Real-World Black Carbon, Particle Number Concentration and Nitrogen Oxide Vehicle Emission Factors: On-Road Chasing Campaign Results

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Outline

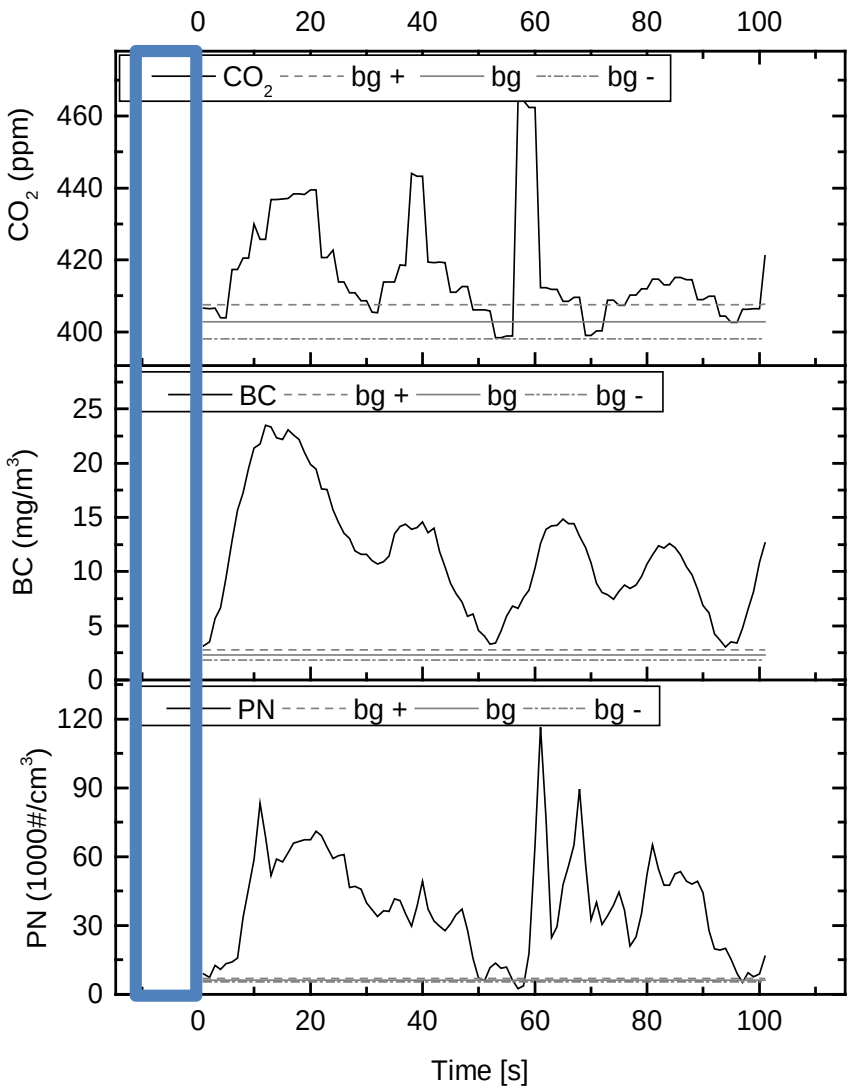
On-road chasing method tests:

- Influence of dilution on EF calculation
- Influence of vehicle performance on the EF distribution

On-road chasing measurement campaign

- first on-road chasing measurements of cars
- sampled vs. European fleet statistic
- influence of vehicle age on EFs
- contribution of super emitters to fleet emissions

