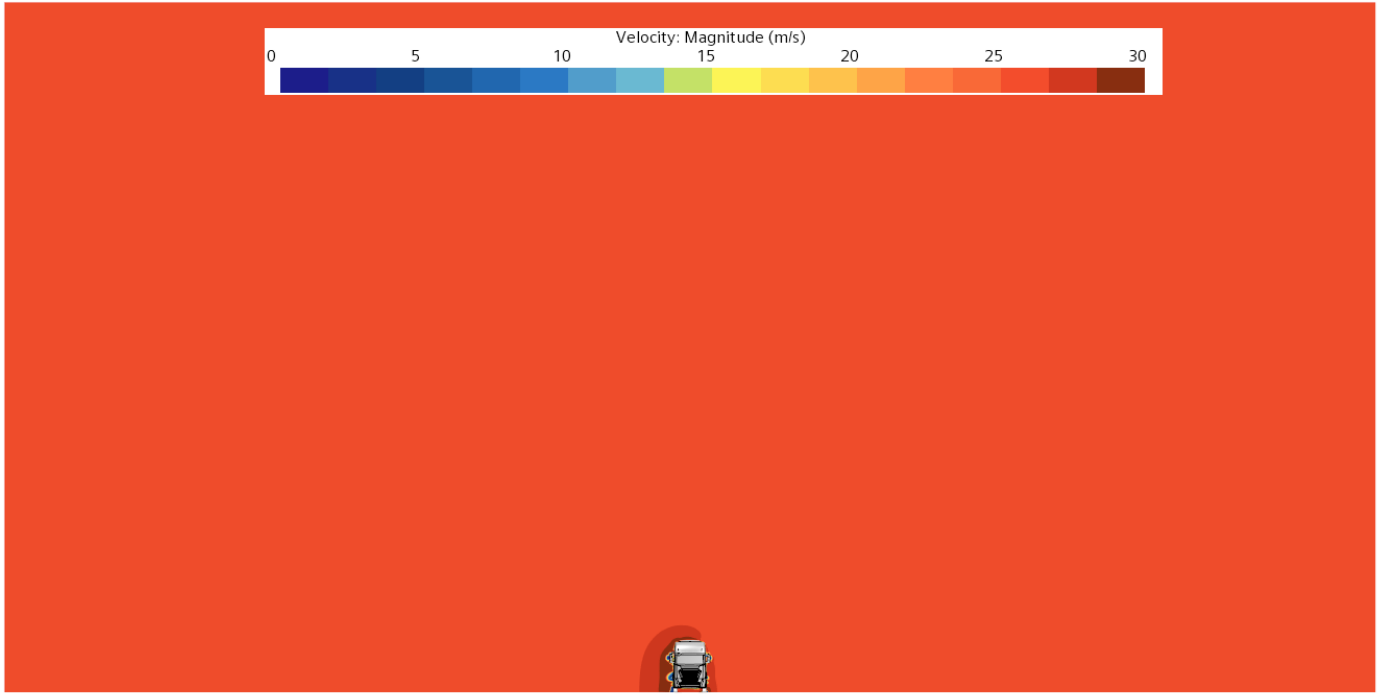
- TRF at 6,0deg. XY plane through the tractor side mirrors. Entire domain



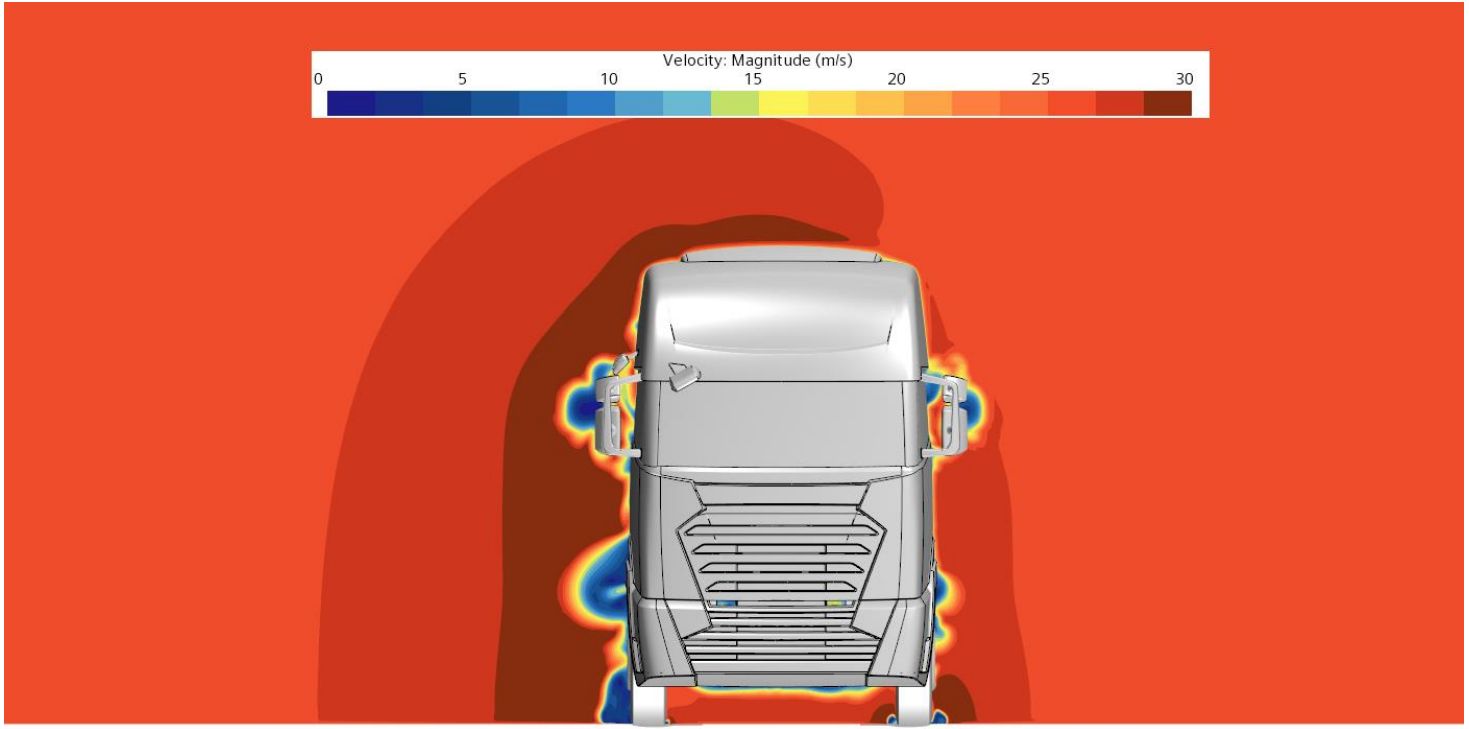
- TRF at 6,0deg. XY plane through the tractor side mirrors. Vehicle detail



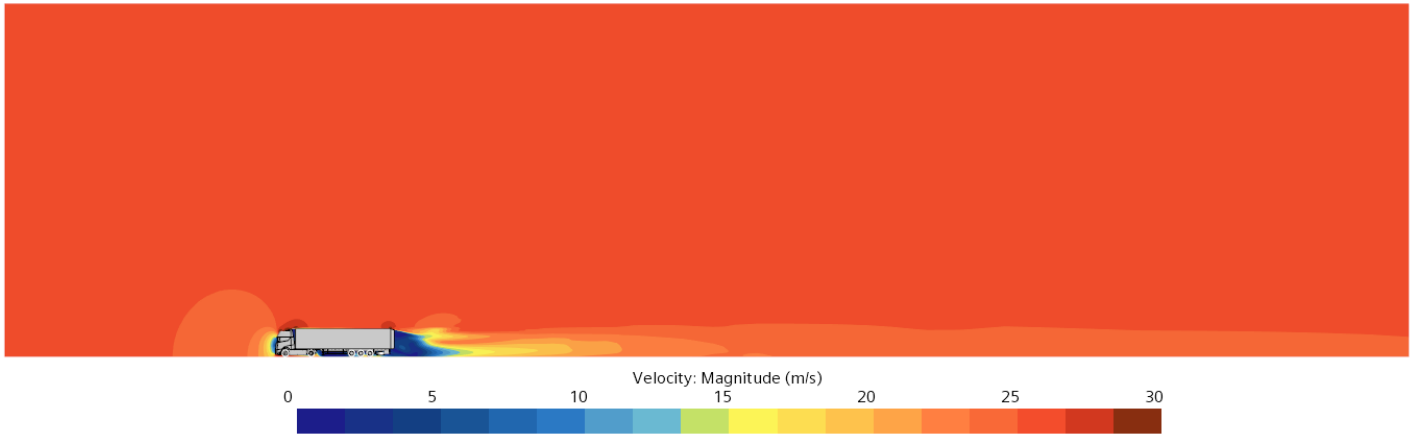
- TRF at 6,0deg. YZ plane through the tractor front axle. Entire domain



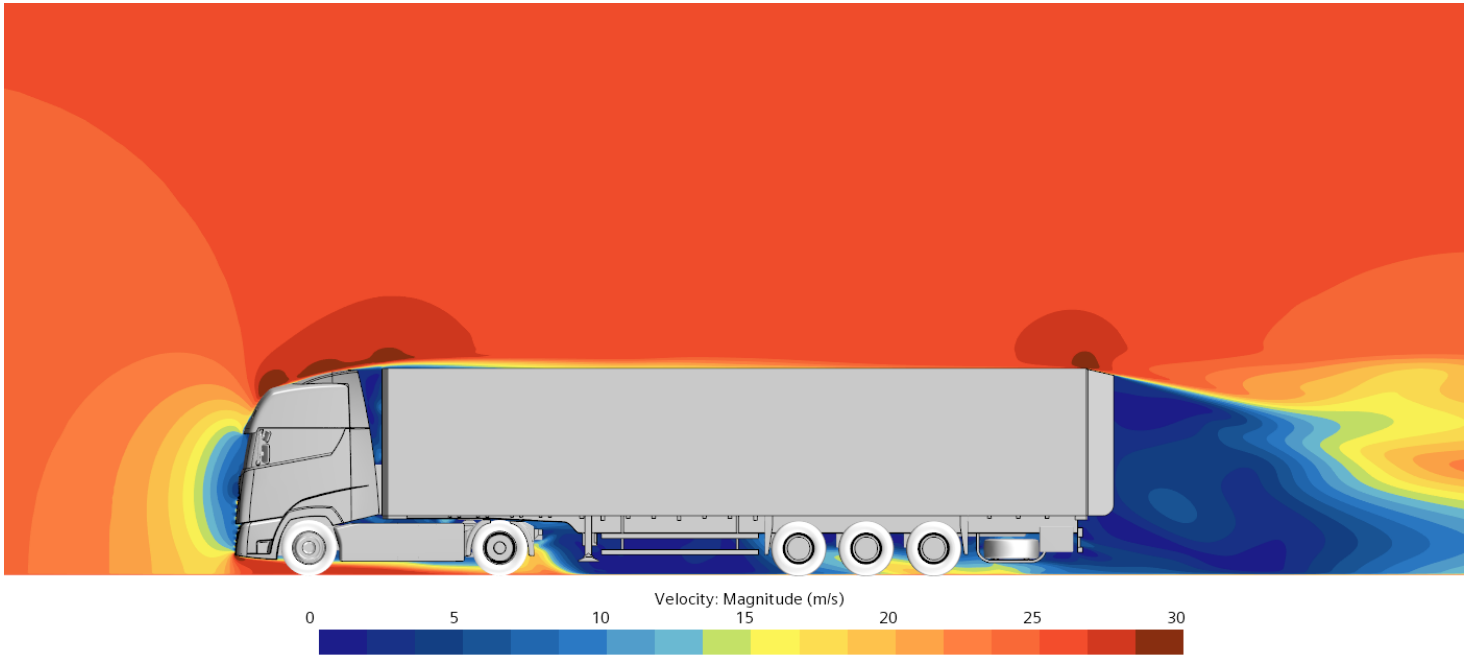
- TRF at 6,0deg. YZ plane through the tractor front axle. Vehicle detail



- TRF at 6,0deg. XZ plane through the centre of the vehicle. Entire domain



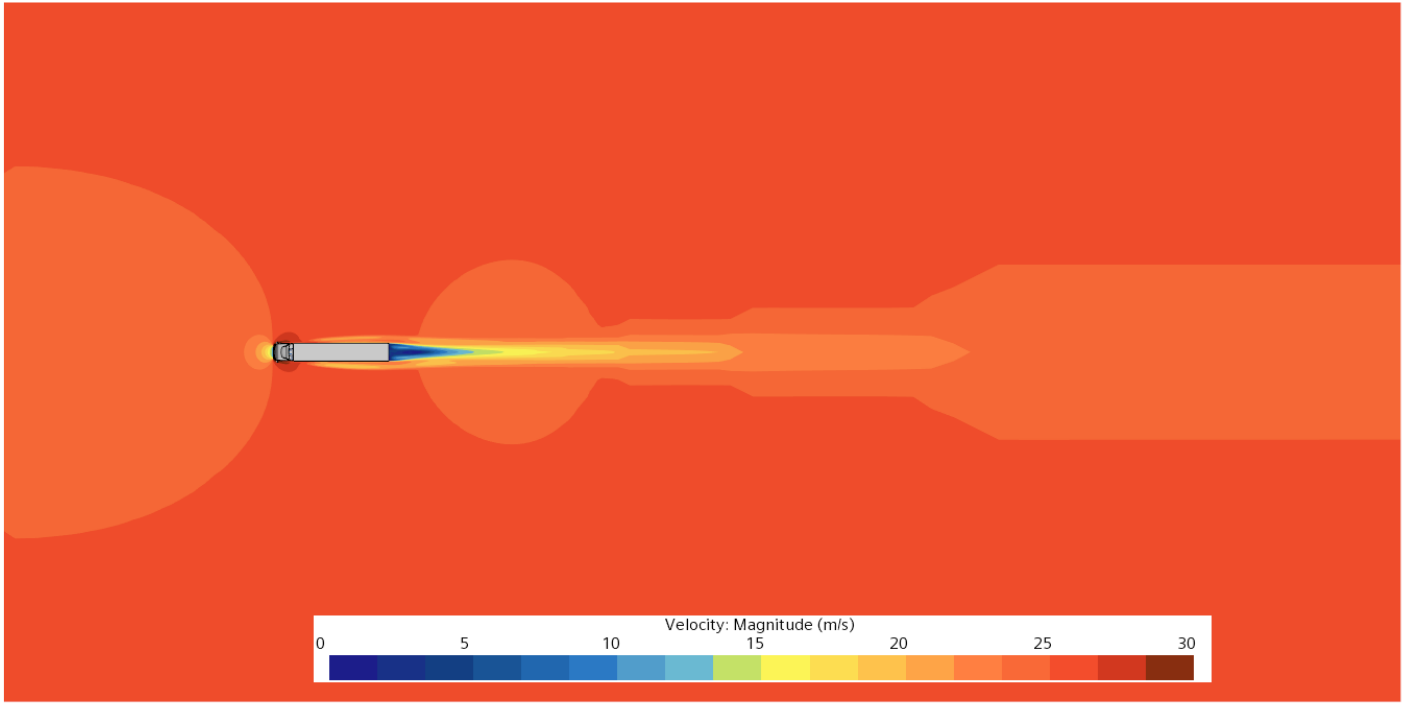
- TRF at 6,0deg. XZ plane through the centre of the vehicle. Vehicle detail



