

# Simultaneous in-cabin and on-road CO<sub>2</sub> concentrations during on-board mobile measurements

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CREATEUR DE NOUVELLES MOBILITES



- CO<sub>2</sub> is often measured to monitor the indoor air quality and ventilation efficiency
  - In indoor environments, CO<sub>2</sub> is related to the occupancy since it is often issued from human breathing
  - For mobile measurements into car-cabin, the indoor CO<sub>2</sub> is related to the passengers but is there any influence of the on-road CO<sub>2</sub> emitted from combustion ?
- Is there a need for simultaneous in-cabin and on-road measurement of CO<sub>2</sub> ?

1. Test methodology
  - Instrumentation
  - Probe positions
  - Vehicle/ filter types
  - Test conditions
  - HVAC settings
  - Route type
2. Results and analysis

# 1. Test methodology

## Instrumentation

Fig. 1 : TSI IAQ-Calc 7525  
CO<sub>2</sub>, Température and Relative  
Humidity measurements

- In-cabin and on-road simultaneous T° and CO<sub>2</sub> concentrations measurements using two TSI-IAQ calc
- Measurements time resolution 1s



- **CO<sub>2</sub>**
- Sensor Type Dual-wavelength NDIR (non-dispersive infrared)
- Range 0 to 5000 ppm
- Accuracy  $1 \pm 3.0\%$  of reading or  $\pm 50$  ppm, whichever is greater
- Resolution 1 ppm
- **Temperature**
- Sensor Type Thermistor
- Range 0 to 60°C
- Accuracy  $\pm 0.6^\circ\text{C}$
- Resolution 0.1°C
- **Relative Humidity**
- Sensor Type Thin-film capacitive
- Range 5% to 95% RH
- Accuracy  $2 \pm 3.0\%$  RH
- Resolution 0.1% RH

## Probe positions

In-cabin probe



The mixing fan



Fig. 2 : Indoor and outdoor probe positions

## Vehicle/ filter types

- Suv type vehicle: combustion engine, mileage 28000 km
- Cabin filter: OEM HE type, new 0 km
- Activated carbon filter
- Length [mm]: 290, width [mm]: 95, thickness [mm]: 30



Fig. 3 : The measurement plateforme

## Test conditions

- The vehicles was parked closed and kept in engine-off for more than 15 hours
- Preconditioning: temperature of parking varied between 12° and 17° and will be parked in the Estaca Bubble Viaoq platform for a better temperature control (22°)
- Test during october (morning/midday)
- Outdoor temperature between 18° and 22°
- One passenger during the test

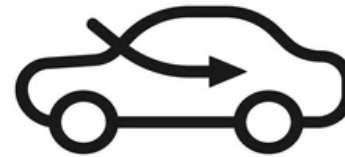


Fig. 4 : The Estaca bubble Viaoq platform



## HVAC settings

- Temperature 22°
- Outdoor air (OA) (Recirculation off)
- Air conditioning off
- Fan speed 4/8 to 8/8



**Medium to maximum fan speed**

## Route type

- RDE type route: Urban and freeway parts of the road
- Includes tunnels and ring road (heavy traffic)
- Round trip with a complete ventilation of the in-cabin at the arrival place in Paris center for around 10 min
- Average duration of the global journey 150 min for 55 km length

