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RDE in Extended Driving Conditions

Commissioned by the Federal Office for the Environment (FOEN)

Project: Research on PEMS Testing Methodology and on Real Driving Emissions (ResRDE2) *)

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note:

This report R008a correspond to the report R008 extended with a new series of RDE measurements performed with a diesel vehicle in order to complete the research work according the initial plan of the working package 3c (WP3c). The figures 17 to 20 and the corresponding comments for the part 3 were added to the original report R008. The measurement list in annex 5-3 was also updated.

1. SUMMARY

The control of real driving emissions (RDE) by means of a portable emission measuring system (PEMS) is generally an accepted way to reduce further the air pollution of traffic.

In several research activities with different PEMS open questions resulted concerning the methodology of testing and of evaluation.

Additionally, there are questions about RDE from different types of vehicles, or on different routes with varying operating conditions, with different testing apparatus and with the use of recent evaluation method.

The project ResRDE(2) considers these objectives in 5 working packages (WP).

This 4th report presents the results of the WP3 – RDE in extended driving conditions – information about the comparisons of results obtained during winter/summer driving, mild/aggressive driving and driving at higher altitude.

After the performed comparisons of the PEMS-RDE-results in extended driving conditions, it can be stated that:

Part 1: winter/summer

- For gasoline vehicle; there are in winter conditions higher values of CO₂ and CO in the total trip. For NO_x and PN, there are no significant differences.
- For Diesel vehicle; the winter-operation increases slightly the CO₂- and NO_x-values. The levels of CO, THC and PN stay unchanged.
- The DPF regeneration increases clearly (both in summer and in winter tests) CO₂-, NO_x- and PN-values.

Part 2: mild/aggressive driving

- The mild and dynamic driving styles have clearly different parameters of the RPA and (v.a pos); both parameters are higher for aggressive driving.
- The driving style has an influence on the CO₂-normality.
- The DPF regeneration (Diesel) has an influence on the CO₂-normality which may cause the check to fail.
- The aggressive driving generally increases the emissions, except PN for gasoline car (w/o GPF) and CO for Diesel car (DOC + DPF).
- The “dynamic” driving requires more energy, causes higher fuel consumption and, therefore, higher CO₂-emissions.
- The PN-emissions of the gasoline vehicle (GDI w/o GPF) are above, the PN-emissions of the Diesel vehicle (with DPF) are below the limit value of $6 \cdot 10^{11}$ [# / km].

Part 3: altitude

For the gasoline measurements:

- The emissions of CO, NO_x, CO₂ and PN are generally increased by higher slope/altitude.
- The sharp increases of CO and NO_x in the diagrams for RDE2 and RDE3 can be attributed to the dynamic driving events combined with higher power demand for the slope.
- Higher slope requires more energy and causes higher CO₂.
- The influence on PN is small.

For the Diesel vehicle measurements:

- Higher slope/altitude influence mainly the NO_x and the CO₂ emissions.
- Higher slope requires more energy and causes higher CO₂.
- The sharp increases of CO can be attributed to the dynamic driving events combined with higher power demand for the slope.
- Due to the efficient DPF, the PN emissions are very low and the influence of higher slope/altitude on tailpipe PN emissions are negligible.
- The cold start phase could have a bigger influence on the total PN emissions than the slope/altitude variation

2. OBJECTIVES OF RESRDE(2)

According to the project proposal from March 2019, the objectives of the working packages are:

WP1: Emission factors from non-driving situations with different vehicles.

Part 1: Analysis of present data

From the present data of RDE obtained with different vehicles, the specific situations of emissions like cold start, warm-up and stop&go, have to be found, analyzed and compared with the average cycle emissions.

Part 2: Reproduction of non-driving situations

It was proposed to investigate two gasoline and two Diesel passenger cars. The tests are performed in idling cold/warm, during the warm-up phase and in stop&go operation with a different portion of idling. The tests are performed on chassis dynamometer with measuring systems: CVS and PEMS (including HC_{FID} and PN).

After cold start, there are different options of operating profile to influence the warm-up phase. It is proposed to use two extreme variants: idling and high load (like highway). The cold start would be at 20-25°C. Other options of the cold start temperature are to be discussed.

To simulate the different portion of idling in stop&go operation, specific cycles have been created in order to repeat the same trials with all vehicles. Testing of stop&go operation will be carried out with warm engine.

WP2: RDE legislation package 4.

From January 2019, new amendments to the RDE-legislation were issued with new requirements of evaluation of results. It is necessary to deepen the new regulation, to perform the new evaluation procedure and to compare it with the previous one.

WP3: Extended RDE conditions – examples and comparisons of RDE for: winter/summer driving, mild/aggressive driving and altitude.

WP3(a): RDE – winter/summer – examples on two vehicles (passenger cars: Diesel, gasoline).

WP3(b): RDE with mild/aggressive driving behavior - examples on two vehicles (Diesel, gasoline).

WP3(c): RDE in “normal» legally valid circle compared with a high-altitude circle – examples on two vehicles (Diesel, gasoline).

WP4: Further comparisons of PN PEMS and GasPEMS: Horiba ↔ NM3 (CPC & NGK) examples on two vehicles (Diesel, gasoline), as well as the comparisons of data from HDV Euro VI (WVU).

The vehicles are tested with warm start on chassis dynamometer and on-road. Compared are: stationary CPC (PMP), PN PEMS Horiba, NM3 and NGK and gaseous components GasPEMS. The comparisons of results from the previous tests HDV Euro VI (WVU) are included.

WP5: RDE results on different RDE routes.

The same vehicle is measured on the test circuits of other associated institutes (EMPA, TCS, TFZ).

2.1 Research topics of present report

This 4th report presents the results of WP3, which consists of three parts:

Part 1 – Comparisons of RDE in winter/summer driving conditions.

Part 2 – Comparisons of RDE with mild/aggressive driving behavior.

Part 3 – Comparisons on normal- and high-altitude driving circuit.

3. TESTING MATERIAL, MEANS AND METHODS

3.1 Test vehicles, fuels and lubricants

The results from three vehicles V1 (Gasoline Euro 5), V2 (Diesel Euro 6) and V3 (Diesel Euro 6) were used for the comparisons in extended driving conditions.

The most important data of these vehicles are listed in the [table1](#).

Name	Type	Model	Fuel	EATS	Displ.	Power	Odometer		
-	-	Year	-	-	ccm	kW	km		
V1	LDV	PC	2012	Gasoline	Euro 5a	3WC	1.596	132	36'637
V2	LDV	PC	2017	Diesel	Euro 6b	DPF+SCR	1.968	110	31'208
V3	LDV	PC	2014	Diesel	Euro 6b	DPF+SCR	1.560	88	199'297

Table 1: Data of the vehicles used for the comparison tests.

All vehicles were operated with the Swiss market fuels and with the lubricating oils, which were present in each vehicle.

3.2 Test methods and instrumentation

3.2.1 Chassis dynamometer and standard test equipment

(not used in the present working package)

- roller dynamometer: AFHB GSA 200
- roller diameter: 502 mm
- driver conductor system: Tornado, version 3.3
- CVS dilution system: Control Sistem R03-700 with roots blower
- air conditioning in the hall
 - automatic for intake- and dilution air
 - temperature: 20 ÷ 30°C
 - humidity: 5.5 – 12.2. g/kg

3.2.2 Test equipment for regulated exhaust gas emissions

(not used in the present working package)


This equipment fulfils the requirements of the Swiss and European exhaust gas legislation.

- regulated gaseous components:
 - exhaust gas measuring system Horiba MEXA-7100
 - CO, CO₂... infrared analysers (IR)
 - HCFID... flame ionisation detector for total hydrocarbons
 - CH₄FID... flame ionisation detector with catalyst for only CH₄
 - NO/NO_x... chemiluminescence analyser (CLA)

The dilution ratio DF in the CVS-dilution tunnel is variable and can be controlled by means of the CO₂-analysis.

3.2.3 PEMS

Most important data of the used Horiba GasPEMS are given in the [table 2](#), for further information see the [annex A1](#).

	Gas PEMS
	
Instruments	Horiba PEMS OBS-ONE
Exhaust concentrations	CO ₂ , CO, NO _x , NO ₂
Measurement principle	heated NDIR*, CLD, heated line
Engine parameters	OBD
Vehicle speed & position	GPS
Exhaust flow	EFM
Ambient parameters	p, T, H
Electrical power	> 300 W (> 800 W with FID and PN)
Dimensions	500 x 500 x 500 mm + Pitot tube + heated line + batteries

* OBS one: H₂O is monitored to compensate the H₂O interference on CO and CO₂ sample cell heated to 60°C.

[Table 2](#): Data of the applied GasPEMS

3.2.4. PN PEMS

For measurements of nanoparticles, a portable system named Horiba OBS-ONE-PN PEMS working on CPC-principle was used. For further information of the manufacturer, see the [annex A2](#). In some previous test series, a Testo NanoMet3 (NM3) system was used. This system is working on DC-principle, for further information of the manufacturer, see the [annex A3](#).

3.3 Test procedures

The RDE part of testing was performed on the road in real driving conditions. An example of a road trip for RDE is given in the [annex A4](#). Some further details about test procedures of the performed test parts are given in the measurement lists, see the [annex A5](#).

The evaluation of data was performed according to the legal requirements with EMROAD program.

4. RESULTS

The results are graphically represented in the attached figures (chap. 6).

4.1 Part 1: winter/summer

The [figures 1 and 2](#) show RDE results obtained with the gasoline vehicle (V1) in summer and winter driving conditions. There were respectively three repetitions performed on the official RDE-circuit. Some emissions differences between the repeated tests are caused by different traffic situations and driving behavior. Especially stronger accelerations, mainly in the urban part, can produce higher emissions increments.

The [figure 3](#) summarizes and compares the results of the gasoline vehicle (V1). Considering the averages of three repetitions, it can be followed that in winter conditions there are higher values of CO₂ and CO in the total trip. For NO_x and PN, there are no significant differences. There are unfortunately no measured values for THC. However, according to the general experience, the tendencies of HC are in line with the tendencies of CO. The winter in the season 2019/2020 was quite mild with the ambient day temperatures around 5°C.

The [figures 4 and 5](#) show RDE results obtained with the Diesel vehicle (V2) in summer and winter driving conditions. In both test series (summer and winter) one of the repetitions was with DPF regeneration, which was ordinary triggered by the electronic control system of the vehicle. The plots “with regeneration” are presented separately, together with one of the trials “without generation”. The regeneration increases clearly the represented emissions.

The [figure 6](#) summarizes and compares the results of the Diesel vehicle (V2). Considering the averages of three repetitions, it can be remarked that the winter-operation increases slightly the CO₂- and NO_x-values. The levels of CO, THC and PN stay unchanged. The regeneration increases clearly (both in summer and in winter tests) CO₂-, NO_x- and PN-values. There are no visible effects on CO and very slight increase of THC, which, being at a very low absolute level, may be considered as insignificant.

It can be stated that in these testing conditions of a quite mild winter period, the effect of regeneration on several emission components is stronger than the effect of the lower ambient temperature of the winter driving conditions.

The fact of increased emissions (especially PN and NO_x) during the DPF regeneration is well known and the type approval legislation considers it adequately by averaging the regeneration cycles with the non-regeneration ones.

4.2 Part 2: mild/aggressive driving

For each vehicle and each variant of driving style three tests were performed. The [figure 7](#) represents the validity check of driving dynamics for both vehicles.

In the top part of the figure, the definition and the legal limit line of the relative positive acceleration (RPA) are given. All results are in the domain “pass”, i.e. the check, if the trip dynamics is not too weak, is fulfilled.

In the bottom part of the figure, the legal limit line of [95% of v. apos] is represented. The domain “fail” means that there are a too hard driving behavior and an excessive dynamic of the trip. This is the case for aggressive driving style with the Diesel vehicle. (This type of vehicles is constructed and well-known for the high torque characteristics at lower engine speeds).

It can be concluded that:

- The mild and dynamic driving styles have clearly different parameters of the RPA and (v.a pos); both parameters are higher for aggressive driving.
- During the road driving, the parameters of the RPA and (v.a pos) are for each variant of vehicle and driving style quite repetitive.
- With Diesel vehicle an excessive driving dynamic, beyond the legal acceptance, was realized.

The [figure 8](#) shows the CO₂-normality check for the gasoline vehicle. The normality check that is the comparison of CO₂ emissions during the RDE-measurement using MAW with the reference CO₂-emissions obtained on the chassis dyno during the WLTC.

There are clearly higher CO₂-values at dynamic driving, but the trips and their dynamic conditions are entirely normal since the characteristic curves are not exceeding the primary tolerance band of +45(40)/-25% (of the average WLTC-CO₂-values).

The diagrams at the bottom are repeated from the figure 7.

The CO₂-normality check for Diesel vehicle is represented in the [figure 9](#). In the highest speed range and with “mild” operation the characteristic line exceeds the primary tolerance domain +45(40)/-25%. In one of the trials with “mild” operation a DPF regeneration happened. This had consequences on CO₂-values and caused them to exceed the primary tolerance band as well at the lowest speed range.

The diagrams at the bottom are also repeated from the figure 7.

It can be concluded that:

- The driving style has an influence on the CO₂-normality.
- The normality check is also passed with the dynamic driving style.
- The DPF regeneration (Diesel) has an influence on the CO₂-normality which may cause the check to fail.

The [figure 10](#) represents the influences of driving style on the emissions of CO, NO_x, CO₂ and PN of the [gasoline car](#). In the upper part of each page, the distance – specific integral average values per test part (urban, rural, highway) are represented for the three performed tests. For the comparison with WLTC (at the right side of the diagram) the integral average values of total trip are represented.

The results for WLTC originate from the laboratory measuring system, which is called for simplicity “CVS”. All other results come from the PEMS.

In the lower part of each page, there are cumulated emissions over the test distance represented for respectively three “mild” and “dynamic” tests.

The following relationships can be remarked:

- The driving style has a very strong influence on CO-emissions and the results from three tests are quite repetitive (except for highway), see the [figure 10-1](#).
- The driving style also influences strongly the NO_x-emissions during cold start and city part; in case of aggressive driving in the urban part, the NO_x-values scatter very much which also explains the large differences of cumulated NO_x with the “dynamic” driving, see the [figure 10-2](#).
- The “dynamic” driving requires more energy, causes higher fuel consumption and, therefore, higher CO₂-emissions, see the [figure 10-3](#).
- There is no visible effect of driving style on the PN-emissions, the absolute values in [# / km] for this GDI-vehicle, without GPF are quite high, above the legal limit of $6 \cdot 10^{11}$ [# / km].
- The gaseous emissions of this gasoline car in total RDE trip with mild driving style are near to the WLTC values.

The [figure 11](#) shows the influences of the driving style on the emissions of CO, NO_x, CO₂, PN and HC of the [Diesel car](#). The logic of the representation is the same as in the figure 10.

The following relationships of emissions can be remarked for this vehicle V2:

- The CO-emissions are very low and they are independent on the driving style.
- All other emissions of NO_x, CO₂, PN and HC are clearly increased by the dynamic driving style.
- Due to the DPF, the PN-emissions are below the limit value of $6 \cdot 10^{11}$ [# / km].

A rough comparison of emissions of these both test vehicles (V1 gasoline Euro 5 and V2 Diesel Euro 6) shows the same typical proportions: higher CO, higher CO₂ and higher PN (w/o GPF) values for gasoline V1; higher NO_x and lower PN (with DPF) for Diesel V2.

The figure 12 summarizes the variations of the emissions in [%] between mild and dynamic driving style. The higher variations of NO_x and CO₂ in the urban part can be generalized as an effect of higher dynamics in city driving. The very high variations of CO of the gasoline car (especially in the rural- and highway parts) must be considered as specific for this vehicle. They certainly could be changed by the measures lowering these emissions (CO) of this vehicle.

The PN-emissions of the Diesel vehicle are at a very low level (due to DPF) and the driving style has a stronger influence than with the gasoline vehicle (GDI w/o GPF).

There is a higher NO_x-emissions level of the Diesel car.

4.3 Part 3: altitude

In this working package, the results obtained on a normal legally valid driving route were compared with two other “high altitude” route. All the RDE routes are represented in the annex A6. Additionally, to the vehicle speed profile (over the time), the altitude profile is given. The normal route (called in further diagrams, as “RDE1”), annex A6-1, is the same as in the example of the annex A4, but the parameters given in both annexes present an indication of possible dispersion by performing the same trip.

The other two routes are:

- RDE route with higher altitude variations, “RDE2” (Pierre-Pertuis, Tavannes).
- RDE route at high altitude, “RDE3” (plateau de Diesse).

These circuits (RDE2 and RDE3) are not legally conform and they are defined and used only for the research in the present working package. The route RDE3 used with the Diesel vehicle is slightly different than the one used with the gasoline vehicle due to new road restriction.

Some legal requirements concerning the altitude of the test route are given in the Regulation EU 2017/1151, annex IIIa, appendix 7b. These are:

- Moderate altitude below 700m above sea level.
- Extended altitude conditions 700m – 1300m above sea level.
- Start and end points of the trip shall not differ in their altitudes more than 100m.
- The cumulative positive gain over the entire trip shall be less than 1200m / 100km.

For the test route used in the present work, it must be remarked that principally the rural part was decisive for the influences of slope and altitude. The city part is identical for all measurement and should be considered as a conditioning and state check phase. The highway part is more or less flat for RDE1 and RDE2 and was not included in RDE3.

The variations of altitude have impact on the final results by increasing or decreasing the work amount provided by the vehicle.

The figure 13 and figure 17 illustrates the validity check of the three used routes/trips for the gasoline and the Diesel engine.

For the gasoline vehicle, the trips “RDE2” and “RDE3” with higher altitude variations do not fulfill entirely the CO₂-normality, exceeding the primary tolerance band of +45(40)/-25% in the middle speed range. The checks of the share of normal windows (r) and of the total cumulative positive elevation gain (in the bottom part of the figure 13) also show the non-conformity of the trips RDE2 and RDE3:

- Route RDE2 could be accepted for elevation check but the increase of the CO₂ emissions due to the performed altitude variation leads to an abnormal CO₂ behavior (not similar to the WLTC CO₂ emissions).
- Route RDE3 shows that both CO₂ emissions and higher altitude variation are beyond the accepted limits.

However, for the Diesel vehicle, the trips RDE1 and RDE2 show a sufficient share of normal windows (CO₂) and a total cumulative elevation gain below the limit. The RDE3 route, which also has no highway part and therefore cannot conform to the regulation, has a too high cumulative elevation gain.

The altitude data are measured by GPS and verified with topographic map. If the differences between the GPS data and the map is greater than 40m, the GPS data have to be corrected.

The [figure 14](#) and [figure 18](#) compares the cumulated emissions CO, NO_x, CO₂, PN of the gasoline and the Diesel car in the three circuits with different slope and altitude. The results concern entire trips, which all were started with cold engine and the same initial urban part.

In the upper part of each sheet, the traces of vehicles speed and of altitude profile of all trips are repeated.

With the gasoline vehicle, the higher slope and /or altitude generally increase CO & NO_x, have a slight influence on CO₂ and a negligible influence on PN. (For PN see the very much extended scale of the ordinate).

CO₂ and NO_x emissions from the Diesel vehicle are similar for the first and common urban part of the three test routes RDE1, RDE2 and RDE3. Differences are first visible once the altitude variations occur. For CO and PN emissions, it appears that the cold start phase as a bigger influence than the altitude variation itself.

In order to better discriminate the influences of the altitude and the slope on the emissions, selected parts of trips were taken into consideration. The [figure 15](#) and [figure 19](#) represents the selected segments, all of them with the same driving distance (14.5 km for gasoline, 15.0 km for Diesel) and with similar average speed (approximately 45-50 km/h). In this way, the segment chosen from the RDE2 represents predominantly the high slope and the segment chosen from the RDE3 represents mainly the high altitude.

The results of evaluations with this part selection are given in the [figure 16](#) and [figure 20](#). The representation is analogous as in the figures 14 and 18.

For the measurements with the gasoline engine, the statement about increasing the measured emissions by higher slope and/or altitude can be extended to all components. The sharp increases of CO and NO_x in the diagram for RDE2 and RDE3 can be attributed to the dynamic driving events combined with higher power demand for the slope. Higher slope (RDE2) in this comparison needs more energy and emits more CO₂ than the high-altitude profile (RDE3), see the figure 16-3.

With the Diesel engine, the influence of the higher slope and/or altitude is mainly observed on the NO_x emissions. PN emissions are very low due to the use of an efficient DPF. The sharp and stepwise increase of CO can also be imputed to some dynamic driving events and the increased CO₂ emissions linked to an increased energy demand in a similar way as observed for the gasoline emissions.

5. CONCLUSIONS

After performing and evaluating the tests in different extended (non-typical) driving conditions the following conclusions can be drawn:

Part 1: winter/summer

- For gasoline vehicle; there are in winter conditions higher values of CO₂ and CO in the total trip. For NO_x and PN, there are no significant differences.
- For Diesel vehicle; the winter-operation increases slightly the CO₂- and NO_x-values. The levels of CO, THC and PN stay unchanged.
- The DPF regeneration increases clearly (both in summer and in winter tests) CO₂-, NO_x- and PN-values.

Part 2: mild/aggressive driving

- The mild and dynamic driving styles have clearly different parameters of the RPA and (v.a pos); both parameters are higher for aggressive driving.
- During the road driving, the parameters of the RPA and (v.a pos) are for each variant of vehicle and driving style quite repetitive.
- With Diesel vehicle an excessive driving dynamic, beyond the legal acceptance, was realized.
- The driving style has an influence on the CO₂-normality.
- The normality check is also passed with the dynamic driving style.
- The DPF regeneration (Diesel) has an influence on the CO₂-normality which may cause the check to fail.
- The driving style has reproducible effects on the emissions.
- The aggressive driving generally increases the emissions, except PN for gasoline car (w/o GPF) and CO for Diesel car (DOC + DPF).
- The "dynamic" driving requires more energy, causes higher fuel consumption and, therefore, higher CO₂-emissions.
- The PN-emissions of the gasoline vehicle (GDI w/o GPF) are above, the PN-emissions of the Diesel vehicle (with DPF) are below the limit value of $6 \cdot 10^{11}$ [# / km].
- There is a higher NO_x-emissions level of the Diesel car.

Part 3: altitude

For the gasoline vehicle measurements:

- The emissions of CO, NO_x, CO₂ and PN are generally increased by higher slope/altitude.
- The sharp increases of CO and NO_x in the diagrams for RDE2 and RDE3 can be attributed to the dynamic driving events combined with higher power demand for the slope.
- Higher slope requires more energy and causes higher CO₂.
- The influence on PN is small.

For the Diesel vehicle measurements:

- Higher slope/altitude influence mainly the NO_x emissions.
- The sharp increases of CO can be attributed to the dynamic driving events combined with higher power demand for the slope.
- Higher slope requires more energy and causes higher CO₂.
- Due to the efficient DPF, the PN emissions are very low and the influence of higher slope/altitude on tailpipe PN emissions are negligible.

6. LIST OF FIGURES

Part 1: winter/summer

- Fig. 1 RDE, vehicle 1 gasoline – summer
- Fig. 2 RDE, vehicle 1 gasoline – winter
- Fig. 3 RDE, vehicle 1 gasoline, comparisons summer – winter
- Fig. 4 RDE, vehicle 2 Diesel – summer
- Fig. 5 RDE, vehicle 2 Diesel – winter
- Fig. 6 RDE, vehicle 2 Diesel, comparisons summer – winter

Part 2: mild/aggressive driving

- Fig. 7 RDE trip validity check for RPA and 95th percentile of v.apos
- Fig. 8 CO₂ emissions normality check and dynamic check, gasoline V1
- Fig. 9 CO₂ emissions normality check and dynamic check, Diesel V2
- Fig. 10 Influences of driving styles on emissions CO, NO_x, CO₂, PN; gasoline V1
- Fig. 11 Influences of driving styles on emissions CO, NO_x, CO₂, PN, THC; Diesel V2
- Fig. 12 Variation in [%] between mild and dynamic driving style

Part 3: altitude

- Fig. 13 Influences of altitude variations on trip validity, gasoline V1
- Fig. 14 Influences of altitude variations on emissions CO, NO_x CO₂, PN, gasoline V1
- Fig. 15 Selection of characteristic parts of trips with altitude variations, gasoline V1
- Fig. 16 Comparisons of emissions in selected parts of trips with altitude variations, Gasoline V1
- Fig. 17 Influences of altitude variations on trip validity, Diesel V3
- Fig. 18 Influences of altitude variations on emissions CO, NO_x CO₂, PN, Diesel V3
- Fig. 19 Selection of characteristic parts of trips with altitude variations, Diesel V3
- Fig. 20 Comparisons of emissions in selected parts of trips with altitude variations, Diesel V3

7. ANNEXES

- A 1 Data of Horiba OBS-ONE Gas PEMS
- A 2 Data of Horiba OBS-ONE-PN PEMS
- A 3 Data of NanoMet3 PN PEMS
- A 4 Example of road trip for RDE
- A 5 Measurement lists
- A 6 Road trips with altitude variations

8. ABBREVIATIONS

AFHB	Abgasprüfstelle FH Biel, CH
AGR	Abgasrückführung
CF	Conformity Factor
CLD	Chemoluminescence Detector
CPC	condensation particles counter
CVS	Constant Volume Samples, abbreviation for entire laboratory test installation
DC	diffusion charging
DI	Direct Injection
DOC	Diesel Oxidation Catalyst
DPF	Diesel Particle Filter
ECU	Engine Control Unit
EFM	Exhaust Flow Meter
EU	European Union
EMROAD	Data processing reference software
FID	Flame Ionization Detector
FOEN	Federal Office of Environment, CH
GDI	gasoline direct injection
GPF	Gasoline particulate filter
GPS	Global Positioning System
ICE	Internal Combustion Engine
LD	Light Duty (personal car)
MAW	Moving Average Window
NDIR	Non-Dispersive Infrared
NM3	NanoMet3
OBD	On Board Diagnosis
OBS	Horiba on board system
PC	passenger car
PEMS	Portable Emissions measurement system
PN	Particle Number
r	share of normal windows (MAW)
RDE	Real Driving Emission
ResRDE	research of RDE
RPA	Relative Positive Acceleration
TWC	Three-way catalyst
V	vehicle
WP	working package



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Commissioned by the Federal Office for the Environment (FOEN)

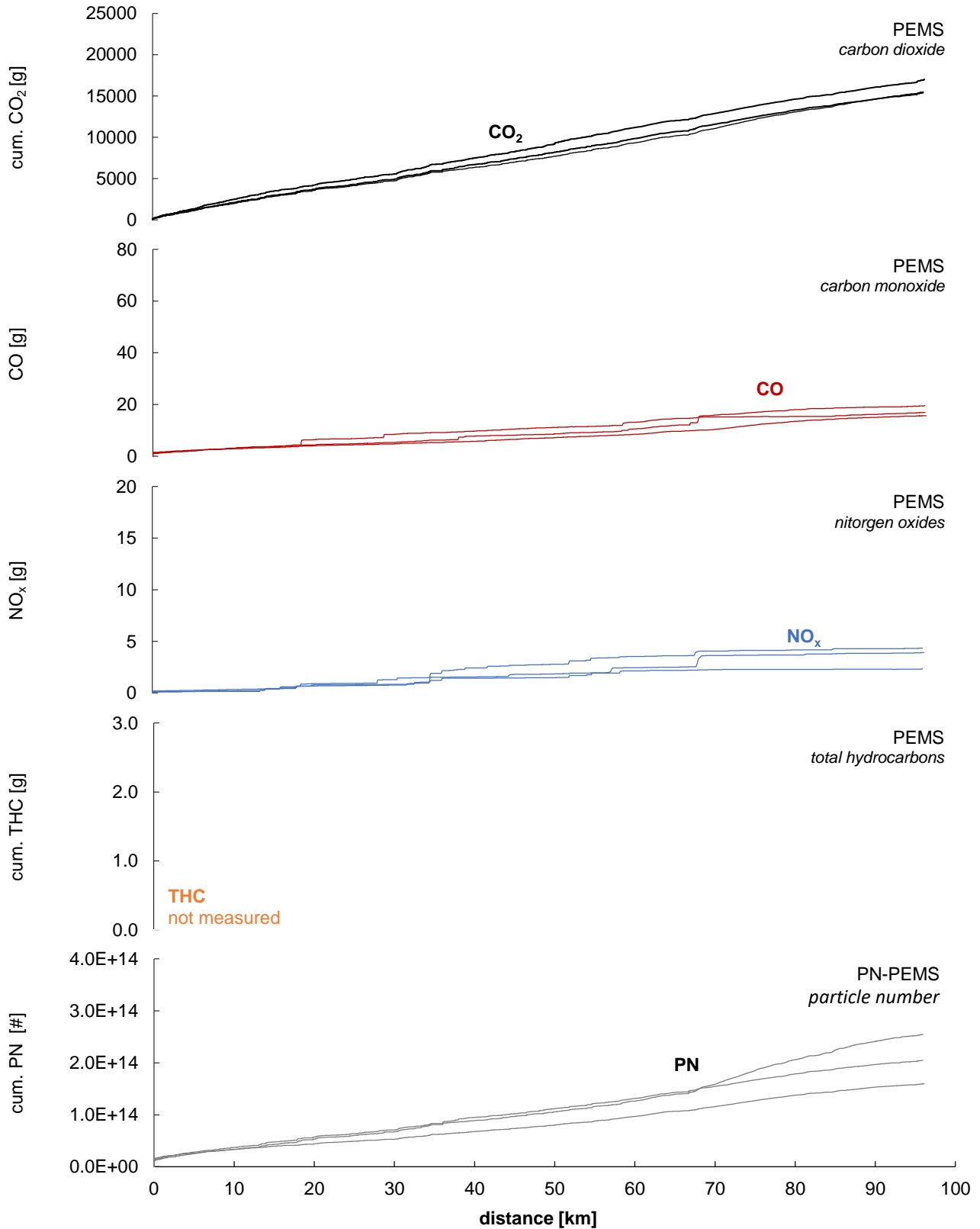
Project: Research on PEMS Testing Methodology and on Real Driving Emissions (ResRDE2) *)