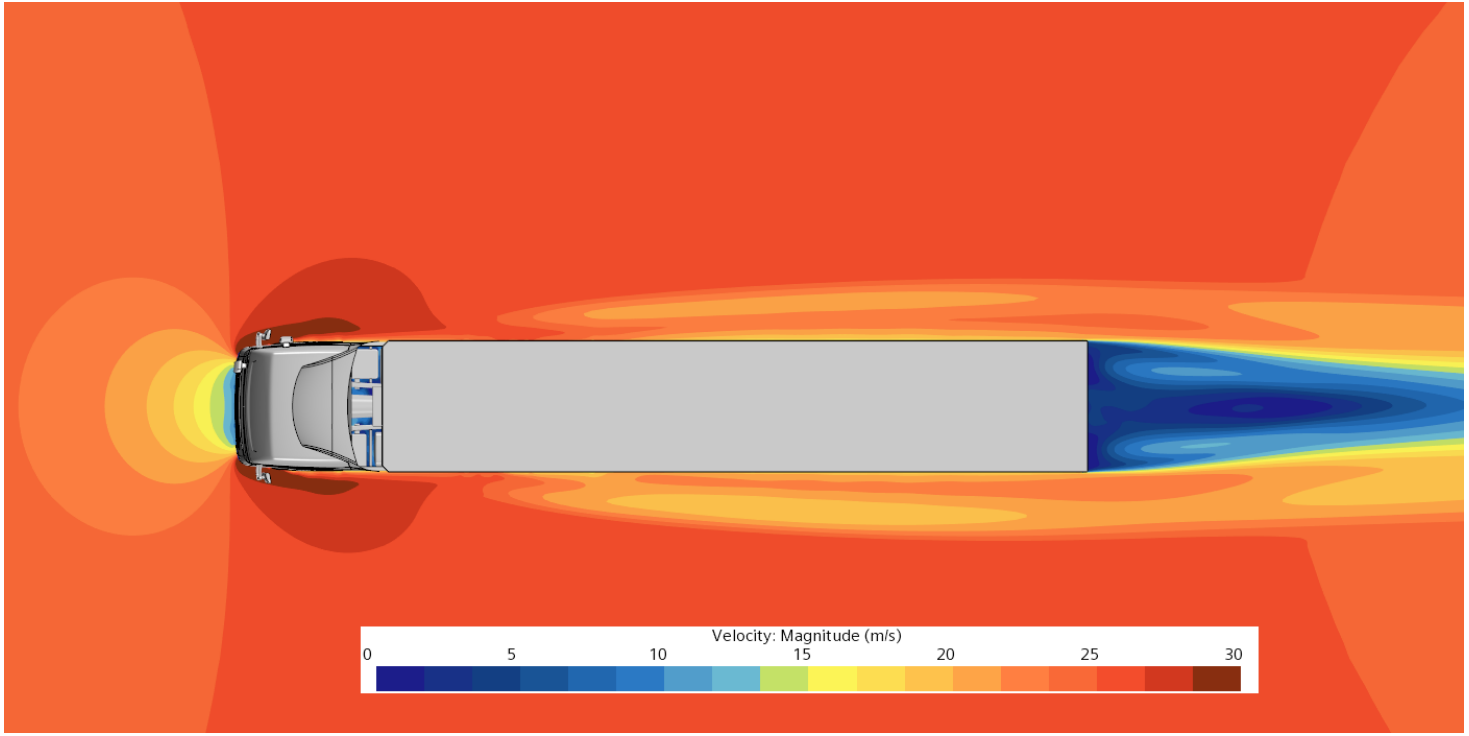
ANNEX VII

LSC AT 0,0 DEG OF YAW

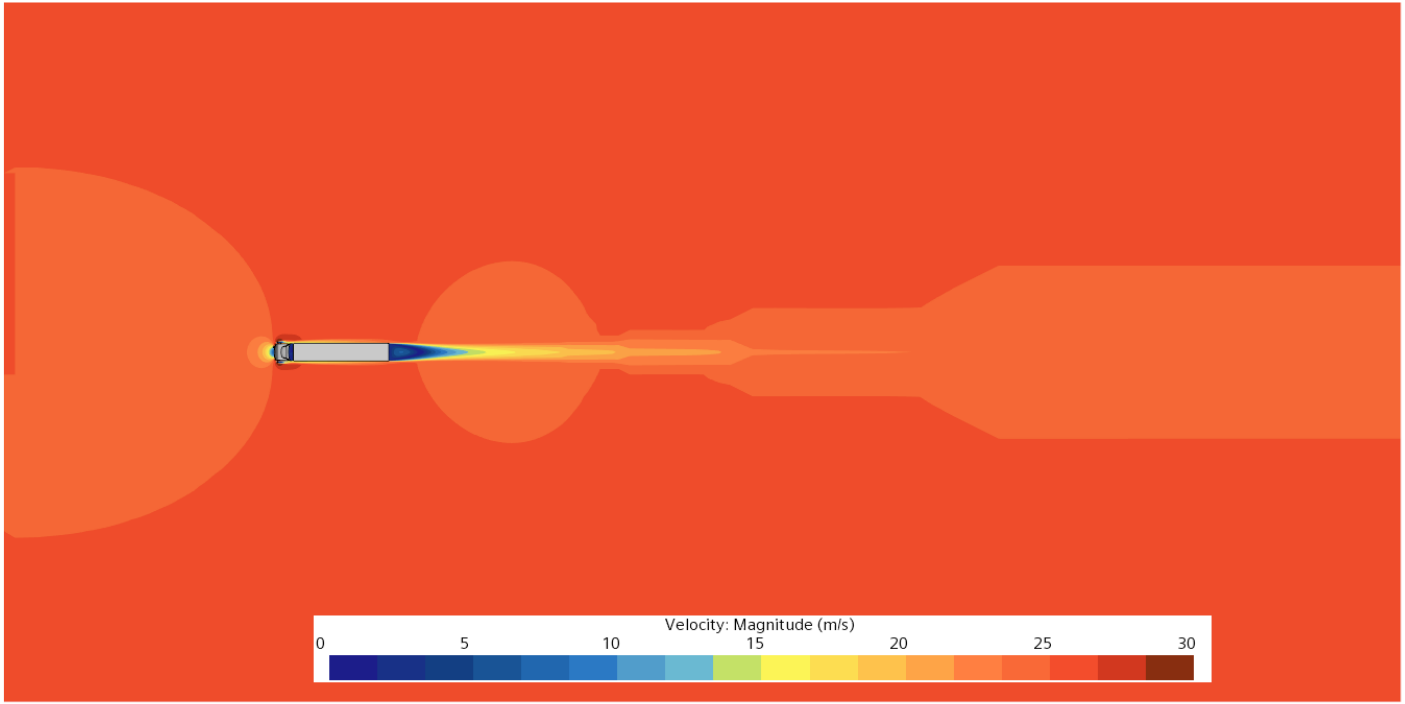
- LSC at 0,0deg. XY plane through the tractor front axle. Entire domain



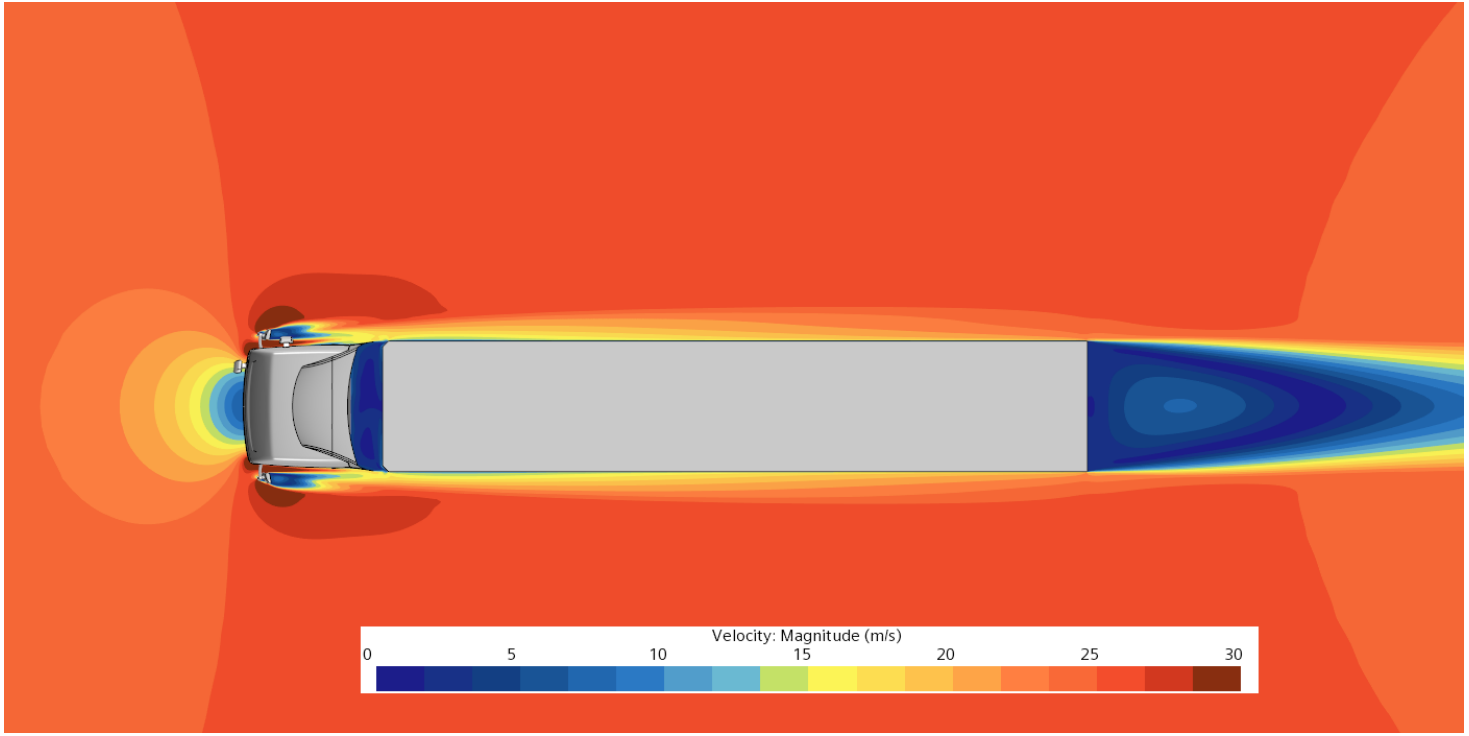
- LSC at 0,0deg. XY plane through the tractor front axle. Vehicle detail



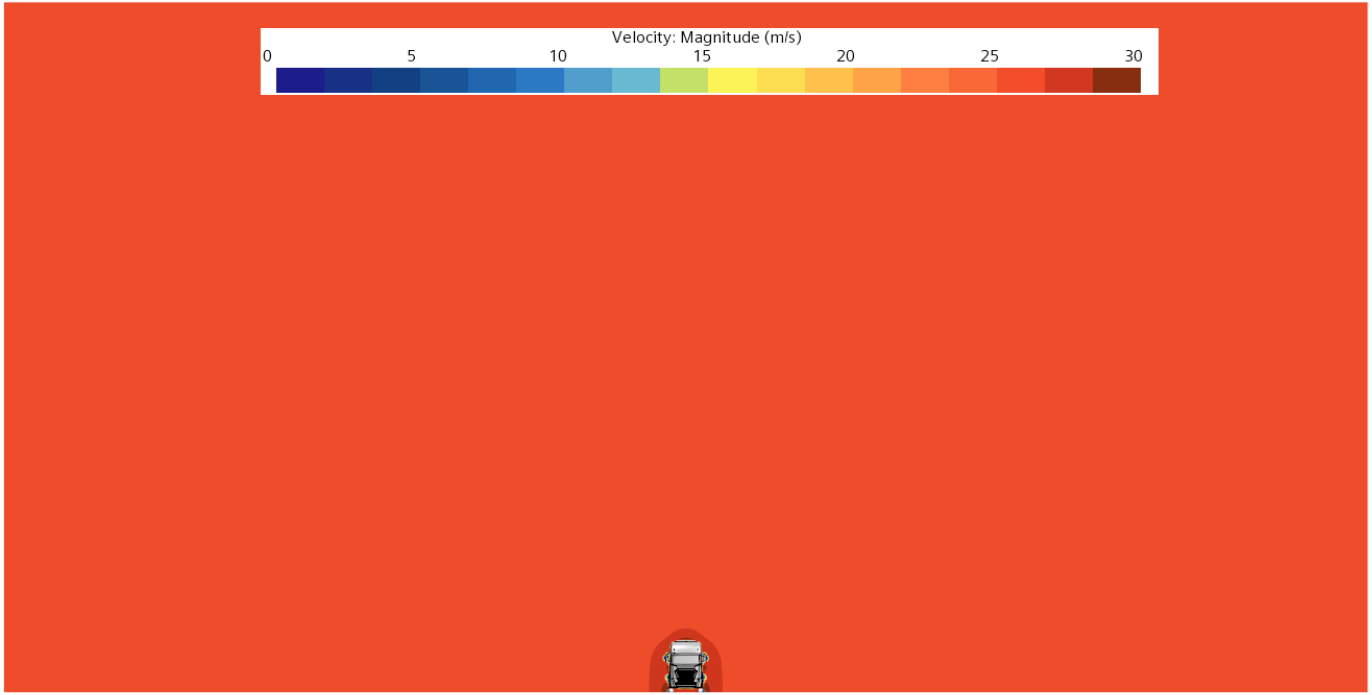
- LSC at 0,0deg. XY plane through the tractor side mirrors. Entire domain