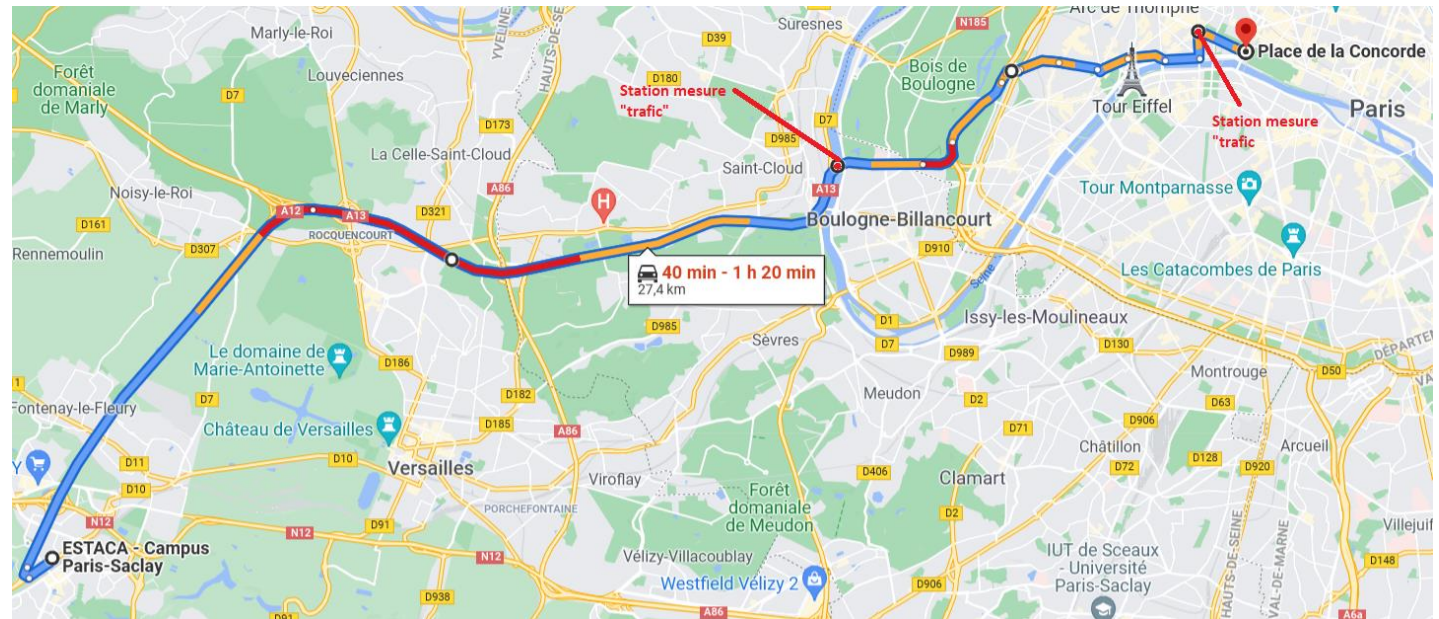


Fig. 5 : Route used for the test

## 2. Results and analysis

## Average concentration ratios

- Two ratios have been defined and calculated:

Ratio of mean concentrations:

$$R_{\bar{I}/\bar{O}} = \frac{\overline{C_{in}}}{\overline{C_{out}}}$$

Average instantaneous ratios:

$$\overline{R_{I/O}} = \overline{\left( \frac{C_{in}}{C_{out}} \right)}$$

## Confirmation of the weak contribution of outdoor CO<sub>2</sub> under RC ventilation mode

- In-cabin CO<sub>2</sub> concentration increases 3 times faster in RC ventilation mode with medium fan speed in the test vehicle used.
- The outdoor CO<sub>2</sub> contribution to in-cabin total CO<sub>2</sub> concentration is negligible in that case.

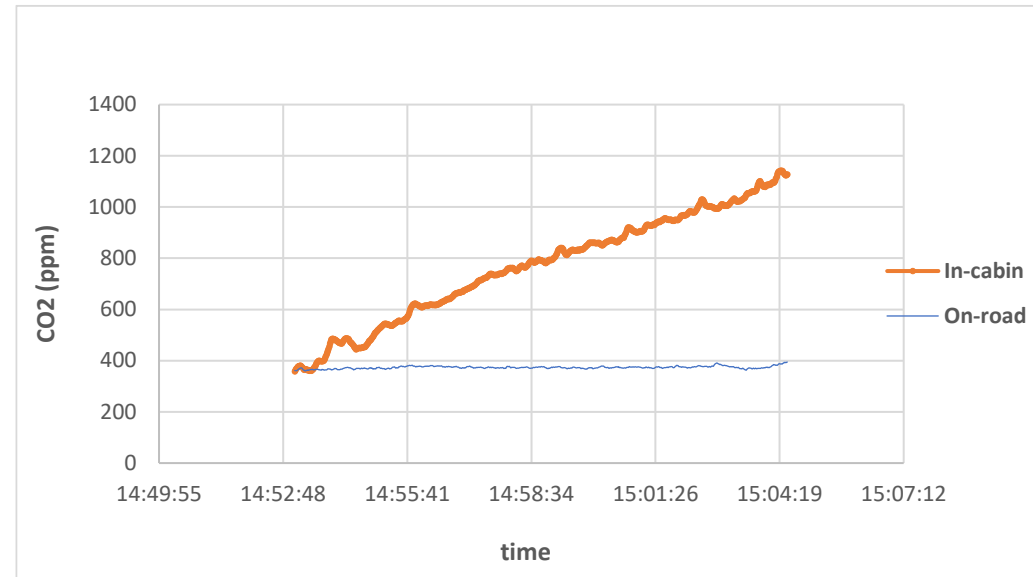


Fig. 6 : Time evolution of in-cabin and on-road CO<sub>2</sub> concentrations under RC ventilation with fan speed 4/8