BAFU contract nbr.: 19.0106.PJ / S081-0349, 4th report, WP3

Figures

Real Driving Emissions
Official RDE Route - Summer
Cumulated Emissions

Vehicle 1 | Gasoline, 135 kW, Euro 5a

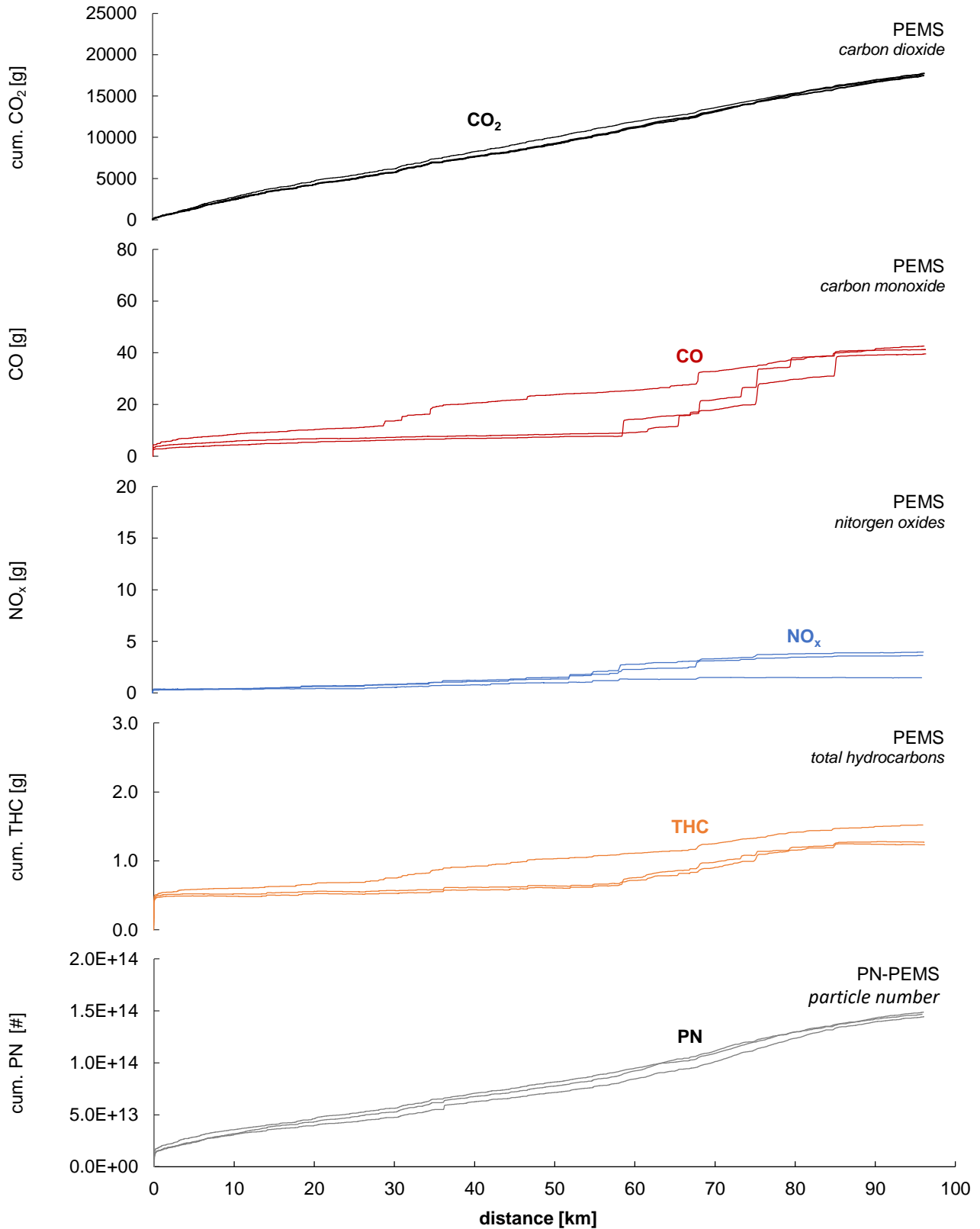


Real Driving Emissions

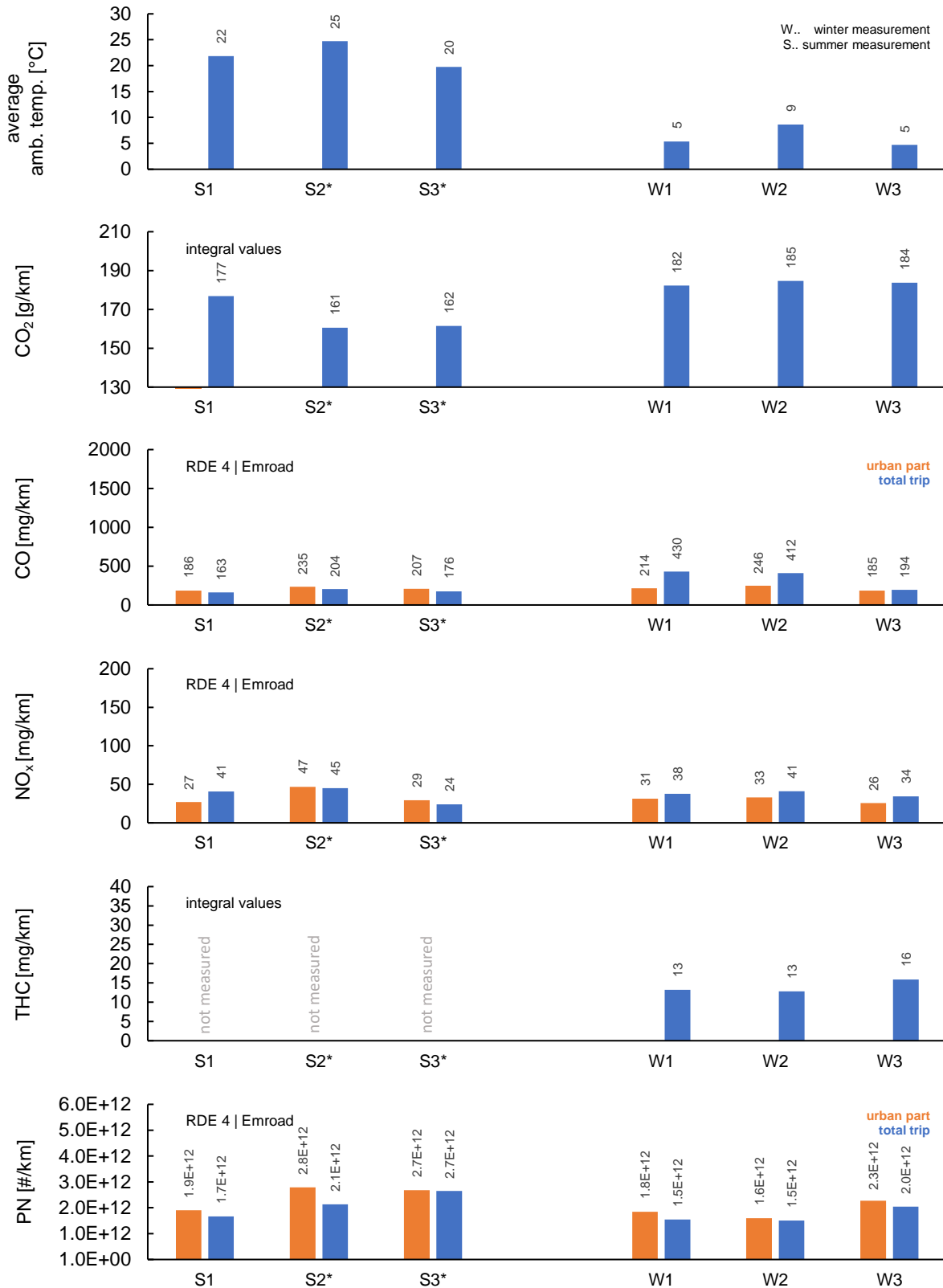
Official RDE Route - Winter

Cumulated Emissions

Vehicle 1 | Gasoline, 135 kW, Euro 5a



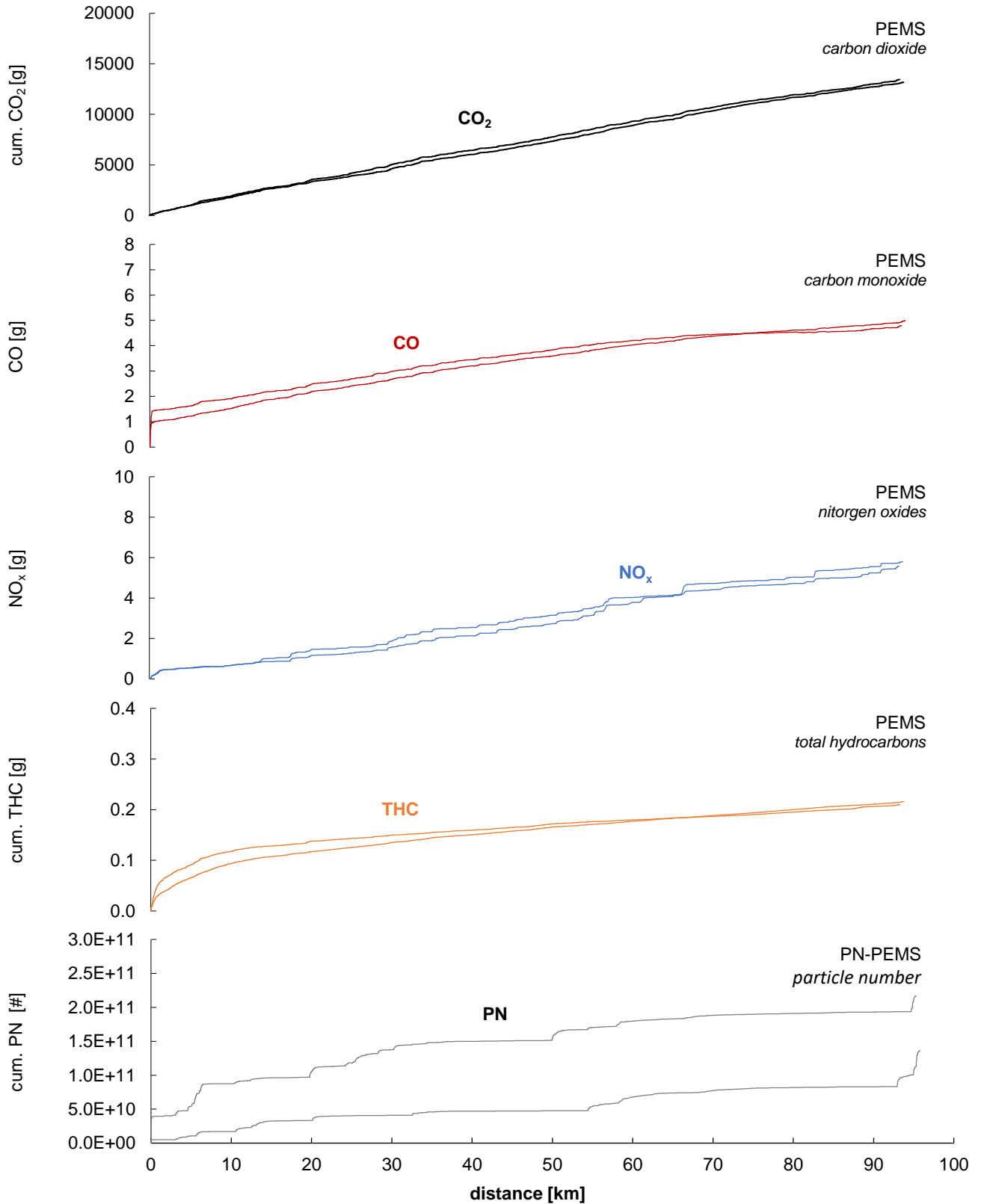
Real Driving Emissions
Official RDE Route
 Integral Average Values
 Vehicle 1 | Gasoline, 135 kW, Euro 5a



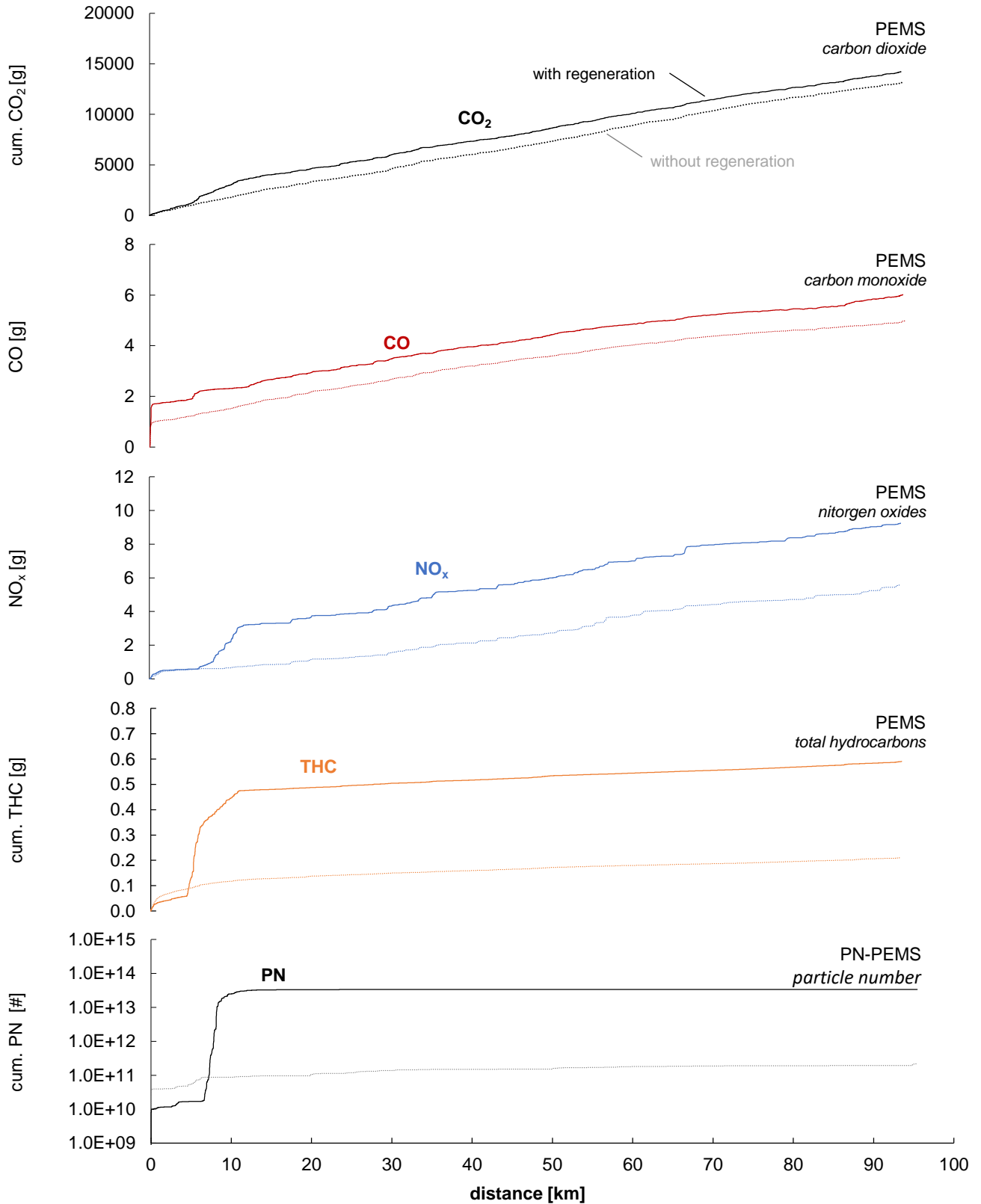
* PN measured with NanoMet 3 instead of OBS-One PN

S = summer measurements; W = winter measurements

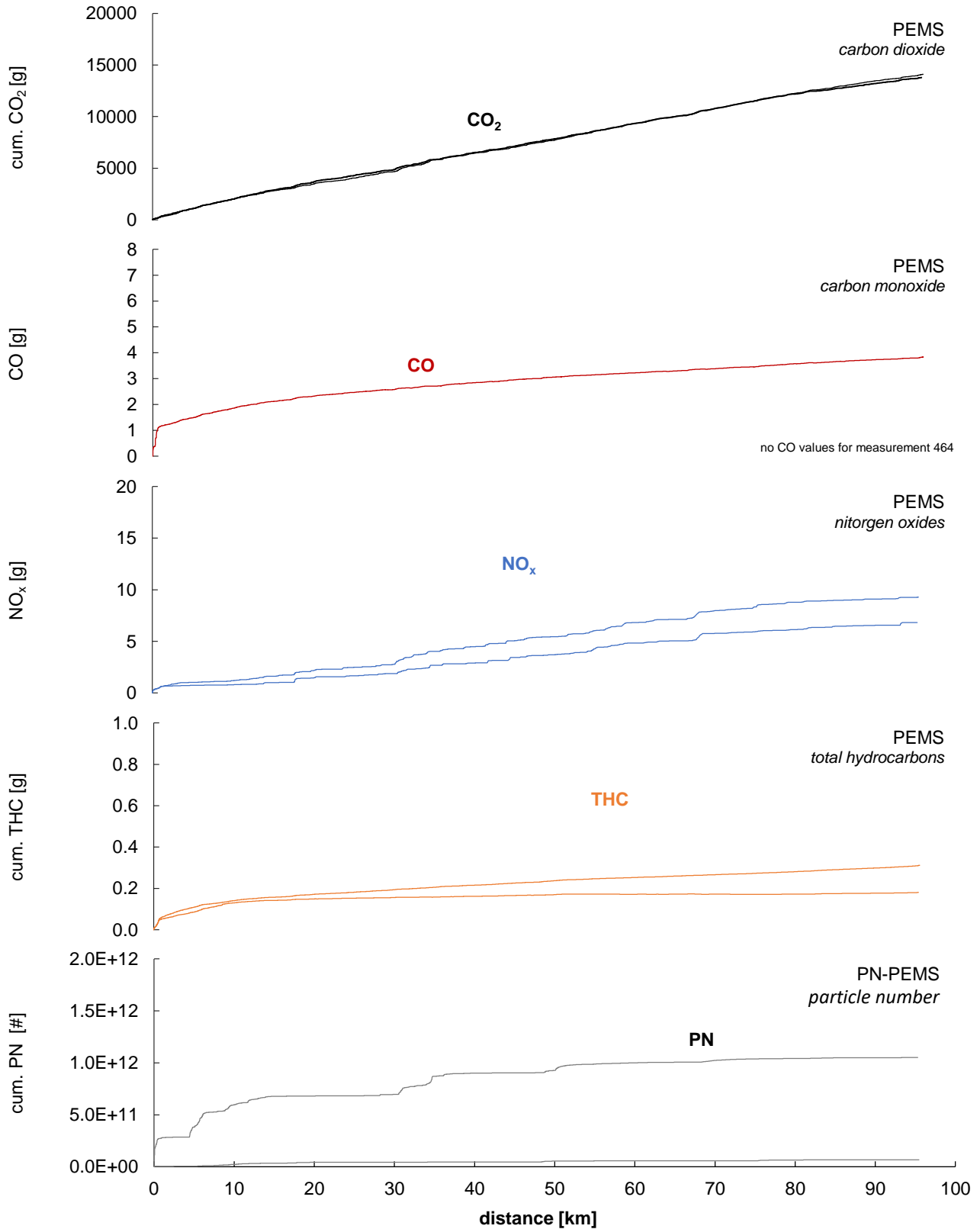
Real Driving Emissions
Official RDE Route - Summer
Cumulated Emissions
Vehicle 2 | Diesel Euro 6



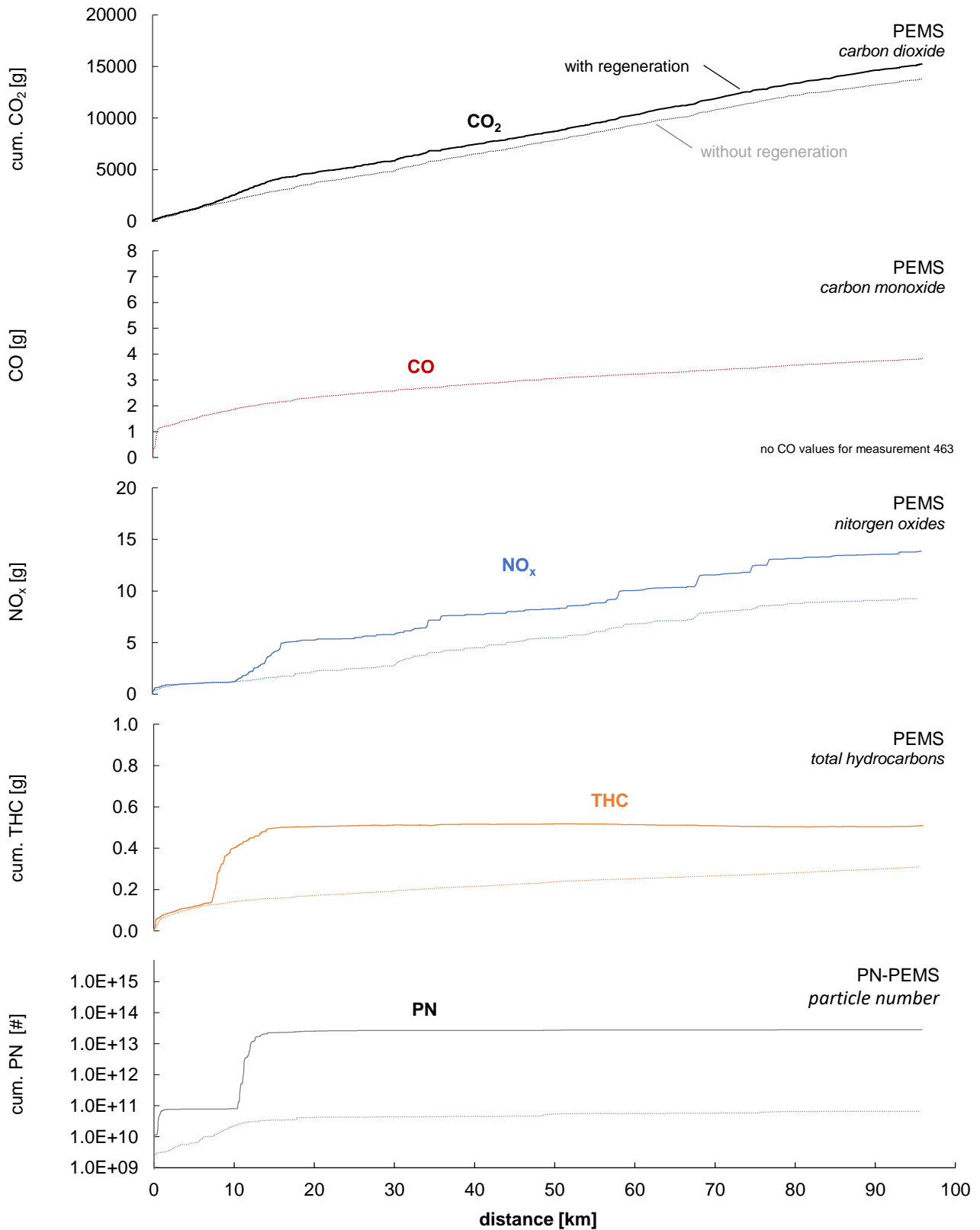
Real Driving Emissions
Official RDE Route - Summer
Cumulated Emissions - with and without DPF Regeneration
Vehicle 2 | Diesel Euro 6



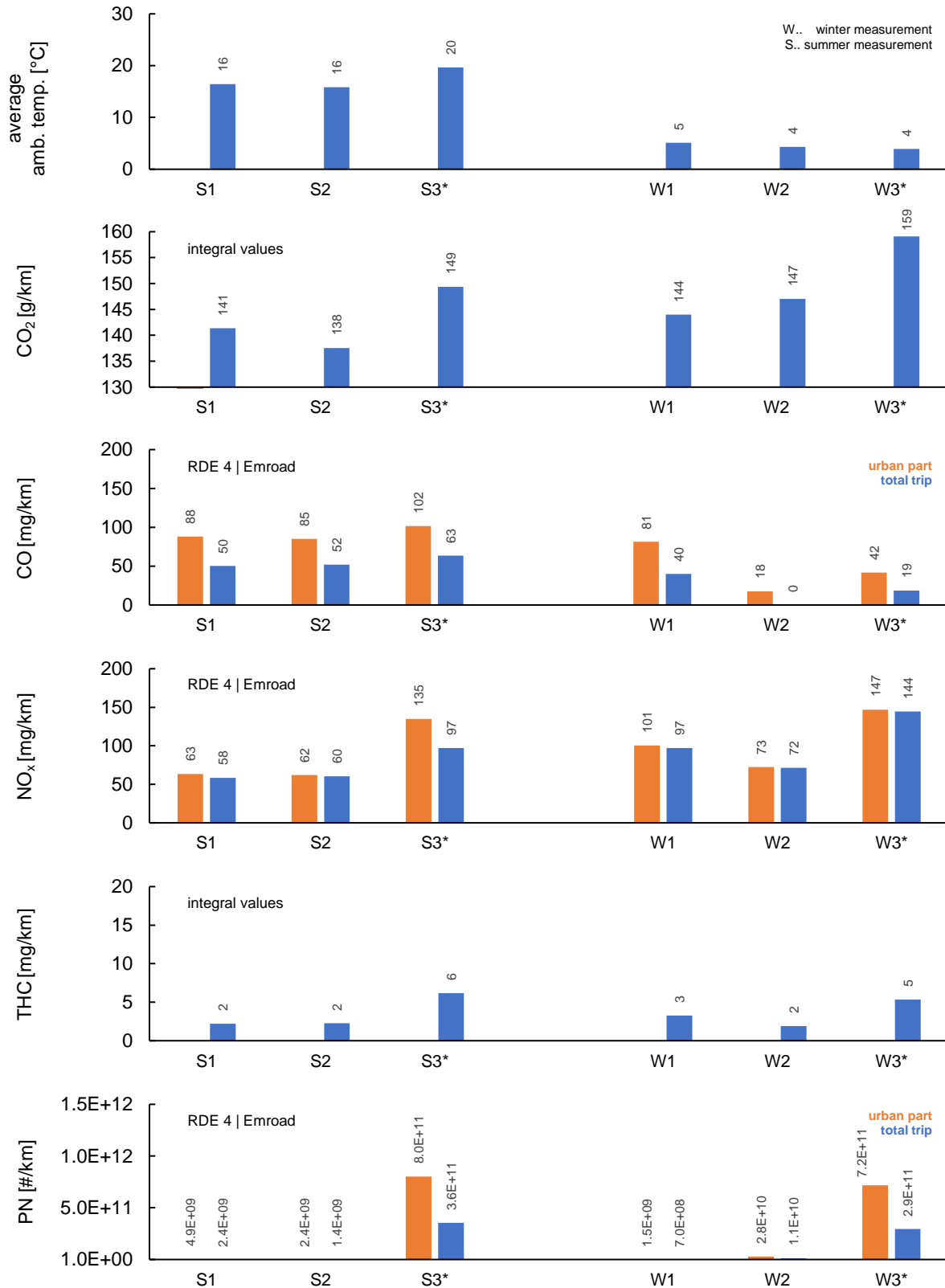
Real Driving Emissions
Official RDE Route - Winter
Cumulated Emissions
Vehicle 2 | Diesel Euro 6



Real Driving Emissions
Official RDE Route - Winter
 Cumulated Emissions - with and without DPF regeneration
 Vehicle 2 | Diesel Euro 6



Real Driving Emissions
Official RDE Route
 Integral Average Values
 Vehicle 2 | Diesel, 110 kW, Euro 6



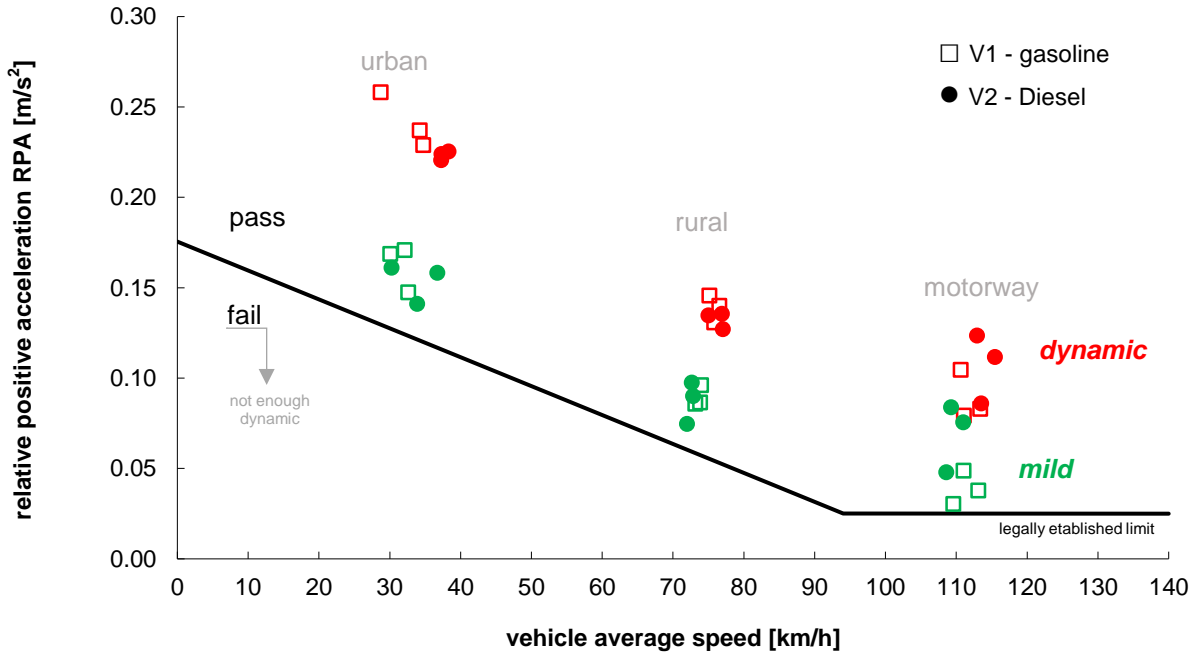
* DPF regeneration occurs during the RDE measurement