Emission factor (EF) determination



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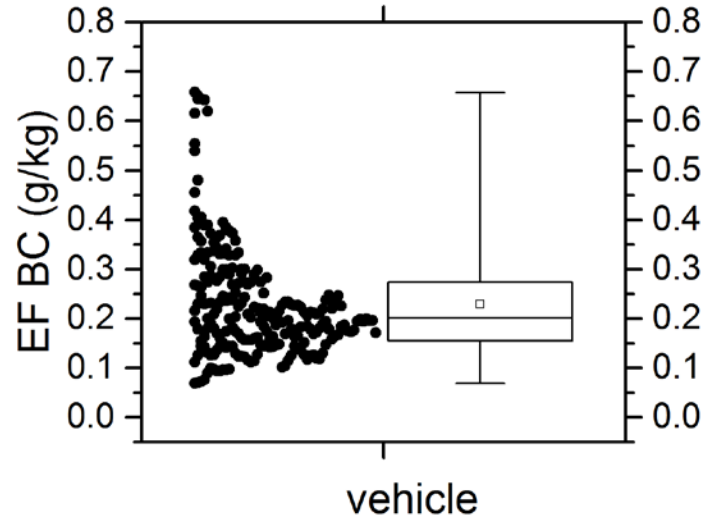
$$EF_P = \frac{\int_{t_1}^{t_2} ([P]_t - [P]_{t_1})dt}{\int_{t_1}^{t_2} ([CO_2]_t - [CO_2]_{t_1})\,dt} \cdot w_c$$

w_c – carbon fraction in fuel

