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Road traffic emissions in Switzerland: Results from the Gubrist tunnel

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1. Introduction

- Road traffic important anthropogenic source of primary pollutants
- Emission inventory description:

$$E_i = EF_i \times Ac_i$$

where: E_i: Amount of emission

of compound i (e.g. CO)

- EF_i: Emission factor (e.g. CO emission by road traffic per 1 km)

- Ac_i: Activity: road traffic

Overview

2. Road traffic emission models and tunnel measurements
3. Determination of EFs from road tunnel measurements
4. Measurements of the Gubrist tunnel
5. Long-term evolution
6. Conclusions

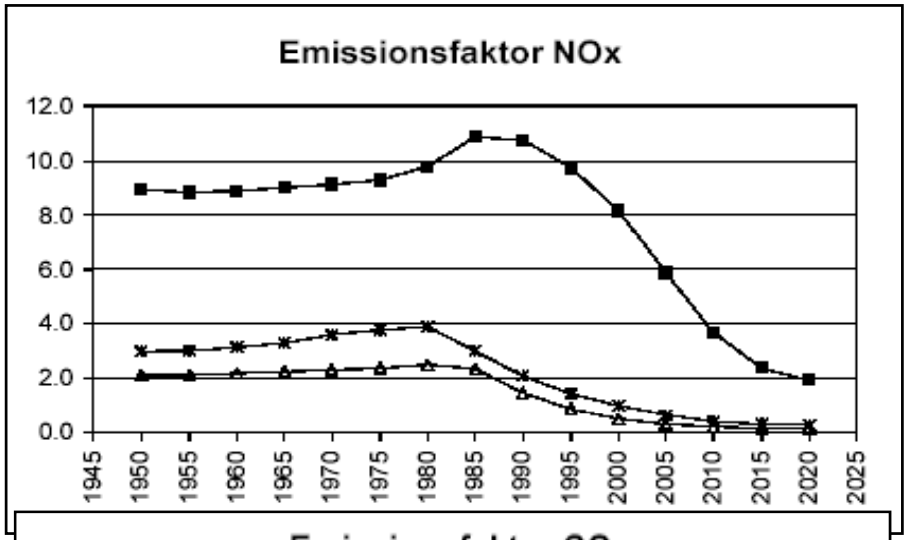
2. Road traffic emission models and tunnel measurements

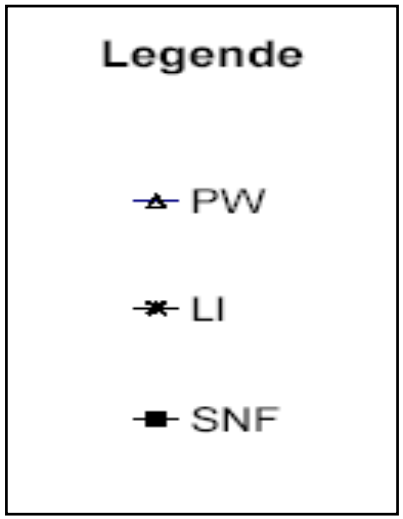
Road traffic emission model e.g. „Hand book of emission factors (HBEFA)“:

Required:- Large number of *dynamometric test data* (different technologies (e.g. with/without controlled catalysts), fuel (gasoline, diesel), engine size, etc.)

- Typical *conditions* (e.g. high way driving) derived from extend. analysis of on-road measurements
- *Typical (Swiss) vehicle fleet composition* including long-term changes

Time series of EF (HBEF)