S = summer measurements; W = winter measurements

Real Driving Emissions

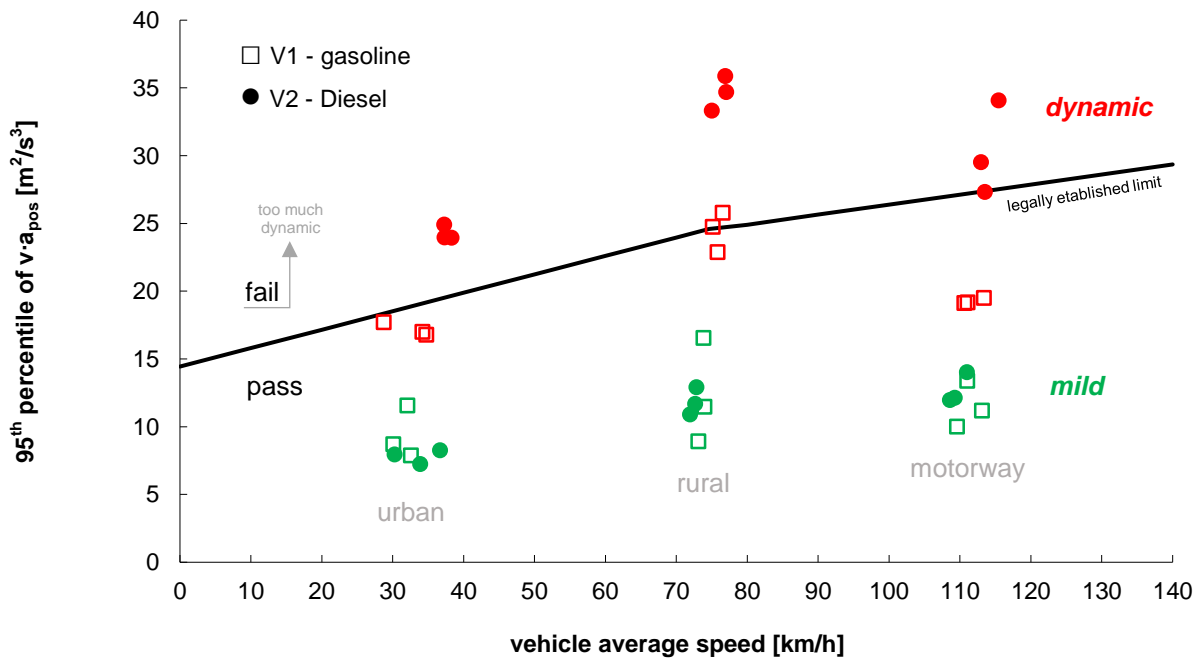
Influences of Mild and Dynamic Drivestyles on RDE Trip Validity for RPA and 95th percentile of $v \cdot a_{pos}$

Vehicle 1 | Gasoline, 135 kW, Euro 5 and Vehicle 2 | Diesel, 110 kW Euro 6

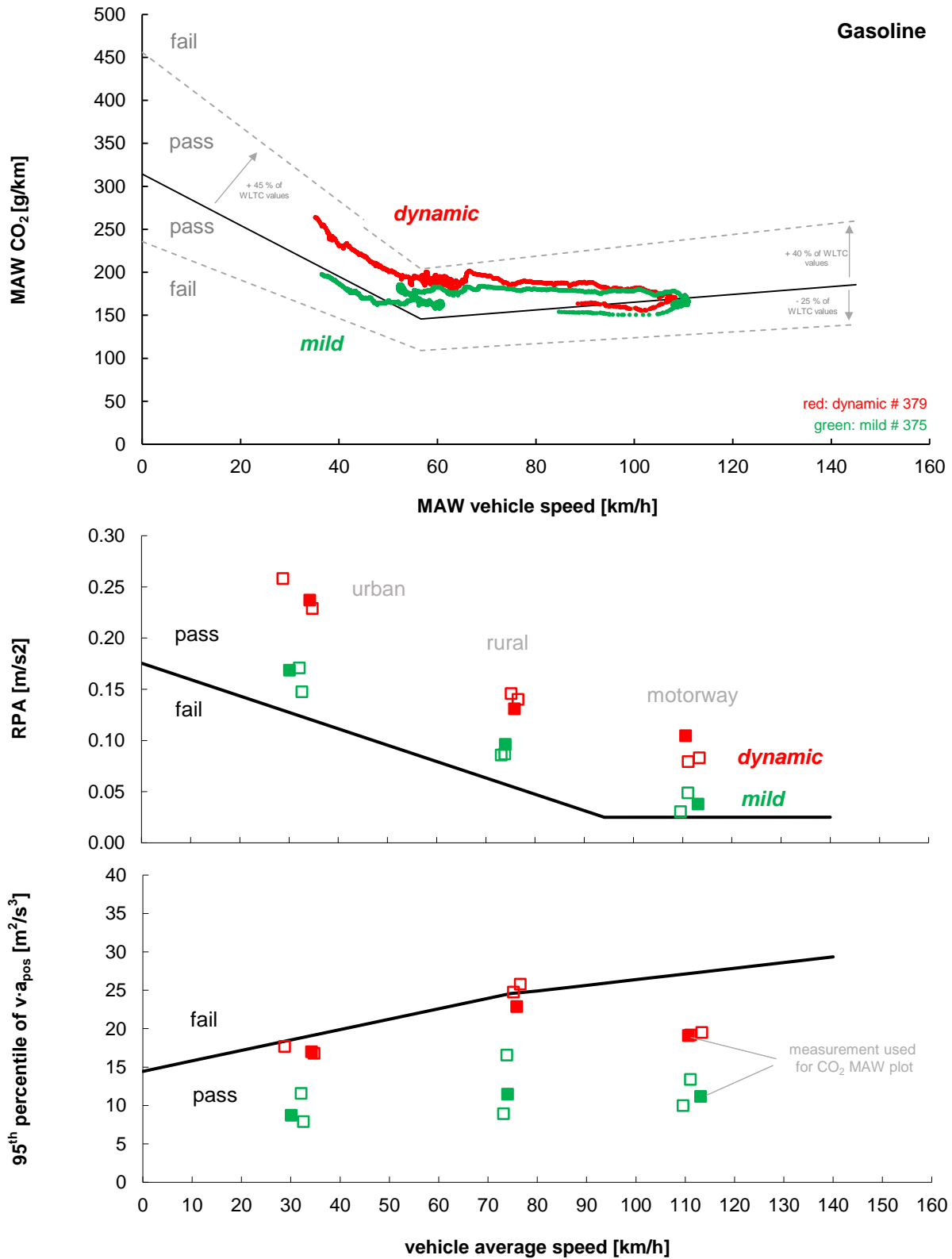


$$RPA_k = \frac{\sum_j (\Delta t \cdot (v \cdot a_{pos})_{j,k})}{\sum_i d_{i,k}}$$

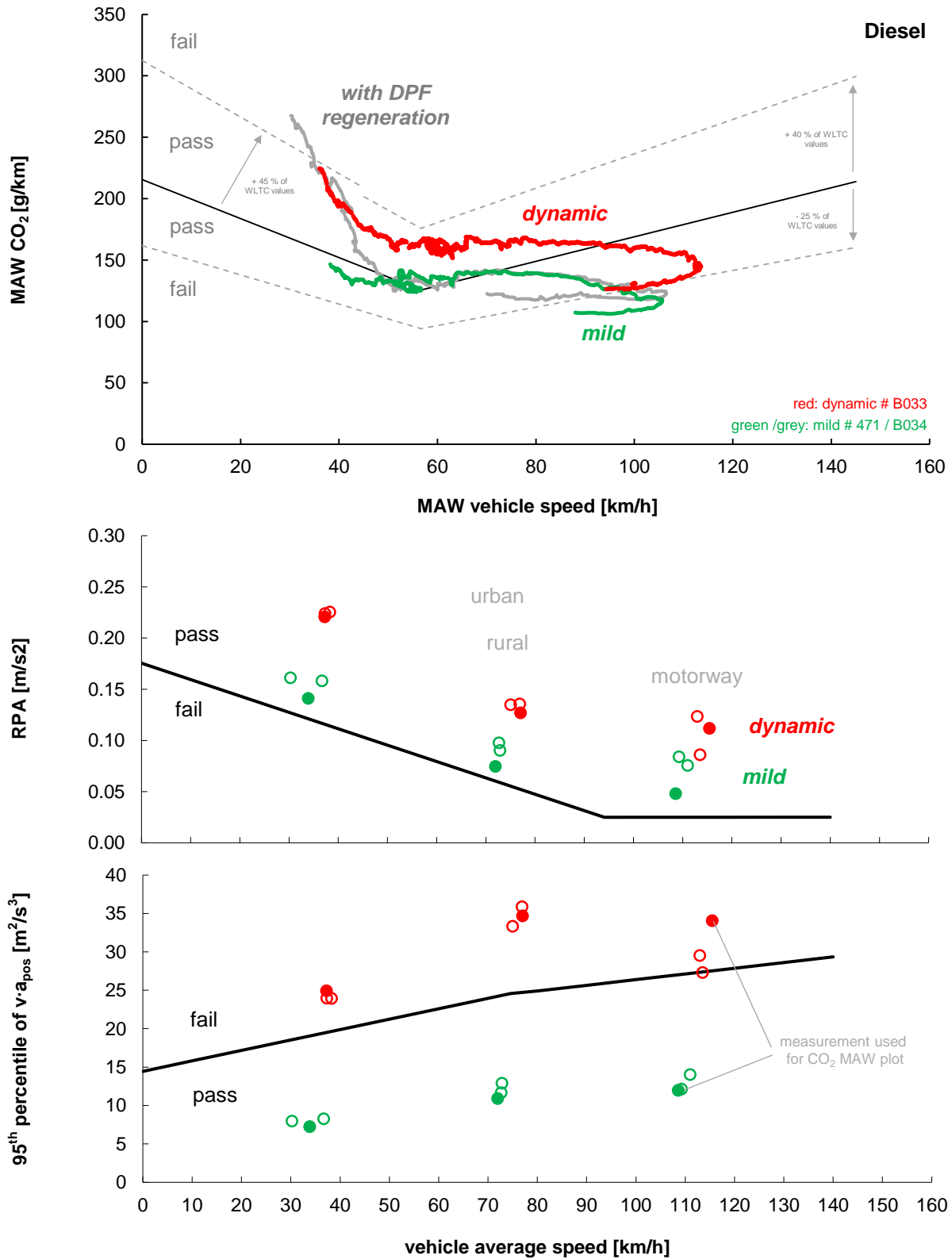
v : vehicle speed; a_{pos} : positive acceleration, d_j : distance, k : for urban, rural or motorway shares



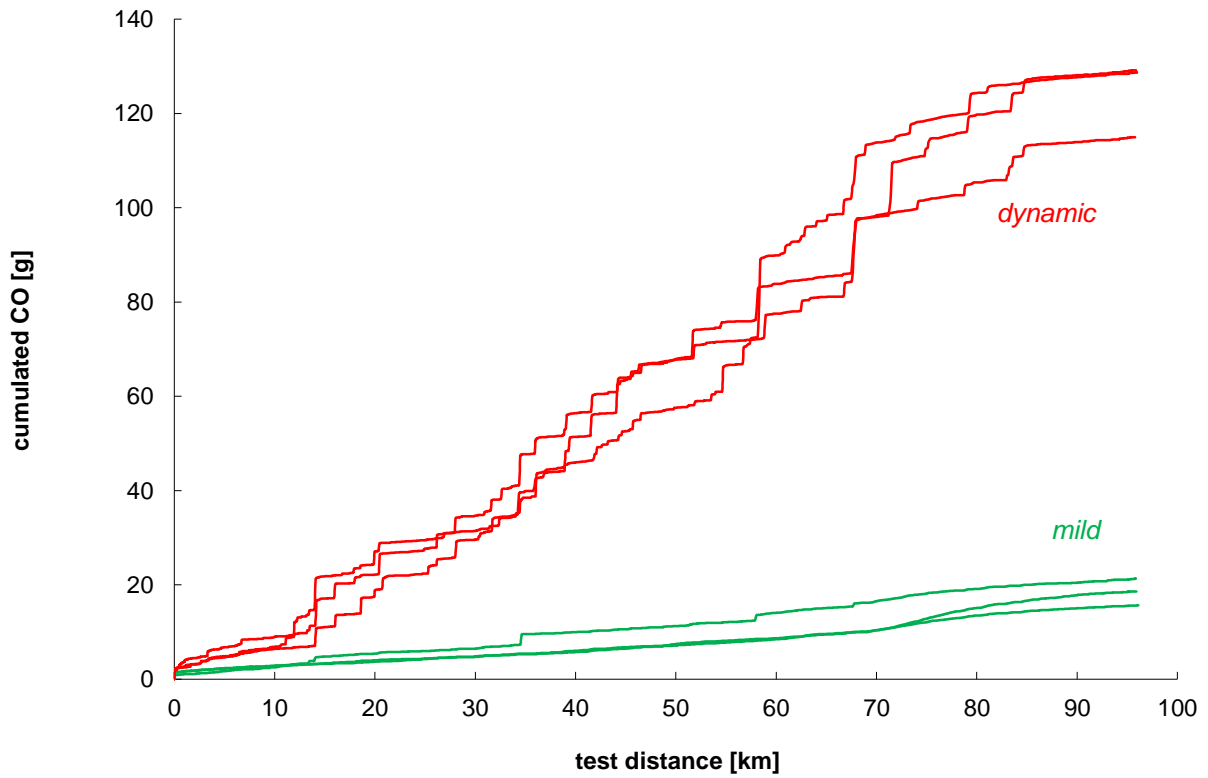
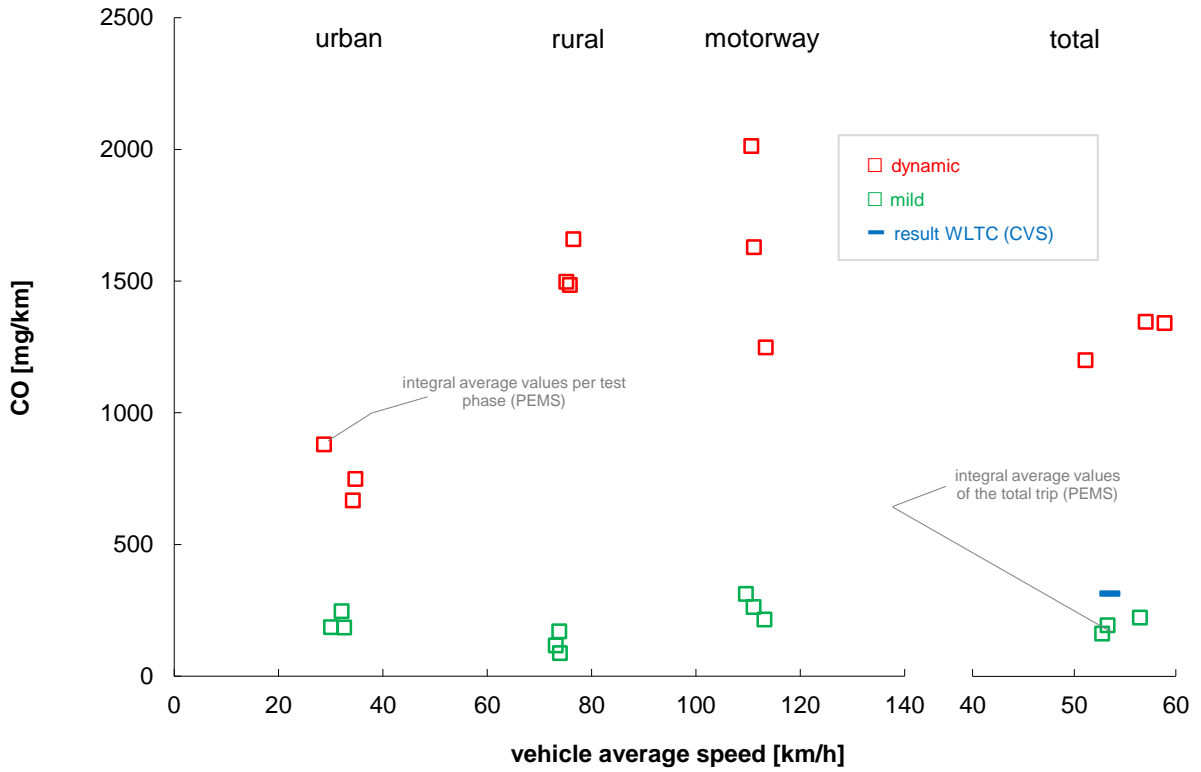
Real Driving Emissions
Influences of Drivestyle
 on CO₂ Emissions for Normality Check
 Vehicle 1 | Gasoline, 135 kW, Euro 5a



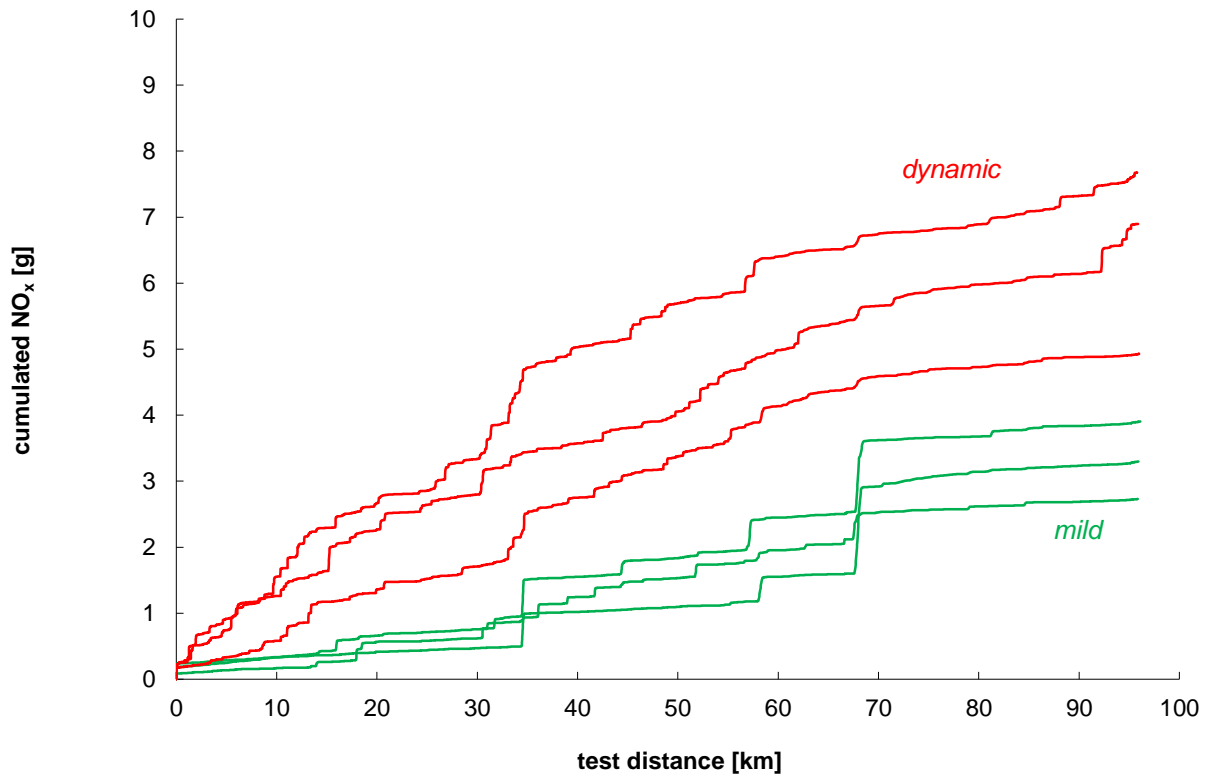
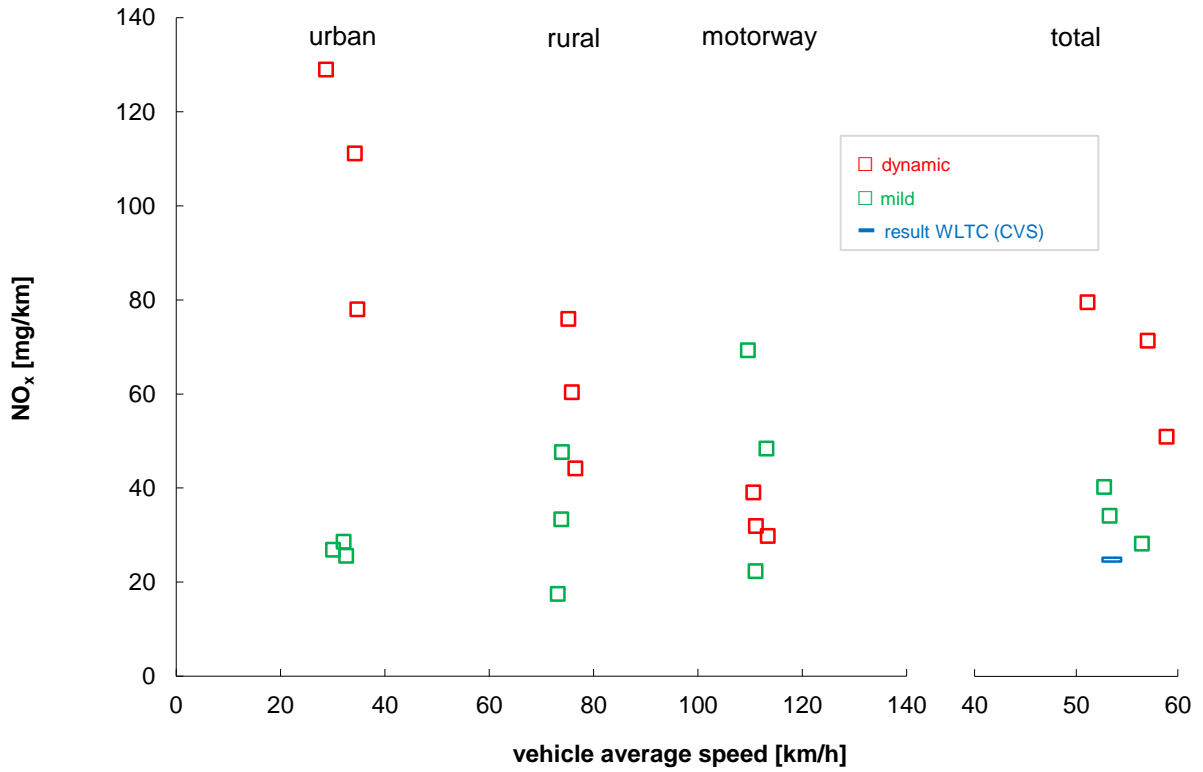
Real Driving Emissions
Influences of Drivestyle
 on CO₂ Emissions for Normality Check
 Vehicle 2 | Diesel, 110kW, Euro 6



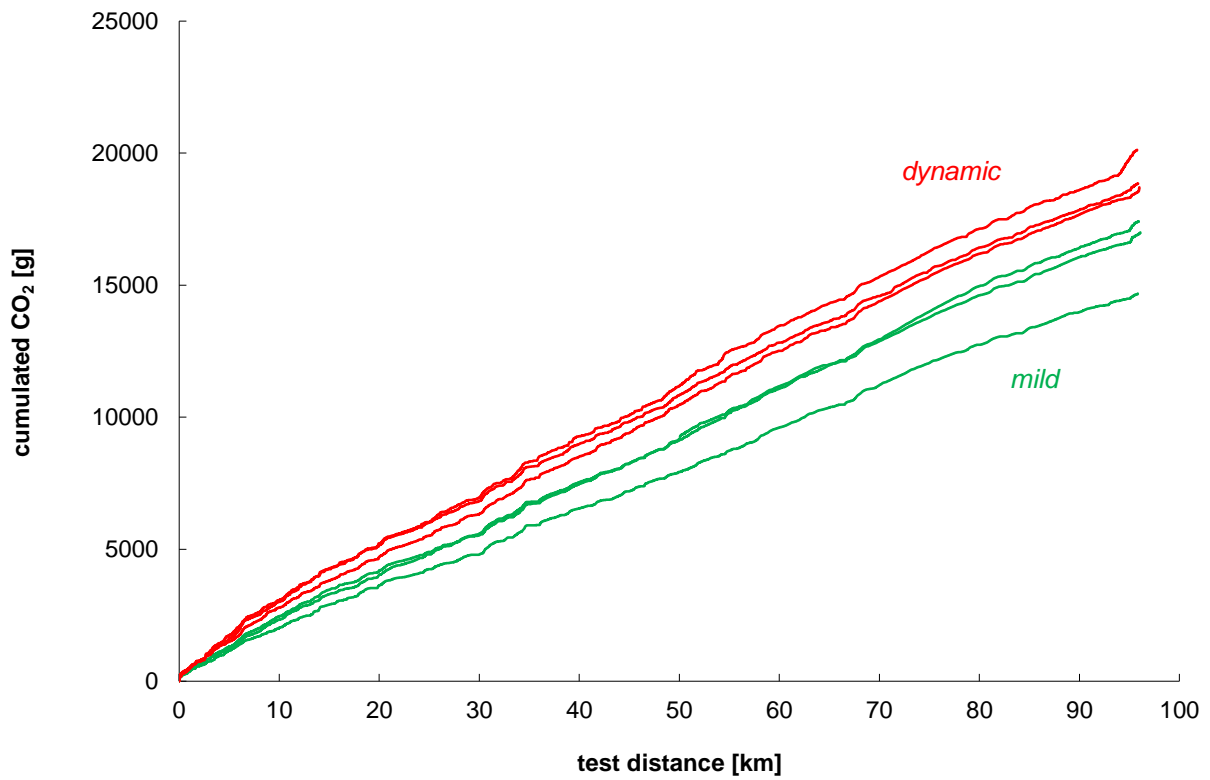
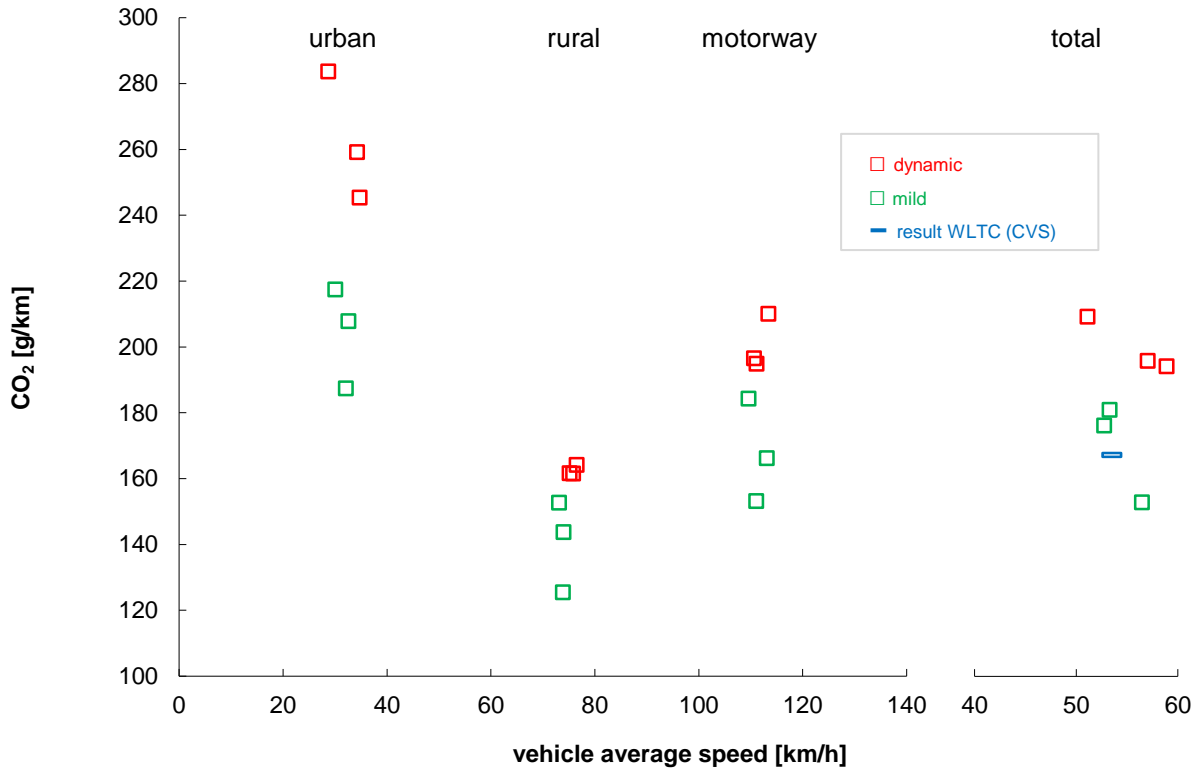
Real Driving Emissions
Influences of Drivestyles
 Gasoline - CO Emissions
 Vehicle 1 | Gasoline, 135 kW, Euro 5a