EF distribution for a single chasing event



On-road emission factor measurement tests

Chasing a vehicle equipped with Portable Emissions Measurement System (PEMS)

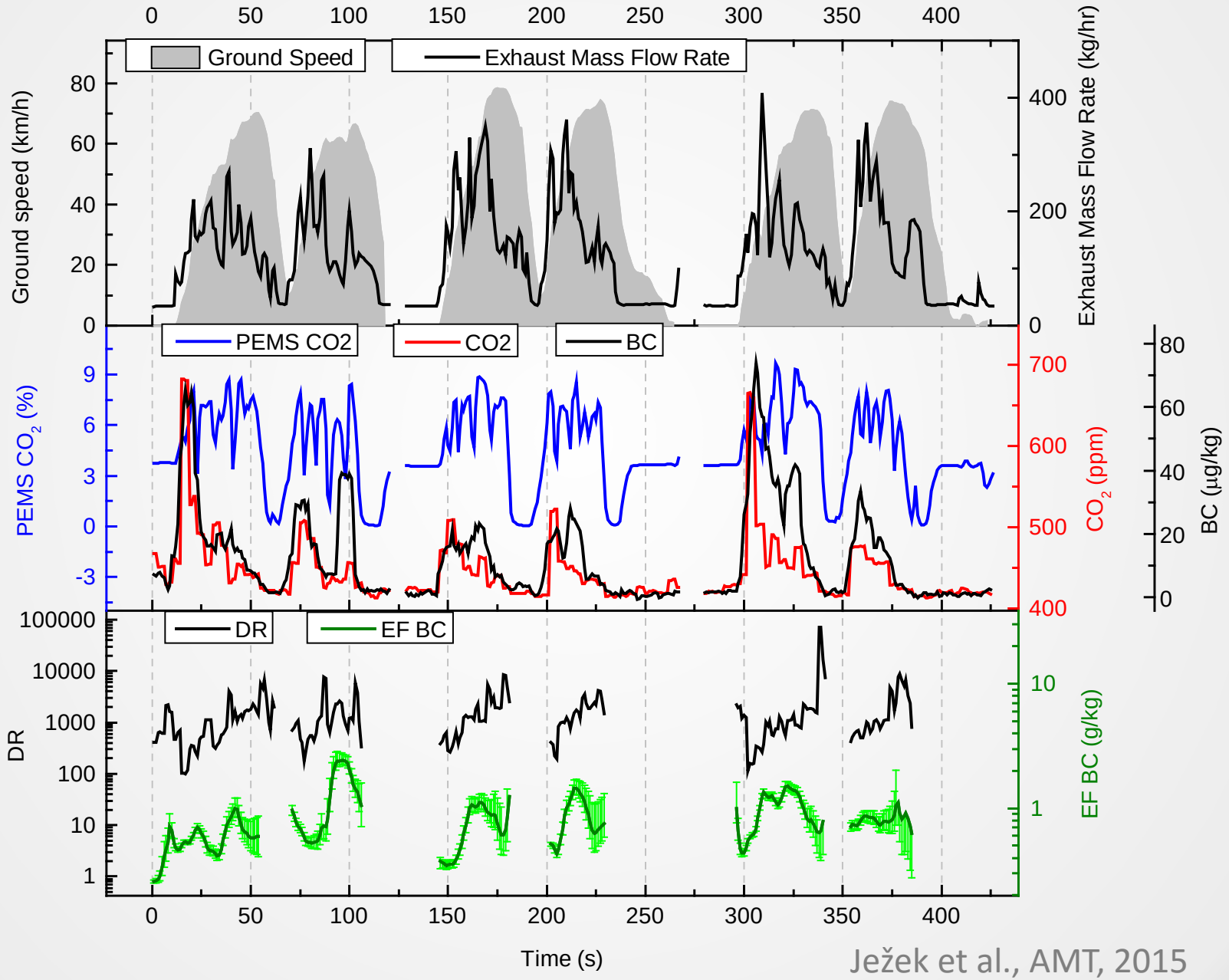
- Influence of dilution
- Relate vehicle performance to measured BC EF