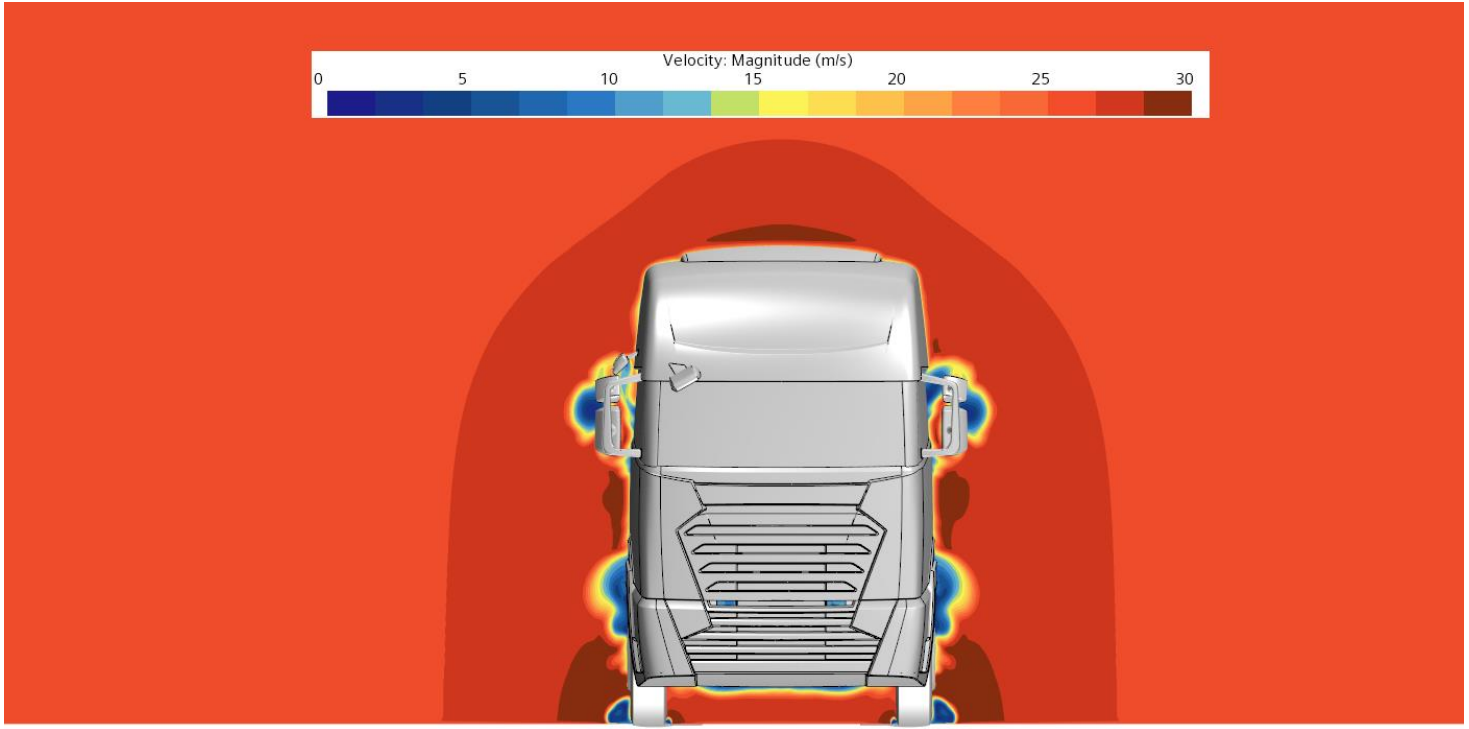
- LSC at 0,0deg. XY plane through the tractor side mirrors. Vehicle detail



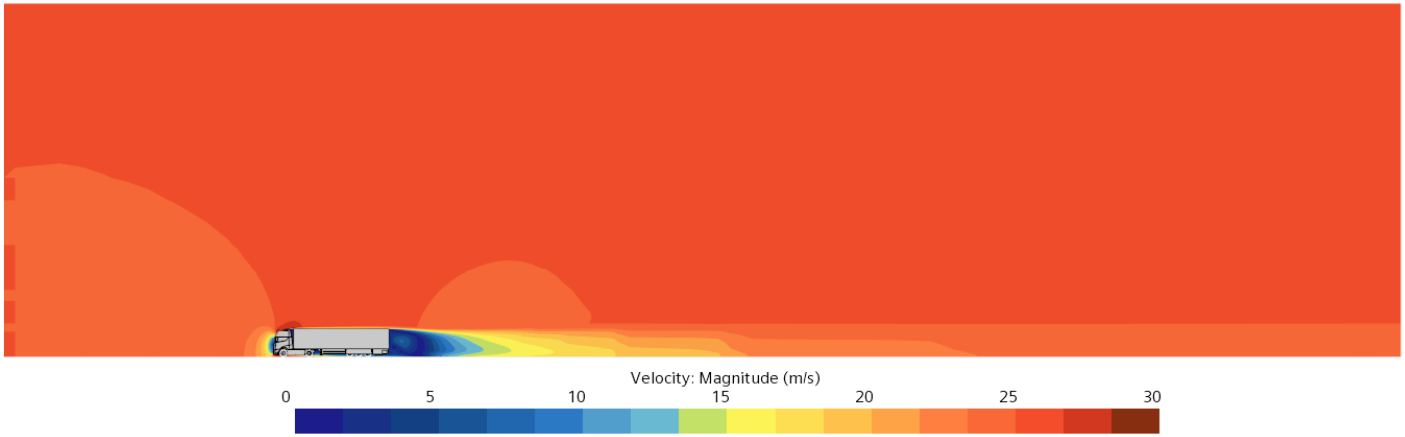
- LSC at 0,0deg. YZ plane through the tractor front axle. Entire domain



- LSC at 0,0deg. YZ plane through the tractor front axle. Vehicle detail



- LSC at 0,0deg. XZ plane through the centre of the vehicle. Entire domain



RESULTS

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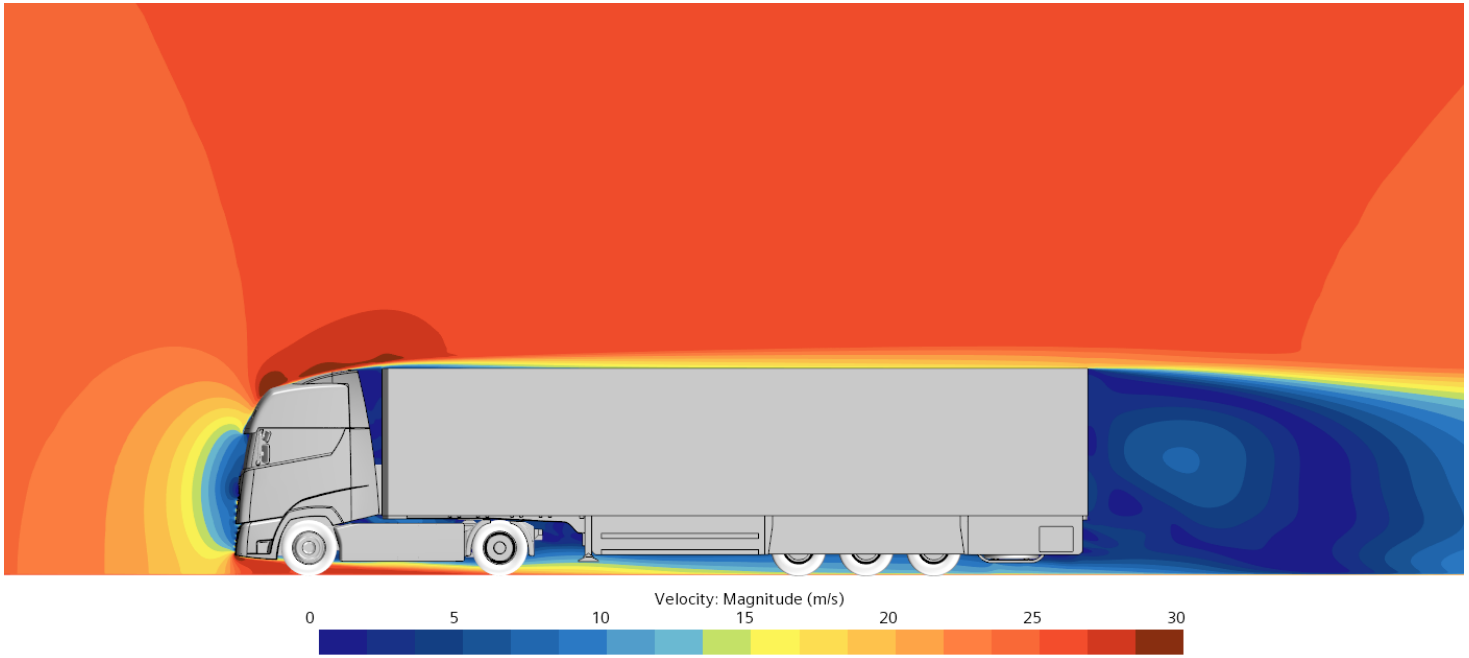
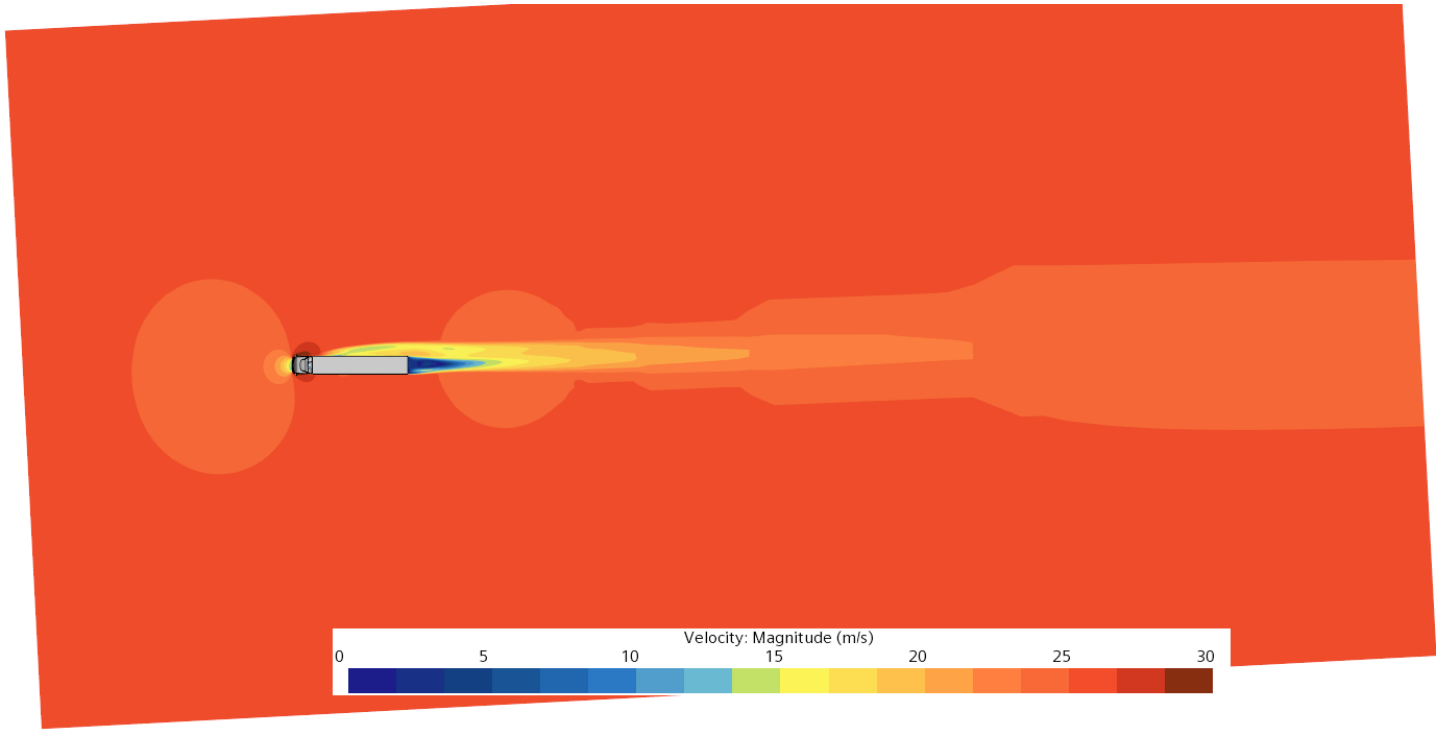
- LSC at 0,0deg. XZ plane through the centre of the vehicle. Vehicle detail