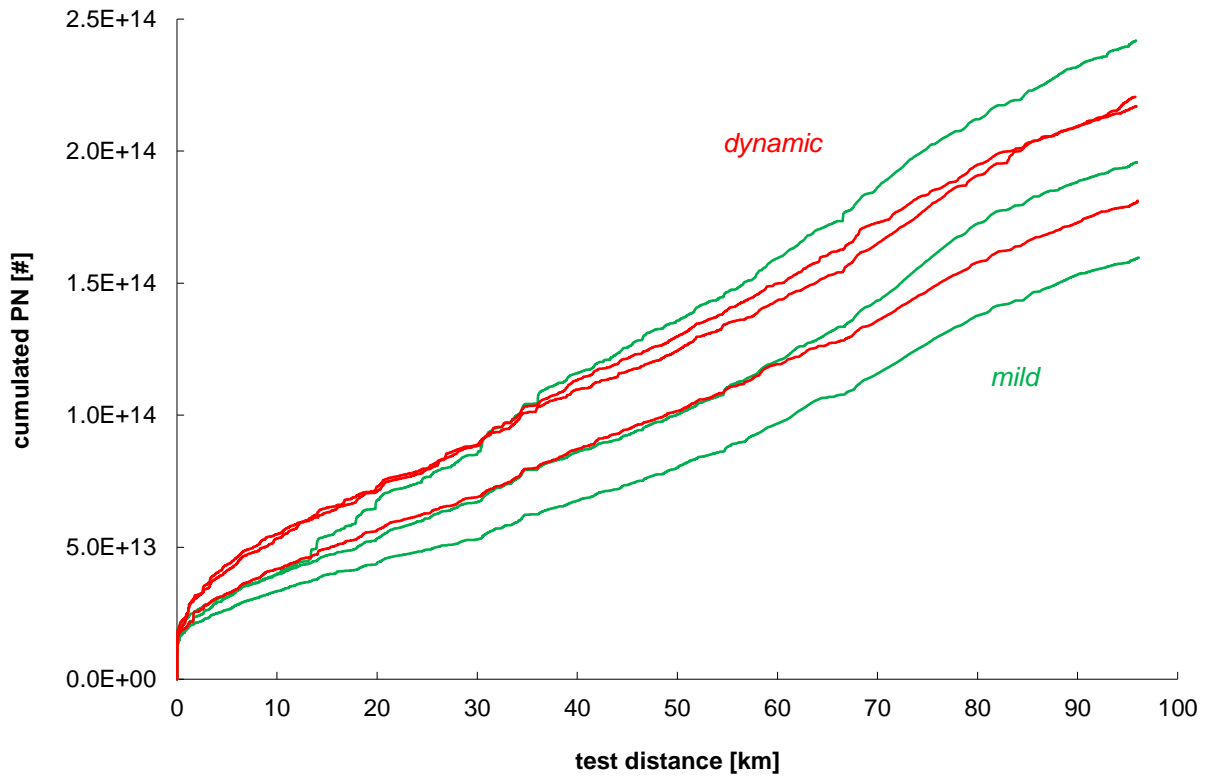
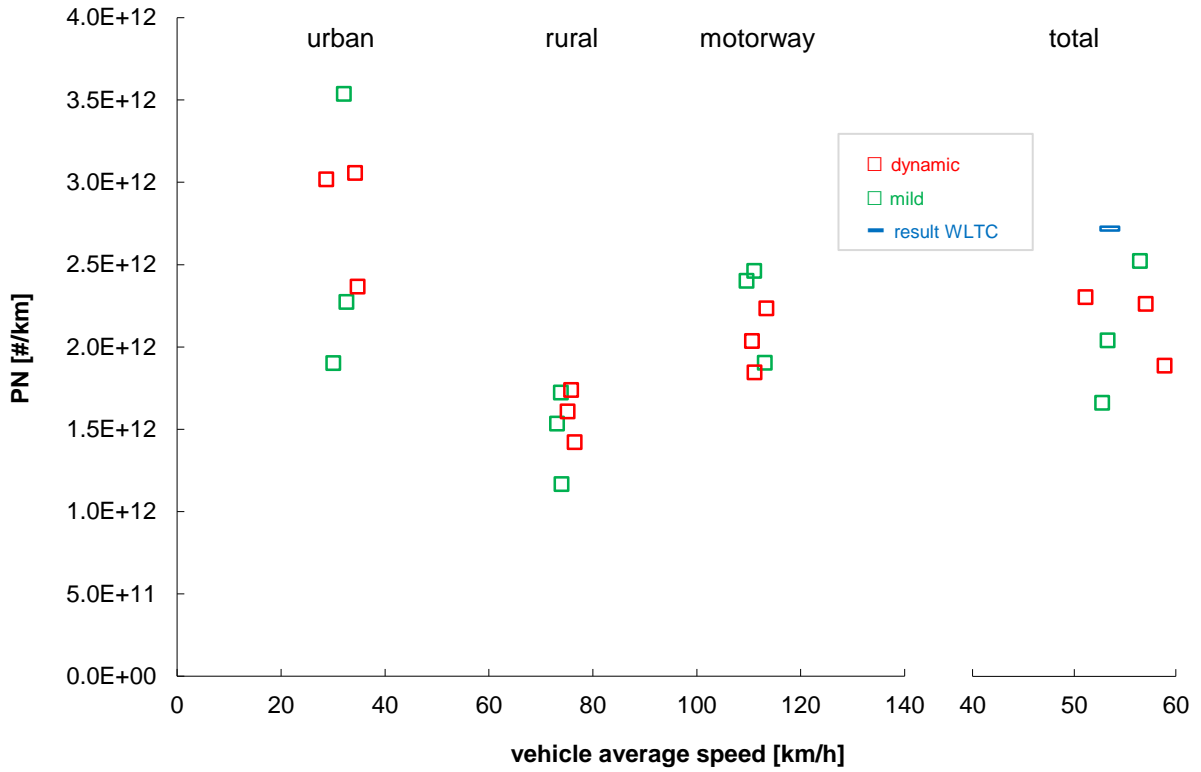
Real Driving Emissions
Influences of Drivestyles
 Gasoline - NO_x Emissions
 Vehicle 1 | Gasoline, 135 kW, Euro 5a



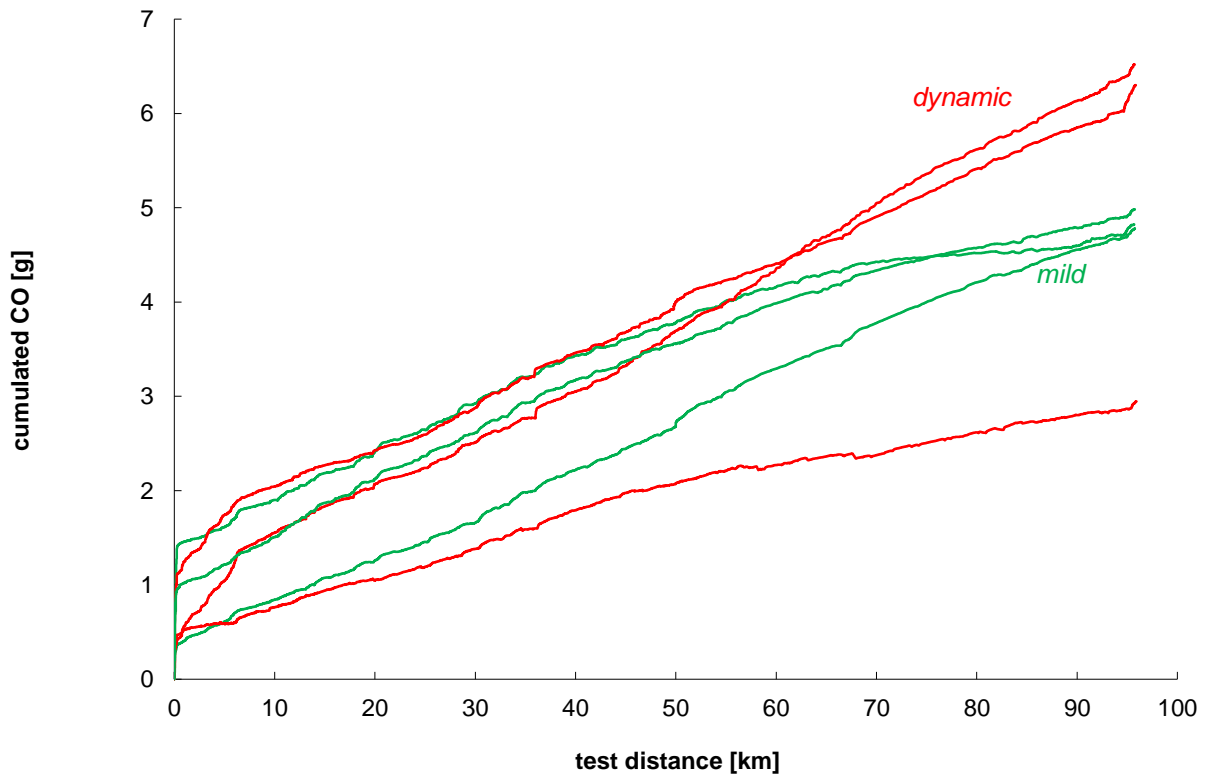
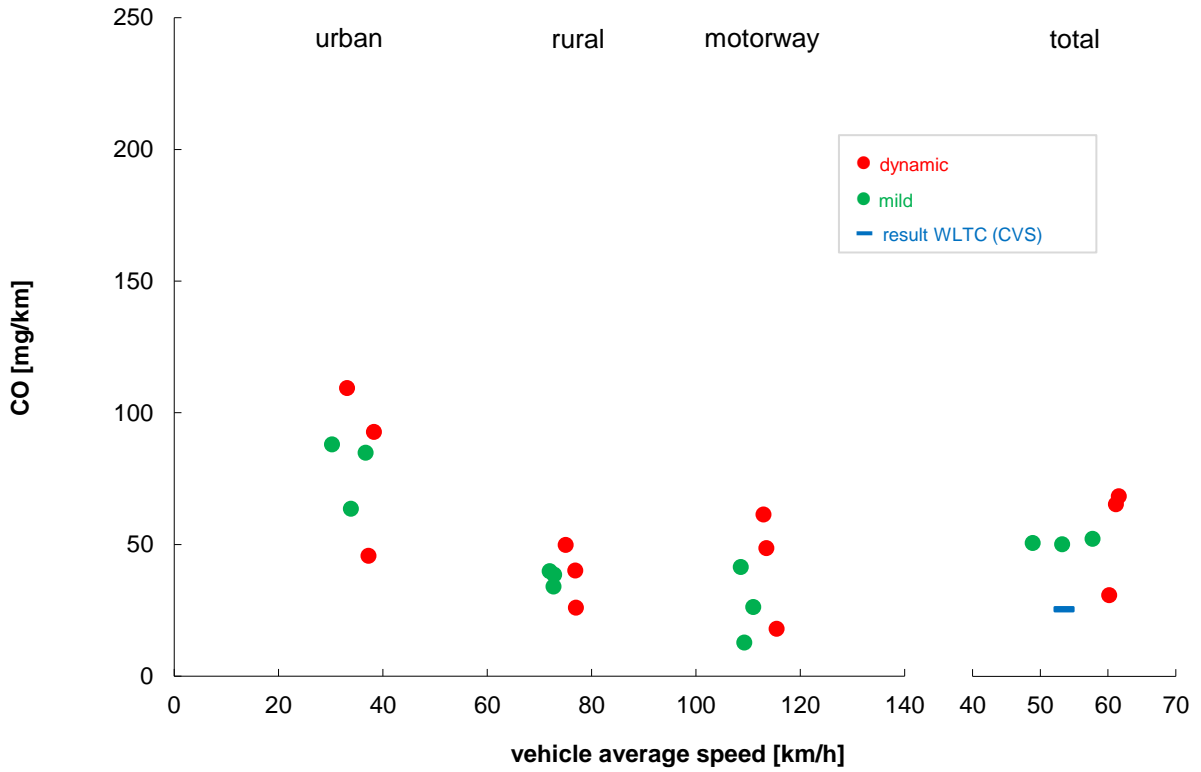
Real Driving Emissions
Influences of Drivestyles
 Gasoline - CO₂ Emissions
 Vehicle 1 | Gasoline, 135 kW, Euro 5a



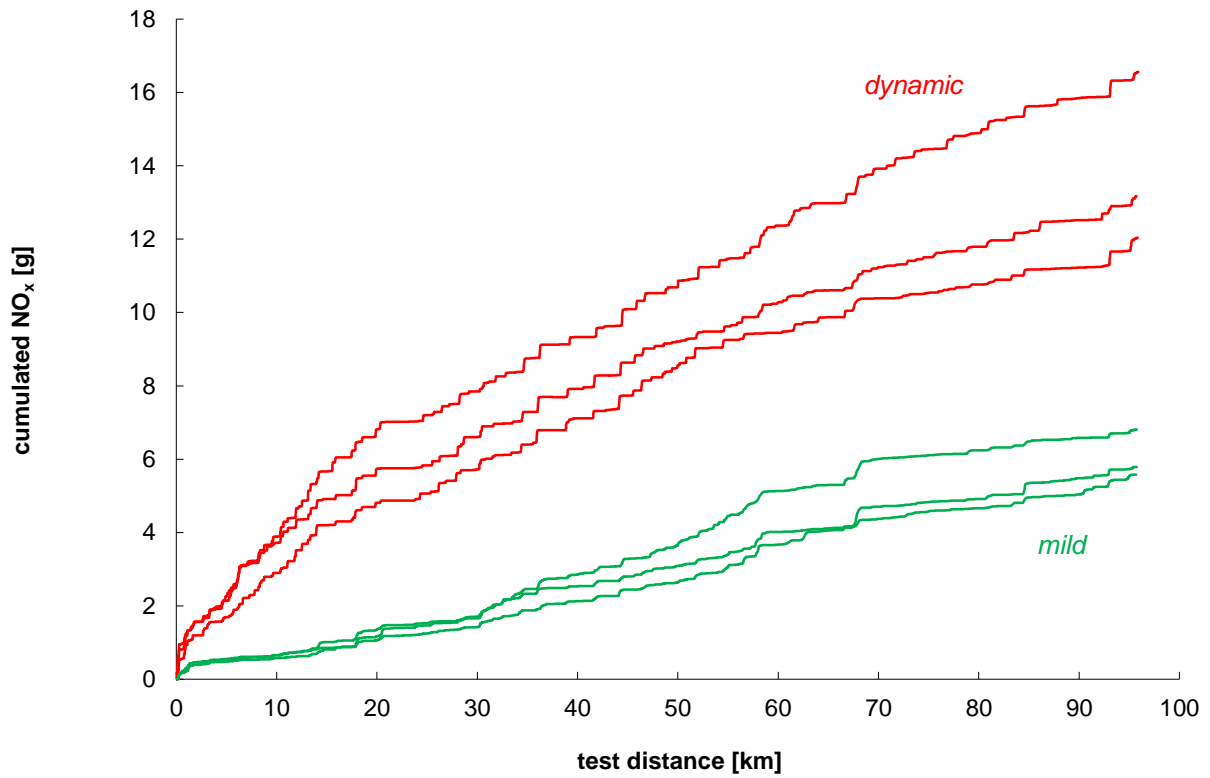
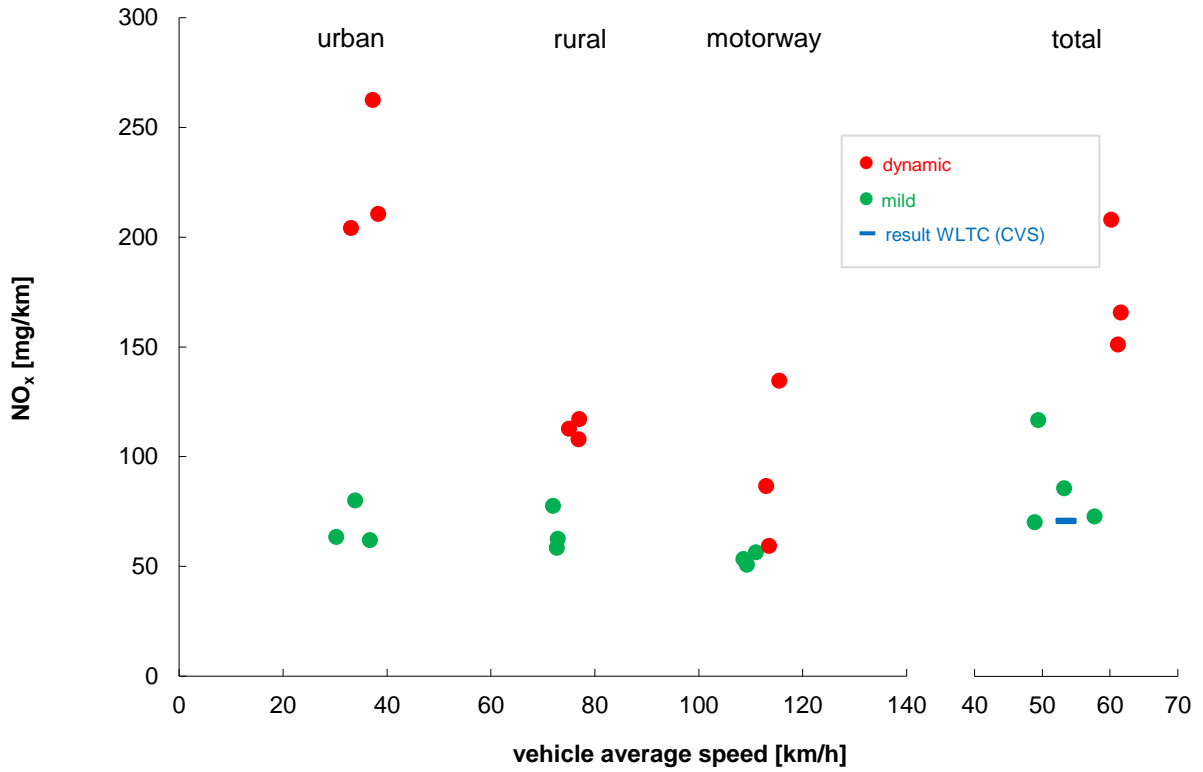
Real Driving Emissions
Influences of Drivestyles
Gasoline - Particle Number (PN) Emissions
Vehicle 1 | Gasoline, 135 kW, Euro 5a



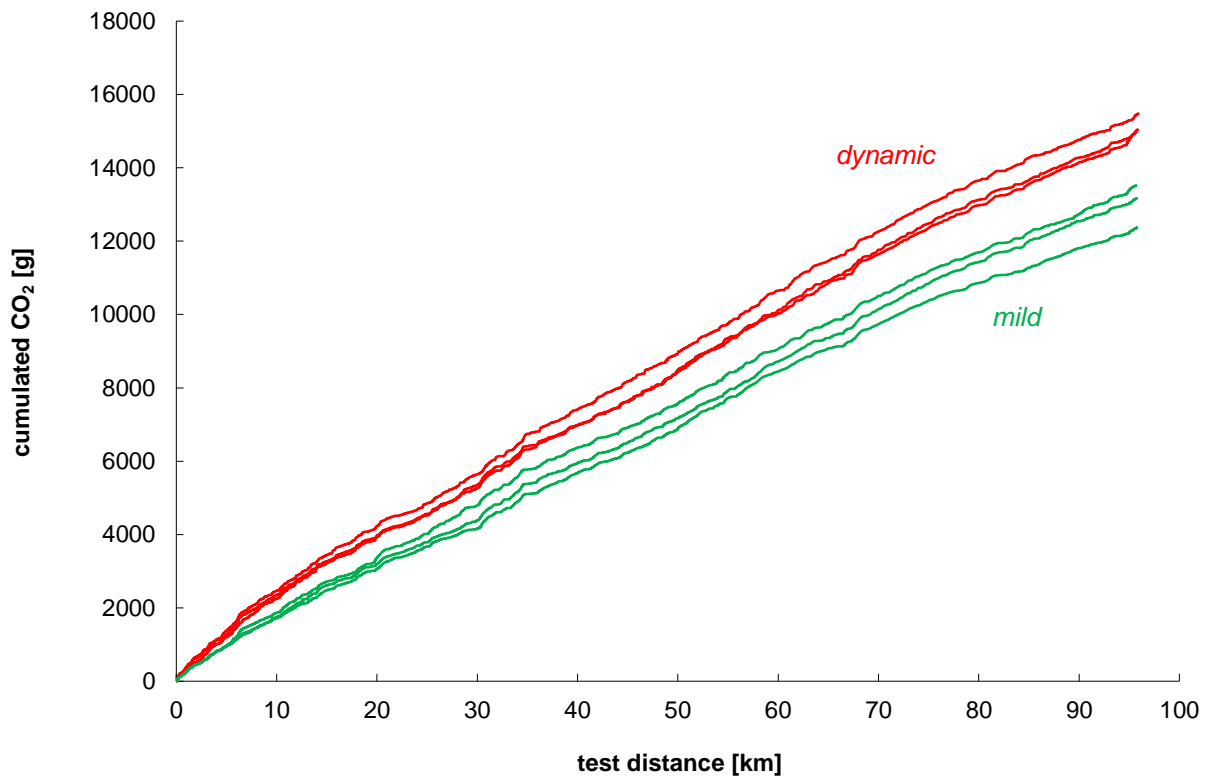
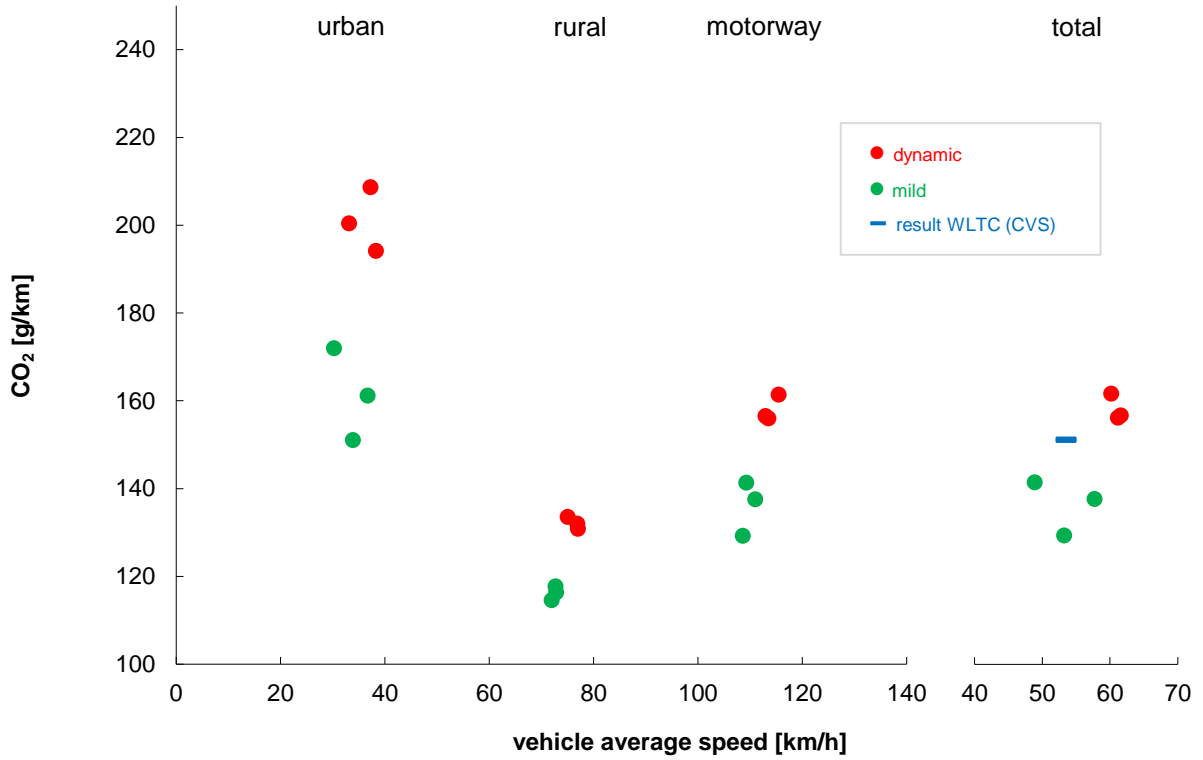
Real Driving Emissions
Influences of Drivestyles
 Diesel - CO Emissions
 Vehicle 2 | Diesel, 110kW, Euro 6



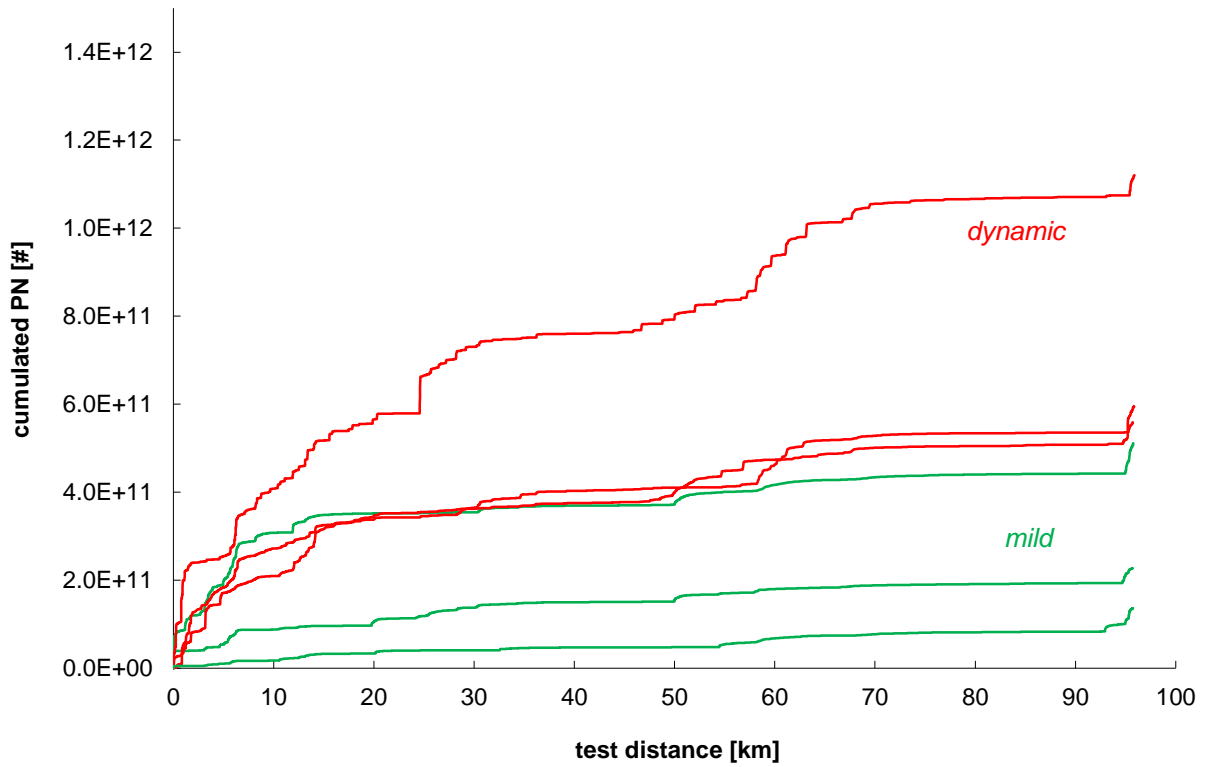
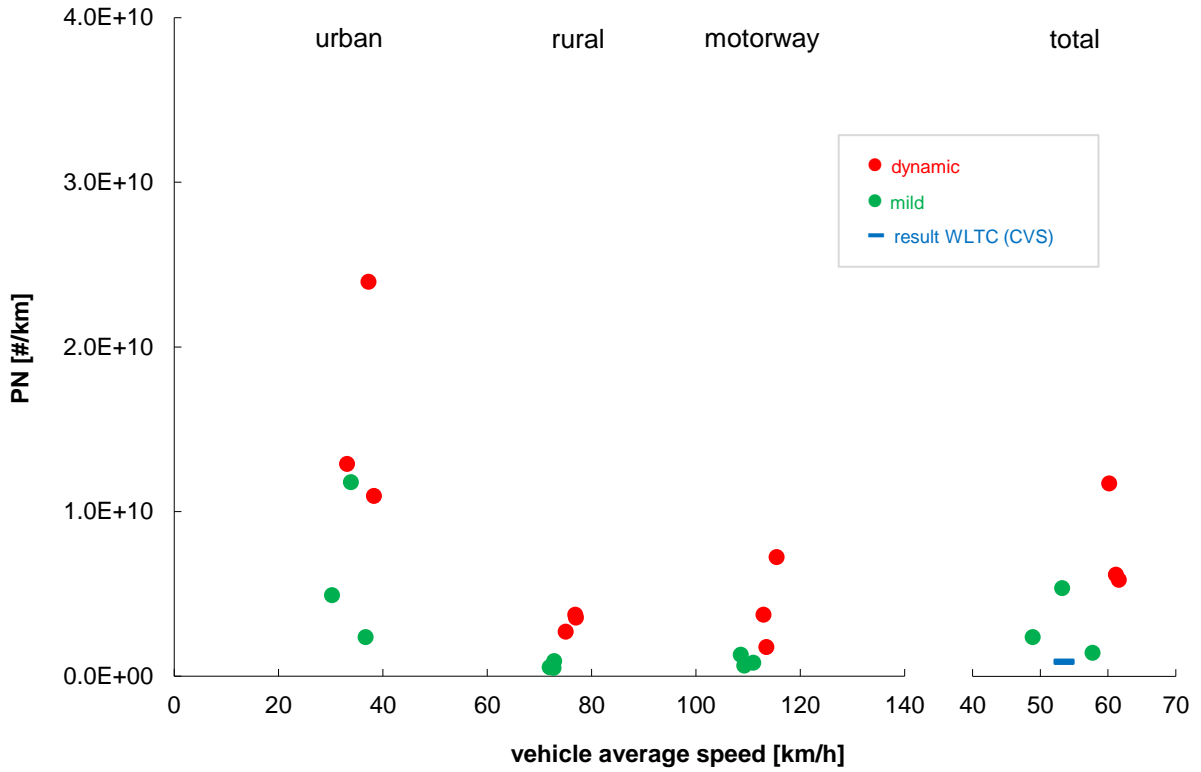
Real Driving Emissions
Influences of Drivestyles
 Diesel - NO_x Emissions
 Vehicle 2 | Diesel, 110kW, Euro 6