Instruments:

- Mobile platform:
  Aethalometer AE33 (BC),
  Carbocap (CO_2)
- Euro 3 van with PEMS:
  CO_2, exhaust mass flowrate, engine rotational frequency, vehicle speed and position, outside air temperature

The van equipped with PEMS on the old part of the Monza F1 race track (Italy)

Results: Influence of dilution on EF



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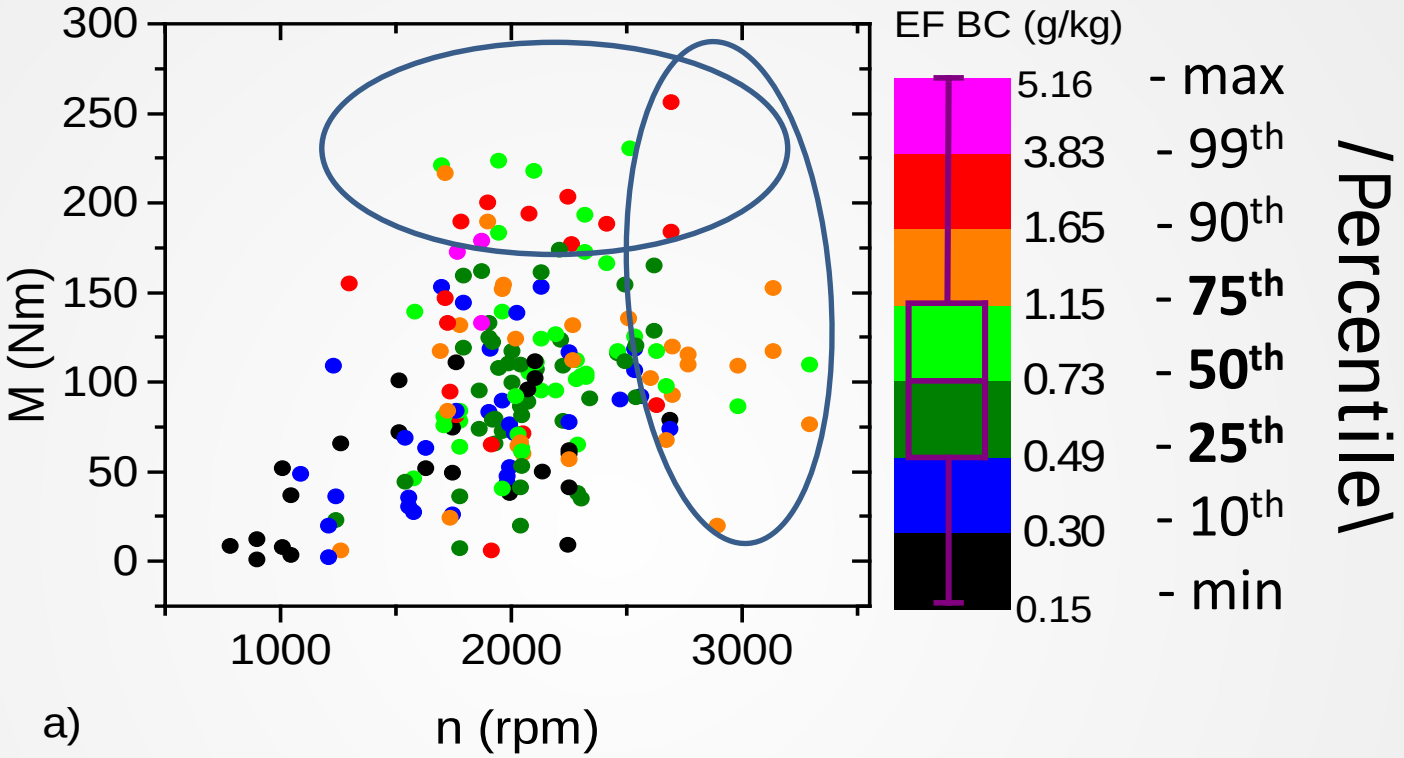
EF distribution and vehicle‘s performance



