Validation of the COPERT road emission inventory model with real-use data

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INTRODUCTION. Key Research Questions

- ***How much does a modern vehicle emit under realistic driving conditions (i.e. outside regulated test cycles)?***
  - ✓ *Portable Emissions Measurement System **(PEMS)** campaign to gather in-use, real-world data*

- ***Can real-world measurement data be used for emission factor development / validation?***
  - ✓ *Development of **engine pollutant and FC maps** from PEMS data*
  - ✓ *Feed them into **Vehicle Simulation tools***
  - ✓ ***Simulation** of experimental routes and production of new EFs*
  - ✓ ***Direct comparison of PEMS data to EFs from model** used in national inventory compilations (COPERT)*

EXPERIMENTAL SETUP

- ***PEMS measurement campaign***
  - ✓ *Stock Euro 5 Diesel PC*
  - ✓ *Three predefined routes*
    - *Rural + Highway (135 km length, ~65 kph average speed)*
    - *Rural + Urban (61 km, ~35 kph)*
    - *Rural + Uphill (65 km, ~40 kph)*
  - ✓ *Second-by-second log*
    - *Tailpipe concentration of exhaust gasses : **O_2, HC, CO, CO_2** (NDIR) and **NOx** (electrochemical cell)*
    - *Exhaust flowmeter*
    - *GPS and vehicle-mounted weather station data*
    - *ECU data: vehicle speed, engine rpm, intake air mass flow, coolant temperature…*

EXPERIMENTAL SETUP

Semtech-DS mobile emission analyzer (manufactured by Sensors, Inc.)

Stock Fiat Bravo 1.6 JTD (DPF Diesel)
88 kW, 300 N·m @ 1500 rpm

DATA ANALYSIS. Models

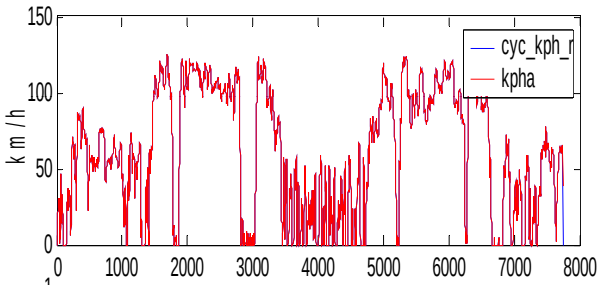
- ***COPERT** (LAT Thessaloniki)*
  - ✓ *Calculates emissions from all major pollutants, incl. exhaust and diffuse sources (evaporation, tyre and break wear), based on mean-speed emission factors*
  - ✓ *Covers all major vehicle cats. (241 individual types/technologies)*
  - ✓ *Applied for national-scale inventories throughout Europe*

http://lat.eng.auth.gr/copert/

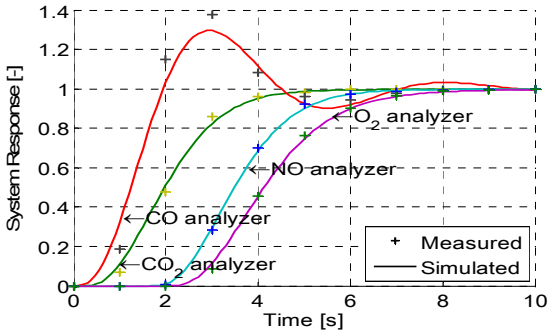
- ***ADVISOR** (US Dpt. of Energy)*
  - ✓ *Matlab/Simulink Analysis package for advanced vehicle modeling. Used to predict the fuel consumption and emissions of test vehicle*