## Similar in-cabin and on-road concentration dynamics during the static stage measurements without passengers

- Static measurements achieved without passengers under OA 4/8 ventilation at Estaca outdoor parking next an intersection
- **In-cabin and on –road CO<sub>2</sub> concentrations** measured during static stage have very **similar trends**

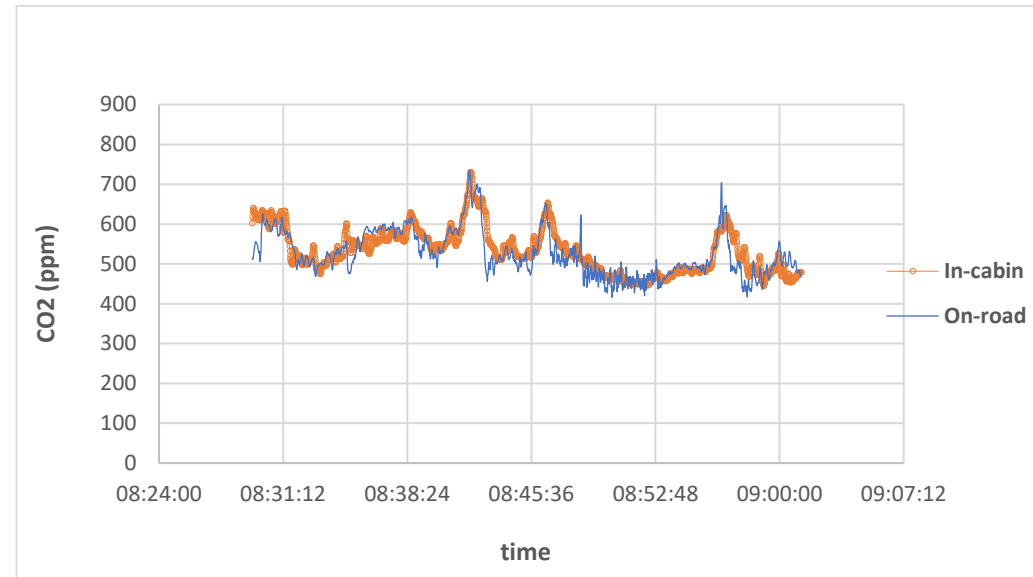


Fig. 7 : Time evolution of in-cabin and on-road CO<sub>2</sub> concentrations under OA ventilation with fan speed 4/8 during static measurements

$\overline{C_{in}}$ (ppm)	$R_{I/O}$
534	1,01
$\overline{C_{out}}$ (ppm)	$\overline{R_{I/O}}$
526	1,02

Table 1 : In-cabin and on-road CO<sub>2</sub> mean concentrations and average instantaneous ratios and the means ratios

## More variability of on-road concentration during mobile measurements

- Mobile measurements achieved under OA 4/8 ventilation during outward and OA 8/8 during the return
- In-cabin and on –road CO<sub>2</sub> concentrations measured during mobil test have similar trends with more dynamics for the on-road curve
- Tunnels (gray box) and ring road (yellow box) are subject of CO<sub>2</sub> concentrations peaks both in car-cabin and outdoor