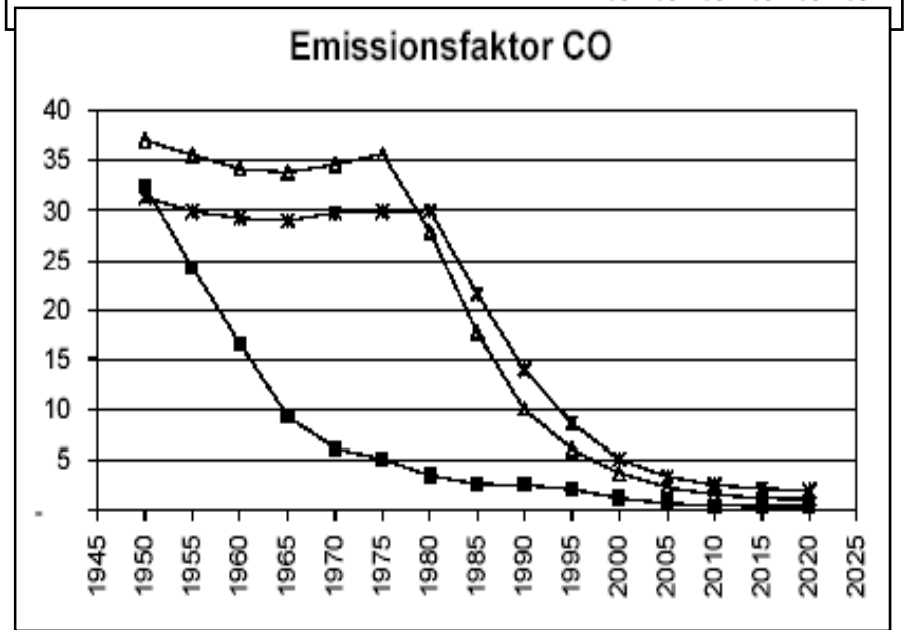


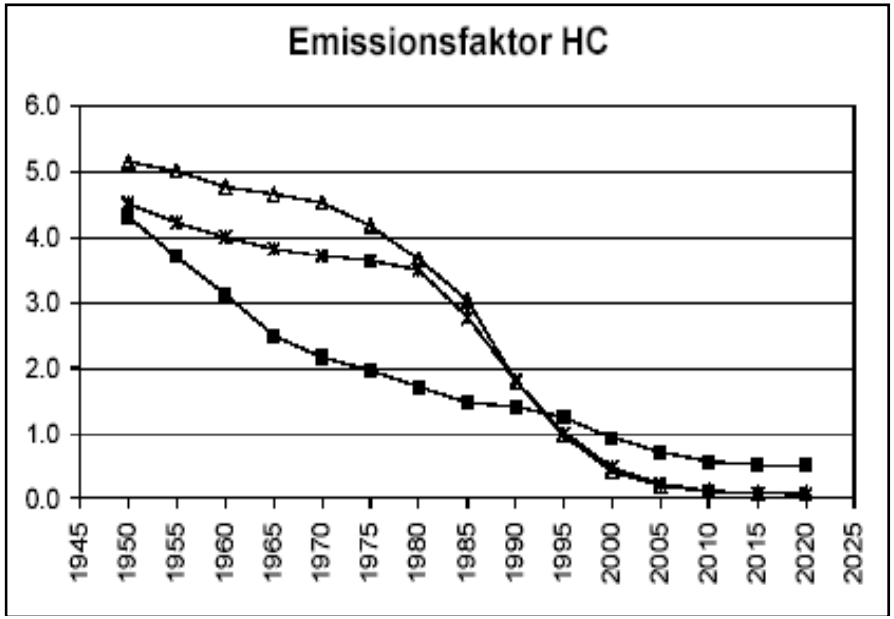


Passenger Car

Delivery Van

Heavy Duty vehicle

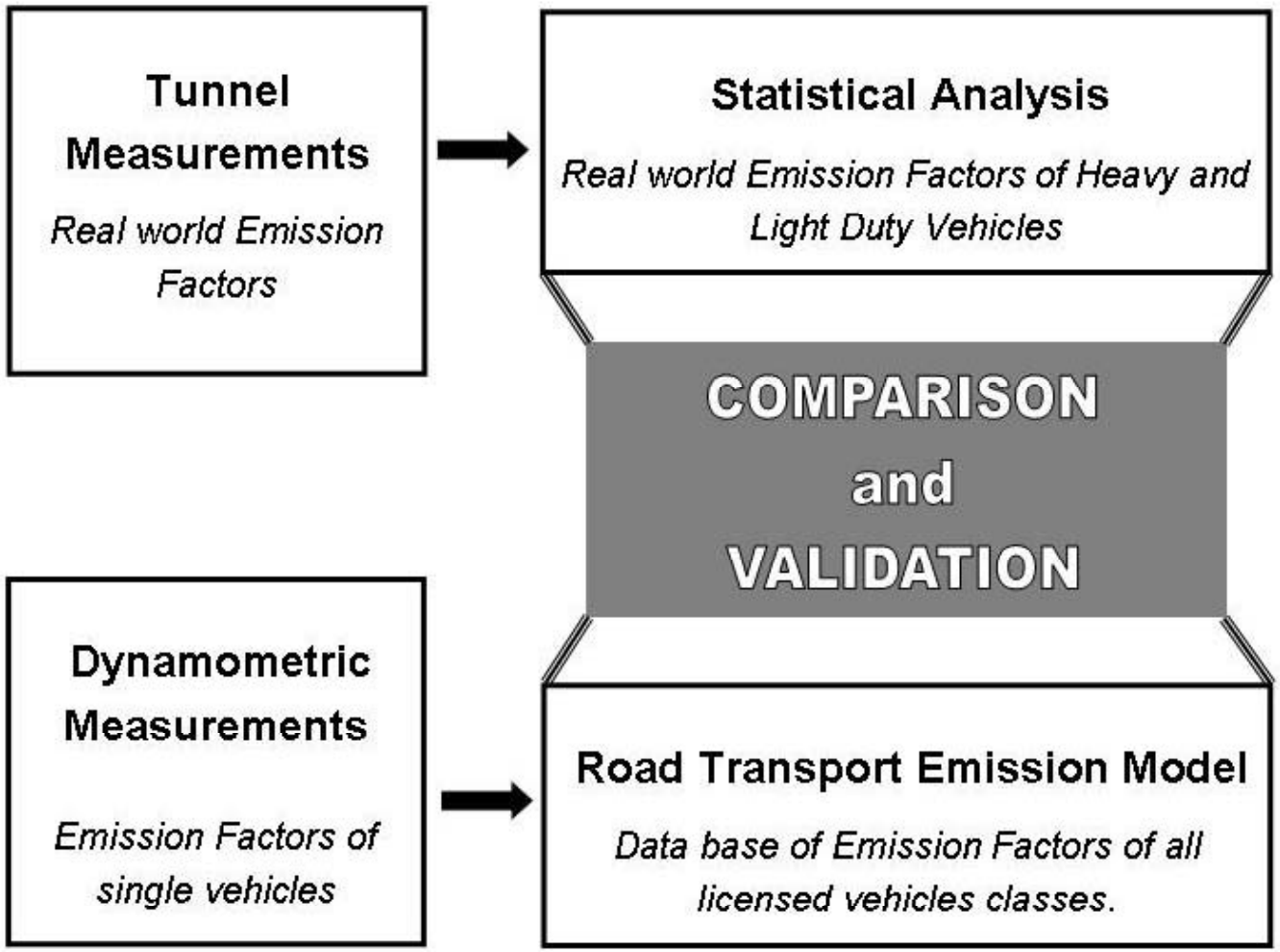




Road tunnel measurements

- Quantification of road traffic emissions
- Comparison with road traffic emission models
- Evaluation of new technologies, valuable measurements from the same tunnel (e.g. Tauerntunnel, Schmid et al., 2001)
- Advantage: Large collective („real world emissions“)
- Limitation: Restricted condition (e.g. high way driving), difficulties for generalization