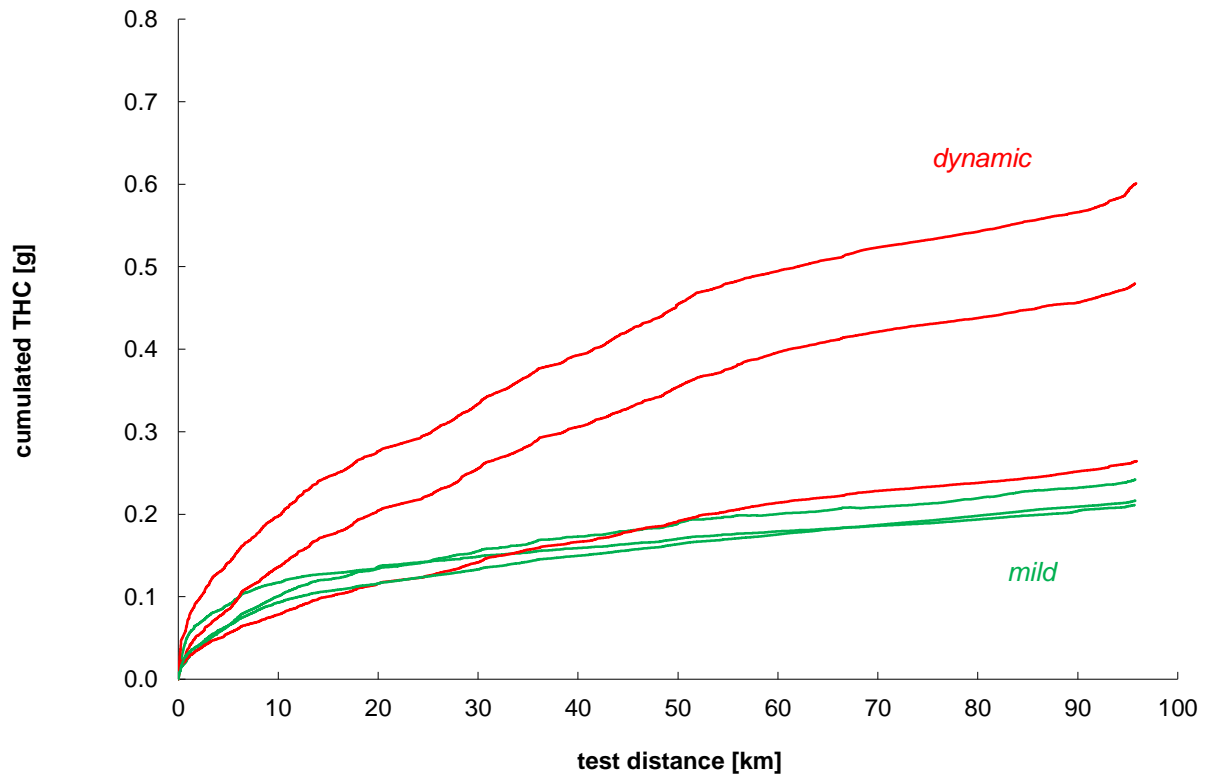
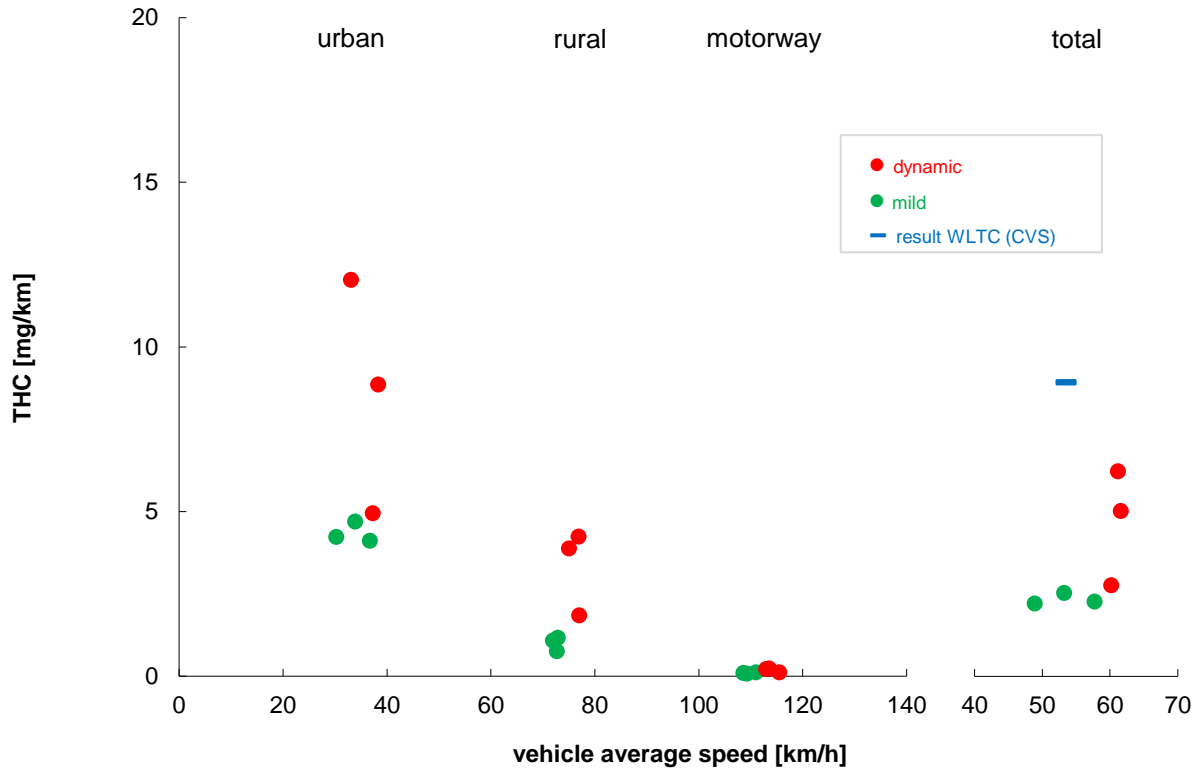
Real Driving Emissions
Influences of Drivestyles
 Diesel - CO₂ Emissions
 Vehicle 2 | Diesel, 110kW, Euro 6



Real Driving Emissions
Influences of Drivestyles
 Diesel - Particle Number (PN) Emissions
 Vehicle 2 | Diesel, 110kW, Euro 6



Real Driving Emissions
Influences of Drivestyles
Diesel - THC Emissions
Vehicle 2 | Diesel, 110kW, Euro 6

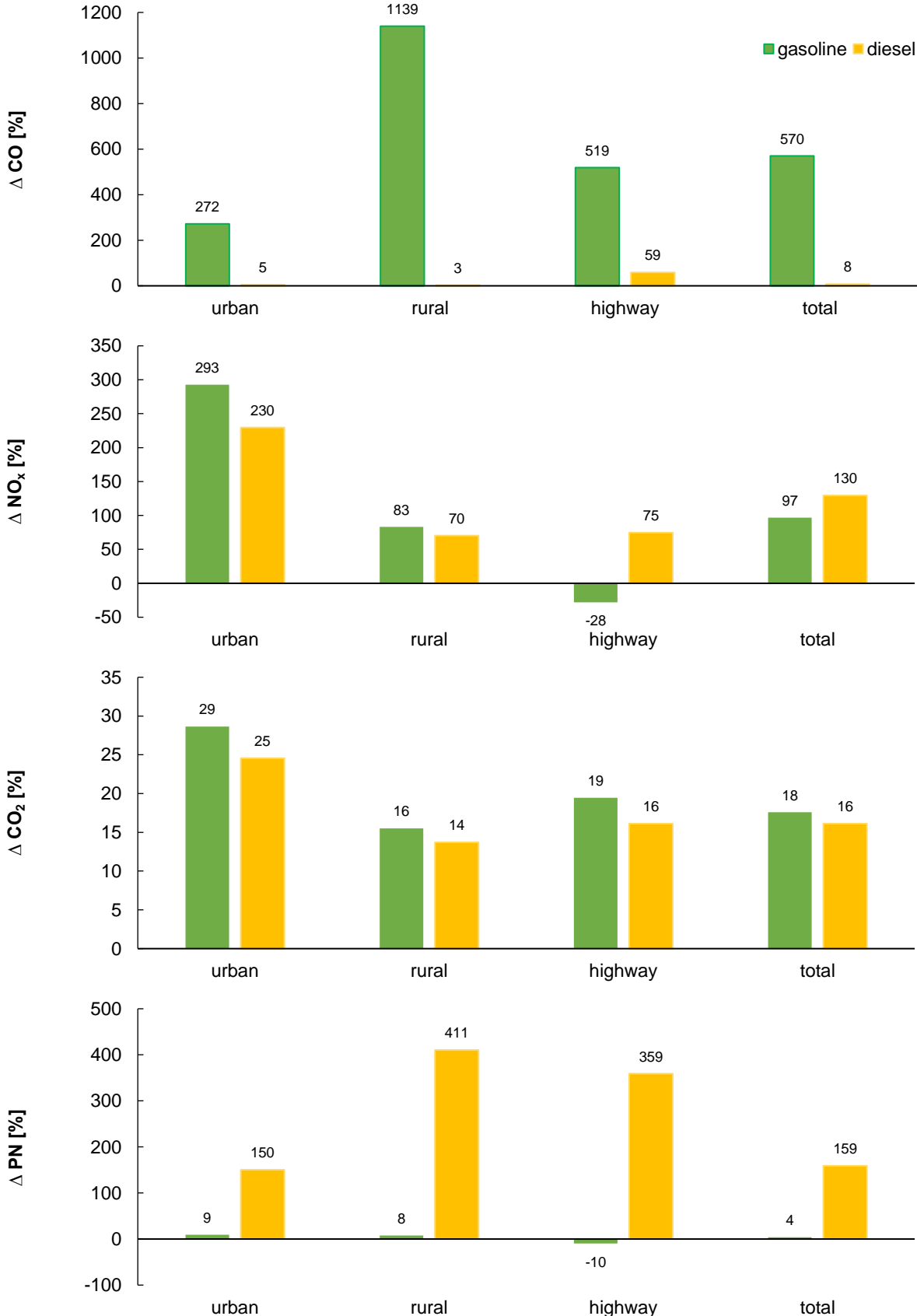


Real Driving Emissions

Influences of Drivestyles

Variation in [%] Between Mild and Dynamic Drivestyle

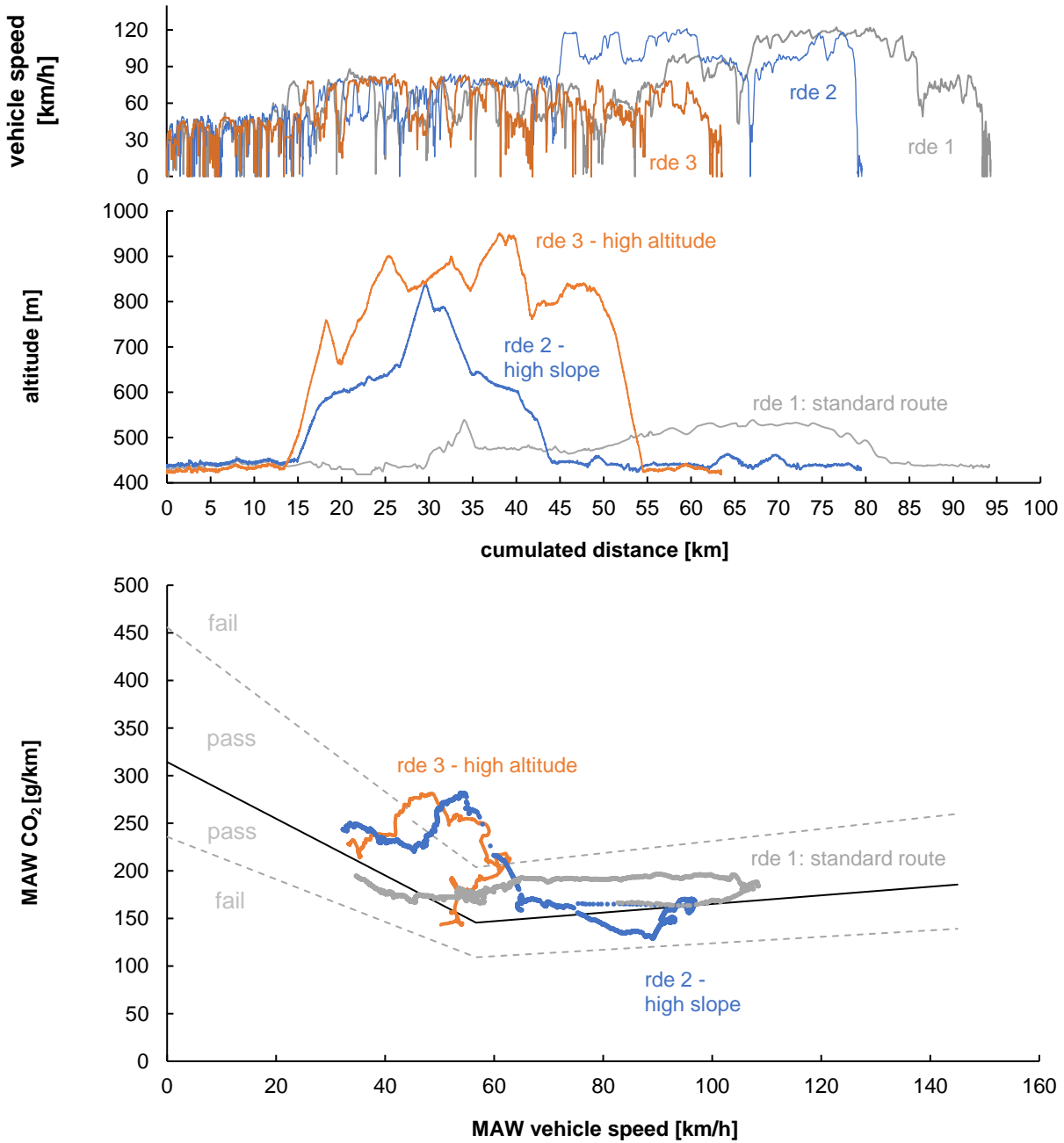
Vehicle 1 | Gasoline, 135 kW, Euro 5a and Vehicle 2 | Diesel, 110kW, Euro 6



► average values based on 12 RDE measurements: 3x RDE mild and 3x RDE dynamic for each vehicles

Real Driving Emissions Influences of Altitude Variations on Trip Validity

Vehicle 1 | Gasoline, 135 kW, Euro 5a



	description	conform to regulation	share of normal windows (CO ₂ MAW)	total cumulative positive elevation gain m/100km
rde 1	standard	yes	u, r, h > 50%	381
rde 2	high slope	no	r < 50% (31%)	670
rde 3	high altitude	no	r < 50% (49%)	1368

u: urban part, r: rural part, h: highway part

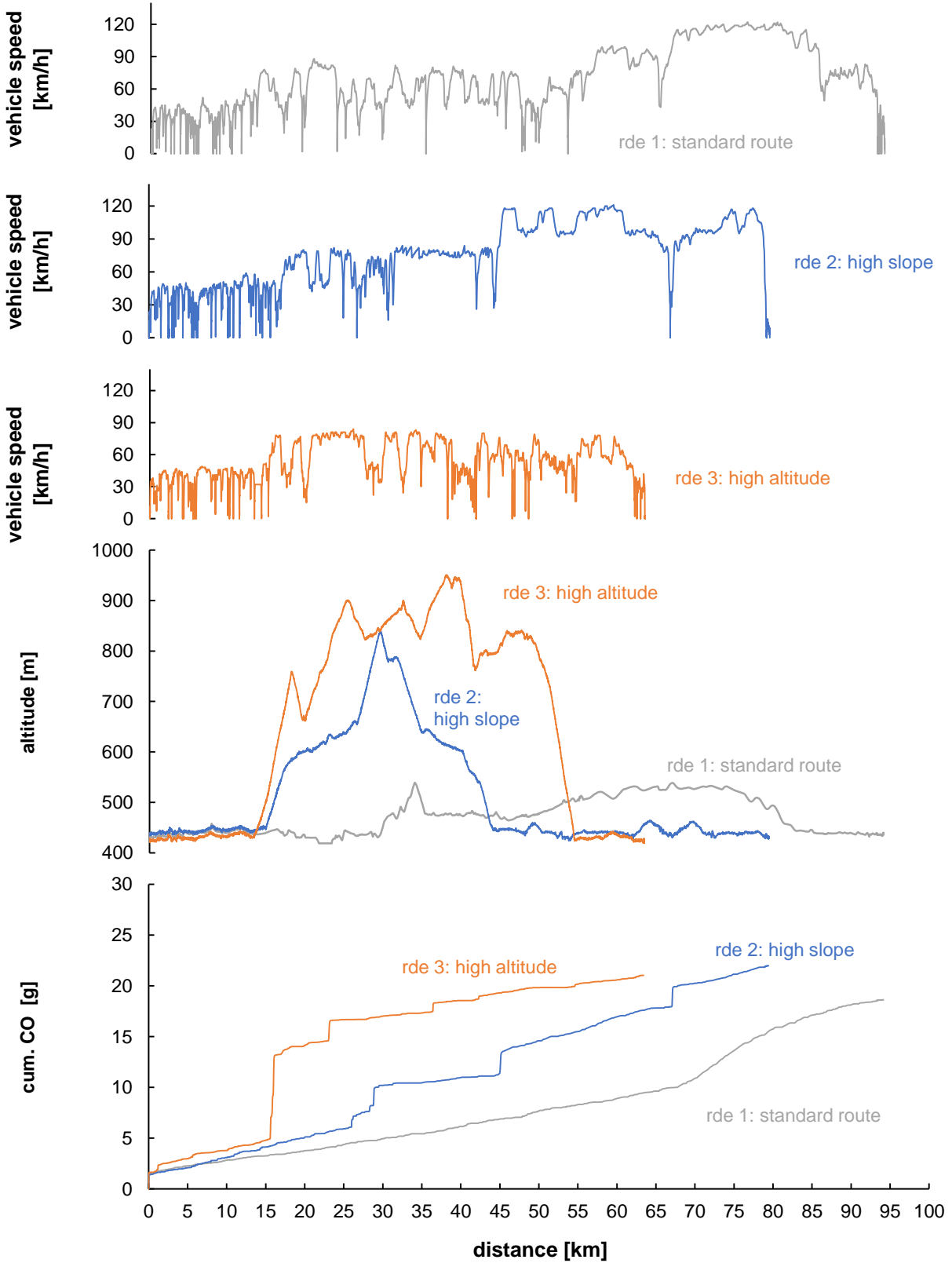
total cumulative positive elevation gain: max = 1200 m / 100km (EU 2017/1151, Annexe IIIa, appendix 7b)