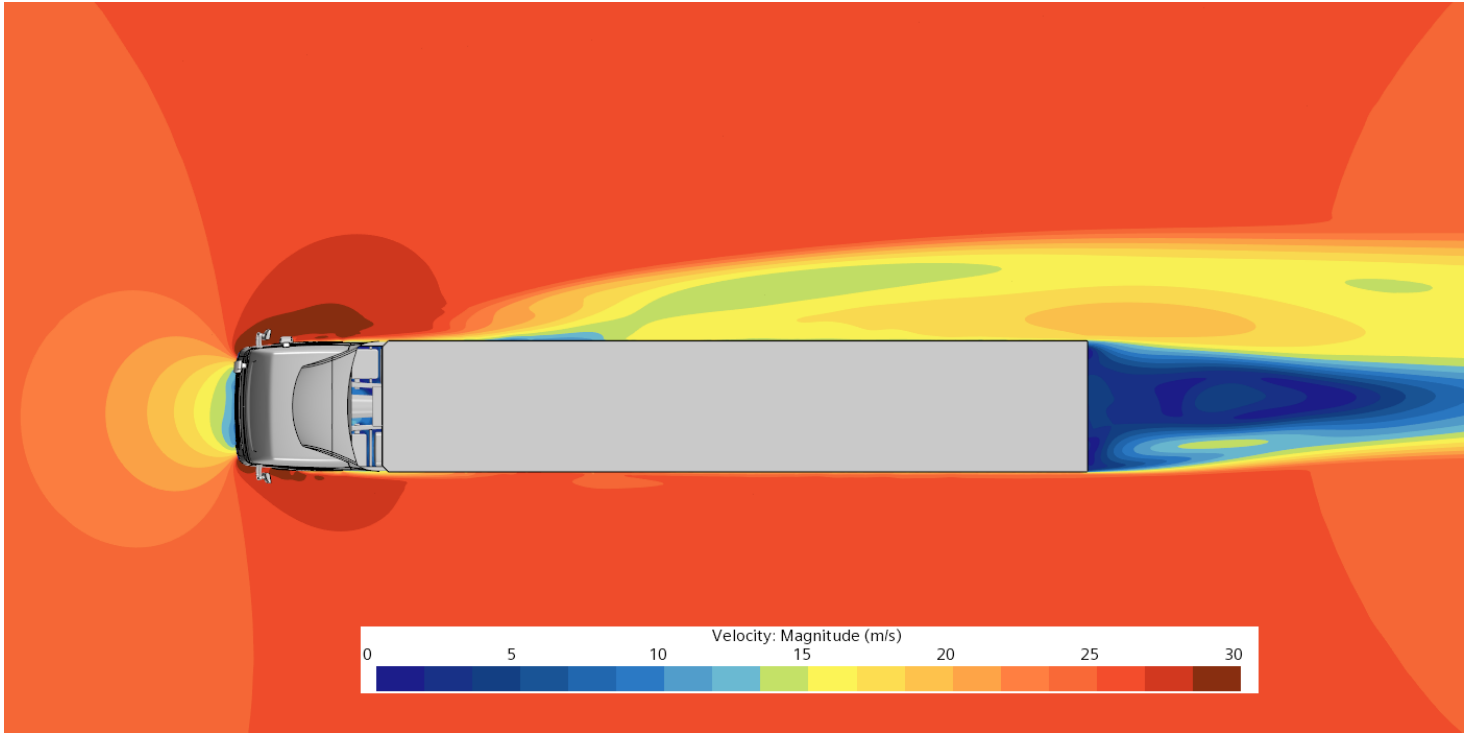
ANNEX VIII

LSC AT 3,0 DEG OF YAW

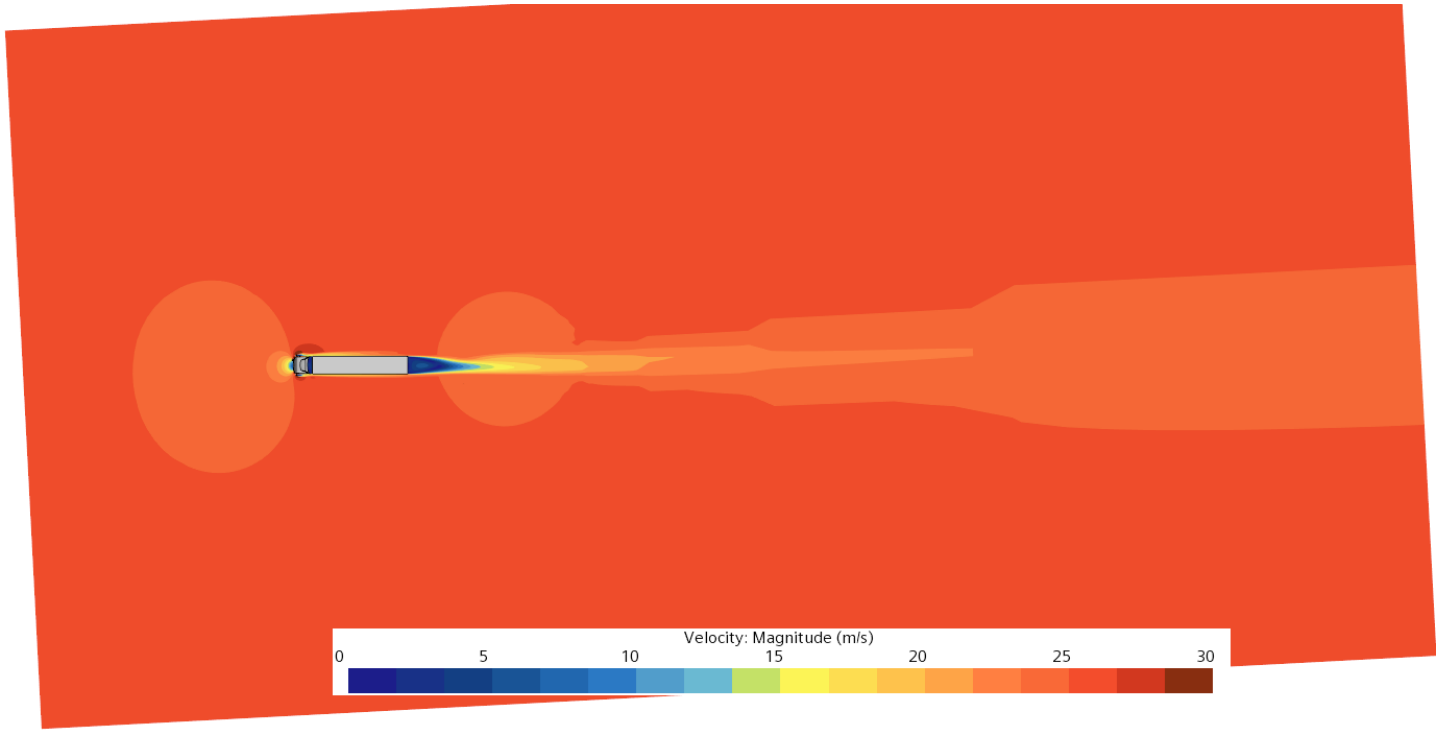
- LSC at 3,0deg. XY plane through the tractor front axle. Entire domain



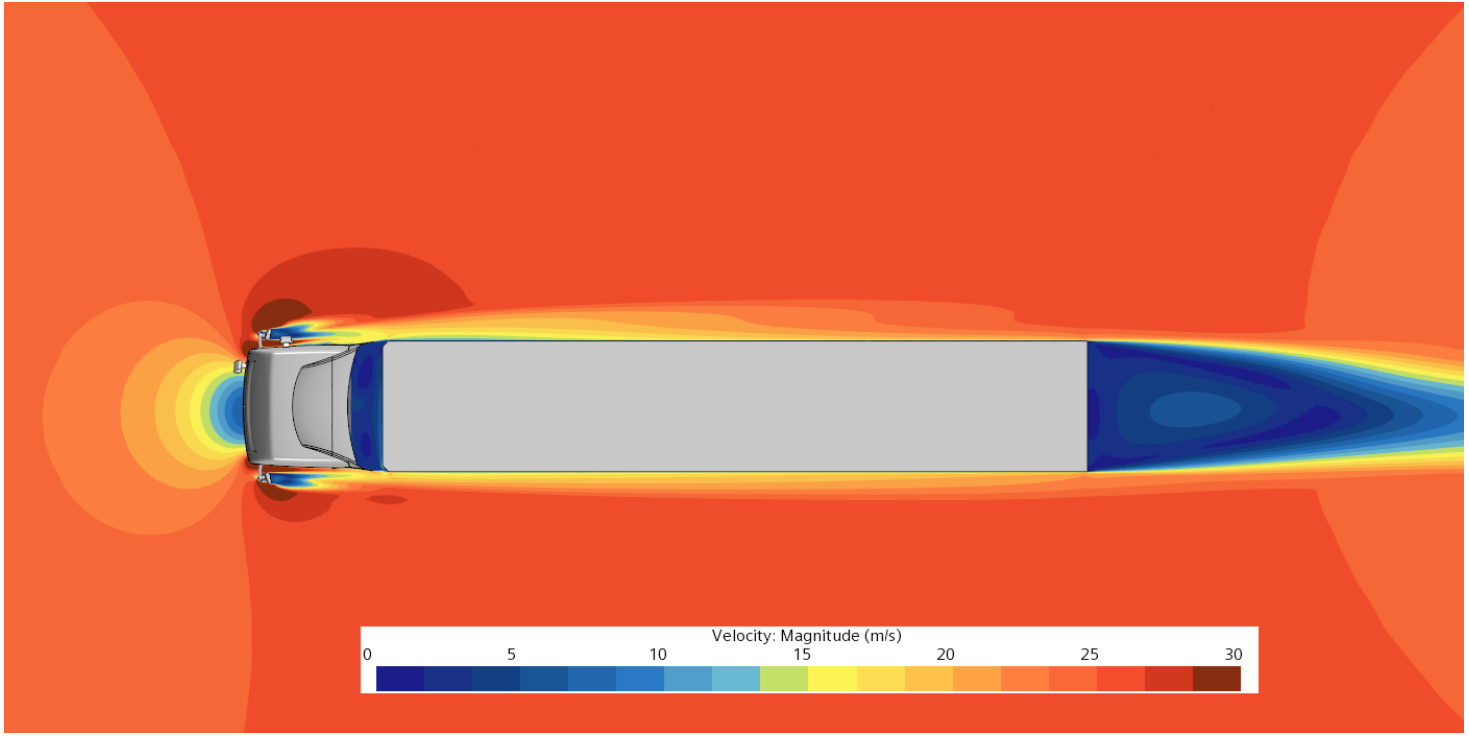
- LSC at 3,0deg. XY plane through the tractor front axle. Vehicle detail



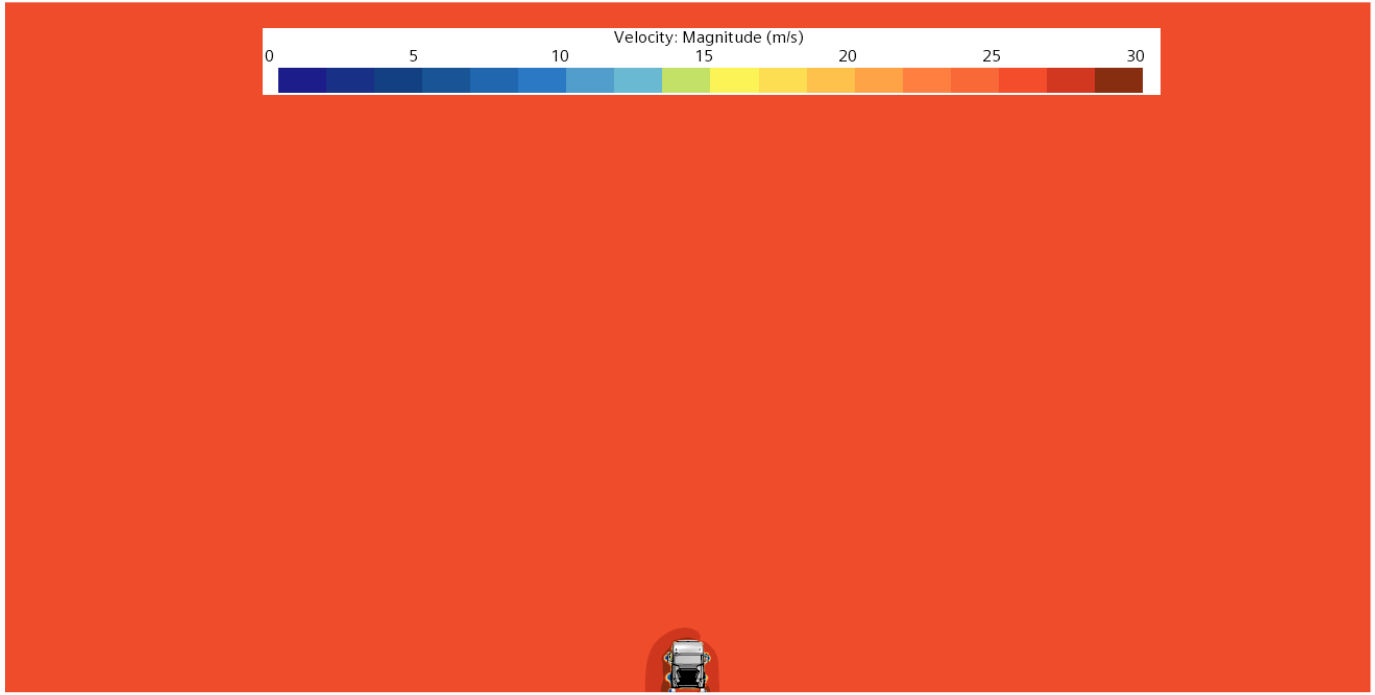
- LSC at 3,0deg. XY plane through the tractor side mirrors. Entire domain