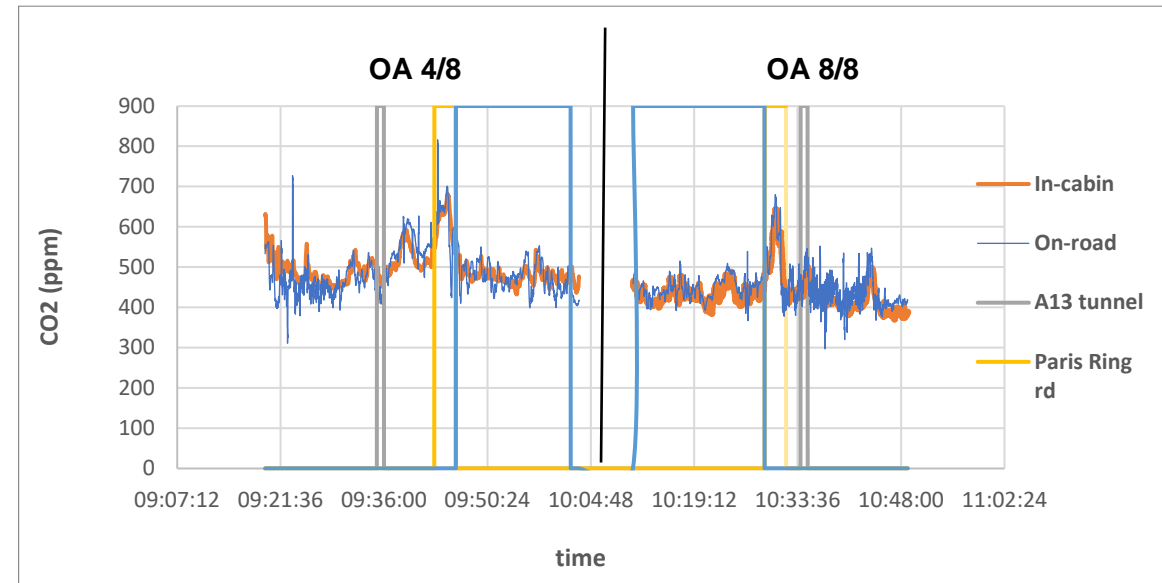


Fig. 8 : Time evolution of in-cabin and on-road CO<sub>2</sub> concentrations under OA ventilation with fan speed 4/8 outward and 8/8 during the return (Morning measurements)

# TIME EVOLUTION OS IN-CABIN AND ON(ROAD CO<sub>2</sub> CNCENTRATIONS

More variability of on-road concentration during mobile measurements

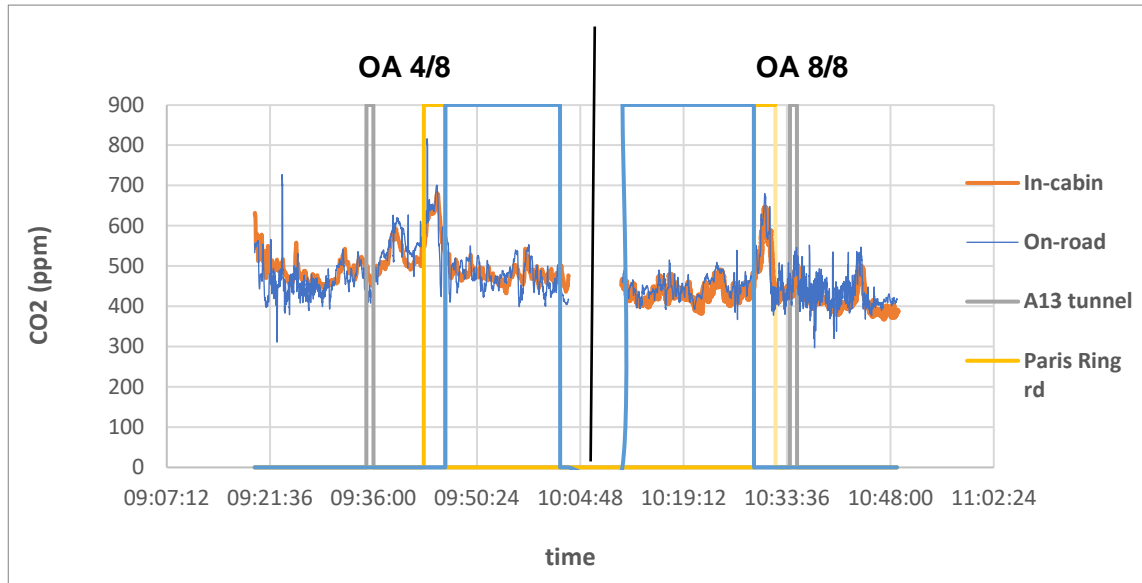


Fig. 8 : Time evolution of in-cabin and on-road CO<sub>2</sub> concentrations under OA ventilation with fan speed 4/8 outward and 8/8 during the return (Morning measurements)