DATA ANALYSIS 1. Overview

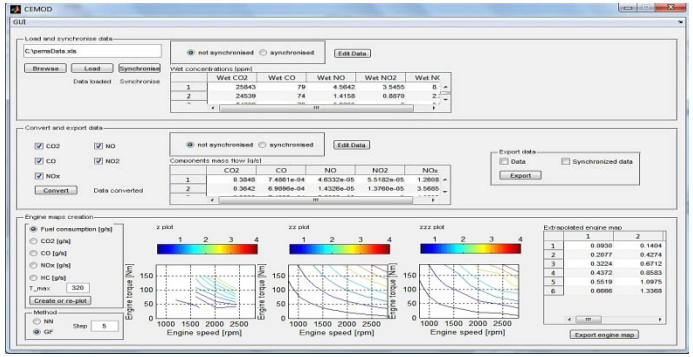
PEMS data



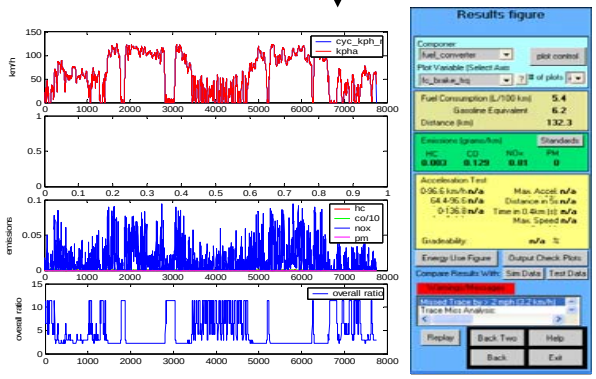
Synchronization of raw data



Matlab tool for the creation of engine maps using synchronized data

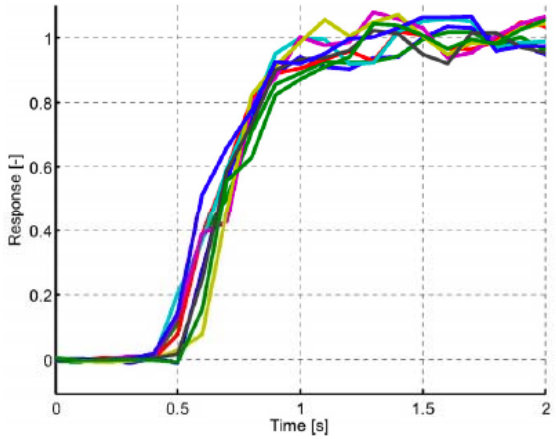


Vehicle Simulation in ADVISOR



DATA ANALYSIS 1. Preprocessing

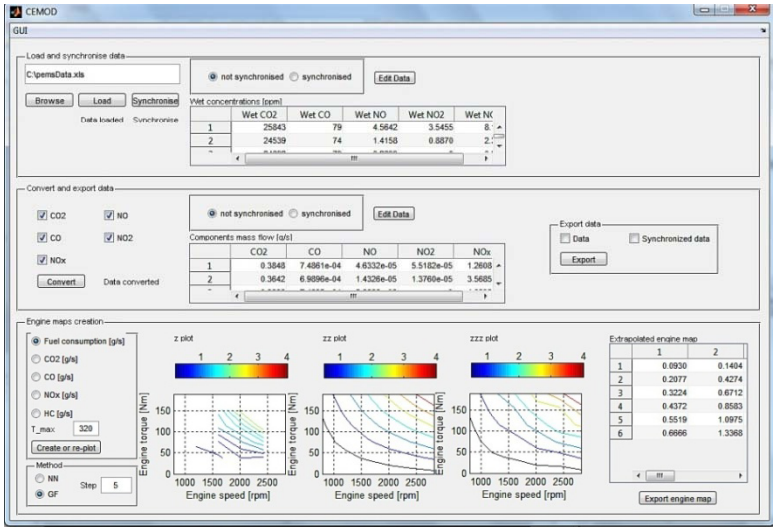
- ***Synchronization of raw PEMS data***
  - ✓ *Model to perform a back correction of the analyzer's signal to correct for time lag and response*
  - ✓ *Highly transient modes are filtered out*