Real Driving Emissions

Influences of Altitude and Altitude Variations

Gasoline - CO Emissions

Vehicle 1 | Gasoline, 135 kW, Euro 5a

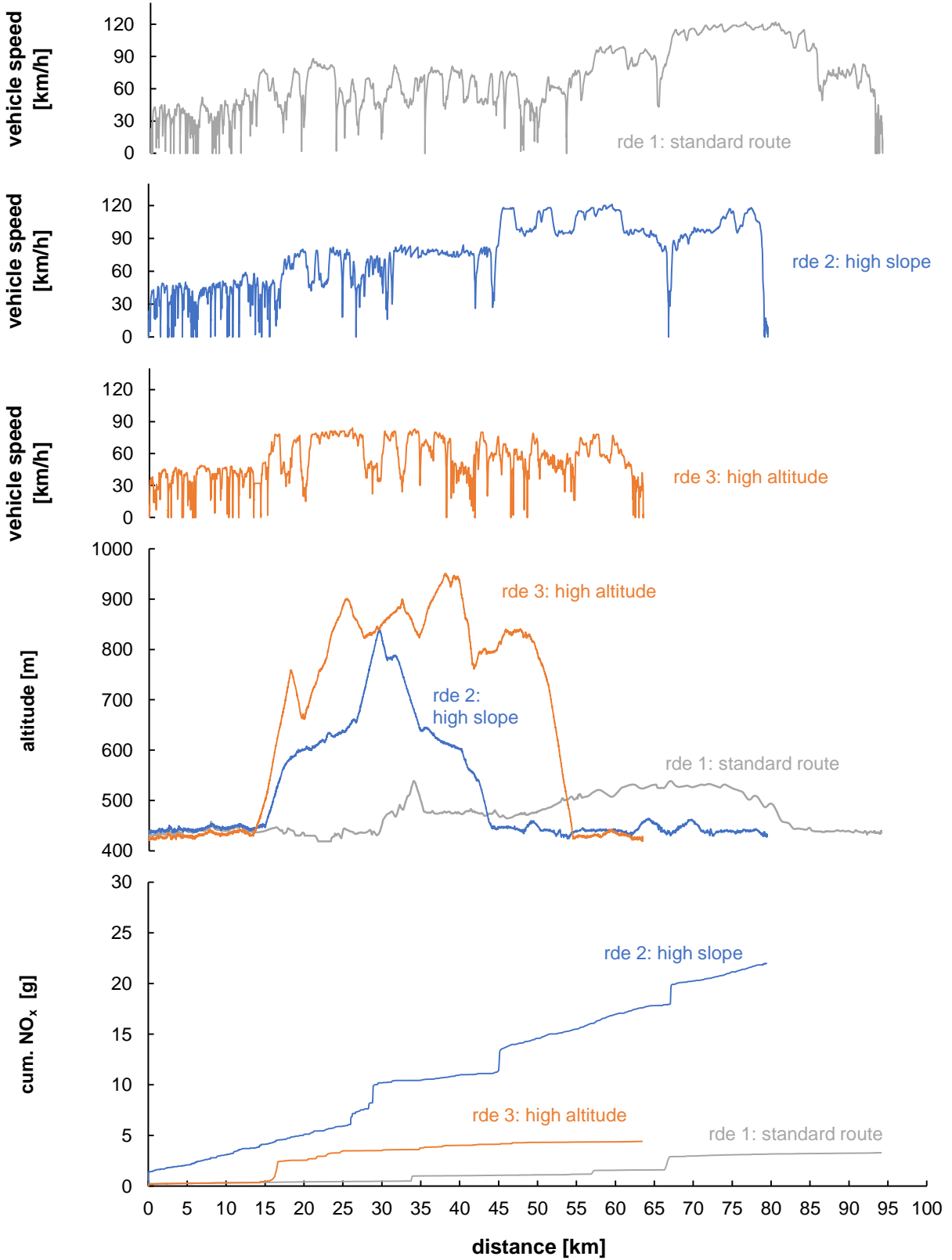


Real Driving Emissions

Influences of Altitude and Altitude Variations

Gasoline - NO_x Emissions

Vehicle 1 | Gasoline, 135 kW, Euro 5a

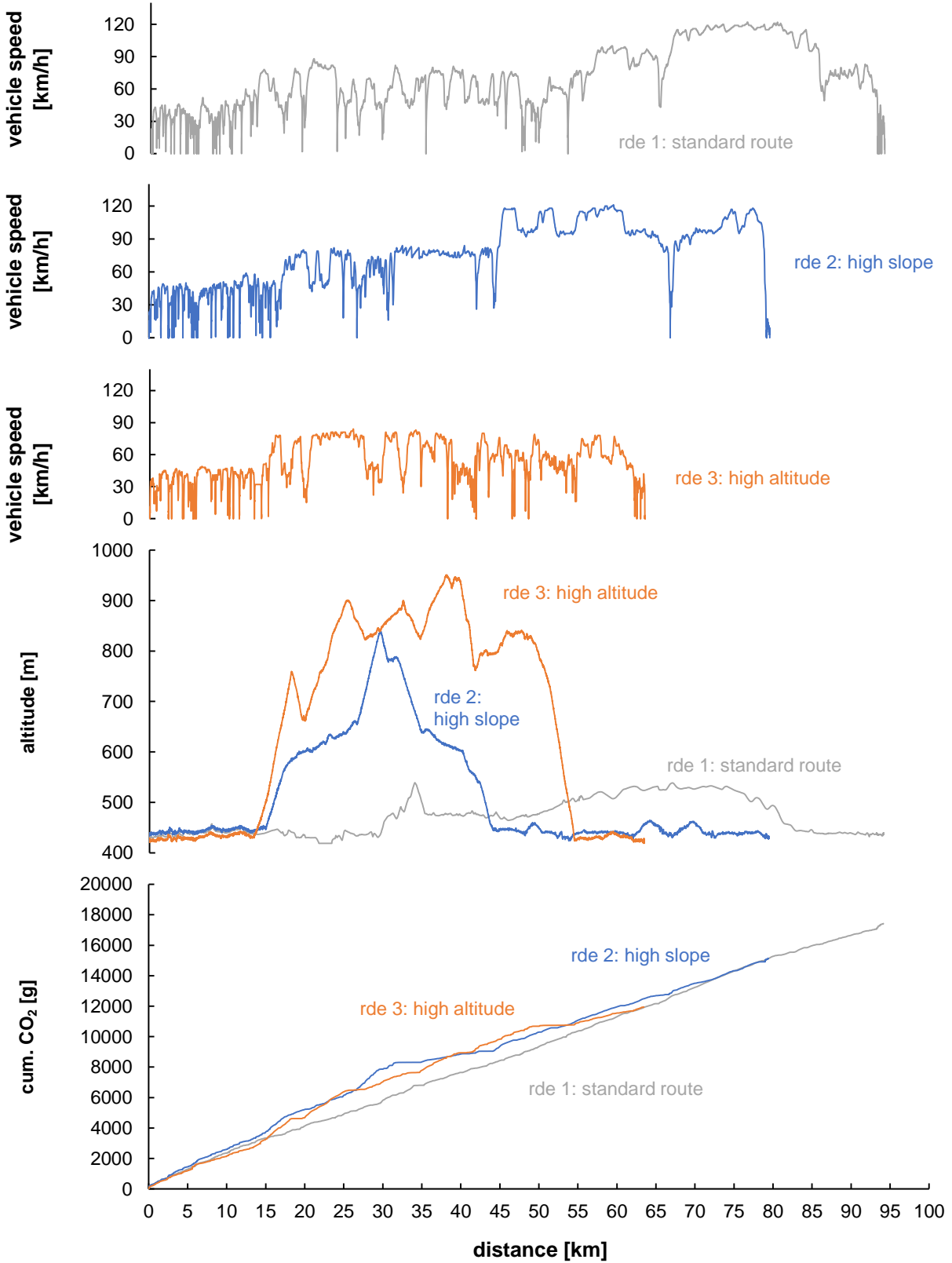


Real Driving Emissions

Influences of Altitude and Altitude Variations

Gasoline - CO₂ Emissions

Vehicle 1 | Gasoline, 135 kW, Euro 5a

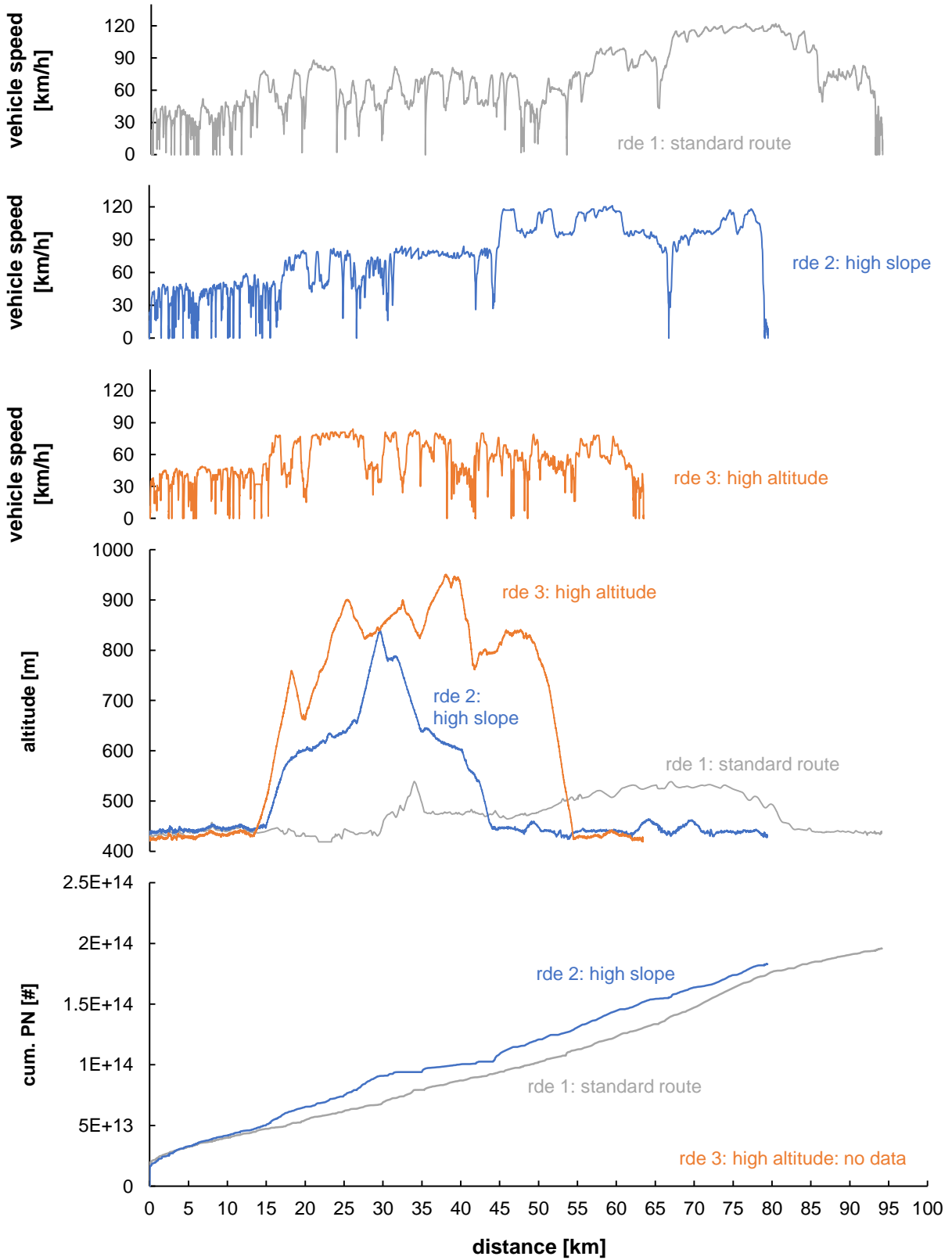


Real Driving Emissions

Influences of Altitude and Altitude Variations

Gasoline - PN Emissions

Vehicle 1 | Gasoline, 135 kW, Euro 5a

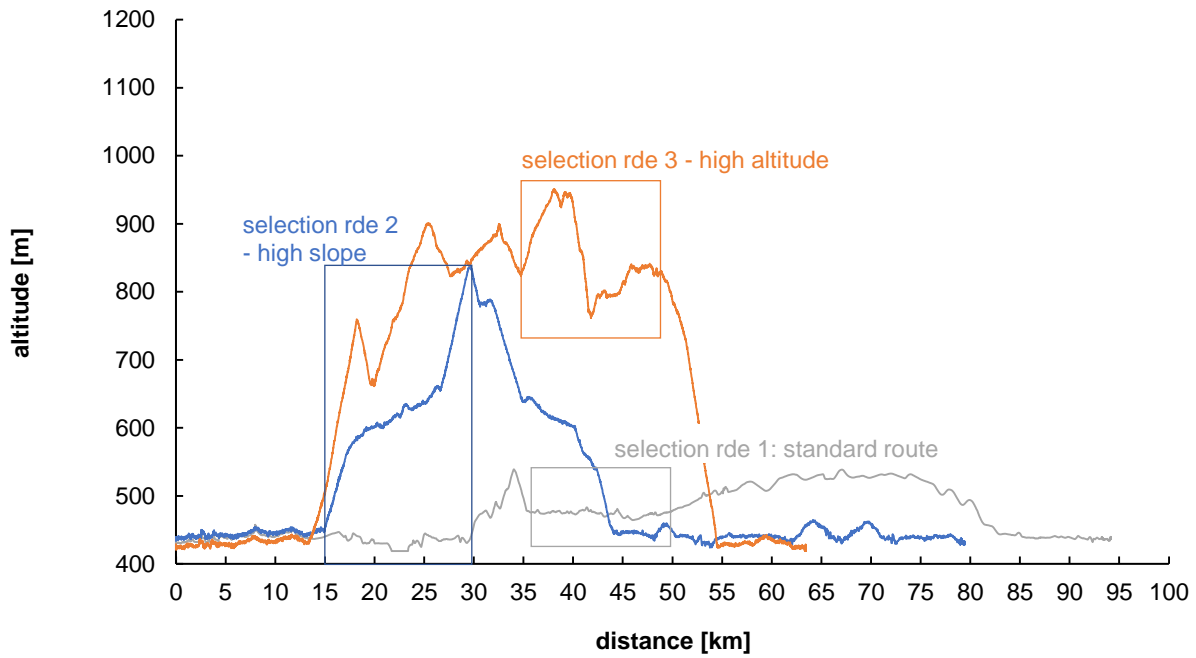


Real Driving Emissions

Influences of Altitude and Altitude Variations

Selection of Characteristic Parts

Vehicle 1 | Gasoline, 135 kW, Euro 5a



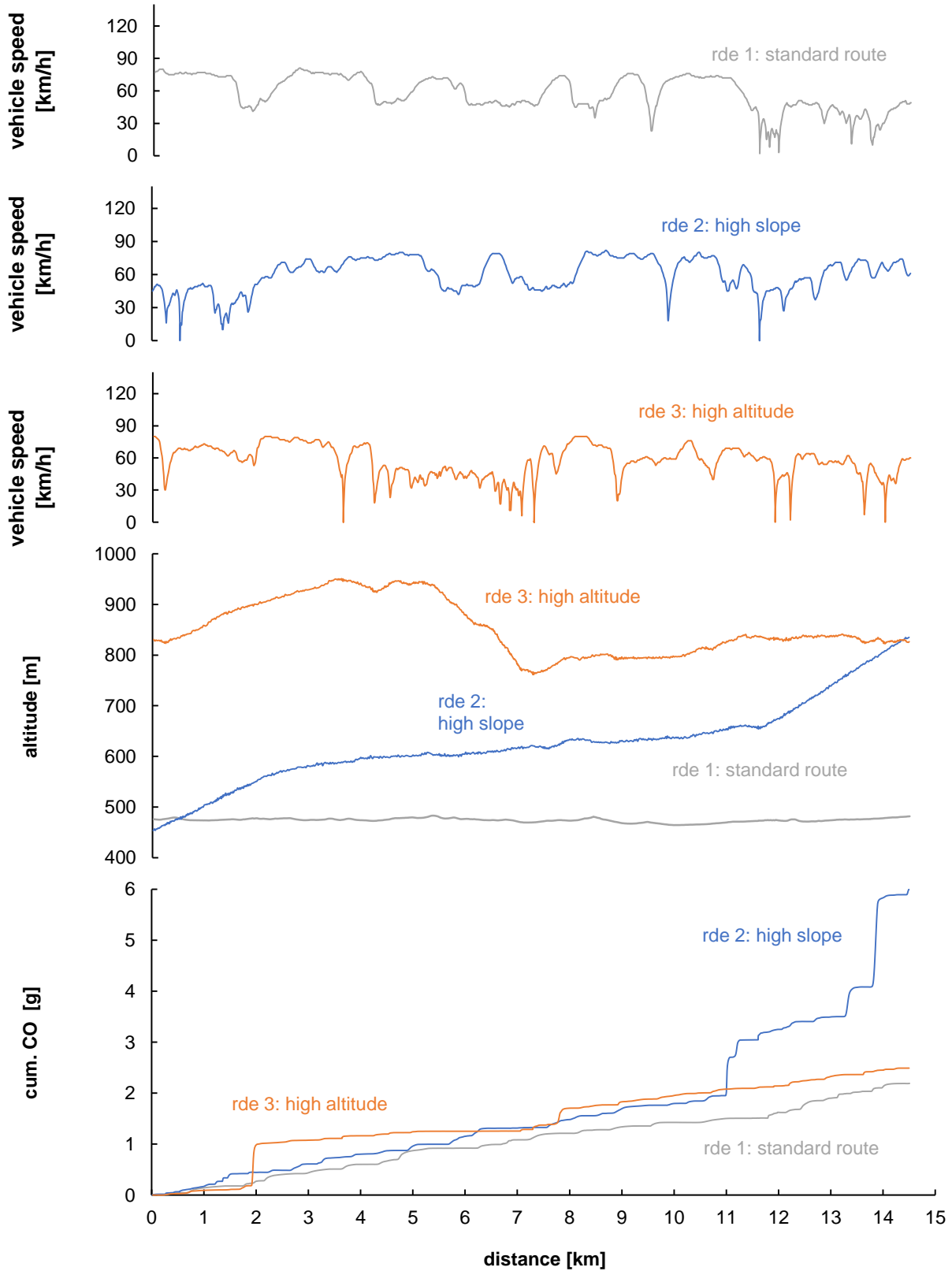
segment of	vehicle speed		altitude	altitude	altitude	Δ altitude begin - end	CO	NOx	CO2	PN
	distance km	average km/h	min m	max m	average m		int. mg/km	int. mg/km	int. g/km	int. #/km
RDE 1	14.5	51.7	464	483	474	5.8	151	7	167.8	1.5E+12
RDE 2	14.5	53.1	453	835	613	382	414	129.5	282.5	2.8E+12
RDE 3	14.5	49.1	761	951	850	-4.3	171	48.7	206.8	-

Real Driving Emissions

Influences of Altitude and Altitude Variations

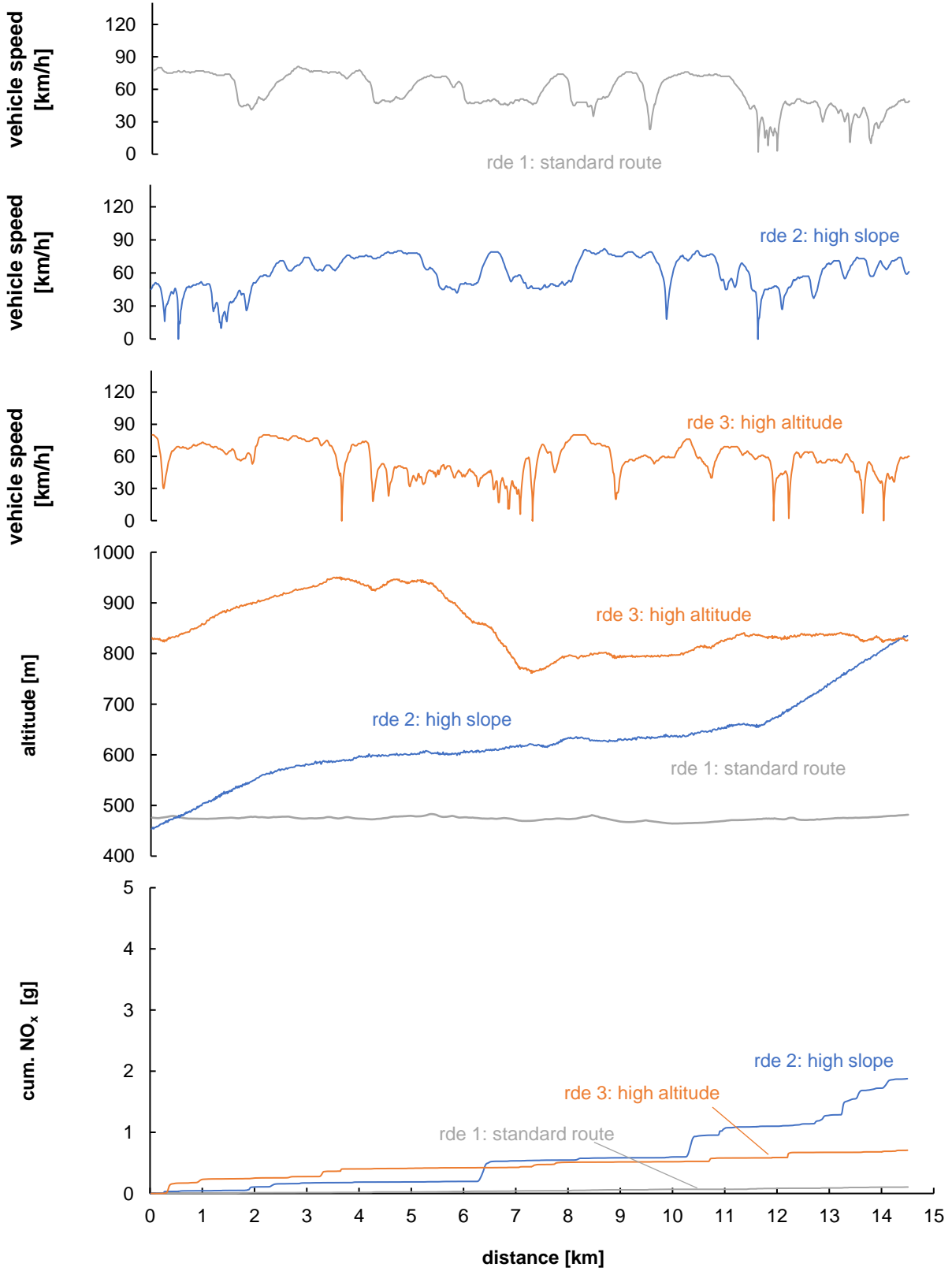
Gasoline - CO Emissions - Part Selection

Vehicle 1 | Gasoline, 135 kW, Euro 5a



Real Driving Emissions
Influences of Altitude and Altitude Variations
 Gasoline - NO_x Emissions - Part Selection

Vehicle 1 | Gasoline, 135 kW, Euro 5a

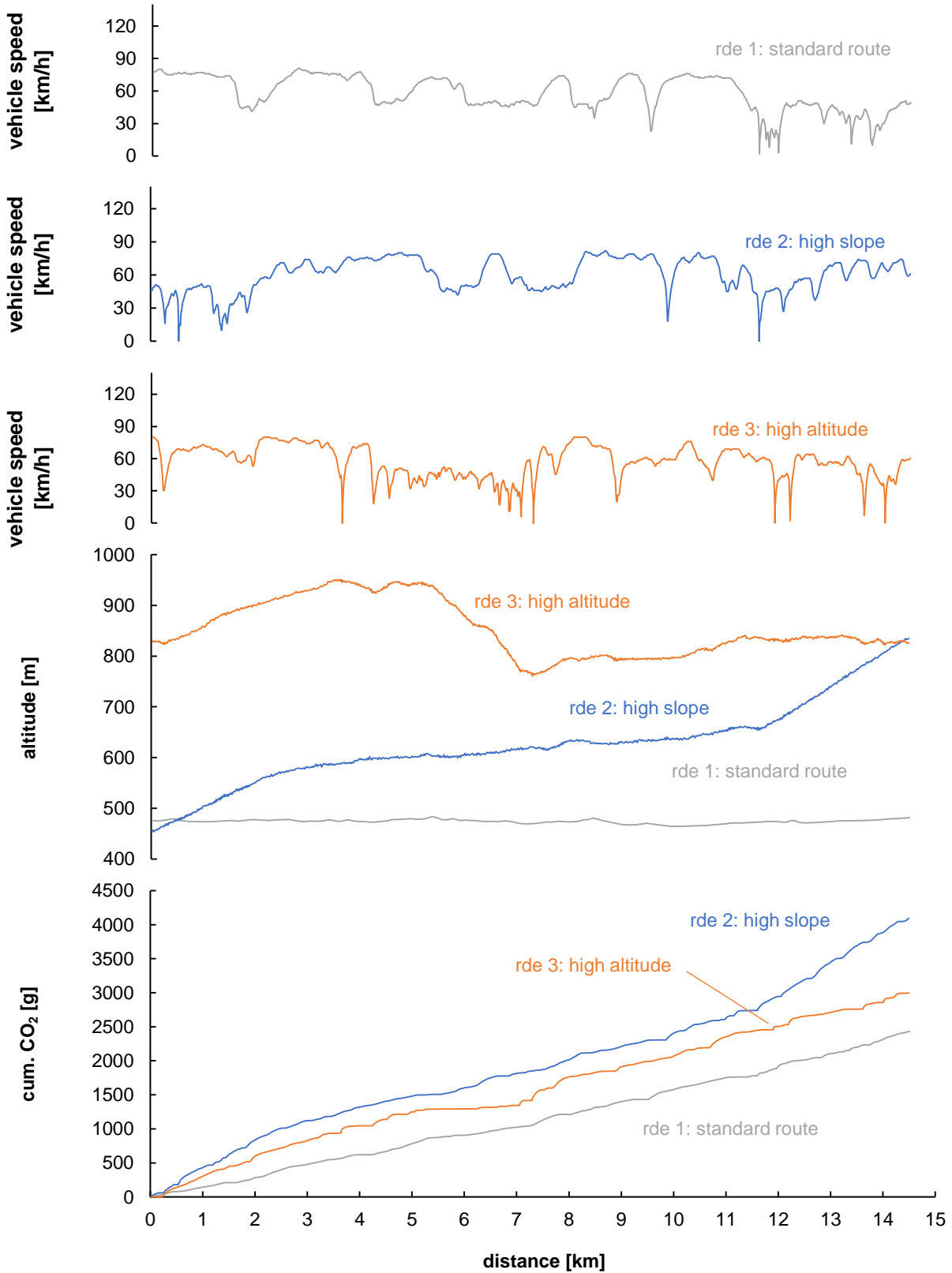


Real Driving Emissions

Influences of Altitude and Altitude Variations

Gasoline - CO₂ Emissions - Part Selection

Vehicle 1 | Gasoline, 135 kW, Euro 5a

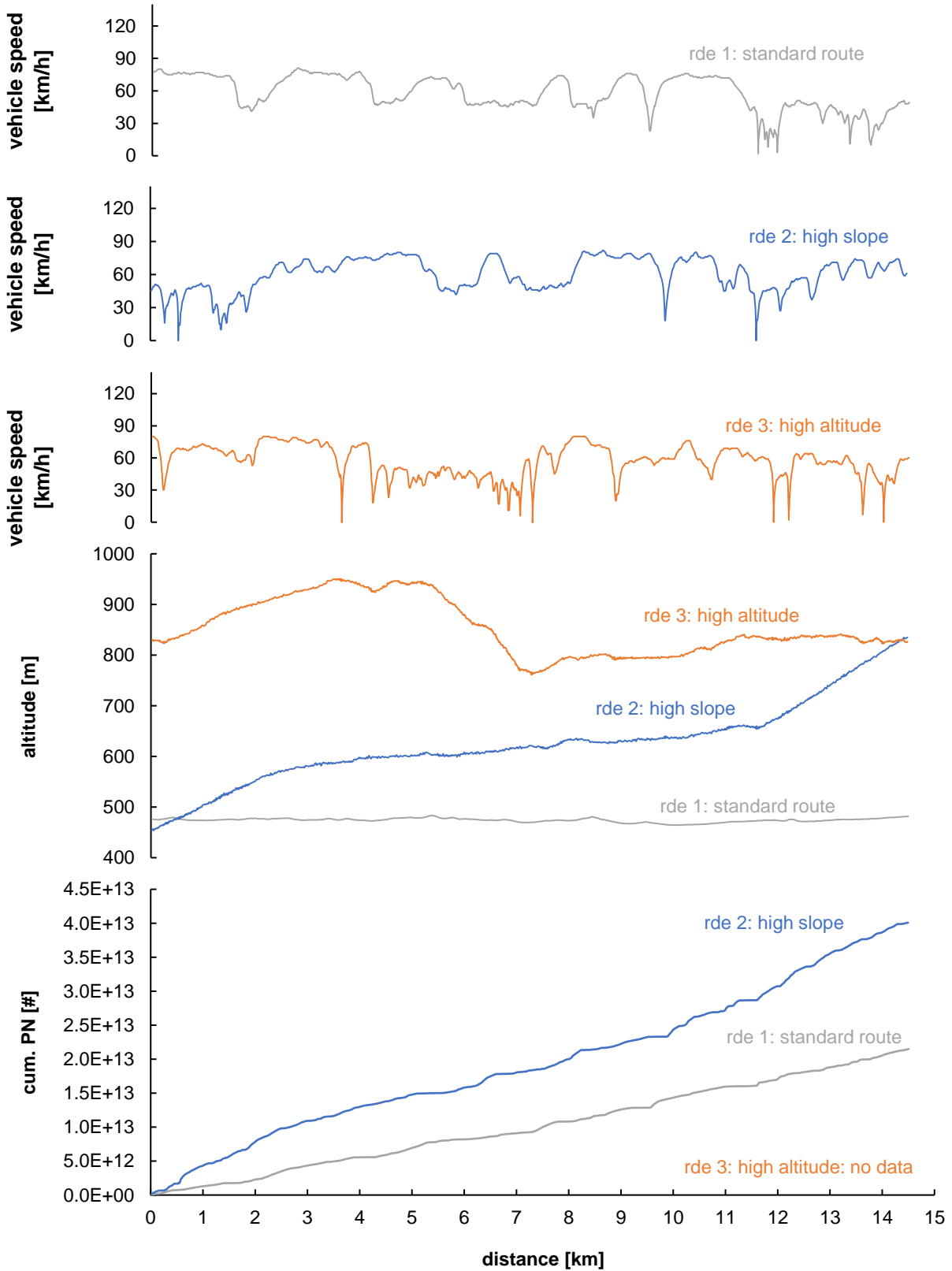


Real Driving Emissions

Influences of Altitude and Altitude Variations

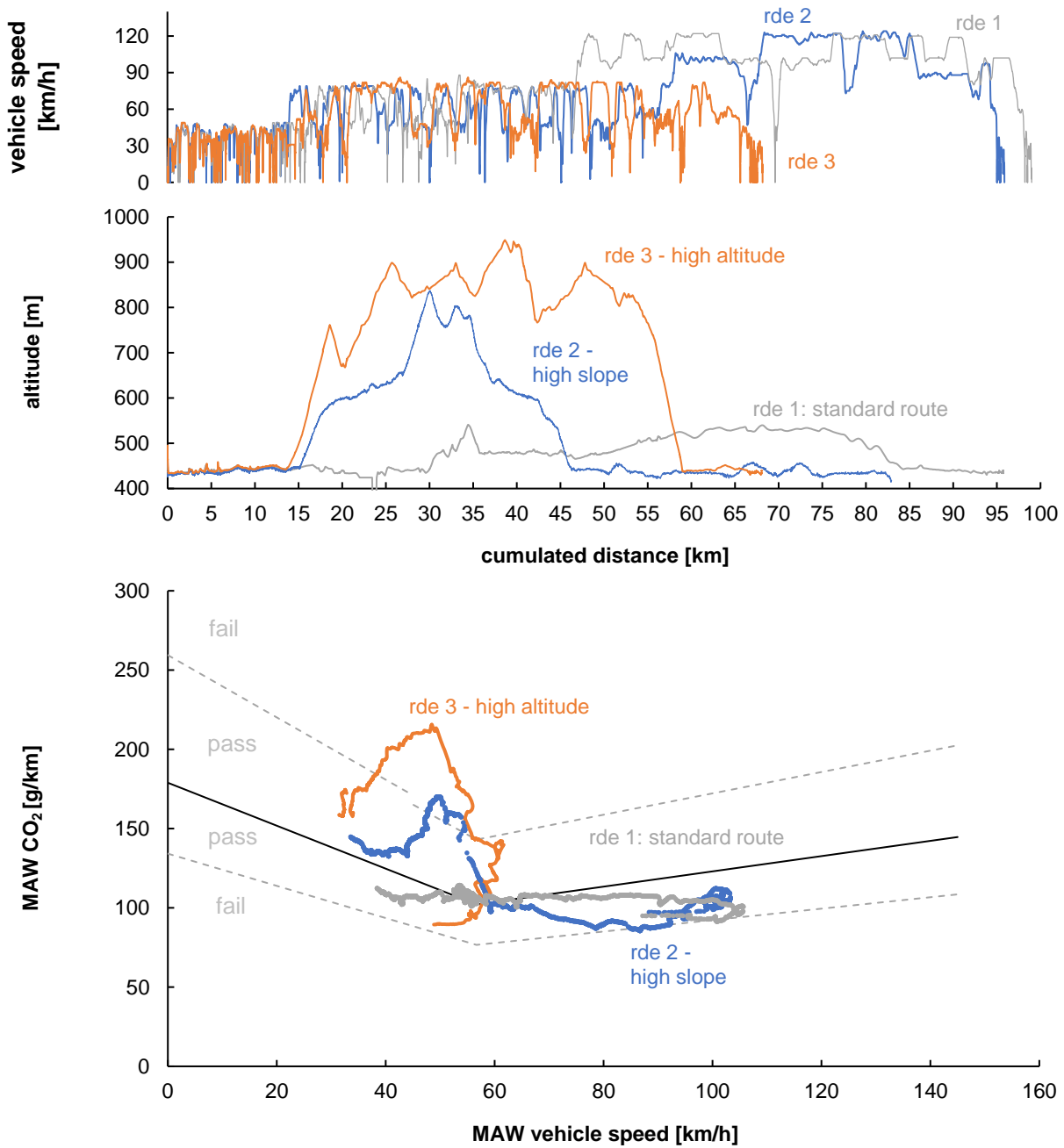
Gasoline - PN Emissions - Part Selection

Vehicle 1 | Gasoline, 135 kW, Euro 5a



Real Driving Emissions Influences of Altitude Variations on Trip Validity

Vehicle 3 | Diesel, 88 kW, Euro 6b



	description	conform to regulation	share of normal windows (CO ₂ MAW)	total cumulative positive elevation gain m/100km
rde 1	standard	yes	u, r, h > 50%	375
rde 2	high slope	no	r < 50% (75%)	623
rde 3	high altitude	no	r < 50% (69%)	1363

u: urban part, r: rural part, h: highway part

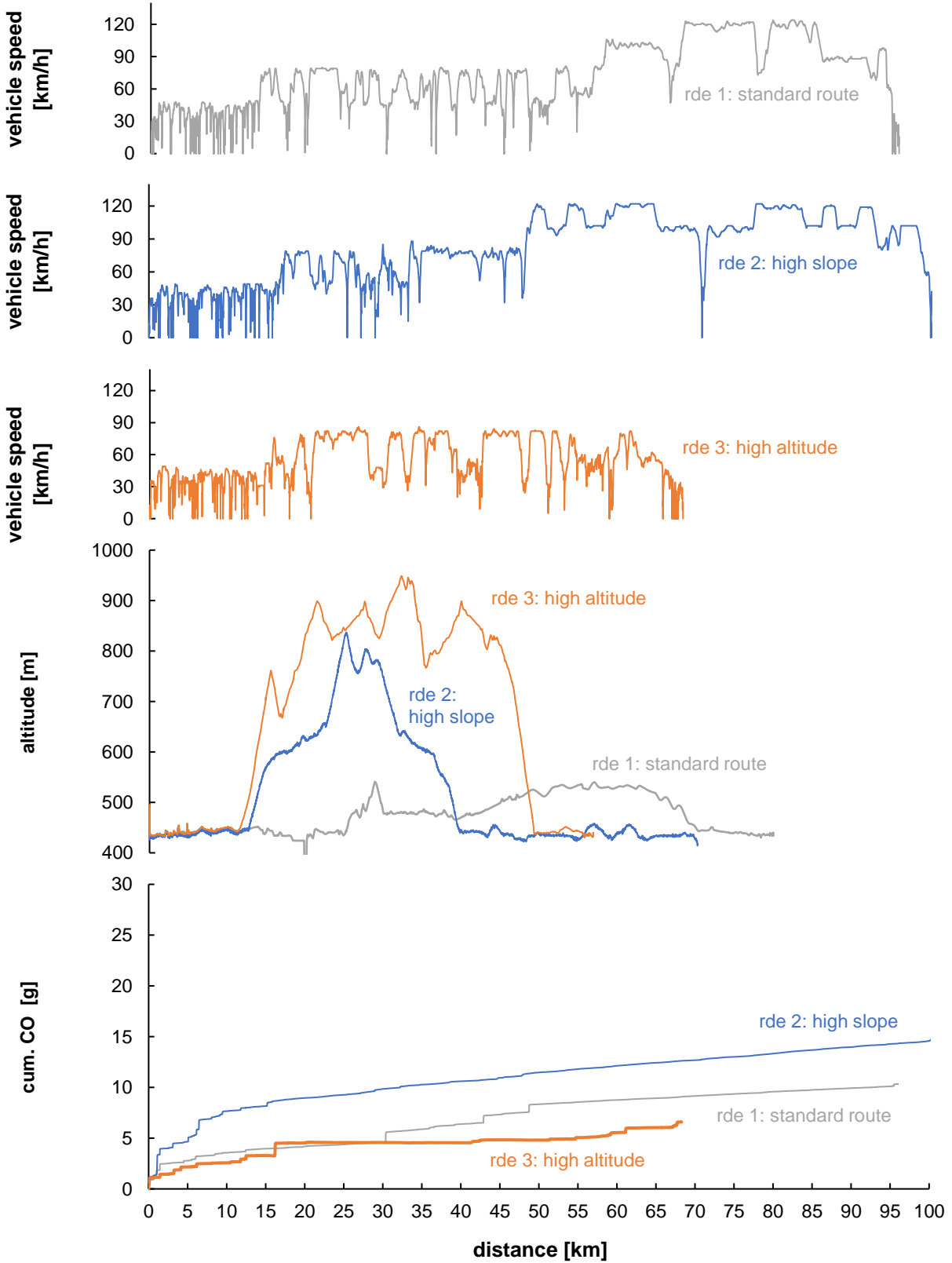
total cumulative positive elevation gain: max = 1200 m / 100km (EU 2017/1151, Annexe IIIa, appendix 7b)