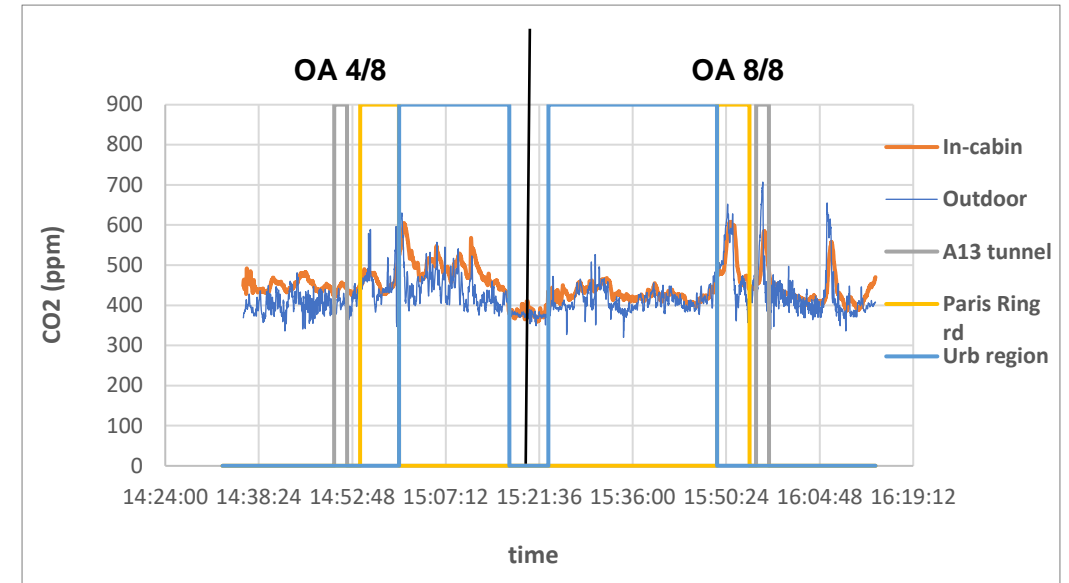


Fig. 9 : Time evolution of in-cabin and on-road CO<sub>2</sub> concentrations under OA ventilation with fan speed 4/8 outward and 8/8 during the return (Midday measurements)



## More variability of on-road concentration during mobile measurements

- The I/O ratios are greater than 1 in all the cases even at 8/8
- The ratios are the lowest (1.02) when the vehicle is stopped during the ventilation stage windows opened
- The ratios are lower at 8/8 than at 4/8
- The instantaneous ratios are almost the same than the ratios of mean concentrations which means that the on-road CO<sub>2</sub> infiltration is a fast process.

Ventilation OA 4/8	$\overline{C_{in}}$ (ppm)	$R_{\overline{I}/\overline{O}}$
	468	1,09
	$\overline{C_{out}}$ (ppm)	$R_{I/o}$
	428	1,10
Open windows during the stop	$\overline{C_{in}}$ (ppm)	$R_{\overline{I}/\overline{O}}$
	381	1,02
	$\overline{C_{out}}$ (ppm)	$R_{I/o}$
	374	1,02
Ventilation OA 8/8	$\overline{C_{in}}$ (ppm)	$R_{\overline{I}/\overline{O}}$
	441	1,04
	$\overline{C_{out}}$ (ppm)	$R_{I/o}$
	425	1,04

Table 2 : In-cabin and on-road CO<sub>2</sub> mean concentrations and average instantaneous ratios and the means ratios

# CONCLUSION AND PERSPECTIVES

- In recirculation ventilation mode, the outdoor contribution of global in-cabin CO<sub>2</sub> concentration is negligible
- The dynamics of the in-cabin and on-road time evolution of CO<sub>2</sub> concentrations is very similar when windows are opened and the same trend are found even with more dynamical curve for outdoor concentration when windows are opened, and ventilation set to Outdoor air
- The I/O ratios are greater than 1 for all ventilation setting under OA.
- The ratios should be correlated to the Air exchange rate
- The contribution of outdoor CO<sub>2</sub> concentration to the global in-cabin concentration in relation to the AER should b assessed at different ventilation settings, traffic condition and number of passengers