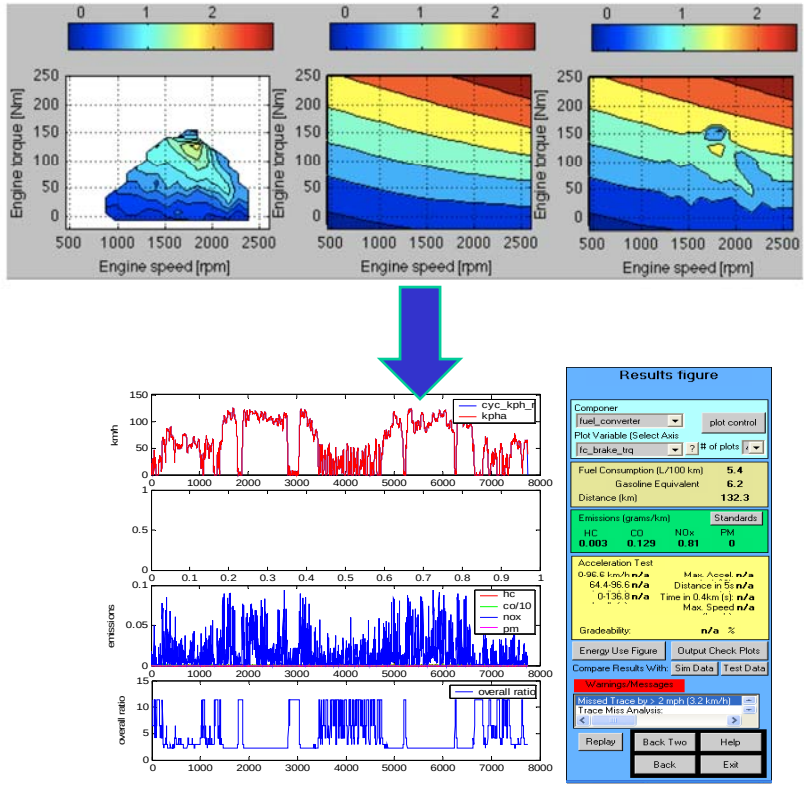


Geivanidis & Samaras, Meas. Sci. Technol. 19, 2008

DATA ANALYSIS 1. Engine pollutant and FC maps

- ***CEMOD*** *(Creation of engine maps using optimized data)*
  - ✓ *Matlab tool develops engine pollutant maps based on available data points of engine speed, torque and PEMS measurements using a neural network approach*





RESULTS 1. PEMS vs. *ADVISOR simulation*

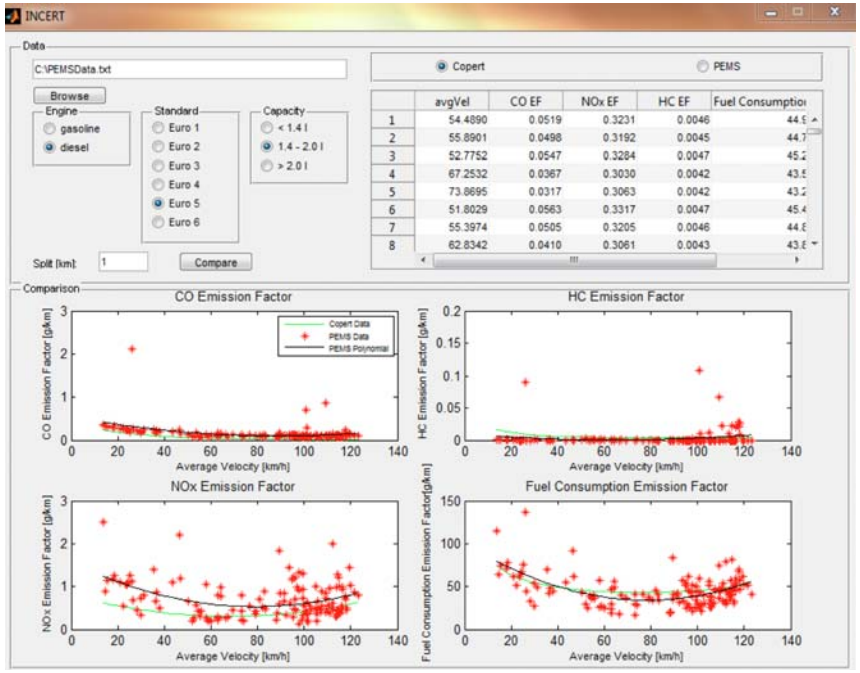
- ✓ *EFs calculated directly from PEMS data* vs. *simulation of the PEMS routes in ADVISOR*