Real Driving Emissions

Influences of Altitude and Altitude Variations

Diesel - CO Emissions

Vehicle 3 | Diesel, 88 kW, Euro 6b

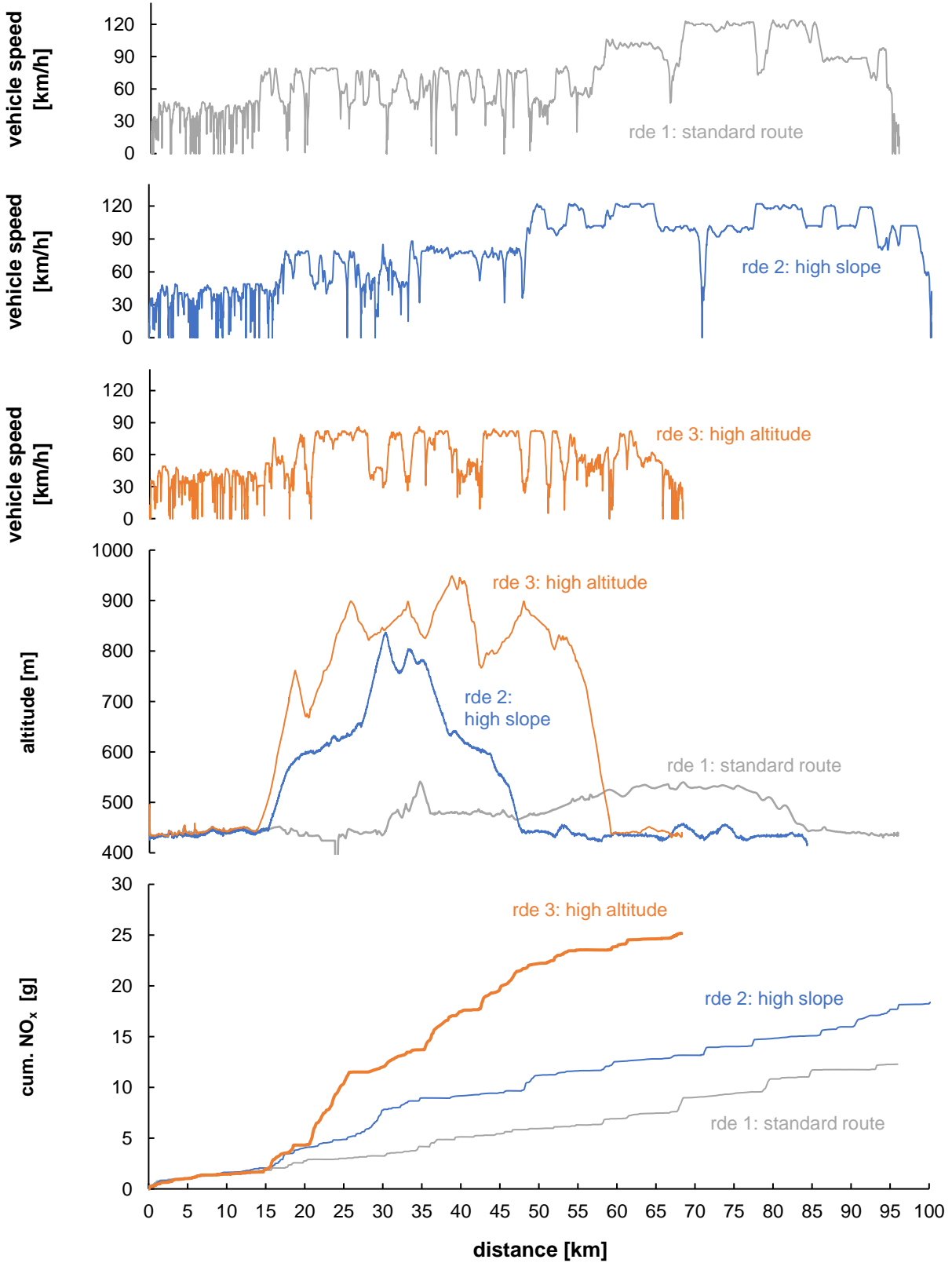


Real Driving Emissions

Influences of Altitude and Altitude Variations

Diesel - NO_x Emissions

Vehicle 3 | Diesel, 88 kW, Euro 6b

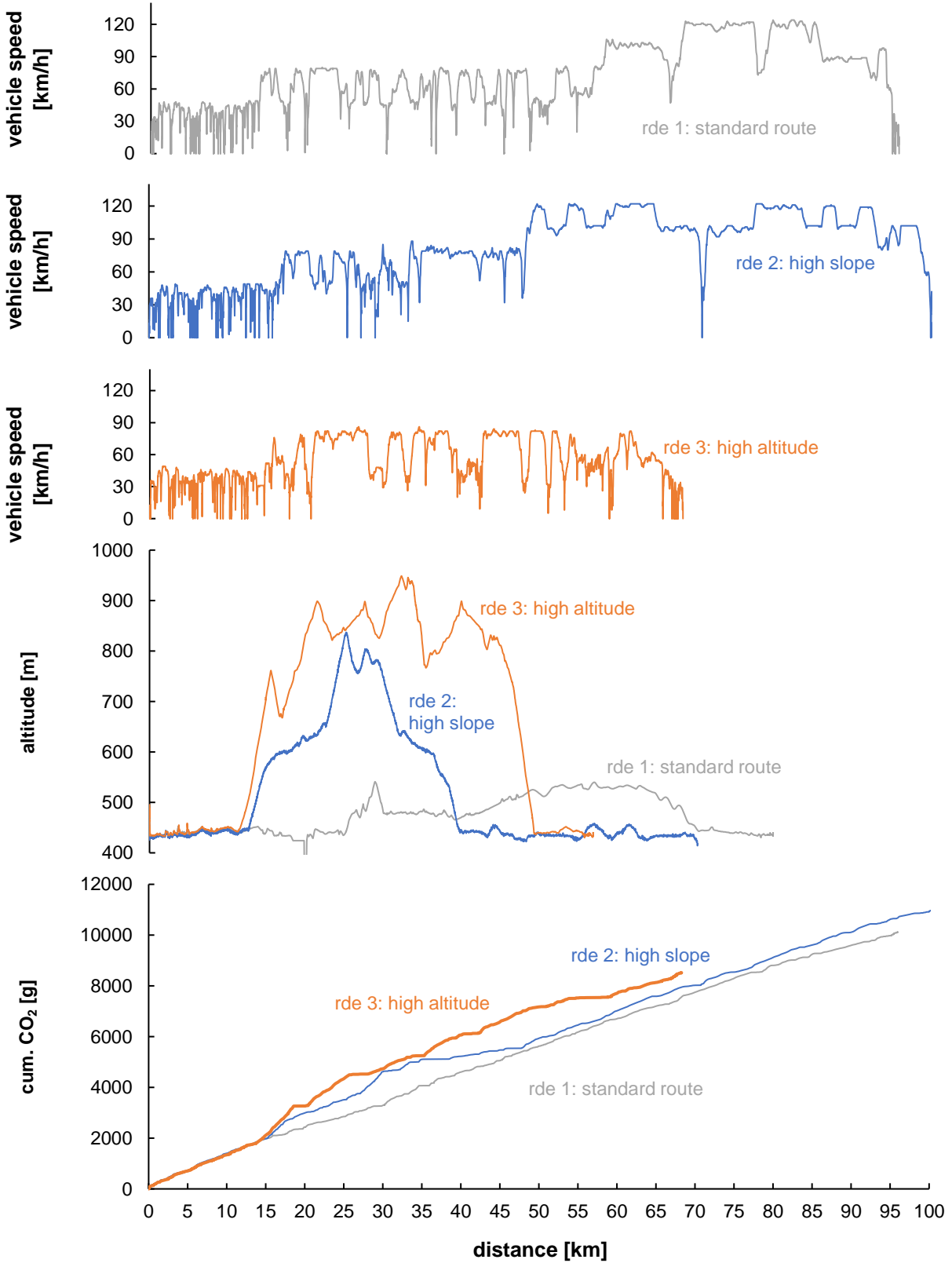


Real Driving Emissions

Influences of Altitude and Altitude Variations

Diesel - CO₂ Emissions

Vehicle 3 | Diesel, 88 kW, Euro 6b

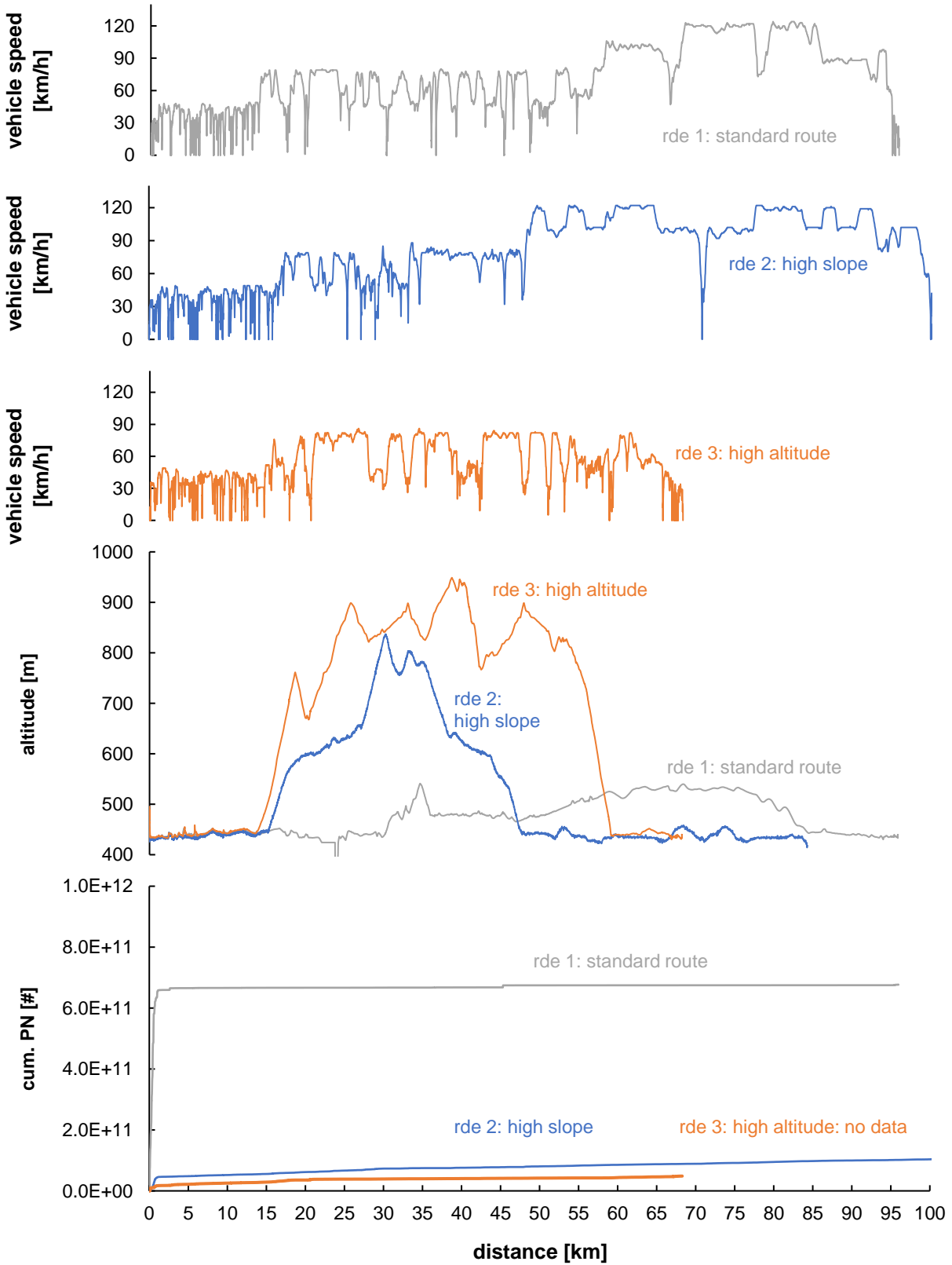


Real Driving Emissions

Influences of Altitude and Altitude Variations

Diesel - CO₂ Emissions

Vehicle 3 | Diesel, 88 kW, Euro 6b

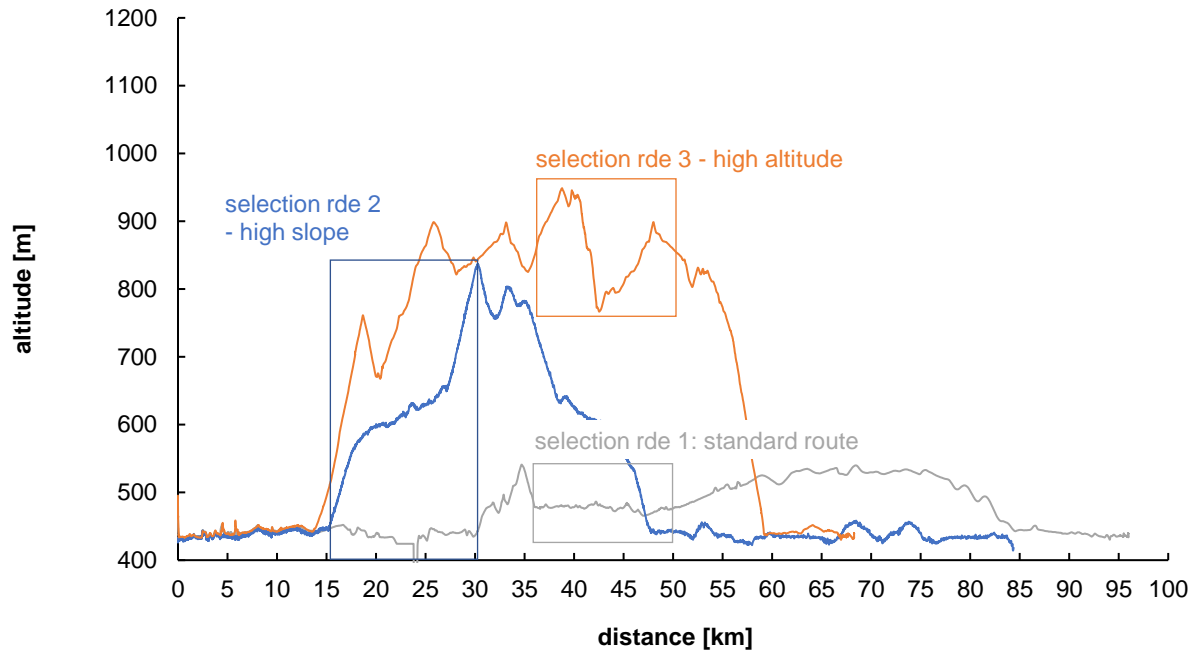


Real Driving Emissions

Influences of Altitude and Altitude Variations

Selection of Characteristic Parts

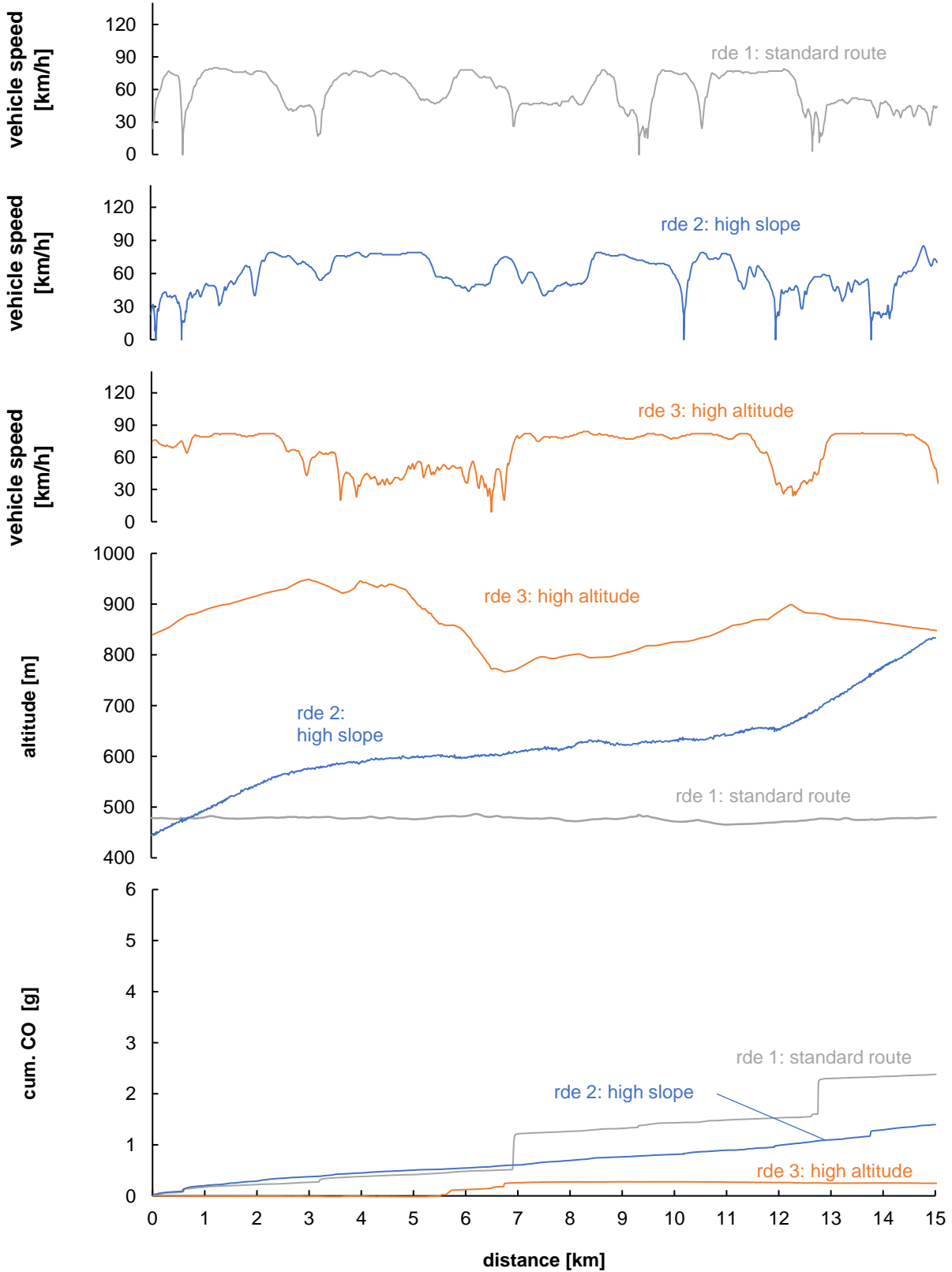
Vehicle 3 | Diesel, 88 kW, Euro 6b



segment of	vehicle speed		altitude	altitude	altitude	Δ altitude begin - end	CO	NOx	CO2	PN
	distance km	average km/h	min m	max m	average m		int. mg/km	int. mg/km	int. g/km	int. #/km
RDE 1	15.0	46.2	466	486	478	-2	159	120	109.2	5.0E+08
RDE 2	15.0	44.3	444	834	618	389	93	385	176.5	1.2E+09
RDE 3	15.0	59.5	767	949	867	5	18	511	117.836	1.4E+08

Real Driving Emissions
Influences of Altitude and Altitude Variations
 Diesel - CO Emissions - Part Selection

Vehicle 3 | Diesel, 88 kW, Euro 6b

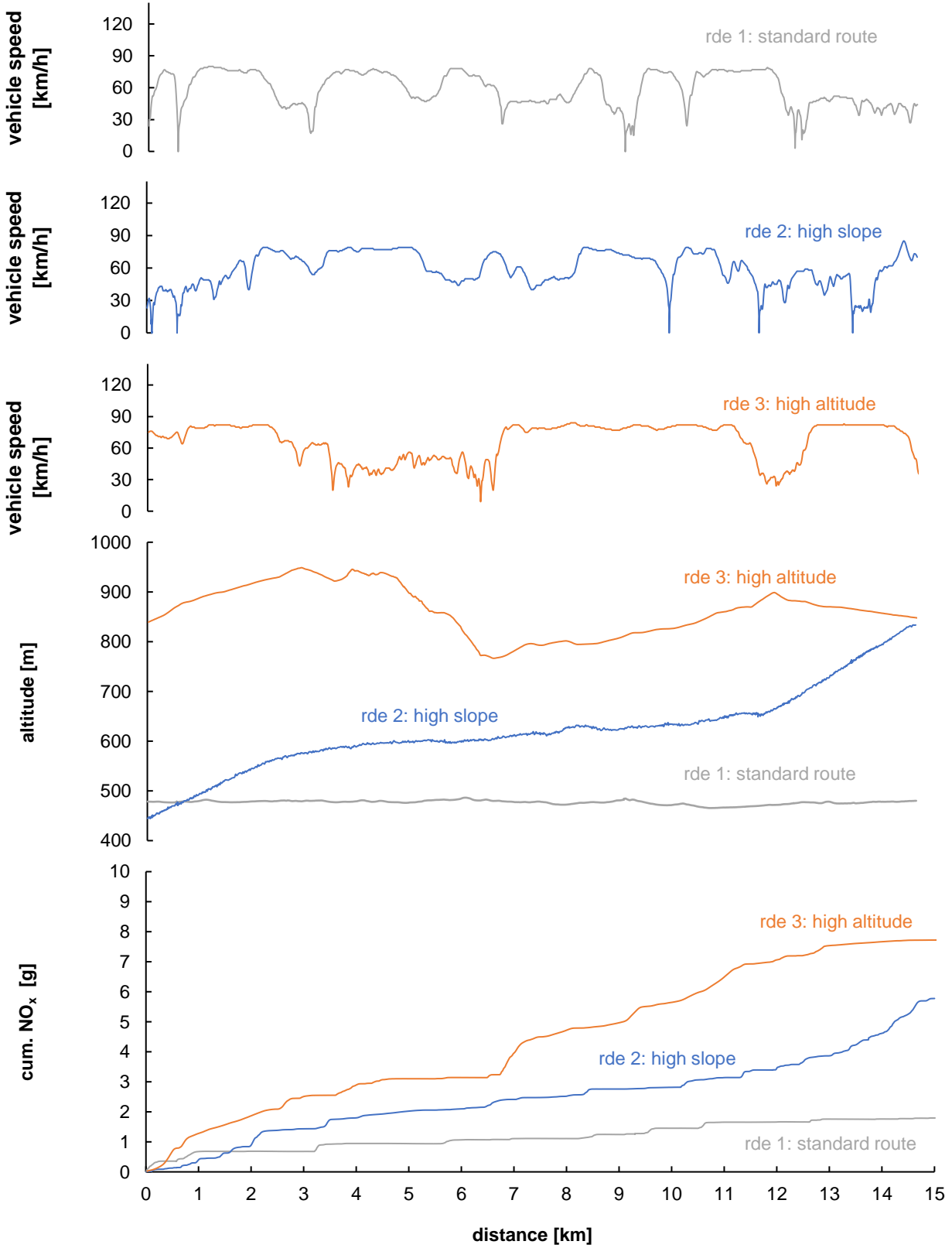


Real Driving Emissions

Influences of Altitude and Altitude Variations

Diesel - NO_x Emissions - Part Selection

Vehicle 3 | Diesel, 88 kW, Euro 6b

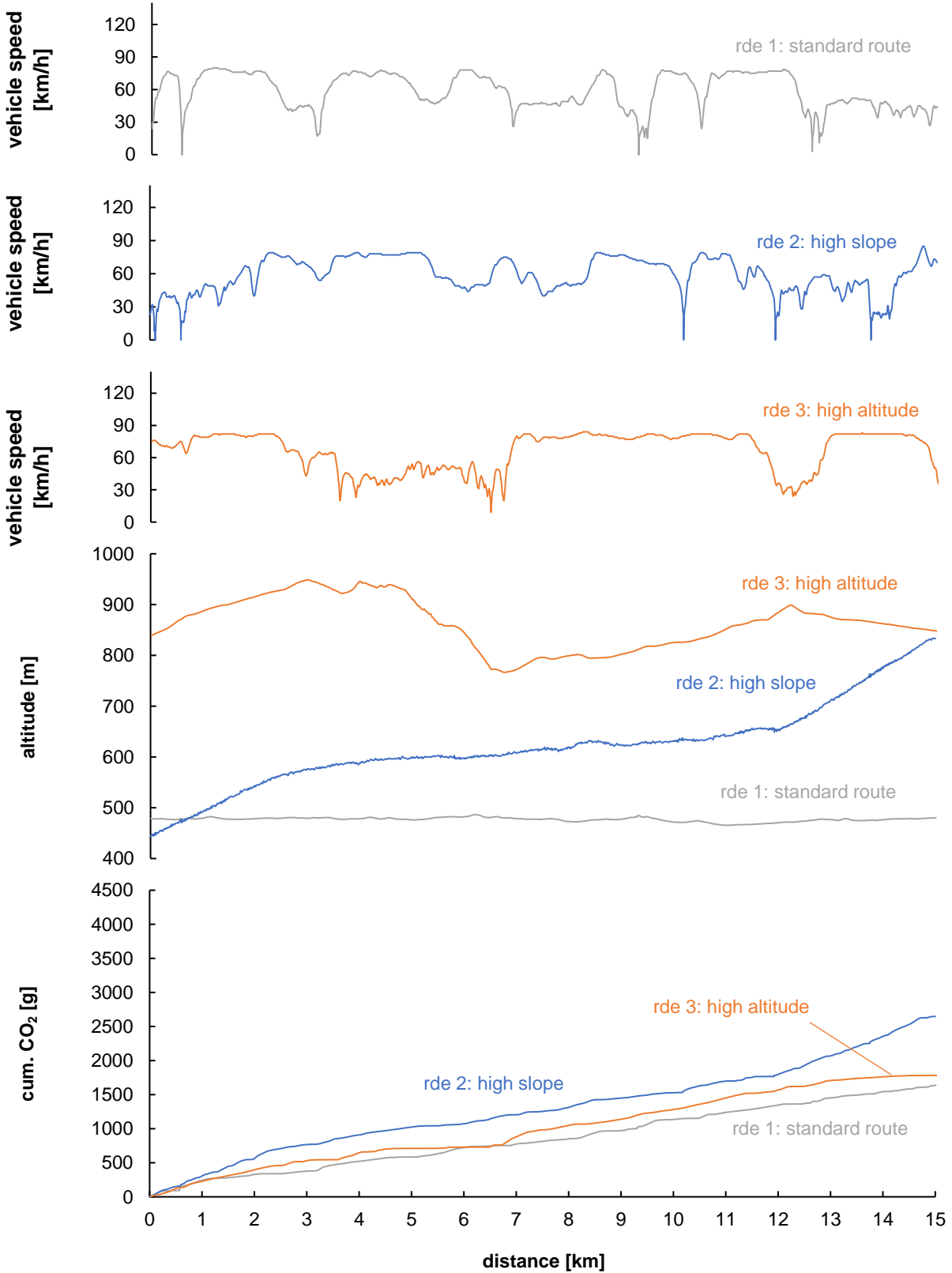


Real Driving Emissions

Influences of Altitude and Altitude Variations

Diesel - CO₂ Emissions - Part Selection

Vehicle 3 | Diesel, 88 kW, Euro 6b

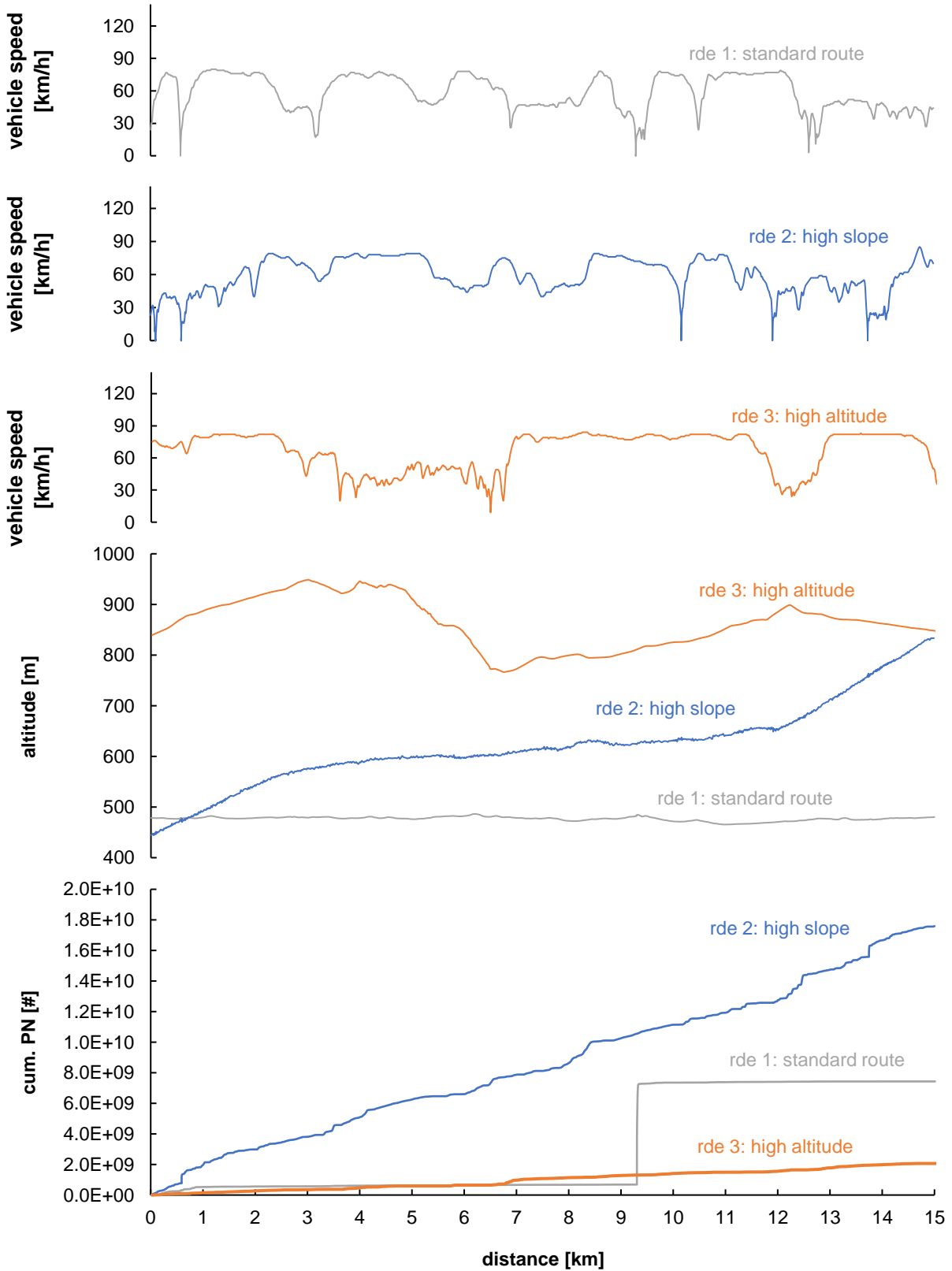


Real Driving Emissions

Influences of Altitude and Altitude Variations

Diesel - PN Emissions - Part Selection

Vehicle 3 | Diesel, 88 kW, Euro 6b





Berner Fachhochschule
Haute école spécialisée bernoise
Bern University of Applied Sciences

Bern University of Applied Sciences
Engineering and Information Technology

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info.afhb@bfh.ch

RDE in Extended Driving Conditions

Commissioned by the Federal Office for the Environment (FOEN)

Project: Research on PEMS Testing Methodology and on Real Driving Emissions (ResRDE2) *)

BAFU contract nbr.: 19.0106.PJ / S081-0349, 4th report, WP3

Annexes

Portable Emissions Measurement System (PEMS) GAS PEMS | Horiba OBS-One GS-22



Product Overview

Item	LDV Type	HDV Type
Measurement Component	CO, CO ₂ , NO/NO _x (or NO, NO _x , NO ₂)	CO, CO ₂ , NO/NO _x (or NO, NO _x , NO ₂), THC (or THC, CH ₄)
Dimensions	Approx. W 350 × D 470 × H 330 mm	Approx. W 350 × D 470 × H 480 mm
Power Requirements	DC 22~28 V	
Power Consumption (at stable state)	Approx. 0.25 kW	Approx. 0.5 kW
Battery (Deep-cycle, sealed lead battery)	DC 24V 35 Ah (5 hour rate), Operation time : Approx. 2.5 hours	DC 24V 100 Ah (5 hour rate), Operation time : Approx. 3.5 hours
Weight (Main unit)	Approx. 32 kg	Approx. 50 kg
Operating Conditions	Temperature: -10 ~ 40°C, Relative humidity: less than 80%, Altitude: 0 ~ 2000 m above sea level	Temperature: 0°C ~ 40°C, Relative humidity: less than 80%, Altitude: 0 ~ 2000 m above sea level

Analyzers and Sensors

- ★ NDIR : Non Dispersive Infrared Detection
- CLD : Chemiluminescence Detection
- FID : Flame Ionization Detection

Component/Item	Measurement Principle ★	Measurement Range
CO	Heated NDIR	0-0.5 ~ 10 vol%
CO ₂	Heated NDIR	0-5 ~ 20 vol%
NO/NO _x	Heated CLD	0-100 ~ 3000 ppm
NO, NO _x , NO ₂	Heated-dual CLD	0-100 ~ 3000 ppm
THC	Heated FID	0-100 ~ 10000 ppmC
THC, CH ₄	Heated-dual FID	0-100 ~ 10000 ppmC
Sampling Method	Wet measurement	-
Exhaust Flow Rate	Pitot flow meter	0-2.0 ~ 0-65.0 m ³ /min
Standard Signal Measurements	Exhaust temperature, Exhaust pressure, Atmospheric pressure, Atmospheric temperature, Atmospheric humidity, GPS signal, Speed	