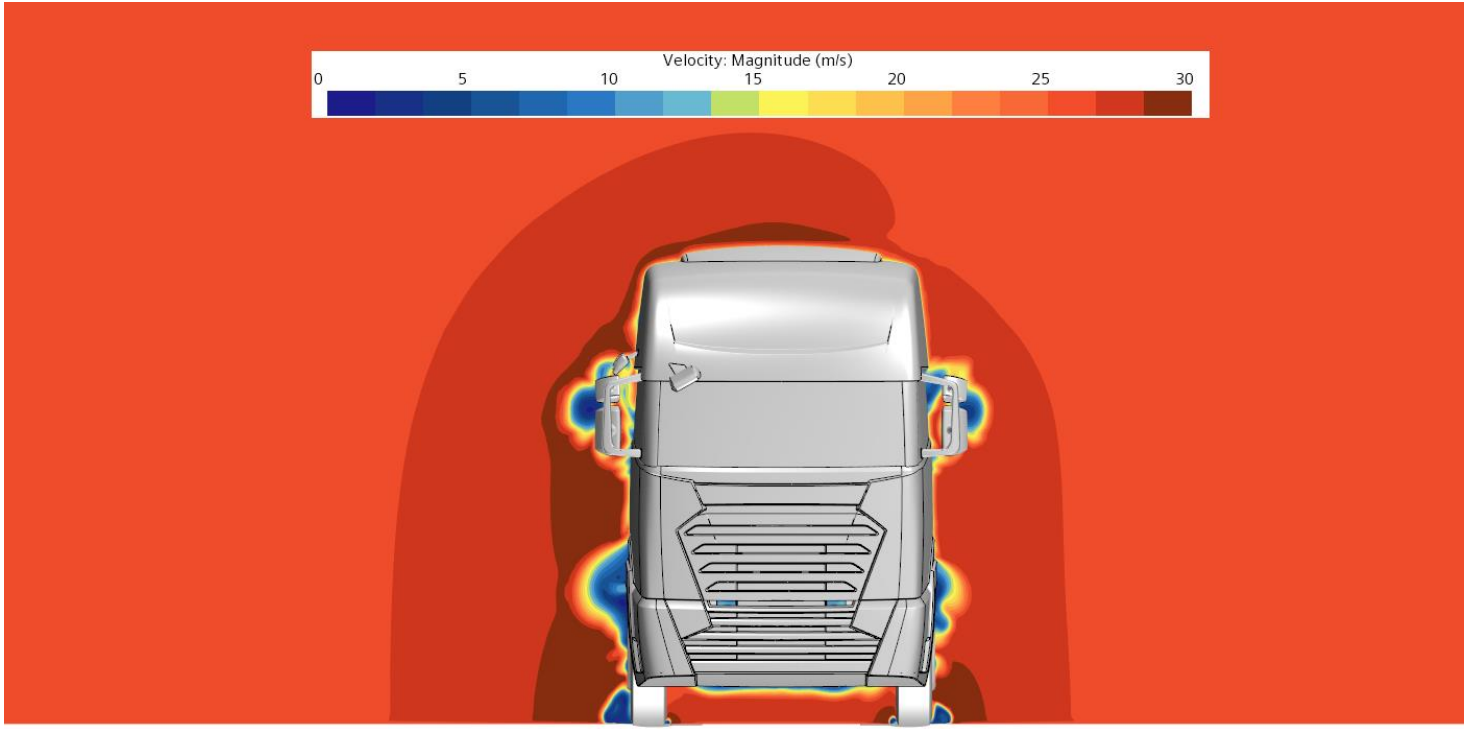
- LSC at 3,0deg. XY plane through the tractor side mirrors. Vehicle detail



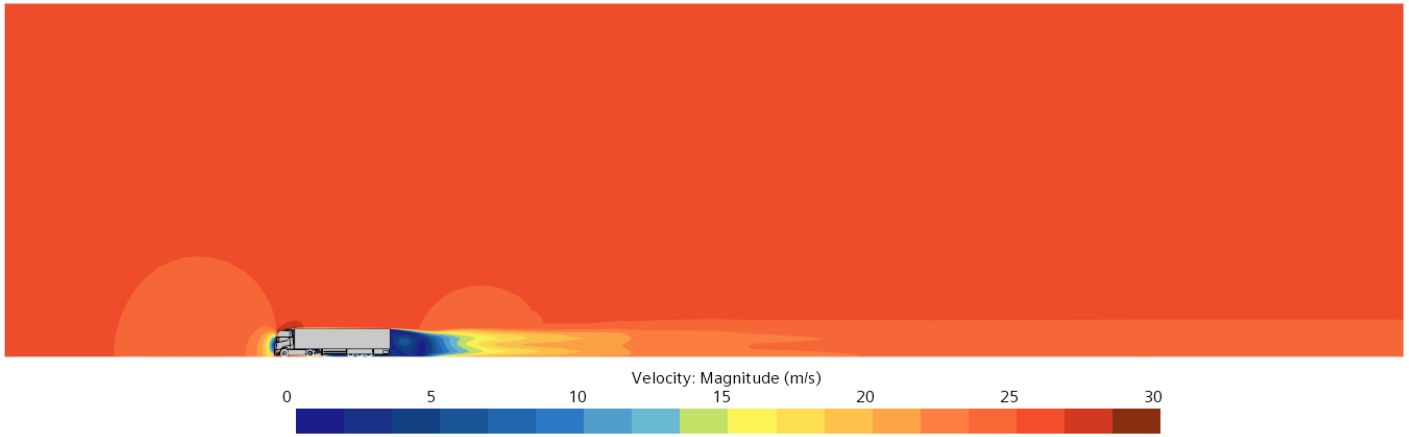
- LSC at 3,0deg. YZ plane through the tractor front axle. Entire domain



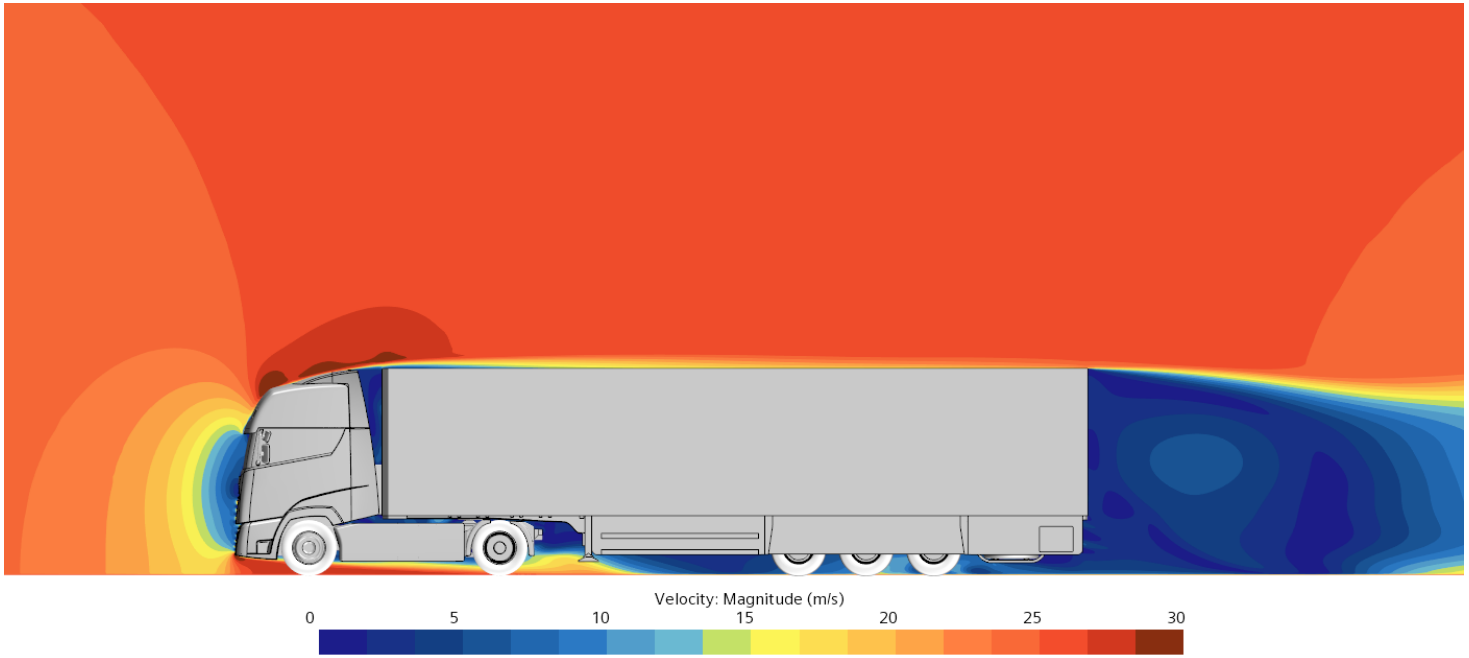
- LSC at 3,0deg. YZ plane through the tractor front axle. Vehicle detail



- LSC at 3,0deg. XZ plane through the centre of the vehicle. Entire domain



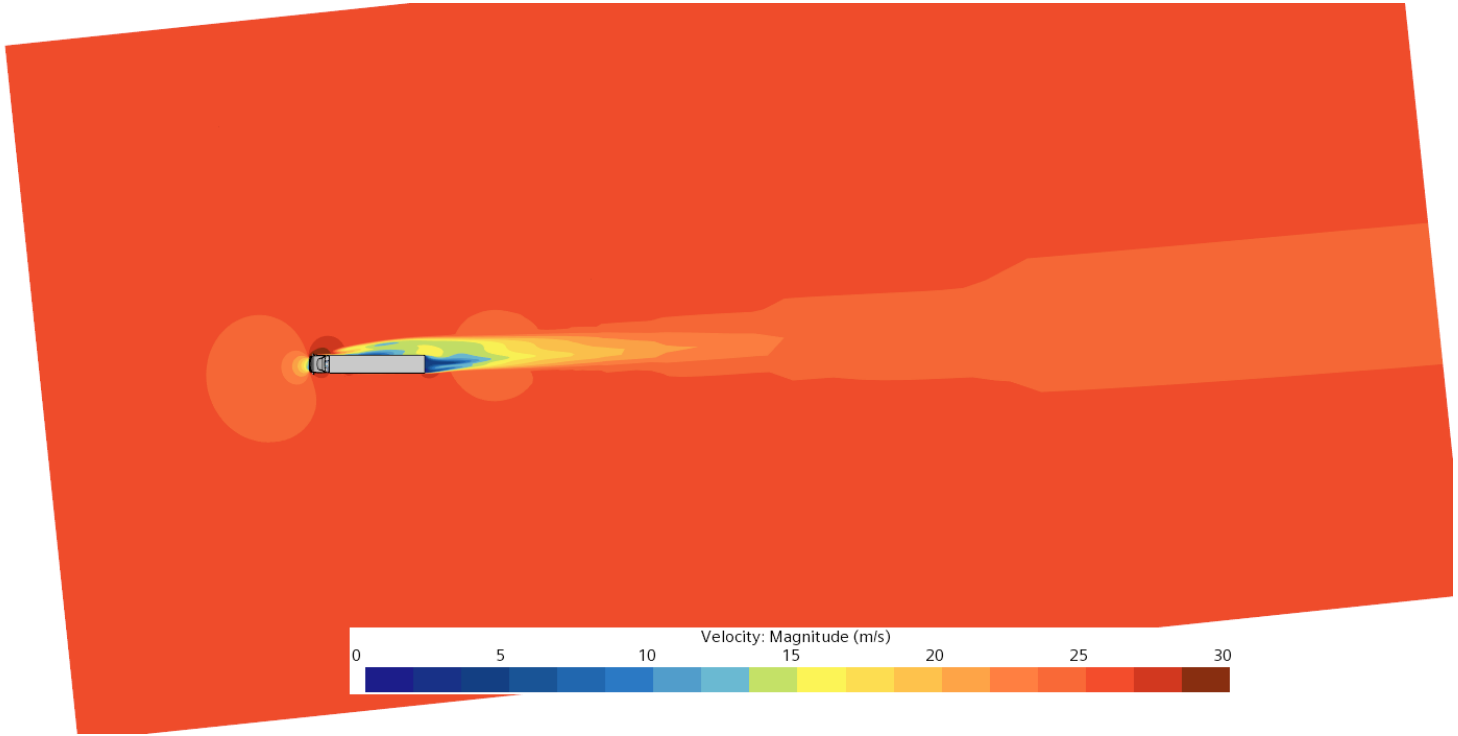
- LSC at 3,0deg. XZ plane through the centre of the vehicle. Vehicle detail