Approach for comparison in this study



3. Determination of EFs from road tunnel measurements

1. Calculate $EF_{k,t}$ of compound *k* of fleet passing the tunnel during given time interval *t*

$$EF_{kt} = \frac{\Delta C_{k,t} u_t dq}{n_t s}$$

Where: $\Delta C_{k,t}$: difference in concentration of compound k (exit-entrance); u_t: air velocity;

d: duration of time interval; *q*: tunnel cross section;

n_t: number of vehicles;

s: distance between measurements sites

EF for vehicle classes

$$EF_{k,t} = \alpha_k + \beta_k \, pHDV + \varepsilon_{k,t}$$

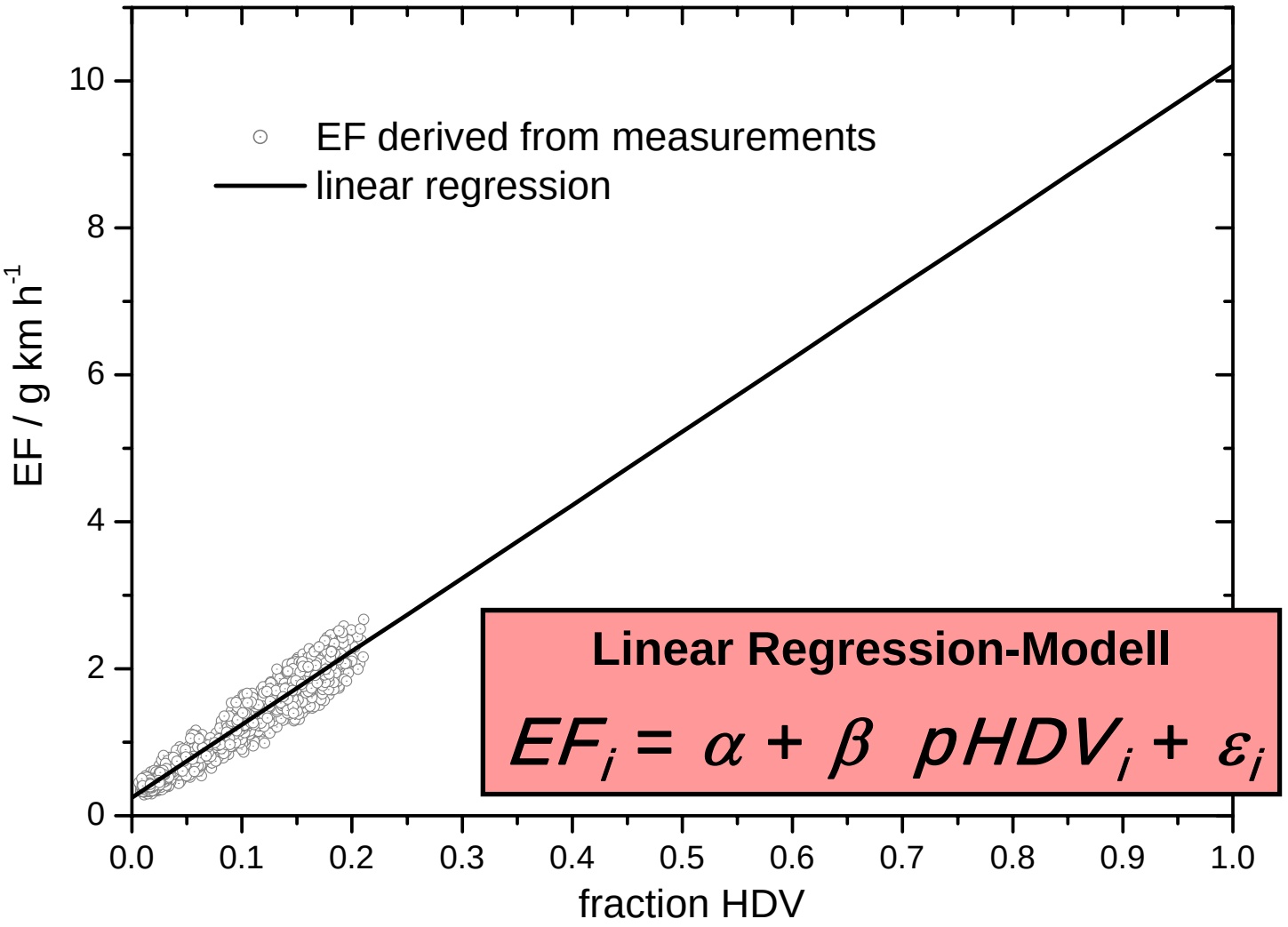
Where: α_k*: EF of light duty vehicles (LDV: passenger cars and delivery vans, mostly gasoline driven)*

β_k*: EF of heavy duty vehicles (HDV, diesel engine);*

pHDV: proportion of HDV;