Portable Emissions Measurement System (PEMS) PN PEMS | Horiba OBS-One PN

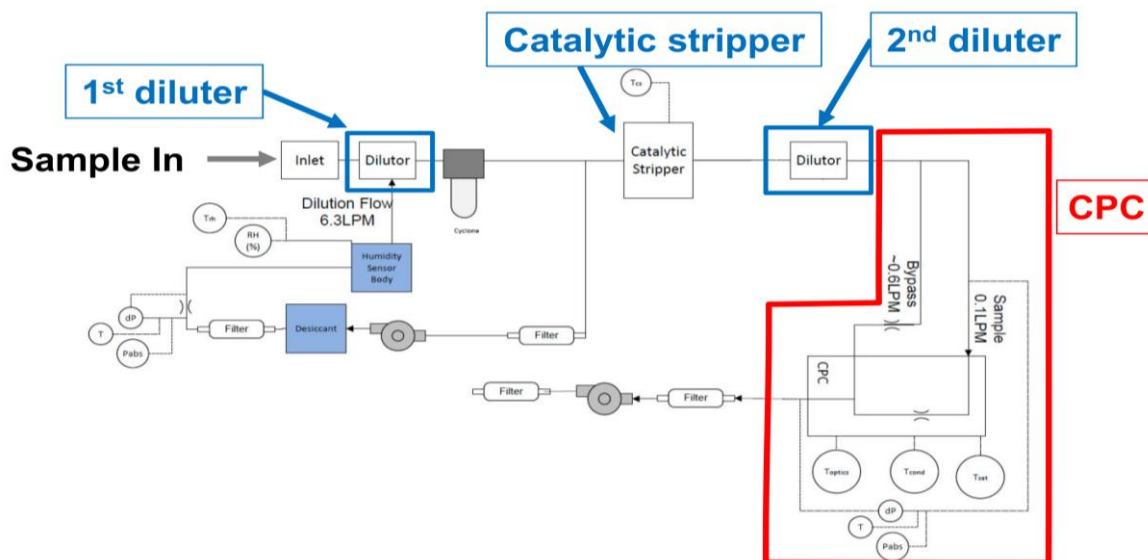


CPC isopropanol based particle counter

Product specifications

Measuring Principles	Condensation particle counter (CPC)
Particle Diameter	23 ~ 1,000 nm
Measuring Range	0 ~ 5 × 10 ⁷ particles/cm ³
Power Supply	DC 24 V
Power Consumption (MAX.)	Approx. 0.25 kW
Mass	Approx. 18 kg
Operating Condition	Temperature: -10 ~ 40 °C , Altitude: 0 to 2,000 m above sea level, Relative humidity: less than 80% (No condensation)
Condensation fluid	Isopropyl alcohol a special grade reagent (99.5%) corresponded
Option	Outer cover for mounting outside the vehicle using a hitch carrier

OBS-ONE PN schematics



Real Driving Measurements
Testo NanoMet 3 | PN-PEMS
 Instrument Description

NanoMet 3 assists you from engine development to vehicle certification

NanoMet3 provides easy and cost-effective access to valuable data such as:

- Particle number concentration [pt/cm³]
- Average particle diameter [nm]
- Calculated particle mass [mg/m³]
- Lung deposition surface area (µm²/cm³)

Communication

- Easy recording on «Secure Digital Memorycard»
- 2 USB ports
- RS232 port
- AO port
- LAN/Ethernet port
- WLAN (Optional)
- AK Protocol



Raw data can be stored in internal HD, exported by SD-card or directly read by a host computer.



matter aerosol
 a testo company

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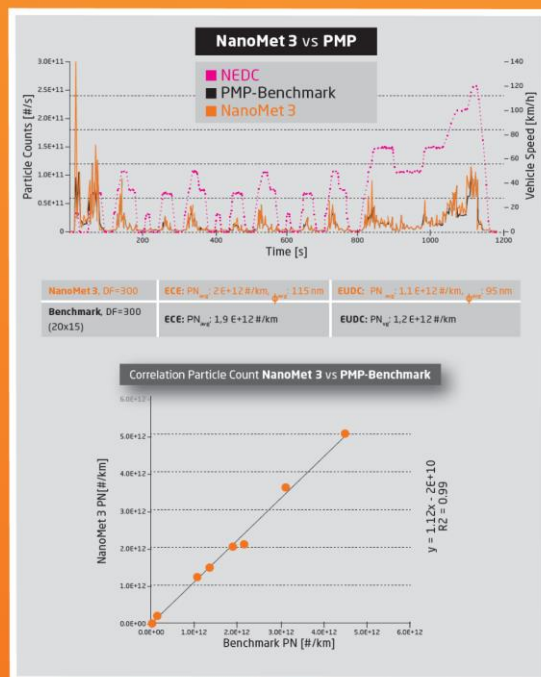
Real Driving Measurements

Testo NanoMet 3 | PN-PEMS

Instrument Description

Technical Specifications

aerosol	primarily diluted exhaust gases or air which contains nanoparticles
raw gas particle concentration range	1e ⁹ ... 3e ⁹ pt/ccm
particle size	10 ... 700 nm = 0.01 ... 0.70 µm (within mode diameter of 10 ... 300 nm)
inlet gas flow	4.0 lN/min, actively fed to the diluter and returning from there
dilution factor	10, 100, 300 (optional customised dilution factors)
power supply	12 VDC - 24 VDC / 100 VAC - 240 VAC
power consumption	300 W under standard ambient conditions
evaporation tube temperatures	ambient ... 300 °C / 572 °F; accuracy +/- 2 °C/4 °F
assembly	19" case with handles evaporation tube mounted inside of 19" case
weight	18 kg; with complete connections: ca. 23 kg
operating conditions	Tamb: 10 ... 40 °C 0 ... 80% relative humidity, max. 80% @ 30 °C, linearly degrading to 50% @ 40 °C, non-condensing
calibration	standard calibration with CAST soot particles, 80 nm



Benchmark measurements on NEDC cycles show 90-99% correlation* between NM3 and PMP systems. * (under regular conditions)

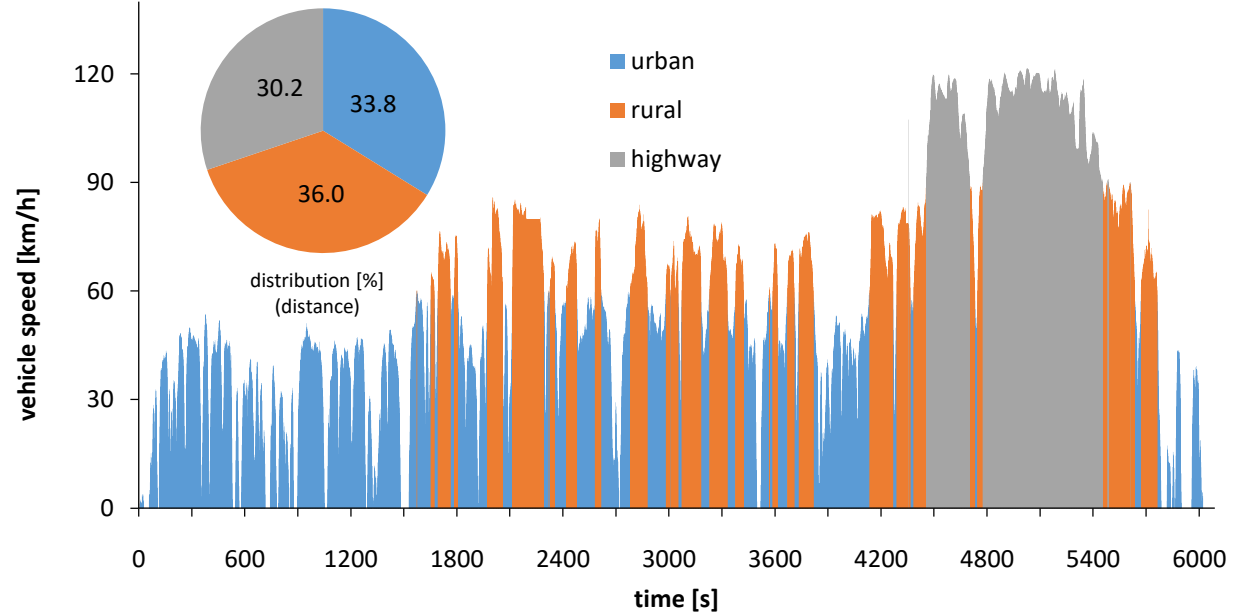
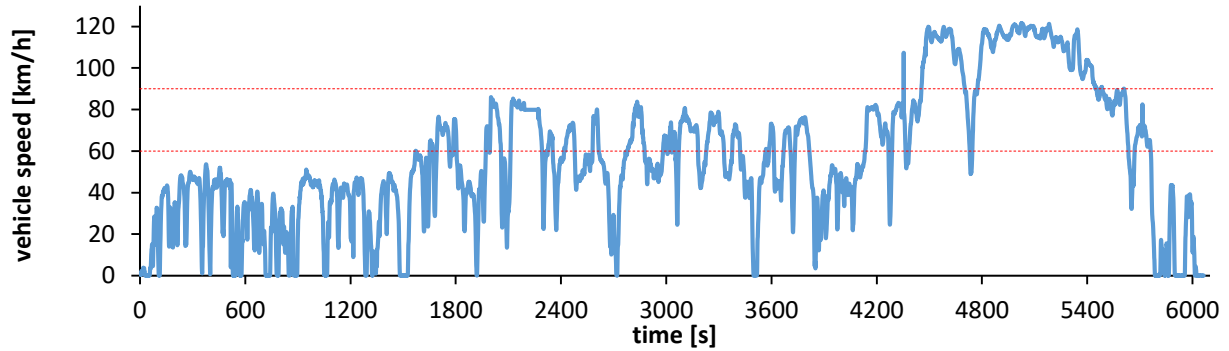
Main features

- Particle number concentration and average particle size plots versus time, total counts provided by software interface
- PMP compliant VPR (sampling & conditioning)
- Fast response to rapid changes in aerosol concentration
- Butanol-free operation
- Embedded PC and pre-installed software
- Built-in data logging and storage capability with removable memory card or internal hard disk
- Matter Aerosol's quick change sensor cartridge
- Rotating disk with easy maintenance
- Long-life disk coating
- Low maintenance, 1000 operation hours of diluter between recommended service

Real Driving Measurements

Road Trip for RDE

Mix of urban, rural and motorway parts



distance	
urban	32.4 km
rural	34.6 km
highway	29.0 km
total	96.0 km
time	
urban	51.1 min
rural	27.9 min
highway	15.6 min
stops	6.5 min
total	101.1 min
average speed	
urban	38.1 km/h
rural	74.2 km/h
highway	111.7 km/h
max	121.0 km/h

AFHB road-test route (AFHB06f)



Real Driving Emissions

Measurement List - Winter / Summer

Date	Vehicle	Fuel	EATS	VIN	TEST	Cycle	Engine State	PEMS Test	TPA	PN	Odometer km	Amb. Temp. °C
06.02.2020	V1	diesel	CI DI DOC-DPF-SCR Euro 6b	#5176 RDE	RDE	afhb06f	cold	462 OBS1-GS12	BL	OBS-One PN	26689	5
07.02.2020	V1	diesel	CI DI DOC-DPF-SCR Euro 6b	#5176 RDE	RDE	afhb06f	cold	463 OBS1-GS12	BL	OBS-One PN	26786	4
08.02.2020	V1	diesel	CI DI DOC-DPF-SCR Euro 6b	#5176 RDE	RDE	afhb06f	cold	464 OBS1-GS12	BL	OBS-One PN	26883	4
08.06.2020	V1	diesel	CI DI DOC-DPF-SCR Euro 6b	#5176 RDE	RDE	afhb06f	cold	B034 OBS1-GS12	BL	OBS-One PN	31184	20
09.06.2020	V1	diesel	CI DI DOC-DPF-SCR Euro 6b	#5176 RDE	RDE	afhb06f	cold	B036 OBS1-GS22	BL	OBS-One PN	31304	17
10.06.2020	V1	diesel	CI DI DOC-DPF-SCR Euro 6b	#5176 RDE	RDE	afhb06f	cold	B037 OBS1-GS22	BL	OBS-One PN	31400	16
10.05.2017	V2	gasoline	SI PFI 3WC Euro 5a	#3598 RDE	RDE	afhb06	cold	81 OBS1-GS12	CL	NanoMet 3	28904	20
11.05.2017	V2	gasoline	SI PFI 3WC Euro 5a	#3598 RDE	RDE	afhb06	cold	83 OBS1-GS12	CL	NanoMet 3	29044	25
23.05.2019	V2	gasoline	SI PFI 3WC Euro 5a	#3598 RDE	RDE	afhb06f	cold	375 OBS1-GS12	CL	OBS-One PN	33536	22
09.01.2020	V2	gasoline	SI PFI 3WC Euro 5a	#3598 RDE	RDE	afhb06f	cold	438 OBS1-GS12	CL	OBS-One PN	36400	5
10.01.2020	V2	gasoline	SI PFI 3WC Euro 5a	#3598 RDE	RDE	afhb06f	cold	439 OBS1-GS12	CL	OBS-One PN	36495	9
16.01.2020	V2	gasoline	SI PFI 3WC Euro 5a	#3598 RDE	RDE	afhb06f	cold	448 OBS1-GS12	CL	OBS-One PN	36827	5

Real Driving Emissions

Measurement List - Mild / Aggressive Driving

Date	Vehicle Fuel	EATS	VIN	TEST Cycle	Engine State	PEMS Test	TPA PN	Odometer km	Drivestyle
23.05.2019	V1	gasoline SI PFI 3WC	Euro 5a #3598	RDE afhb06f	cold	375 OBS1-GS12	CL OBS-One PN	33536	mild
28.05.2019	V1	gasoline SI PFI 3WC	Euro 5a #3598	RDE afhb06f	cold	378 OBS1-GS12	CL OBS-One PN	33823	mild
09.05.2017	V1	gasoline SI PFI 3WC	Euro 5a #3598	RDE afhb06f	cold	78 OBS1-GS12	CL OBS-One PN	28786	mild
24.05.2019	V1	gasoline SI PFI 3WC	Euro 5a #3598	RDE afhb06f	cold	376 OBS1-GS12	CL OBS-One PN	33631	dynamic
27.05.2019	V1	gasoline SI PFI 3WC	Euro 5a #3598	RDE afhb06f	cold	377 OBS1-GS12	CL OBS-One PN	33726	dynamic
29.05.2019	V1	gasoline SI PFI 3WC	Euro 5a #3598	RDE afhb06f	cold	379 OBS1-GS12	CL OBS-One PN	33918	dynamic
26.05.2020	V2	diesel CI DI DOC-DPF-SCR	Euro 6b #5176	RDE afhb06f	cold	471 OBS1-GS12	BL OBS-One PN	30507	mild
09.06.2020	V2	diesel CI DI DOC-DPF-SCR	Euro 6b #5176	RDE afhb06f	cold	B036 OBS1-GS22	BL OBS-One PN	31304	mild
10.06.2020	V2	diesel CI DI DOC-DPF-SCR	Euro 6b #5176	RDE afhb06f	cold	B037 OBS1-GS22	BL OBS-One PN	31400	mild
26.05.2020	V2	diesel CI DI DOC-DPF-SCR	Euro 6b #5176	RDE afhb06f	cold	473 OBS1-GS12	BL OBS-One PN	30700	dynamic
03.06.2020	V2	diesel CI DI DOC-DPF-SCR	Euro 6b #5176	RDE afhb06f	cold	476 OBS1-GS12	BL OBS-One PN	30895	dynamic
08.06.2020	V2	diesel CI DI DOC-DPF-SCR	Euro 6b #5176	RDE afhb06f	cold	B033 OBS1-GS22	BL OBS-One PN	30991	dynamic

Real Driving Emissions

Measurement List - Altitude

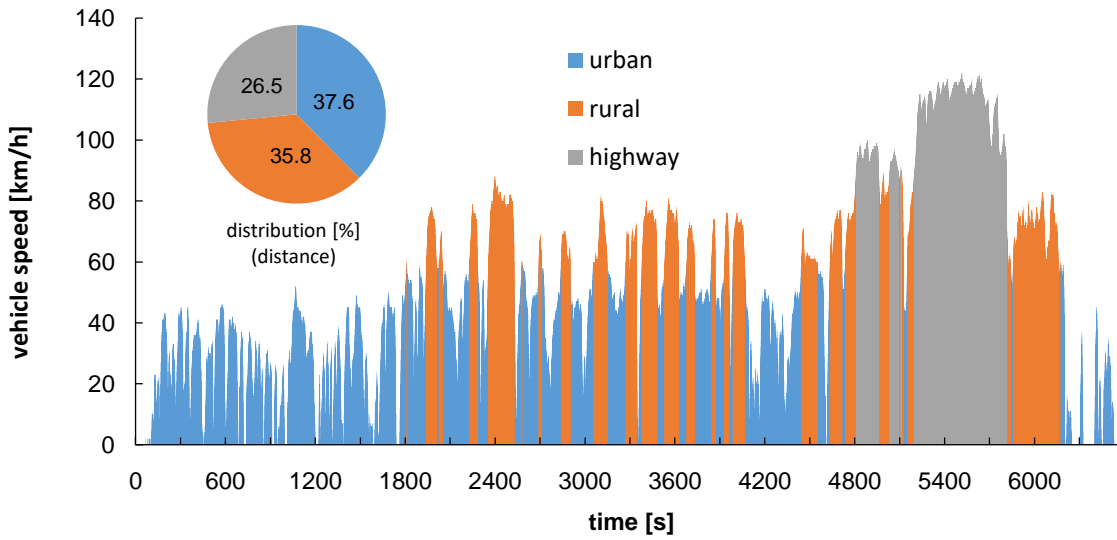
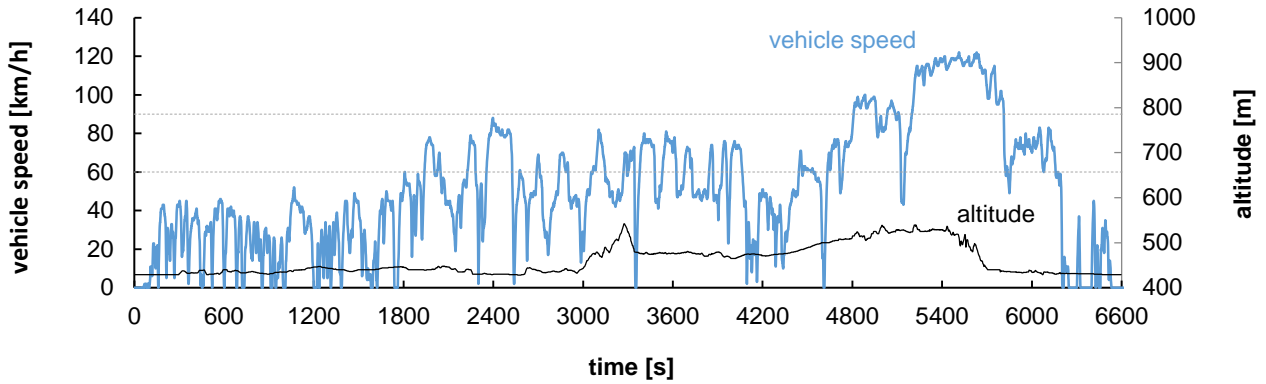
Date	Vehicle	Fuel	EATS	VIN	TEST	Cycle	Engine State	PEMS Test	TPA	PN	Odometer km	used in report	
28.05.2019	V1	gasoline	SI PFI 3WC	Euro 5a	#3598	RDE	afhb06f	378	OBS1-GS12	CL	OBS-One PN	33823	yes
11.06.2019	V1	gasoline	SI PFI 3WC	Euro 5a	#3598	RDE	afhb09	383	OBS1-GS12	CL	OBS-One PN	34144	yes
12.06.2019	V1	gasoline	SI PFI 3WC	Euro 5a	#3598	RDE	afhb09	384	OBS1-GS12	CL	OBS-One PN	34241	no
12.06.2019	V1	gasoline	SI PFI 3WC	Euro 5a	#3598	RDE	afhb09	385	OBS1-GS12	CL	OBS-One PN	34321	no
06.11.2020	V1	gasoline	SI PFI 3WC	Euro 5a	#3598	RDE	afhb14a	503	OBS1-GS12	CL	-	40824	no
10.11.2020	V1	gasoline	SI PFI 3WC	Euro 5a	#3598	RDE	afhb14b	504	OBS1-GS12	CL	-	40898	yes
30.08.2021	V3	diesel	EGR, DPF, SCR	Euro 6b	#5565	RDE	afhb06f	577	OBS1-GS12	CL	OBS-One PN	199392	yes
31.08.2021	V3	diesel	EGR, DPF, SCR	Euro 6b	#5566	RDE	afhb09	578	OBS1-GS12	CL	OBS-One PN	199488	yes
02.09.2021	V3	diesel	EGR, DPF, SCR	Euro 6b	#5567	RDE	afhb14b	581	OBS1-GS12	CL	OBS-One PN	199656	no
02.09.2021	V3	diesel	EGR, DPF, SCR	Euro 6b	#5568	RDE	afhb09	582	OBS1-GS12	CL	OBS-One PN	199724	no
03.09.2021	V3	diesel	EGR, DPF, SCR	Euro 6b	#5569	RDE	afhb14b	583	OBS1-GS12	CL	OBS-One PN	199824	yes

Route:	AFHB06f	AFHB09	AFHB14
Time:	0 - 1800 s 1800 - 4800 s 4800 - 6600 s	0 - 2100 s 2100 - 3100 s 3100 - 3850 s 3850 - 5100 s	0 - 2150 s 2150 - 2650 s 2650 - 4700 s 4700 - 5050 s 5050 - 5800 s 5200 m (430-950 m)
Alt. variation:	120 m (430-550 m)	400 m (430-830 m)	urban v < 50km/h, flat, altitude: 430m uphill 430m -> 750m downhill 830 -> 430 m highway v> 90 km/h, flat, altitude: 430m urban & rural higher altitude, hilly 750-950 m downhill urban & rural flat, altitude: 430m

Real Driving Measurements

Road Trip for RDE route AFHB06f (RDE 1)

Mix of urban, rural and motorway parts



distance	
urban	35.4 km
rural	33.7 km
highway	25.0 km
total	94.1 km
time	
urban	60.0 min
rural	28.0 min
highway	13.9 min
stops	8.0 min
total	109.9 min
average speed	
urban	35.4 km/h
rural	72.4 km/h
highway	108.0 km/h
max	100.0 km/h

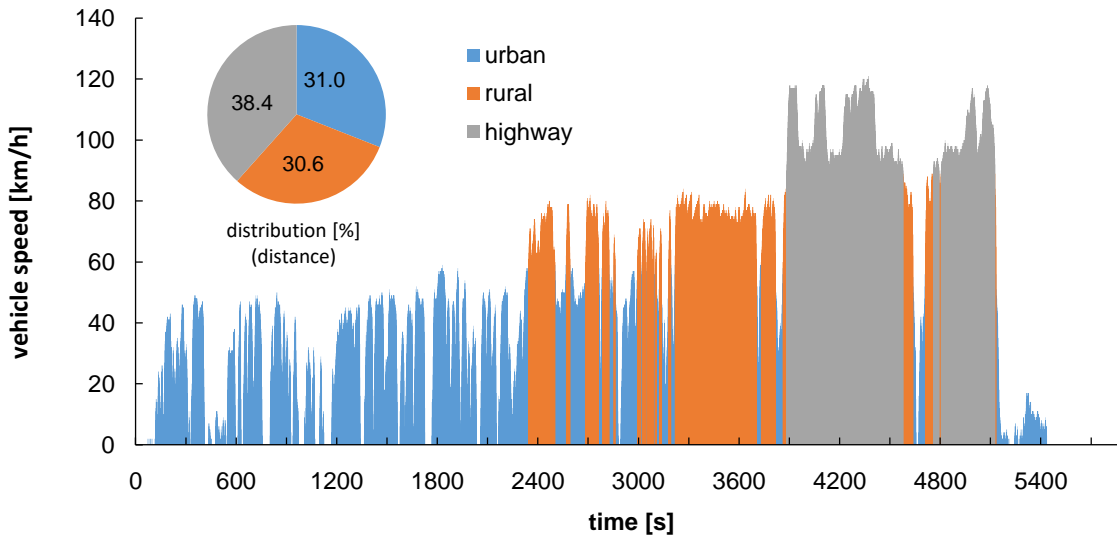
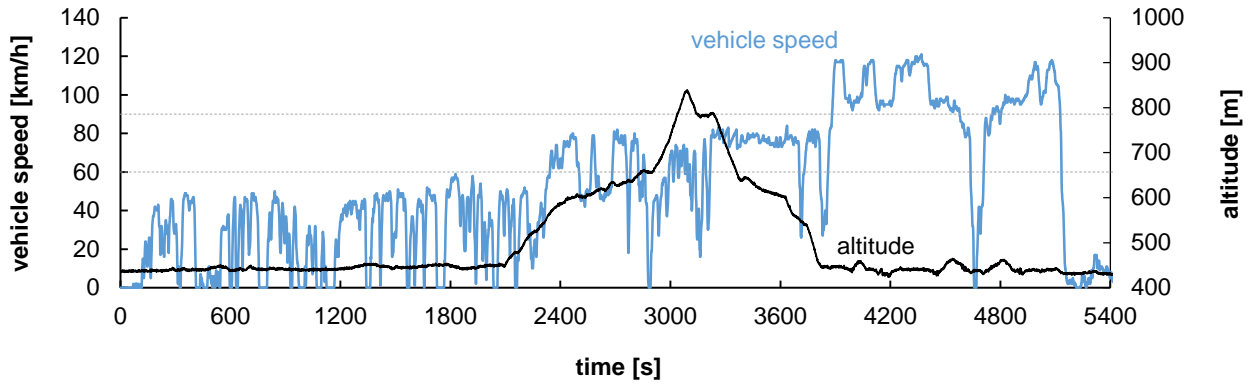
AFHB road-test route (AFHB06f)



Real Driving Measurements

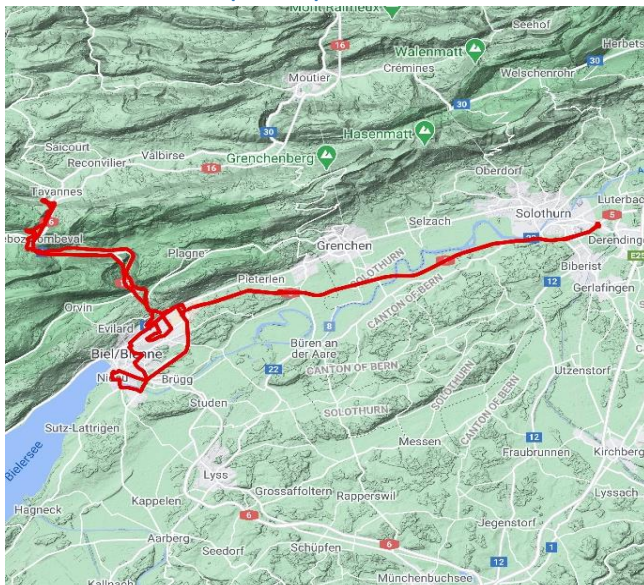
Road Trip for RDE route AFHB09 (RDE 2)

Mix of urban, rural and motorway parts



distance	
urban	24.6 km
rural	24.3 km
highway	30.5 km
total	79.4 km
time	
urban	44.9 min
rural	19.4 min
highway	17.6 min
stops	7.9 min
total	89.7 min
average speed	
urban	32.9 km/h
rural	75.3 km/h
highway	103.7 km/h
max	121.0 km/h

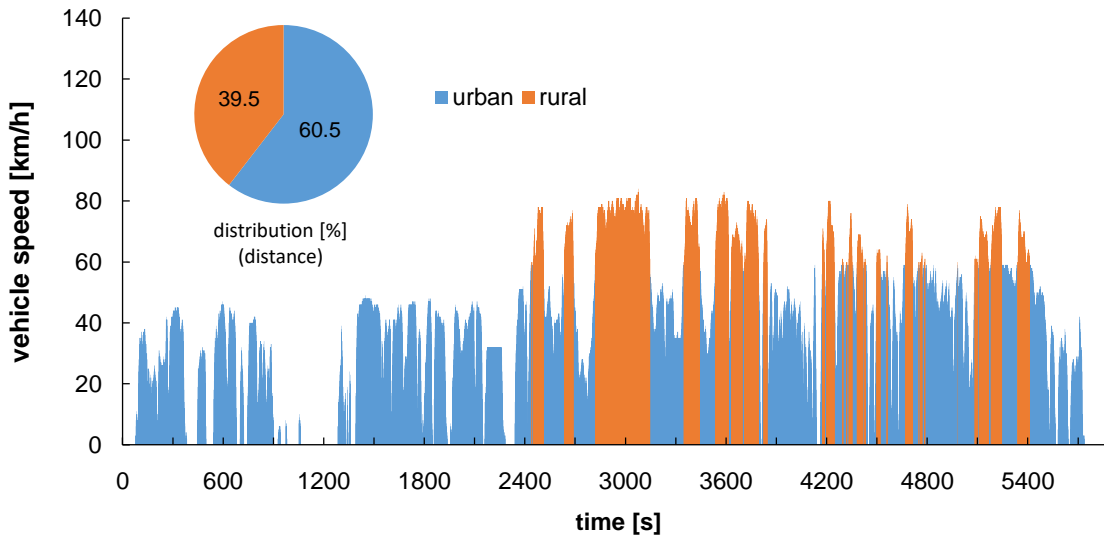
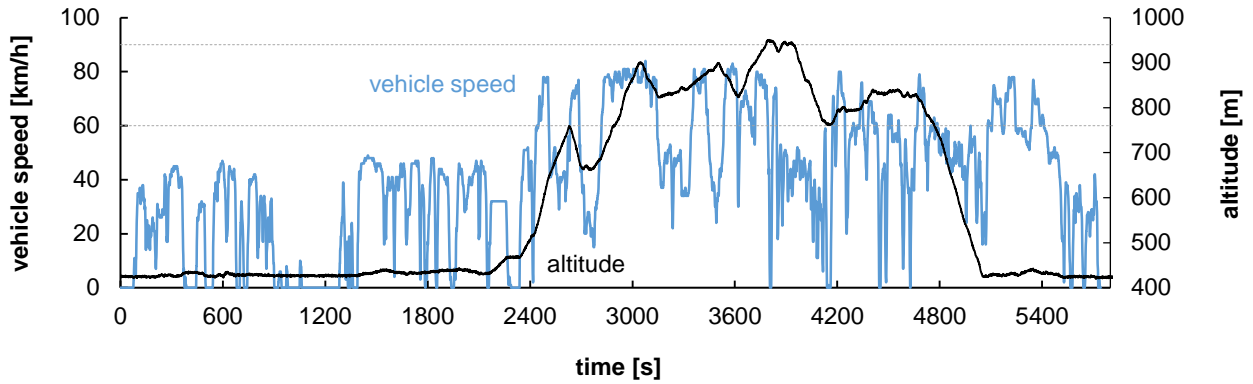
AFHB road-test route (AFHB09)



Real Driving Measurements

Road Trip for RDE route AFHB14 (RDE 3)

Mix of urban and rural parts



distance	
urban	38.3 km
rural	25.1 km
highway	0.0 km
total	63.4 km
time	
urban	62.2 min
rural	20.9 min
highway	0.0 min
stops	12.2 min
total	95.2 min
average speed	
urban	37.0 km/h
rural	72.1 km/h
highway	- km/h
max	84.0 km/h

AFHB road-test route (AFHB14)