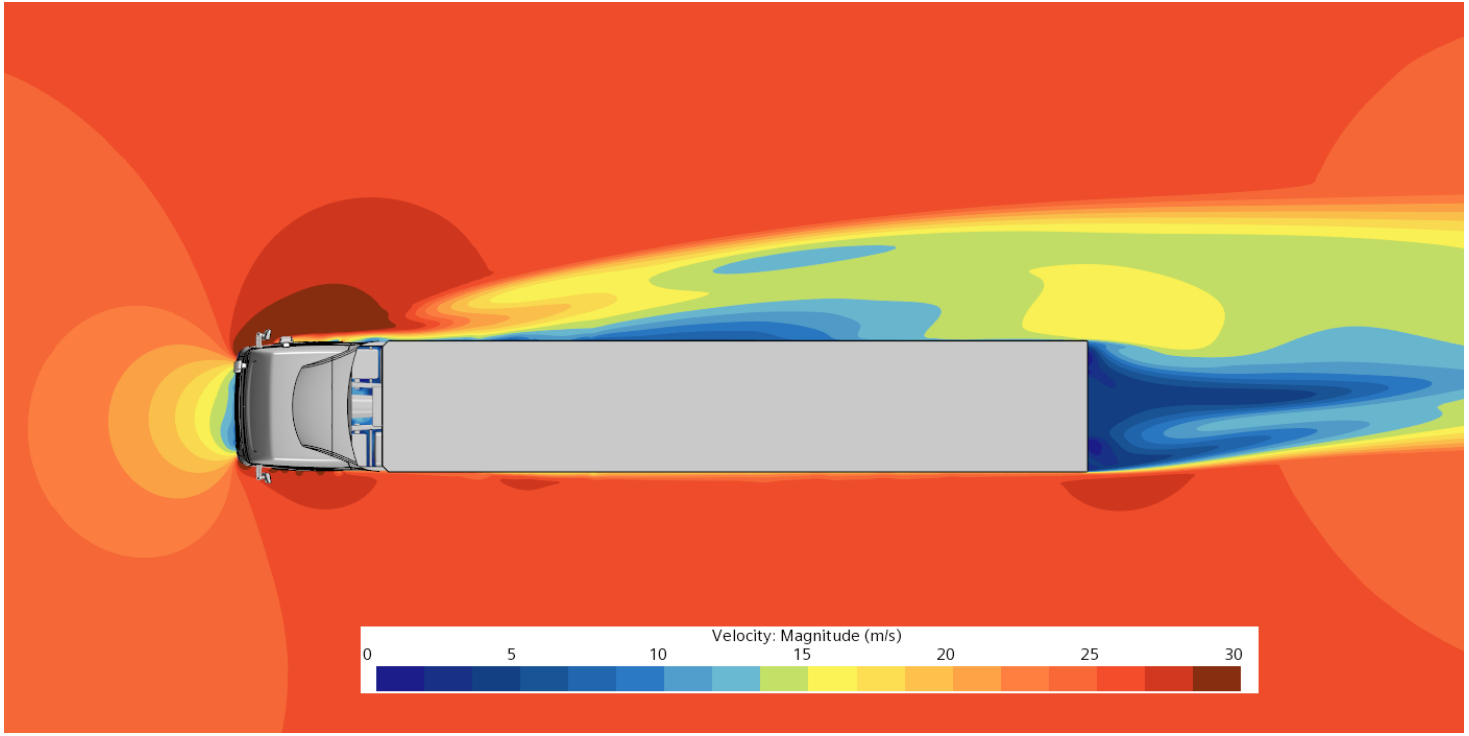
ANNEX IX

LSC AT 6,0 DEG OF YAW

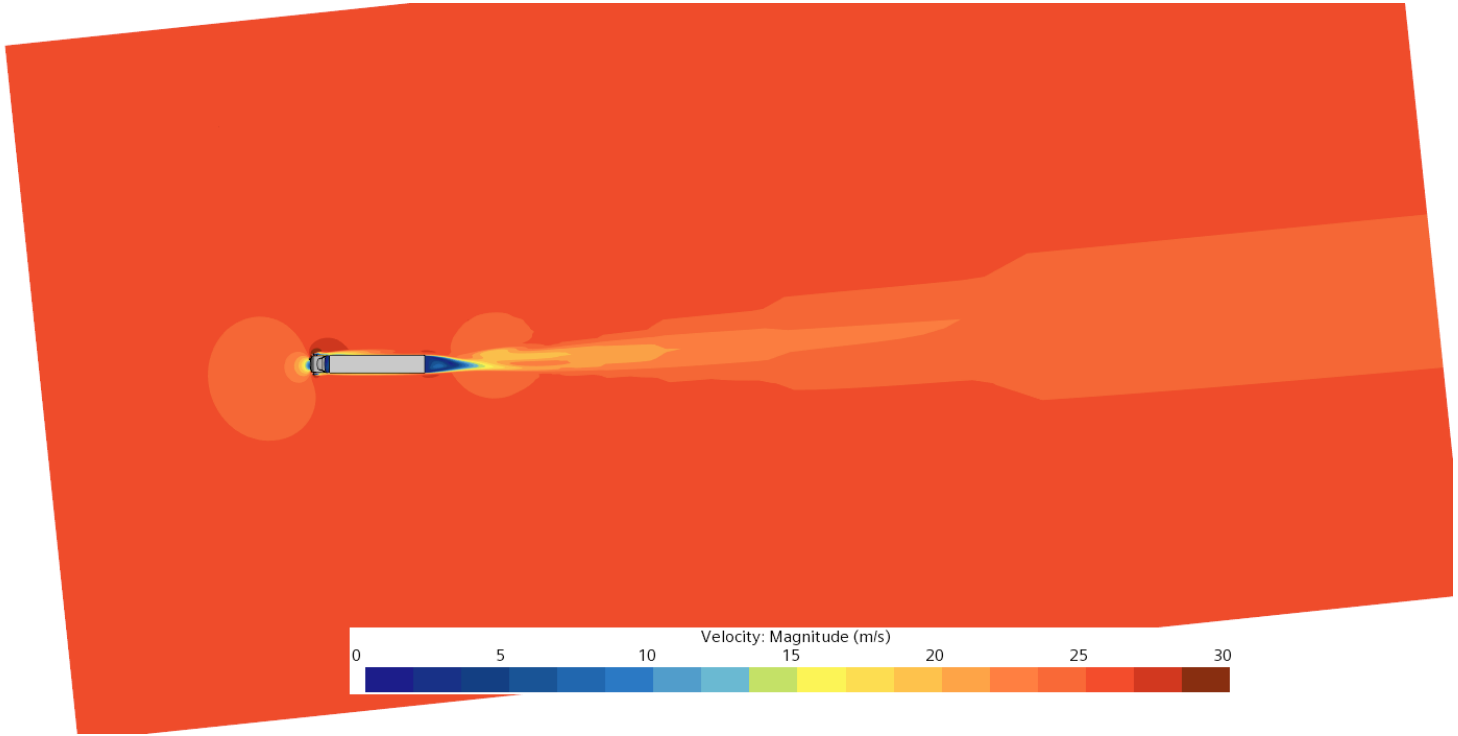
- LSC at 6,0deg. XY plane through the tractor front axle. Entire domain



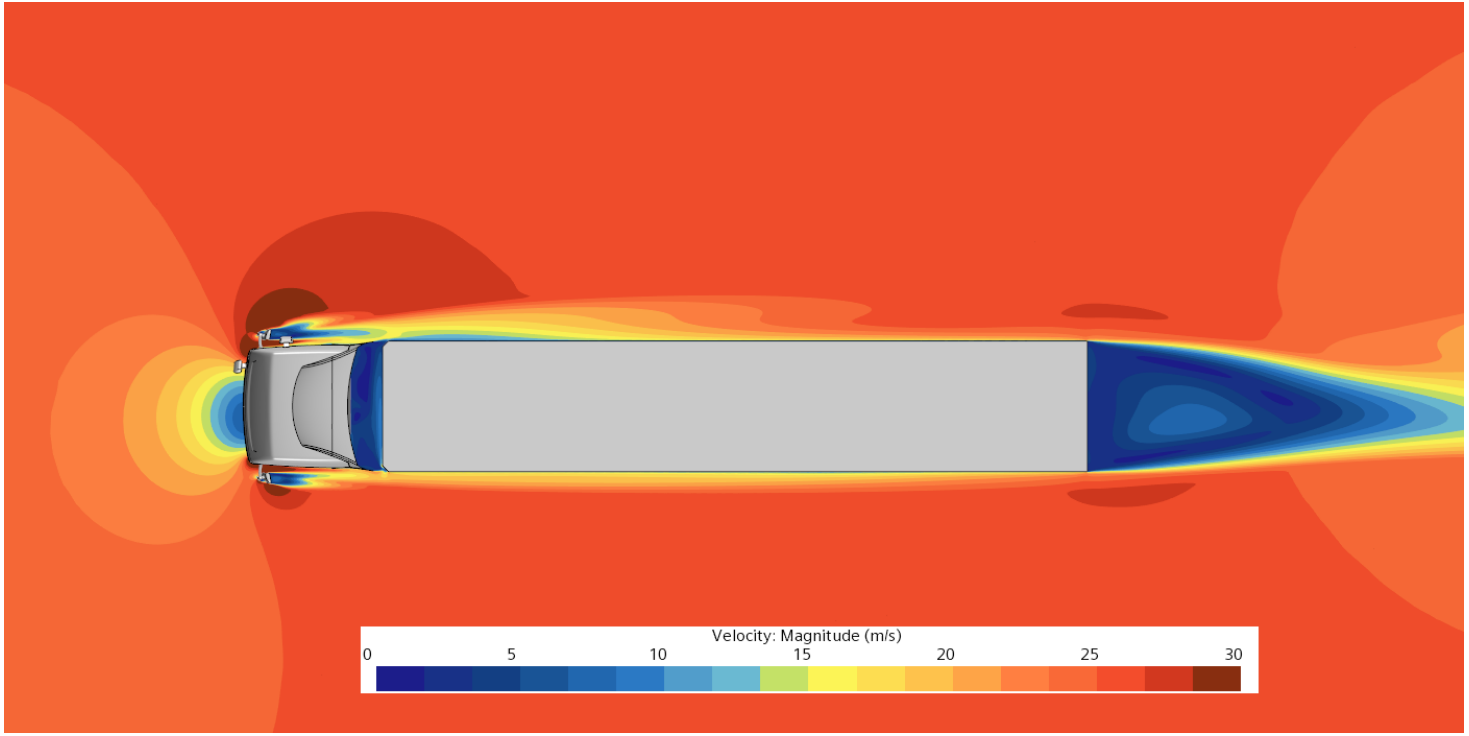
- LSC at 6,0deg. XY plane through the tractor front axle. Vehicle detail



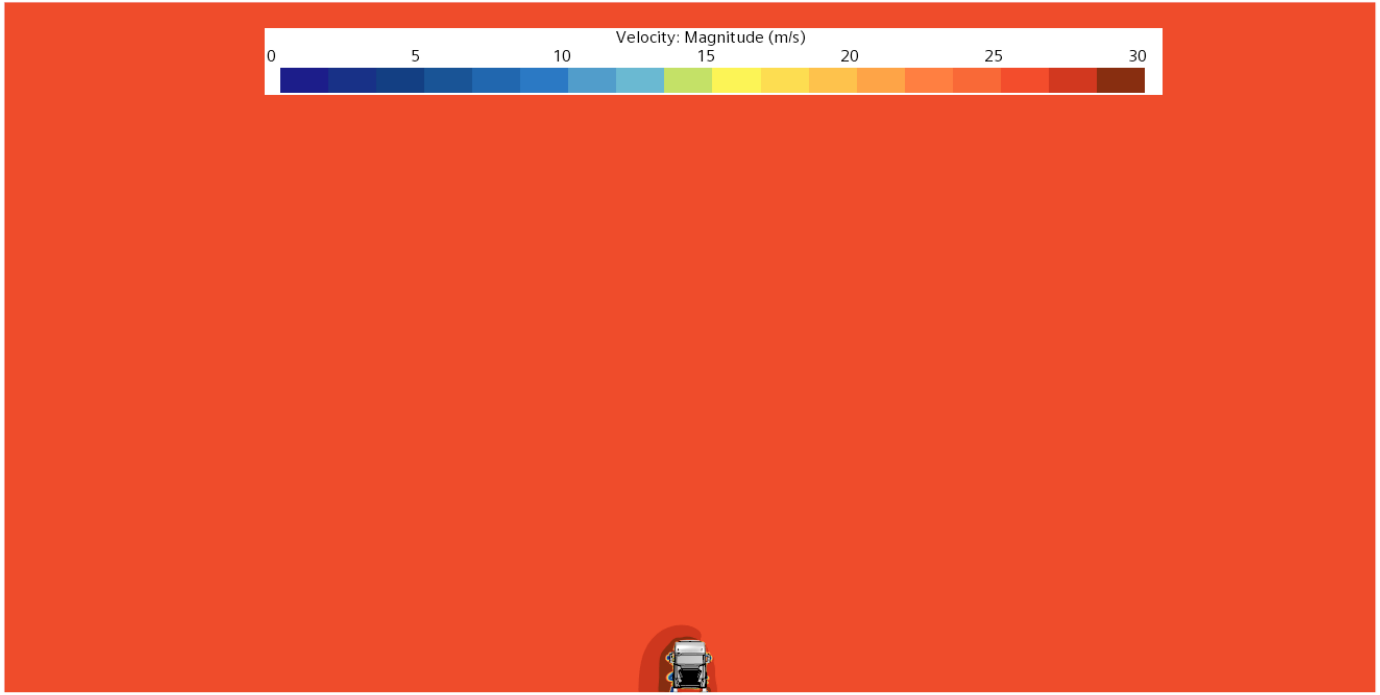
- LSC at 6,0deg. XY plane through the tractor side mirrors. Entire domain



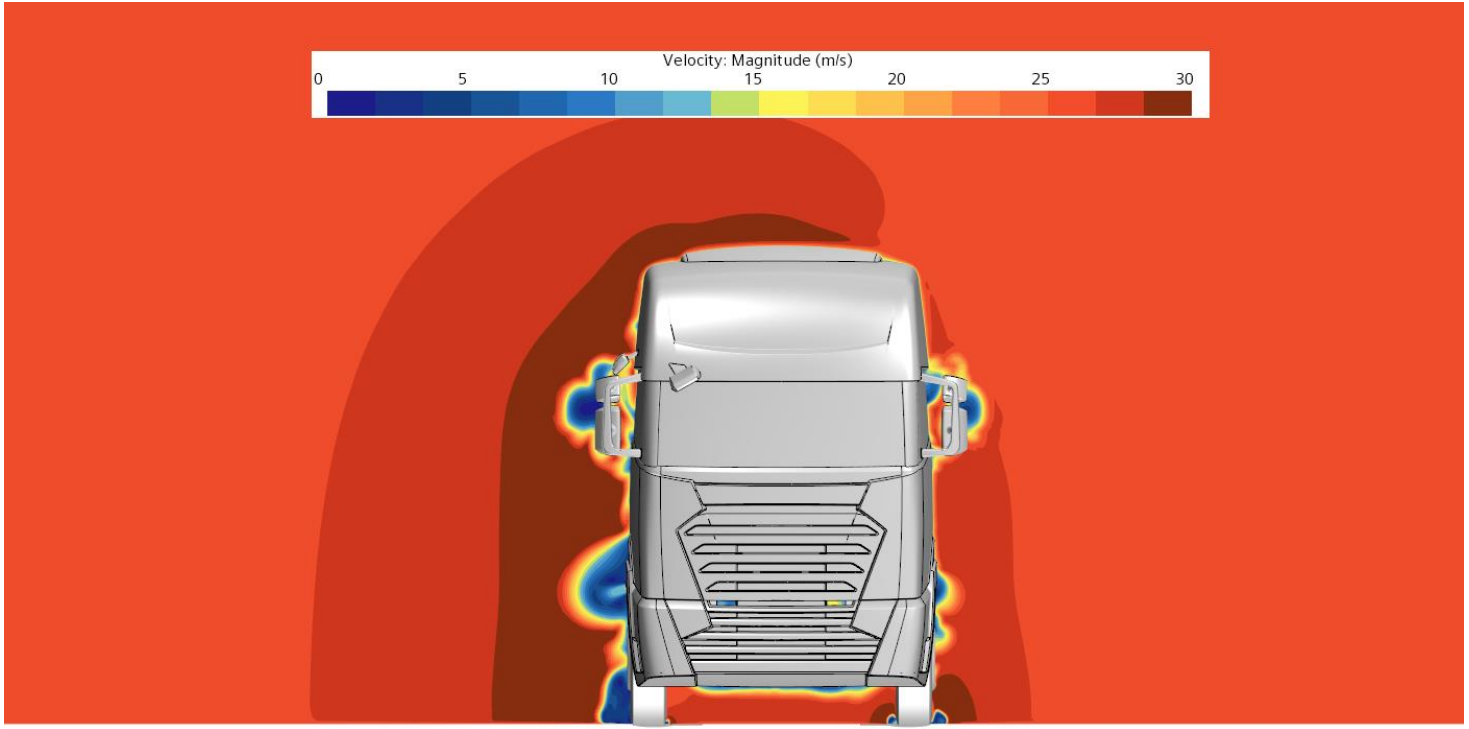
- LSC at 6,0deg. XY plane through the tractor side mirrors. Vehicle detail