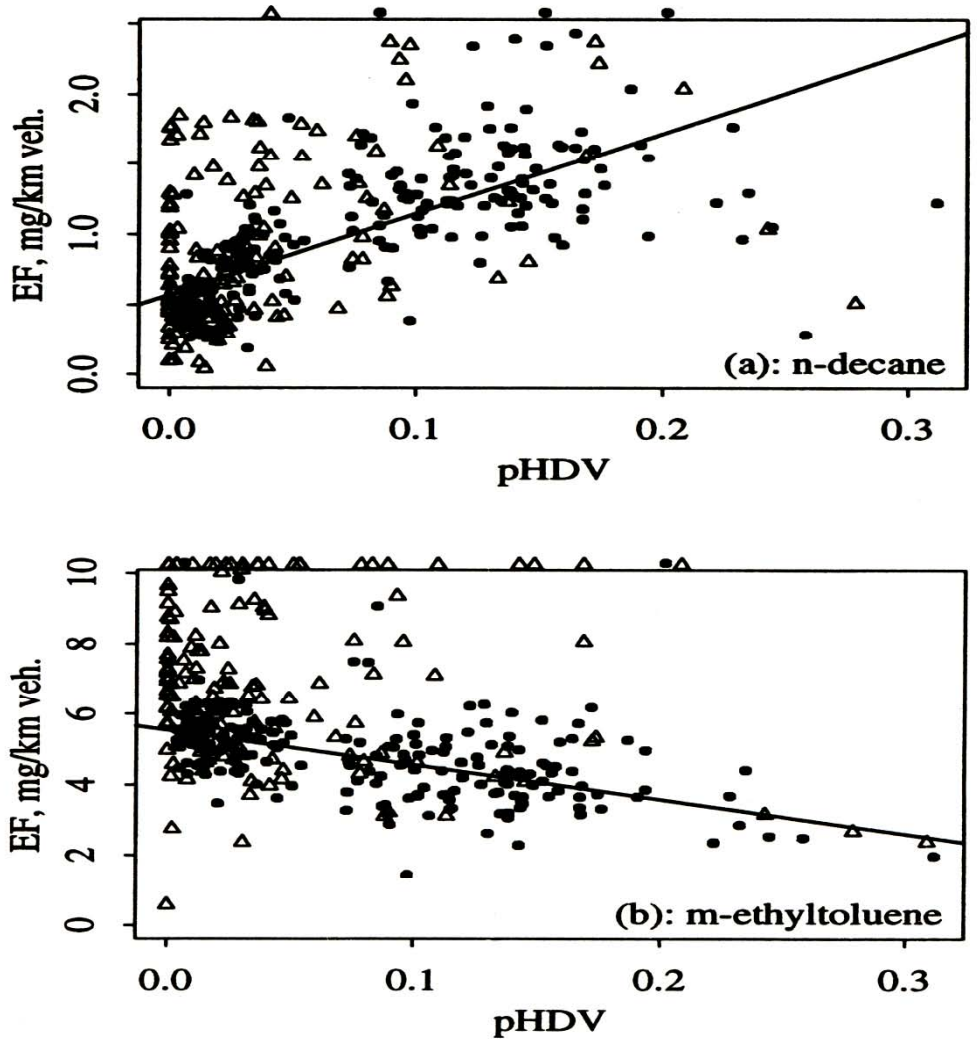
$\varepsilon_{k,t}$ *: random error*

Data analysis tunnel measurements (NO_x)



Gubristtunnel-Measurements 2002

Example of analysis of measurements of tunnel study (Staehelin et al., 1997): LDV emit more m-ethyltoluene whereas HDV emit more n-decane (triangles include all data, circles only those with vehicle speed >90 km/h and tunnel ventilation u >5.2 m/s



Statistical analysis

- EF for categories based on variability of fleet composition:
- Heavy duty traffic forbidden in CH fro week ends (pHDV very small on weekends, but never exceeds 25%)
- Determination of EF of HDV: Limited precision

4. Measurements Gubrist tunnel (close to Zürich, Switzerland)

Tunnel installation: Passively ventilated tunnel, sampling in one tube with two lanes (traffic in one direction, road gradient: 1.3 %)

- Simultaneous measurements of NO_x, CO and t-VOC (regulated) and others (VOCs) at entry and exit site
- Traffic data from loop detectors (number and speed of vehicles and classification in LDV and HDV
- Wind speed measurements inside the tunnel

Det.: EF(time) of entire vehicle collective

(Earlier) tunnel studies and HBFA

NO_x emissions of HDV:

tunnel measurements larger than expected from road traffic emission model (HBEFA, vs. 1999):

Plabutsch tunnel (Austria):