	PEMS	ADVISOR	Deviation
FC [l/100km]	5.37	5.4	–1%
CO [g/km]	0.169	0.129	24%
HC [g/km]	0.0033	0.003	9%
NOx [g/km]	0.704	0.81	–9%

Results from Ispra – Milano route (Rural + Highway)

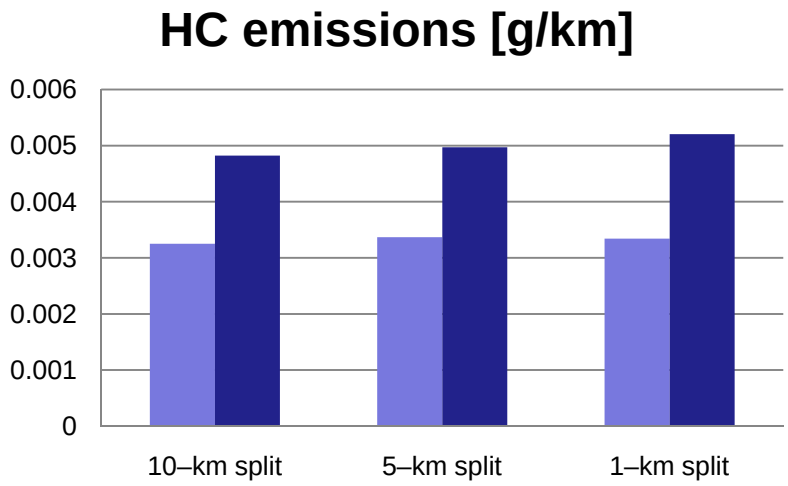
DATA ANALYSIS 2. Direct Comparison

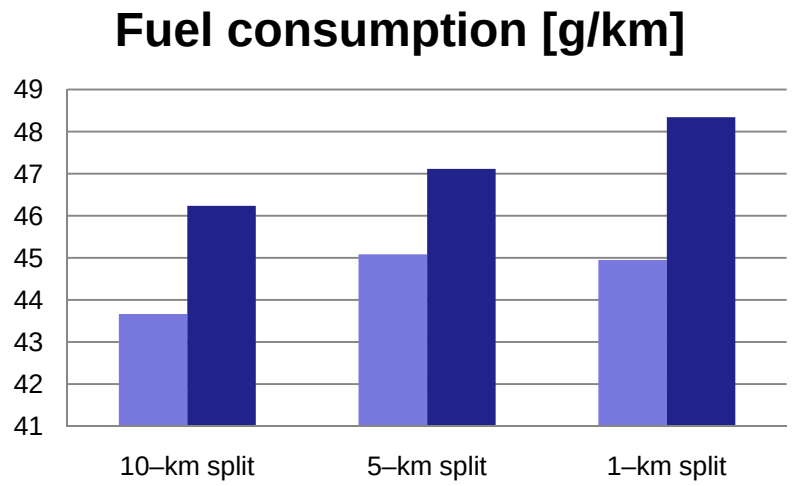
- ***INCERT*** *(Interface for the Comparison of Emissions from Road Transport)*
  - ✓ *Graphical interface for the comparison between the emission factors derived within COPERT and those from PEMS*
  - ✓ *Results for 1, 5 and 10-km data splits for average speed calculations*