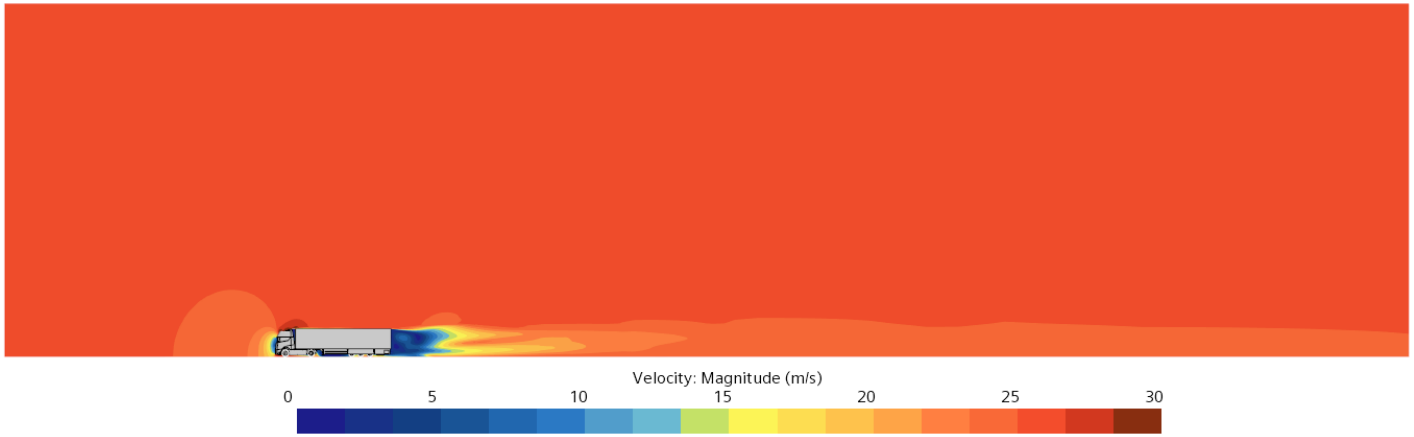
- LSC at 6,0deg. YZ plane through the tractor front axle. Entire domain



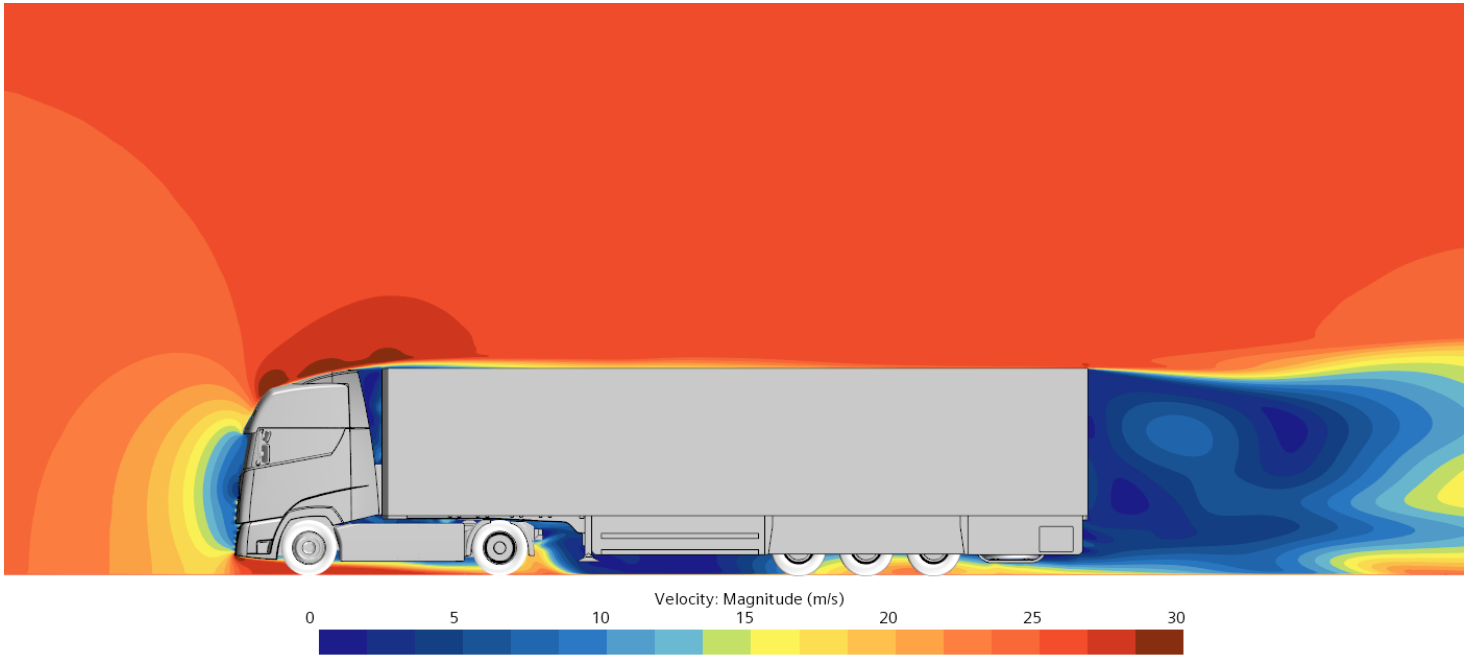
- LSC at 6,0deg. YZ plane through the tractor front axle. Vehicle detail



- LSC at 6,0deg. XZ plane through the centre of the vehicle. Entire domain



- LSC at 6,0deg. XZ plane through the centre of the vehicle. Vehicle detail



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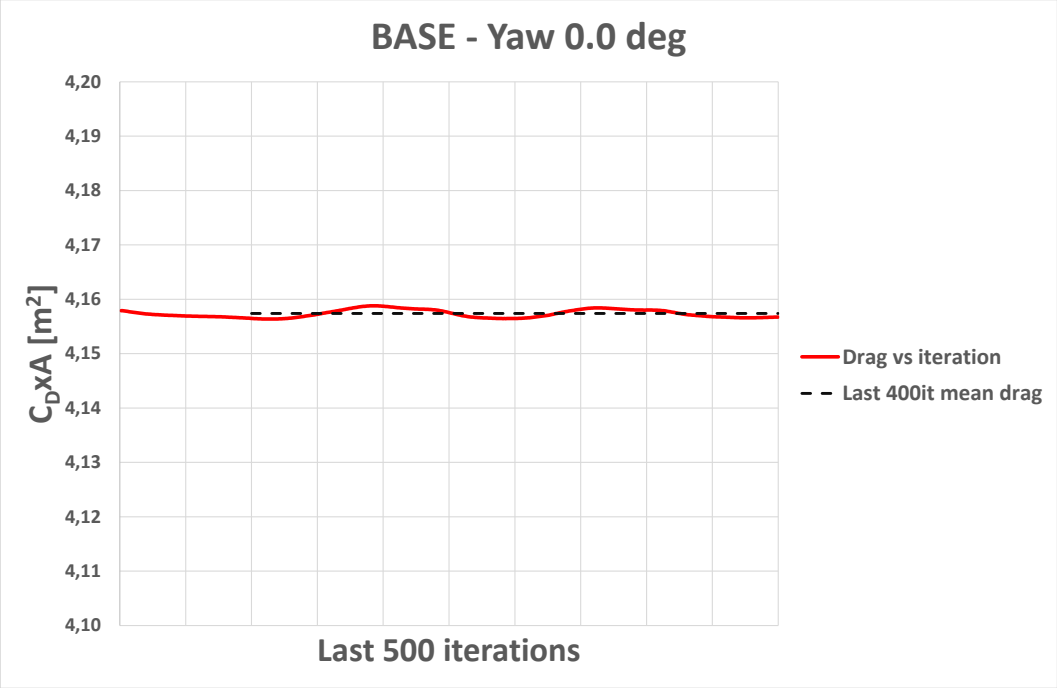
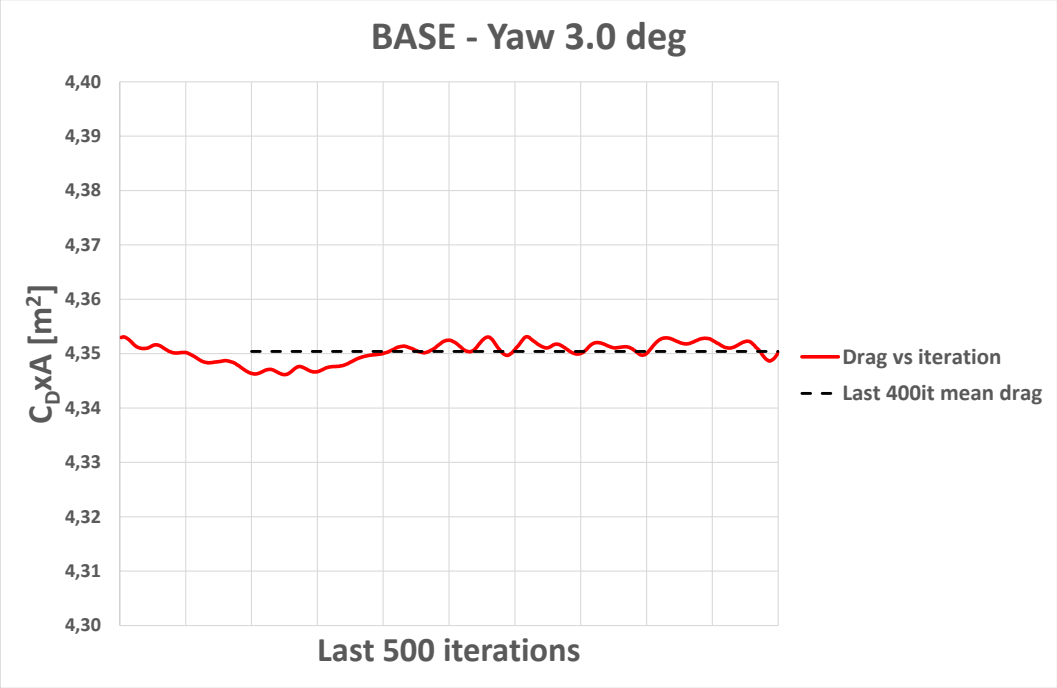
ANNEX X

C_DxA[m²] VS ITERATION

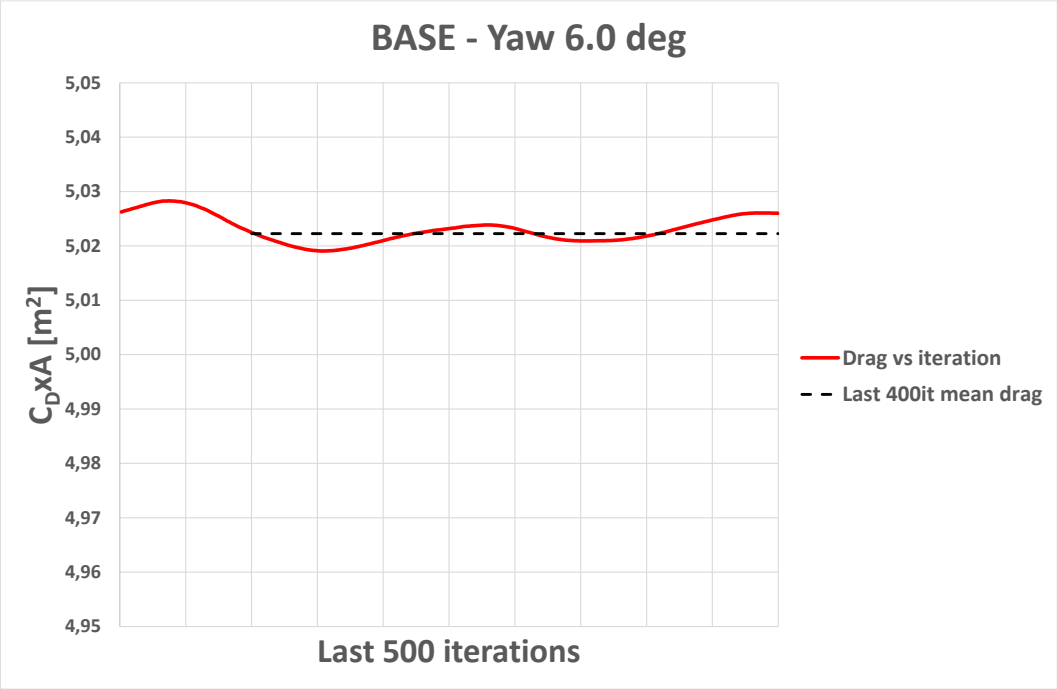
- C_DxA[m^2] over the last 500 iterations for BASE at 0,0 deg of yaw