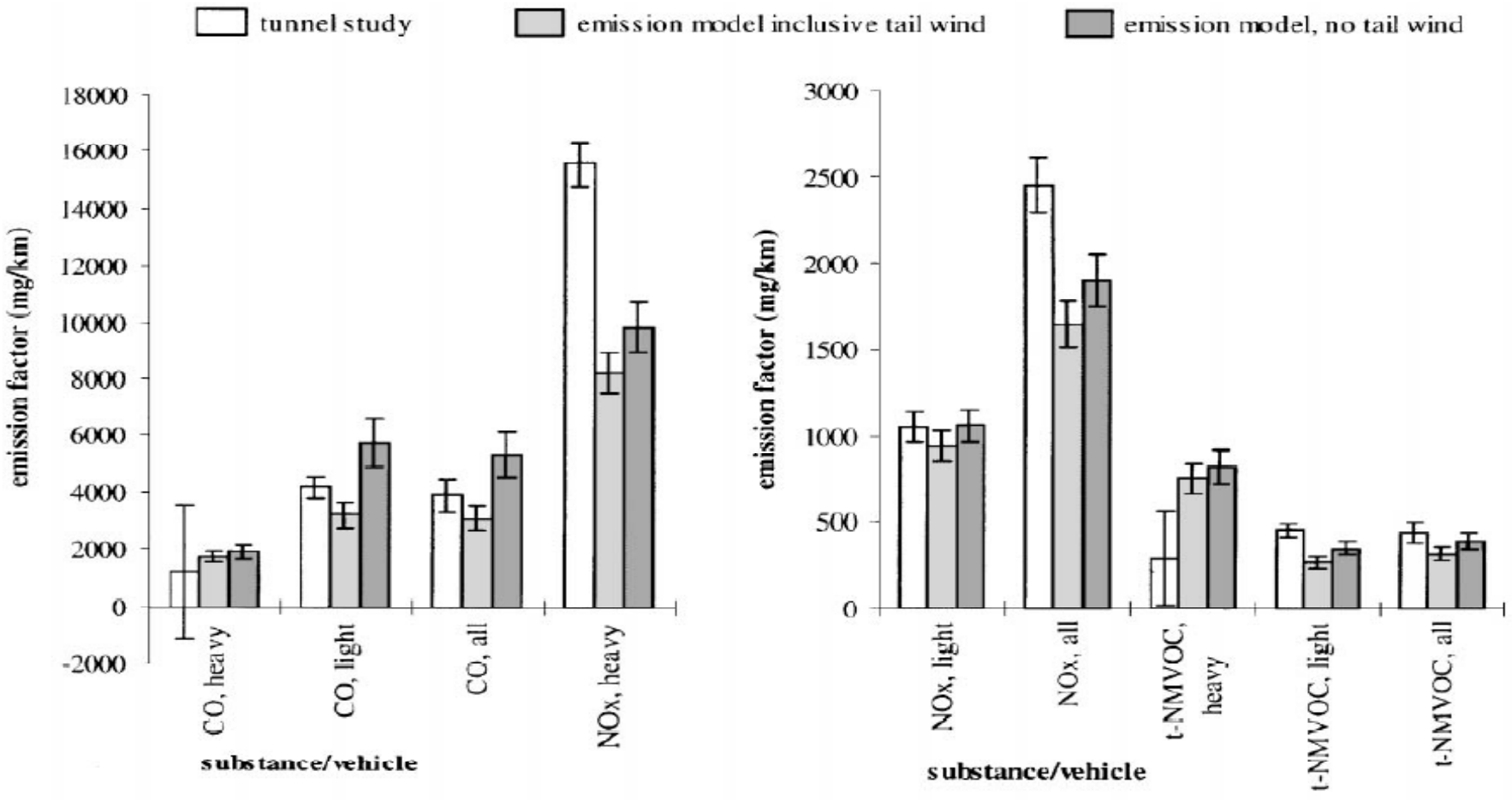
1998/99 (Sturm et al., 2001)

Gubrist tunnel (Switzerland):

1993 (John et al., 1999)

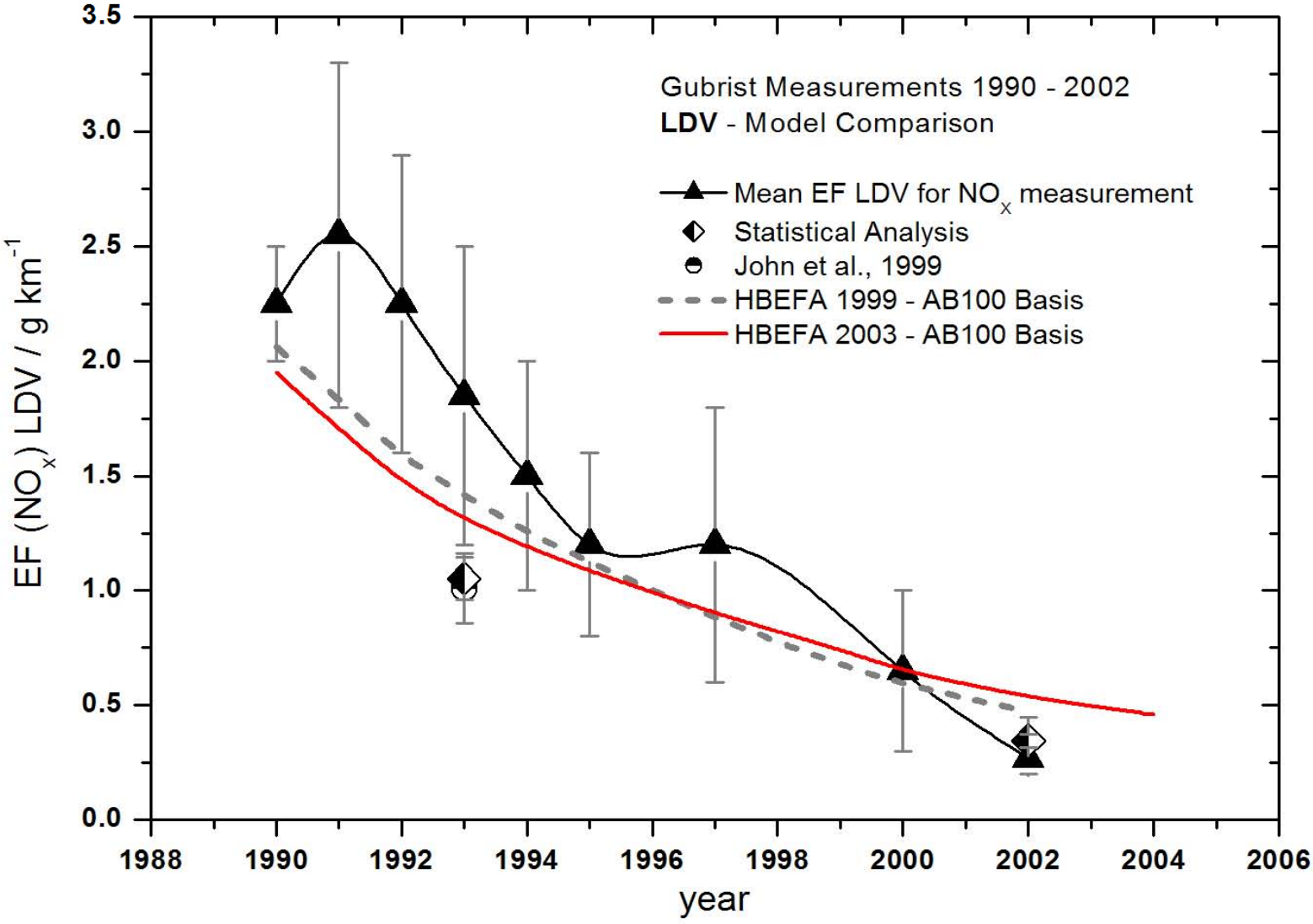
Comparison of Gubrist tunnel EFs with HBEFA (1999),