RESULTS. PEMS vs. *COPERT EFS*

- ✓ *EFs calculated from PEMS data vs. corresponding mean-speed COPERT values*





Mean deviation ≈ 34%

PEMS

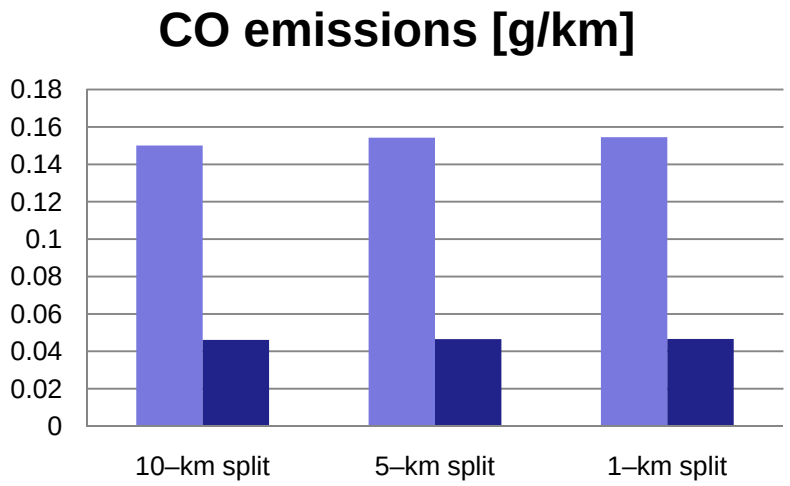
COPERT

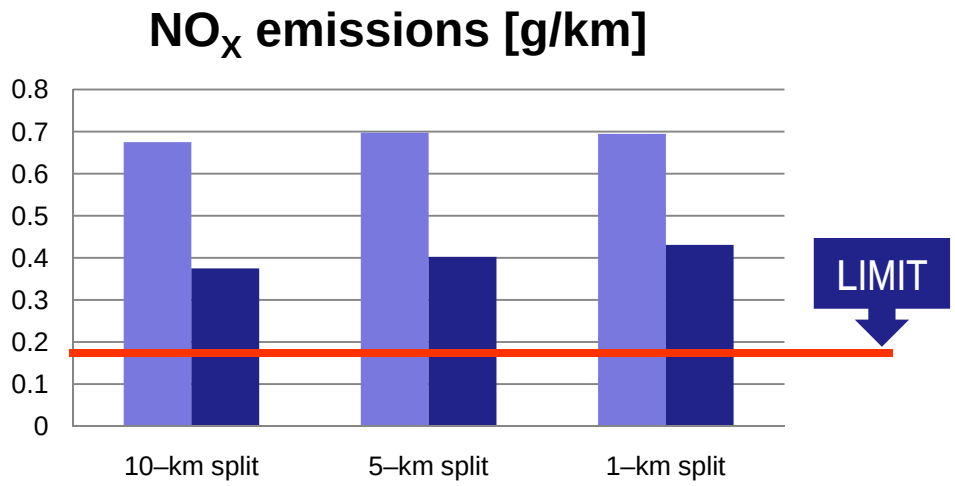
Mean deviation ≈ -6%

Results from Ispra – Milano route (Rural + Highway)