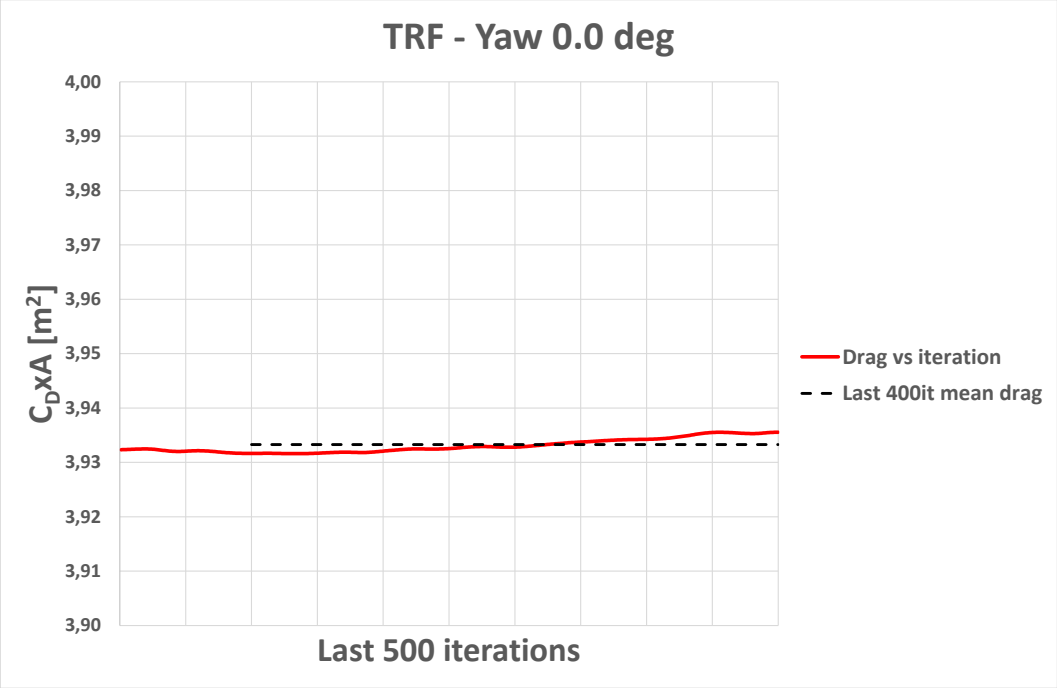
- C_DxA[m^2] over the last 500 iterations for BASE at 3,0 deg of yaw



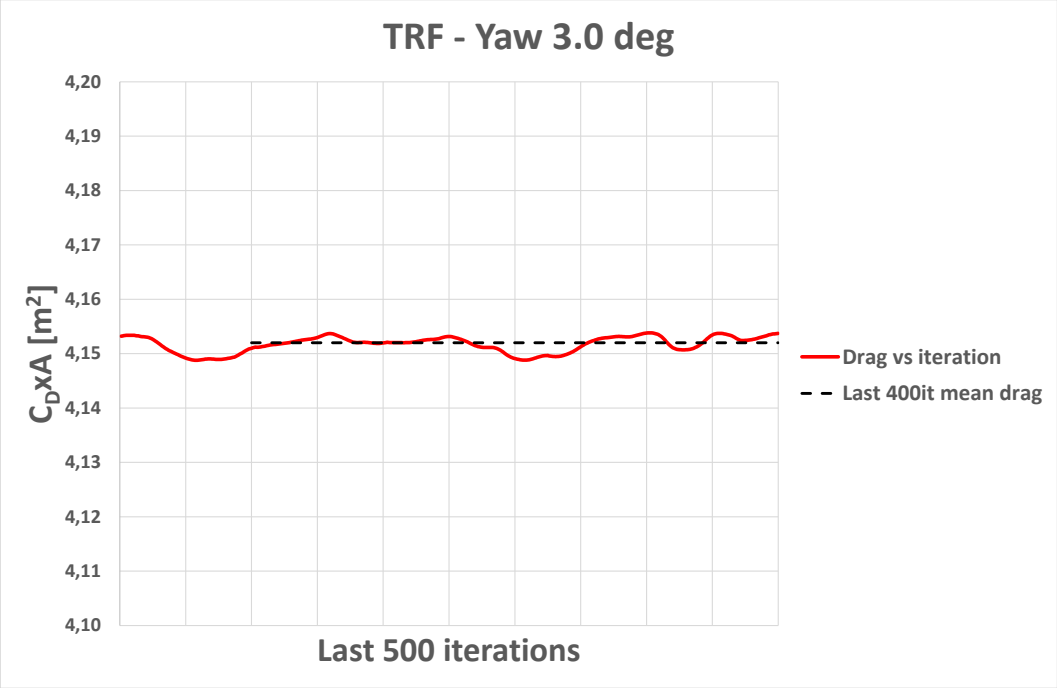
- $C_D xA[m^2]$ over the last 500 iterations for BASE at 6,0 deg of yaw



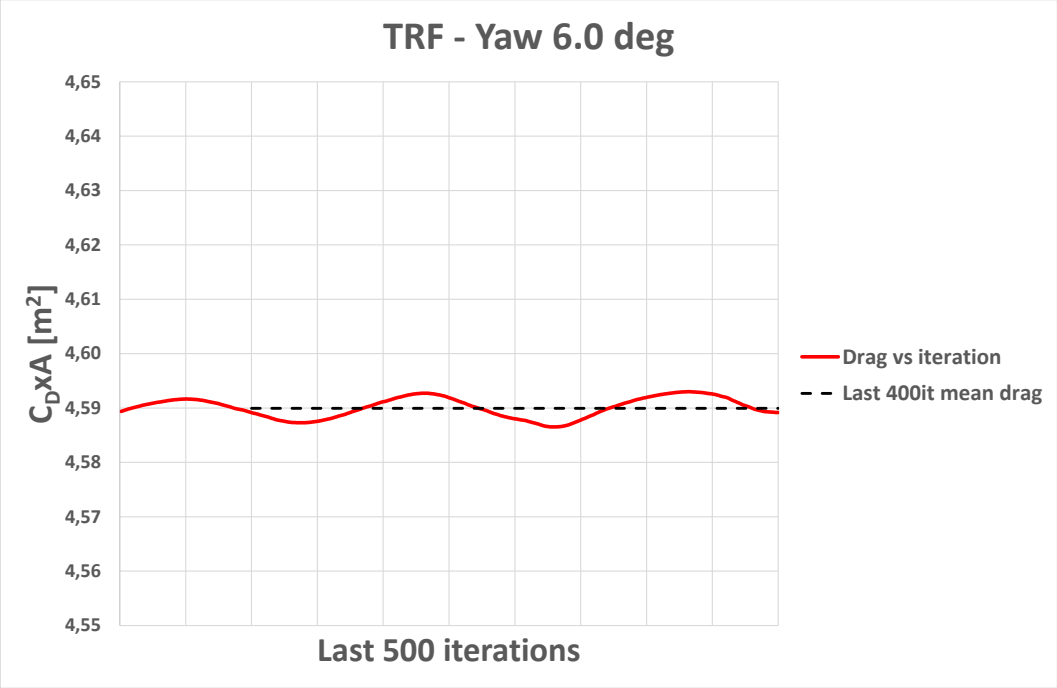
- C_DxA[m^2] over the last 500 iterations for TRF at 0,0 deg of yaw



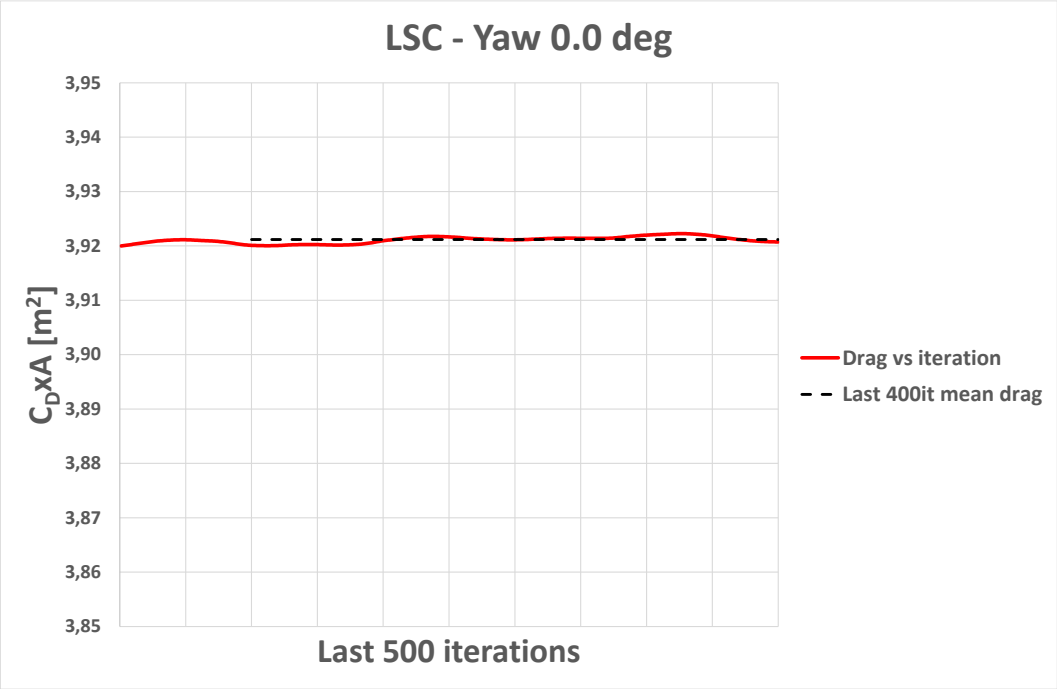
- C_DxA[m^2] over the last 500 iterations for TRF at 3,0 deg of yaw



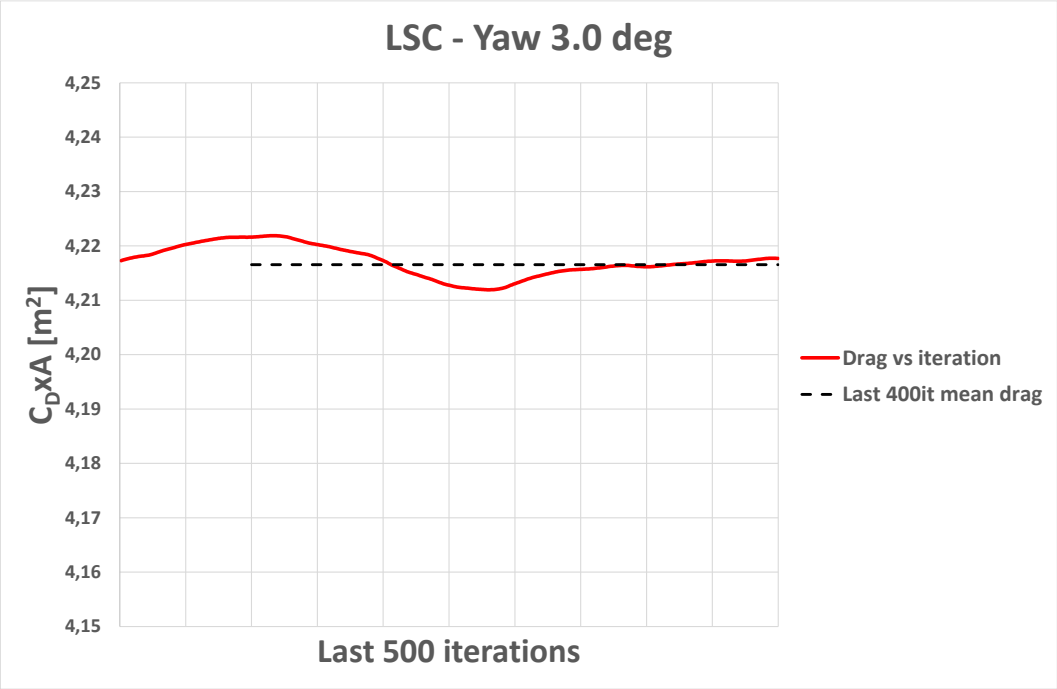
- C_DxA[m^2] over the last 500 iterations for TRF at 6,0 deg of yaw



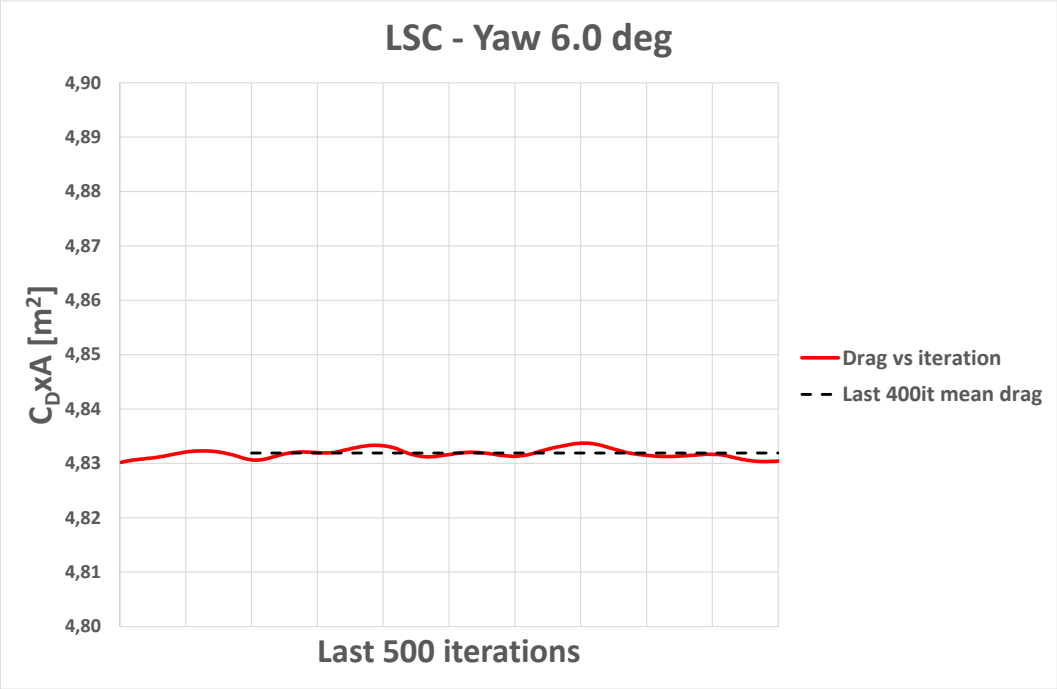
- C_DxA[m^2] over the last 500 iterations for LSC at 0,0 deg of yaw



- C_DxA[m^2] over the last 500 iterations for LSC at 3,0 deg of yaw



- C_DxA[m^2] over the last 500 iterations for LSC at 6,0 deg of yaw



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