(John et al., 1999 - data from license plates)

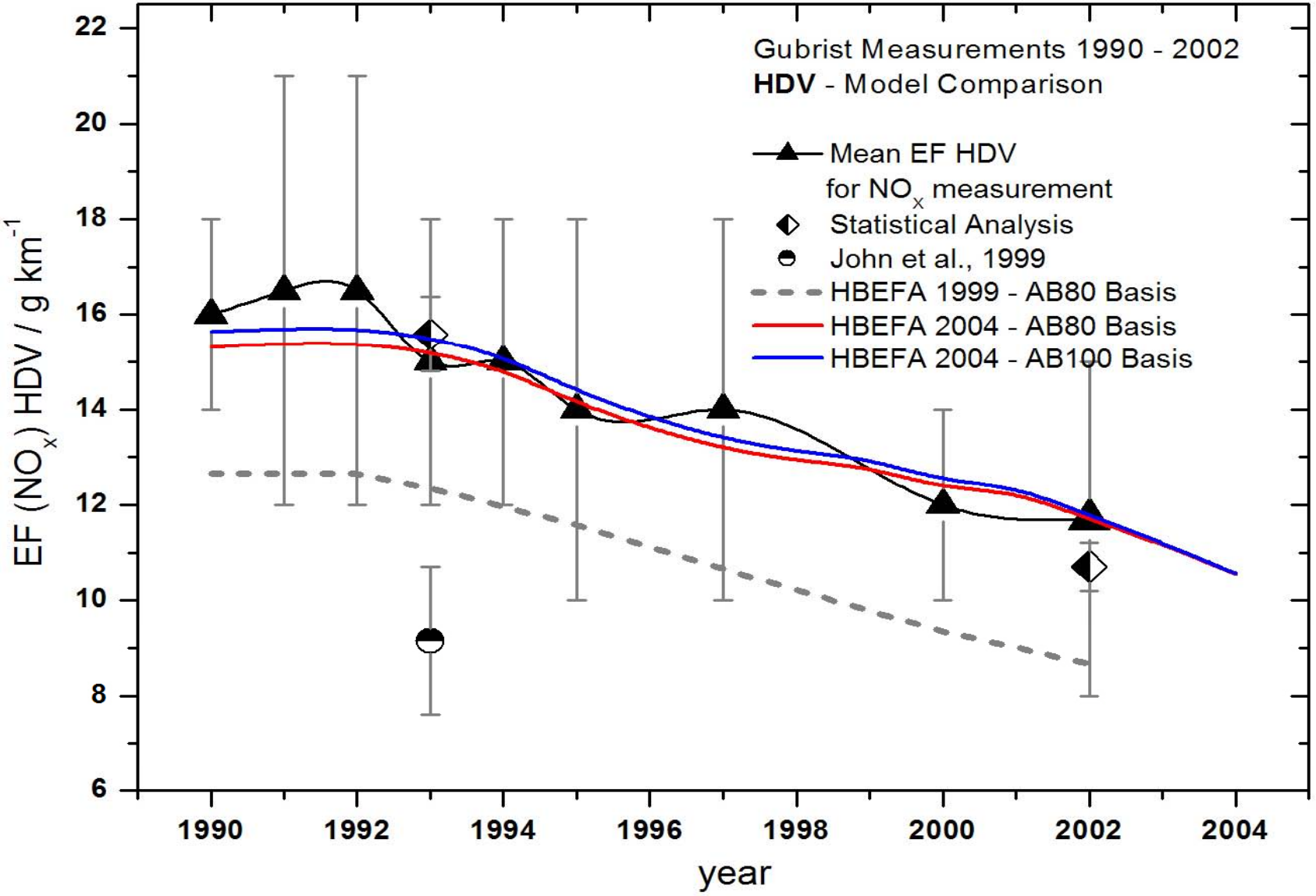


5. Long-term evolution

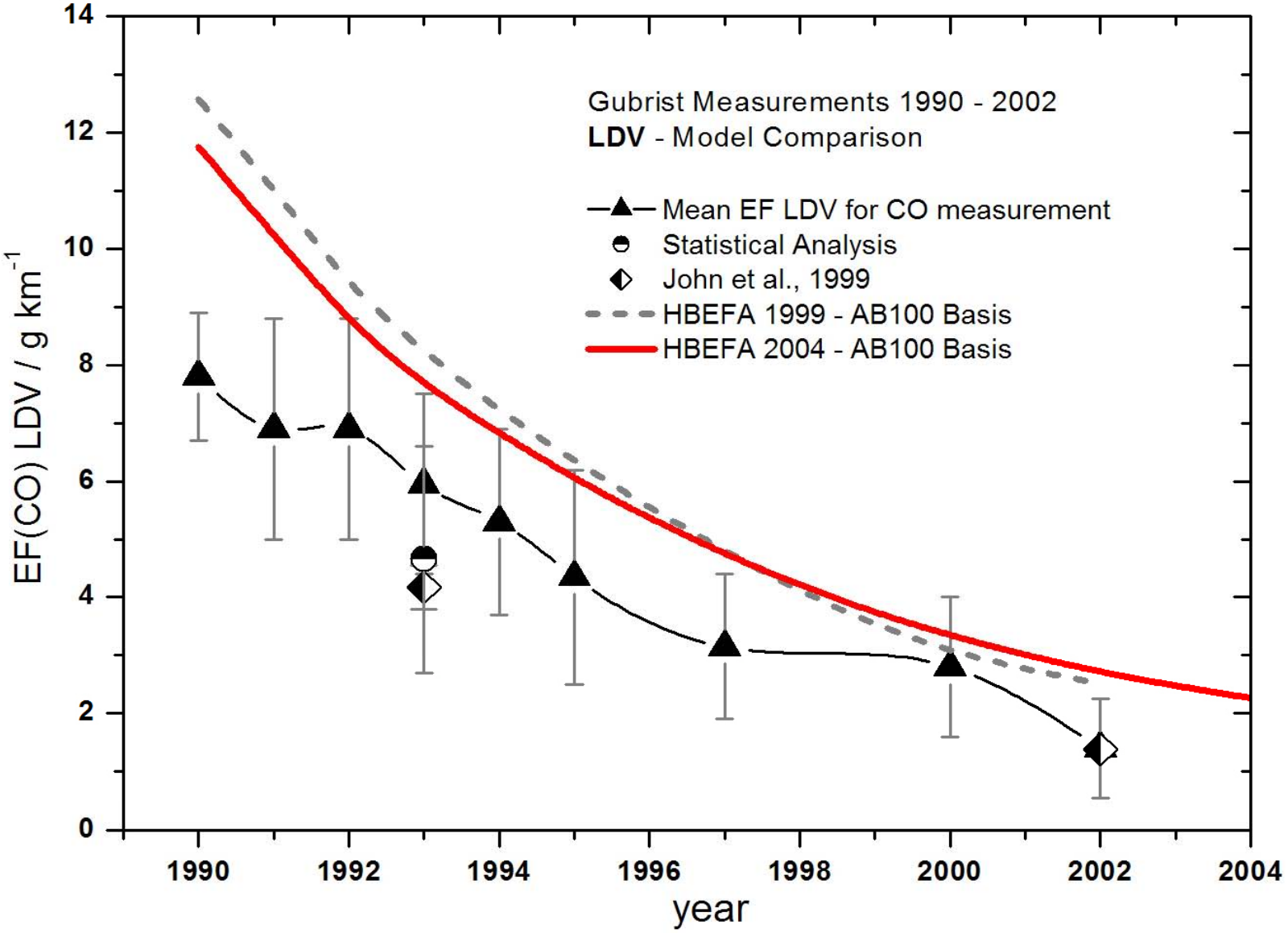
NO_x LDV



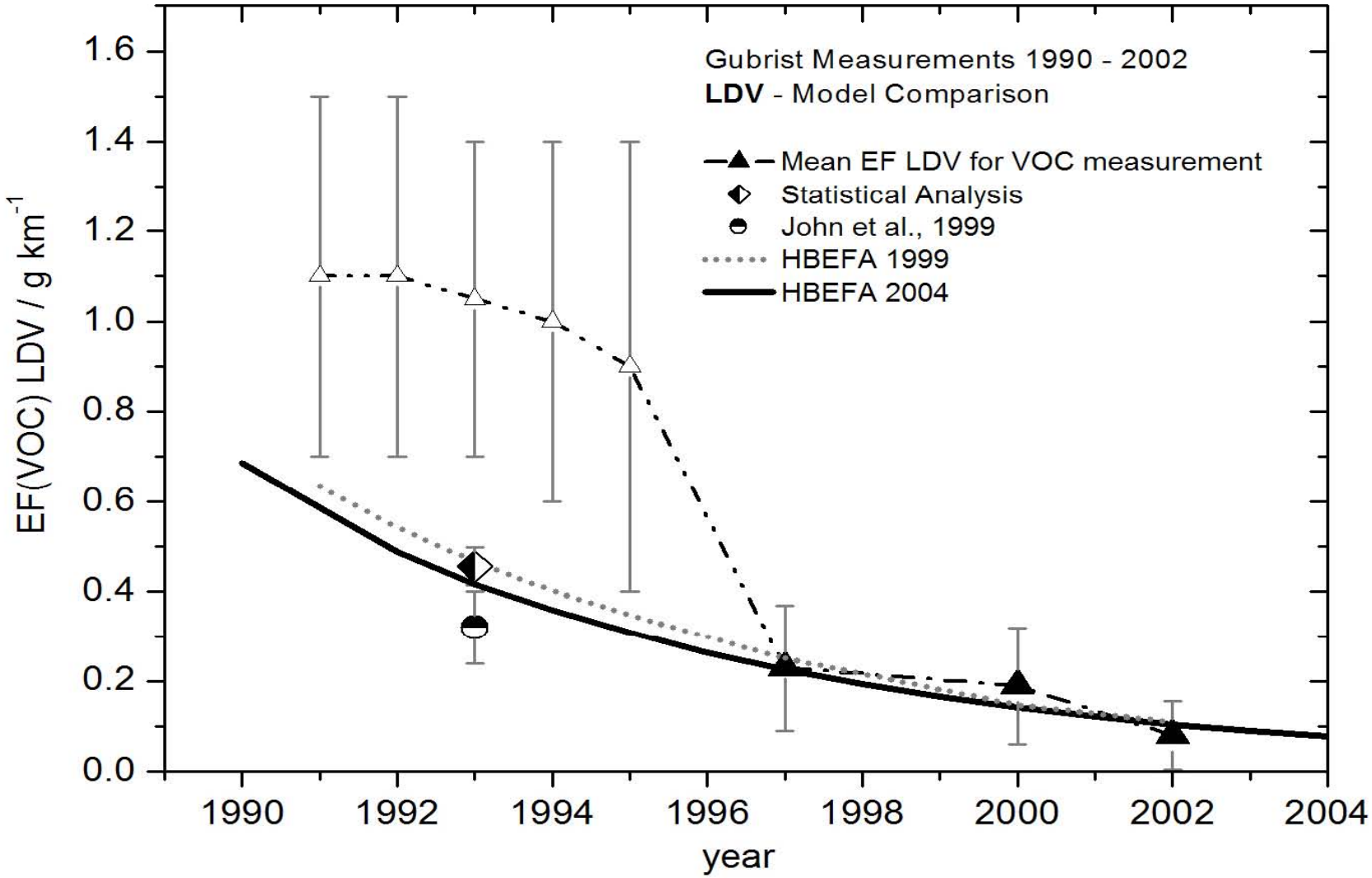
Long-term development: NO_x HDV



Long-term development: CO LDV



Long-term development: t-VOC LDV



VOC measurements from Gubrist tunnel (Legreid et al., 2007)

Compounds	Gubrist 2004 (mg/km)		Gubrist 2002 (mg/km)		Gubrist 1993 (mg/km)	
	LDV	HDV	LDV	HDV	LDV	HDV
Acetaldehyde	2.1 ± 0.6	5.3 ± 6.6			2.3±1.1	14.6±5.1
Propanal	0.08 ± 0.03	1.10 ± 0.30			0.18±0.45	3.1±2.0
Butanal	0.11 ± 0.01	0.31 ± 0.11				
Pentanal	0.16 ± 0.01	0.45 ± 0.16				
Hexanal	0.07 ± 0.02	0.60 ± 0.19				
Benzaldehyde	0.64 ± 0.06	0.75 ± 0.70				
Acrolein	0.36 ± 0.07	0.71 ± 0.77			1.3±0.4	7.2±1.6
Methyl-t-butyl-ether	0.24 ± 0.02	-0.18 ± 0.24			0.06±0.05	0.27±0.25