RESULTS. PEMS vs. *COPERT EFS*

- ✓ *EFs calculated from PEMS data vs. corresponding mean-speed COPERT values*





Mean deviation ≈ 229%

PEMS

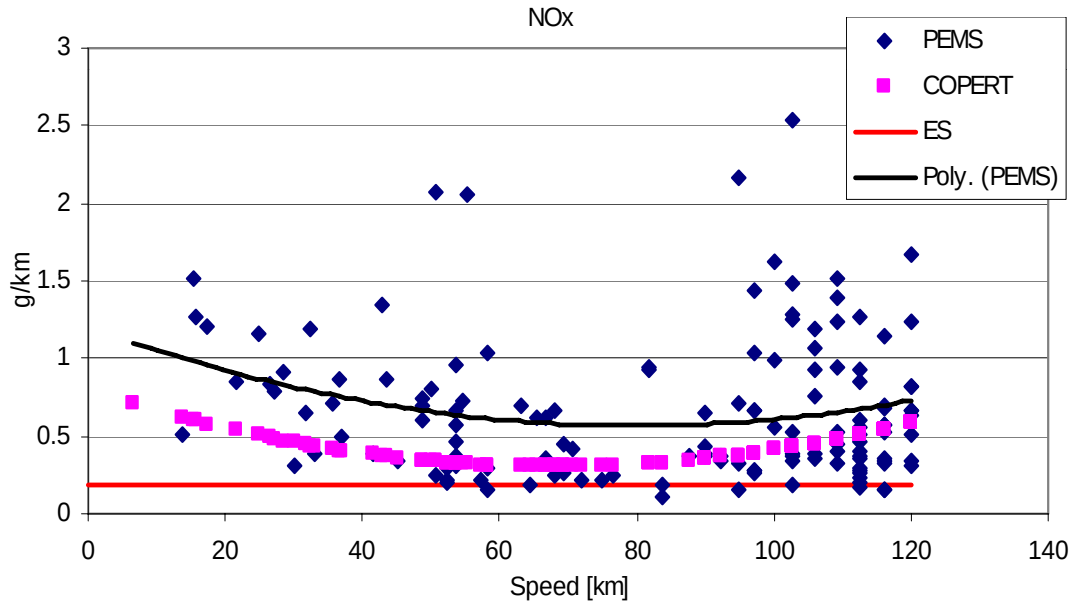
COPERT

Mean deviation ≈ 71%

Results from Ispra – Milano route (Rural + Highway)

RESULTS. PEMS vs. *COPERT EFS*

- ✓ *Plots generated by INCERT for easy comparison of results*



NOx emissions (1-km split)

DISCUSSION. PEMS vs. *COPERT EFs*

- **Distance splits** have little influence upon results
- **CO emissions**: COPERT and PEMS EFs present similar trends. PEMS values up to 200% higher than COPERT, yet well below emission limits
- **HC emissions** remain generally low.
- **Fuel consumption** lower compared to the COPERT values. Modern low engine capacity Diesel vehicles not fully covered by model.
- **NO_X emissions** approx. 60% higher than COPERT values. This increase may be attributed to real-world (higher load) operation. **Both COPERT and PEMS values lie above current emission limits**

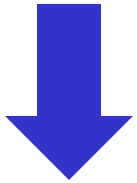
CONCLUSIONS 1

- Good agreement between PEMS data and ADVISOR results (esp. FC). Vehicle simulation with the use of real-life data is a promising approach for the production of Emission Factors, by simulating any cycle/condition needed

- Other more advanced and updated vehicle simulation models should be tested in the future like CRUISE, AUTONOMIE (ex-PSAT)

CONCLUSIONS 2

- Good agreement between PEMS –derived and COPERT EF values. In the case of NO_X, **both values are well above the applicable emission limit** (up to 3.8 times higher; PEMS results are worse than corresponding Euro 1 EF!)



- PEMS flags the issue of excessive NO_X emissions of modern diesel vehicles when driven outside regulated test cycles

GENERAL CONCLUSIONS

- PEMS can characterize the emissions of regulated pollutants of light–duty vehicles over a full range of **real-world driving** states: idling, cruising, uphill & downhill roads. Still **not as accurate or comprehensive** as testing in permanent labs

- PEMS measurement campaigns in Europe to date cover only a small number of vehicles; insufficient for the derivation of technology–specific EFs, **best used for validating existing EFs** or making relative comparisons

Thank you for your attention

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