- Torque (M) - engine‘s ability to work (Heywood , 1988)
- n – crankshaft rotational frequency
- In p^{th} **percentile** p% of the sample values are less than the p^{th} percentile and (100 – p)% are greater

On-road EF measurement campaign

- We measured CO_2, BC, PN and NO_x concentrations.
- We obtained **registry information on vehicles** (fuel, age, category, weight, engine displacement …)
- Comparison of sampled **fleet statistic** to **Eurostat data**

The total of 139 vehicles measured

and distributed to **three vehicle** categories :

- 68 cars with compression ignition engine - **diesel cars**;
- 24 cars with spark ignition engine - **gasoline cars**;
- 47 **goods vehicles** (included light goods vehicles N2, busses M2 and M3, and heavy goods vehicles N3)

Representativeness of car fleet

		10 years or over	From 5 to 10 years	From 5 to 2 years	Less than 2 years
Europe	Total	42%	28%	19%	11%
Slovenia	Total	39%	34%	18%	9%
	Gasoline	50%	25%	15%	9%
	Diesel	18%	48%	23%	11%
This study	Total	27%	47%	29%	7%
	Gasoline	50%	25%	17%	8%
	Diesel	16%	49%	29%	6%

	% of diesel cars
Europe	34
Slovenia	36
This study	68

Ježek et al., ACP, 2015

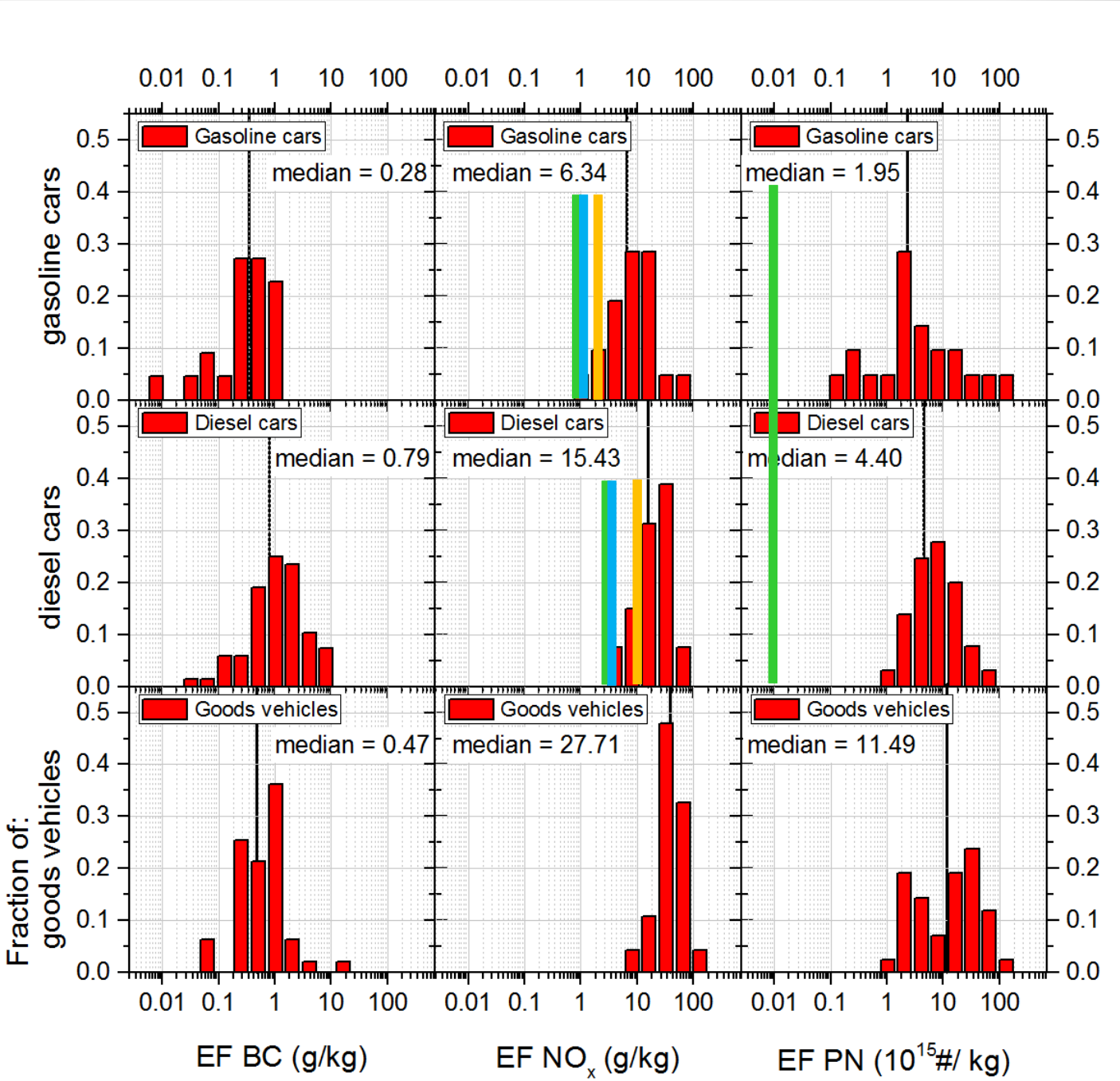
Results:

EURO3

EURO4

EURO5

First on-road BC EFs for diesel cars



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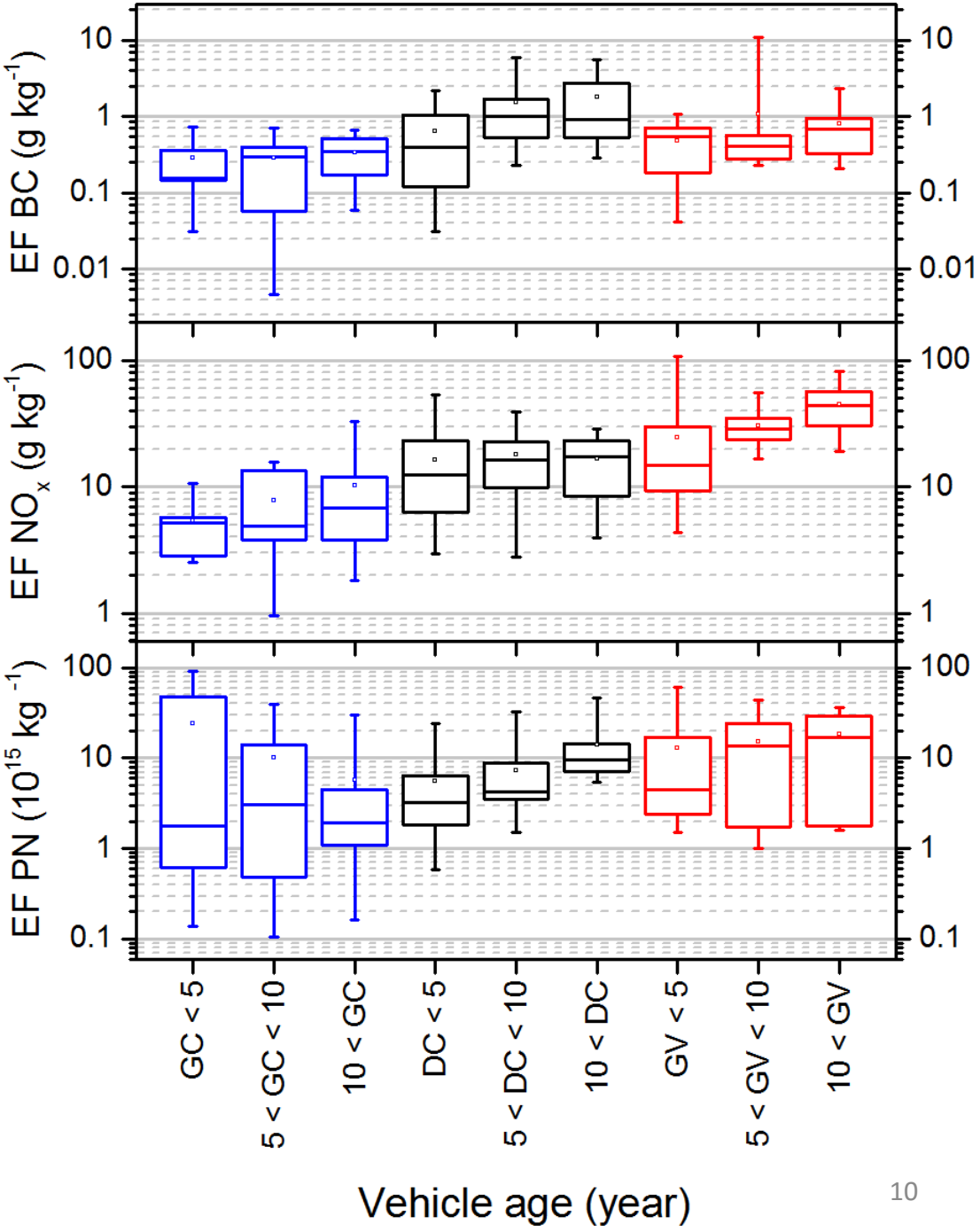
Effect of vehicle age

Less than 5 years ≈ Euro 4 and 5
Between 5 and 10 ≈ Euro 3
10 and more ≈ Euro 2 or less

- The median BC EF of diesel cars that were in use for less than 5 years was **reduced by a 60%** compared to those in use for 5 – 10 years.
- **No decrease** in median BC EF of the goods vehicles.
- PN and NO_x EF of goods vehicles were **reduced by 52% and 67%,** respectively.



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Comparing our results to other on-road studies