Acetone	0.57 ± 0.13	3.94 ± 1.54			1.1±1.8	8.0±8.1
2-Butenone	0.08 ± 0.01	0.93 ± 0.13				
Butanone	0.11 ± 0.02	0.64 ± 0.19			0.08±0.44	1.2±2.0
Ethanol	6.6 ± 2.8	58.8 ± 33.7				
Iso-propanol	2.0 ± 0.4	2.5 ± 5.3				
1-Propanol	0.08 ± 0.02	0.32 ± 0.24				
Iso-butanol	0.02 ± 0.01	0.06 ± 0.08				
Methyl acetate	0.03 ± 0.01	0.08 ± 0.10				
Ethyl acetate	0.07 ± 0.02	0.52 ± 0.18				
Butyl acetate	0.12 ± 0.02	0.31 ± 0.20				
Butane	2.4 ± 0.2	-0.9 ± 1.9	2.7±0.3	0±3	9.7±5.3	27.3±27.1
1,3-Butadiene	0.56 ± 0.04	0.8 ± 0.5			1.6±0.2	-1.6±1.1
Isoprene	0.55 ± 0.04	0.0 ± 0.5				
Benzene	2.3 ± 0.1	-1.3 ± 1.8	3.3±0.2	0.7±1.6	10.3±6.2	20.9±34.1
Toluene	5.7 ± 0.4	-4.7 ± 5.0	8.7±0.5	1±5	20.4±6.9	33.1±35.0
m,p-Xylene	3.3 ± 0.2	-2.2 ± 2.6	4.2±0.3	1±3	10.8±3.0	27.2±15.3
o-Xylene	1.3 ± 0.1	-0.8 ± 1.1	1.9±0.1	0±2	4.8±0.6	6.3±2.9
1,2,4-Trimethylbenzene	2.0 ± 0.1	0.2 ± 1.4			4.6±1.1	9.6±5.5

VOCs and OVOCs from tunnel studies

- Only limited data of organic species available from dynamometric tests
- Large uncertainties of EF for different vehicle classes
- EF of hydrocarbons strongly decreased over time for gasoline driven vehicles (introduction of catalytic converters and further improvements of vehicle technology)

6. Conclusions

- Tunnel measurements suitable for quantification of road traffic emissions
- Advantage: “Real flight”/disadvantage: problem of generalization (no cold start)
- Simple desgin of experiment (measurements at entry/exit site, fleet composition)

Conclusions cont.

- Pronounced disagreement for NO_x HDV emissions with HBFA (1999)
- Much better agreement tunnel measurements with HBEF (2004)
- Suitable for EF of VOCs
- Tunnel measurements at same site (Gubrist tunnel): Documentation of success of new vehicle technology