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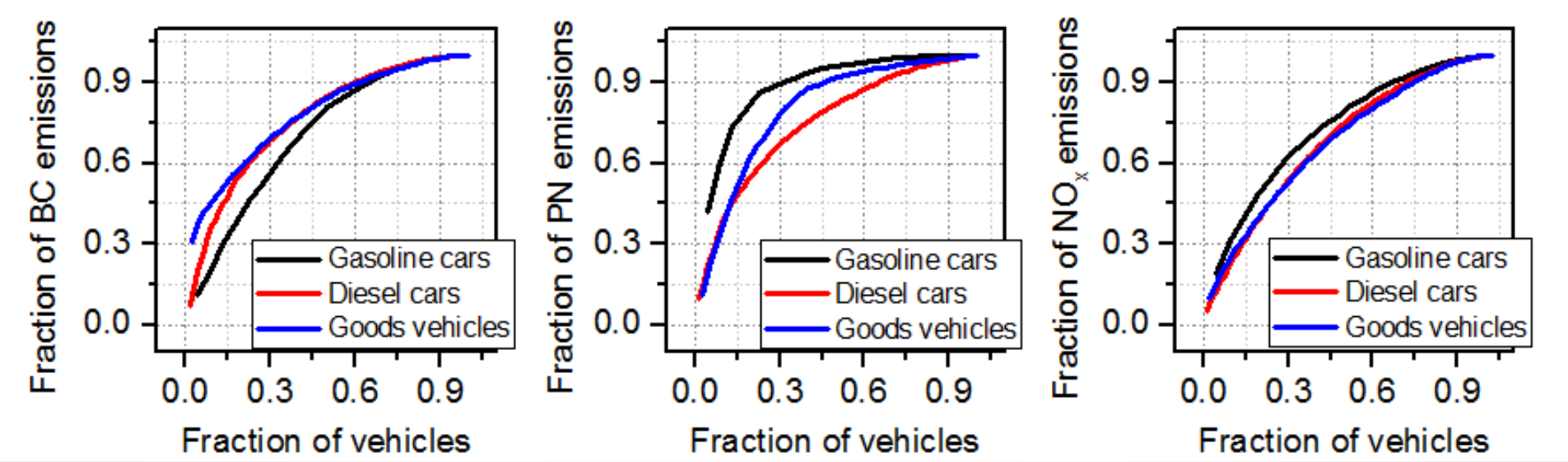
Study	Study type	Vehicle type	EF BC (g kg^{-1})	EF NO_X (g kg^{-1})
Shorter et al., 2005	Chasing [a]	Diesel buses		34.5 (8.1 – 117.1)
		CRT		27.8 (±6.3)
Wang et al.,2012	Chasing [b]	HGV Beijing	0.4 (0.2-0.8)	47.3 (38.1 - 62.5)
		HGV Chongqing	1.1 (0.7-1.6)	40.0 (31.7-48.1)
Dallmann et al., 2011	Remote s. [c]	HGV (2009)	1.07 ± 0.18	25.9 ± 1.8
		HGV (2010)	0.49 ± 0.08	15.4 ± 0.9
Dallmann et al., 2013	Remote s. [c]	HGV	0.62 ± 0.17	
Carslaw and Rhys-Tyler, 2013	Remote s. [d]	Gasoline cars		5.34 (1.15 - 26.83)
		Diesel cars		16.37 (14.82 – 20.65)
		Van		18.1 (16.87 – 23.59)
		HGV (all)		37.88 (35.13 – 48.37)
This study	Chasing [b]	Gasoline cars	0.35 (0.005–1.52)	6.74 (3.3 – 13.16)
		Diesel cars	0.92 (0.03–5.87)	15.47 (9.15 – 23.28)
		LGV	0.56 (0.05–5.24)	20.25 (11.84 – 28.22)
		HGV	0.45 (0.04–11.01)	29.6 (23.18 – 48.67)

[a] mean and range in parenthesis; [b] median (1st and 3rd quartile); [c] mean ± 95% confidence interval; [d] emission ratios from Carslaw and Rhys-Tyler paper were converted to EFs using the same molecular weights and carbon fraction as in formula 1; presented are average values for all Euro standards in a group, in parenthesis are the smallest and largest mean value of emission standards.

„Super emitters“ contributions to total fleet emissions



- Contribution of super emitters: 25% of vehicles was found to disproportionately contribute to the total fleet emissions 47% to 87%.
- 25% of emitting diesel cars contributed:
  63% of BC, 61% of PN and 47% of NO_x emissions

Ježek et al., ACP, 2015

Conclusions

- The **first tests** of the on-road chasing method.
- **First reported BC EF for individual diesel** cars measured in real driving conditions.
- Good agreement with the results of previous studies.
- The median BC EF of diesel cars that were in use for less than 5 years was **reduced by a 60%** compared to tho
- **No** **es**. PN and NO_x EF of goods vehicles were reduced by 52% and 67%, respectively.
- Simple and efficient methodology for monitoring emissions of the in-use vehicle fleet
- Identification of supper emitters

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