Automating Car Chaser Emissions Measurement

Karl Ropkins

Presented at the

2023 OSAR Conference

(Onboard Sensing, Analysis, and Reporting)

CE-CERT, Riverside, California

March 30 to 31, 2023

Transport Studies, Environment,
University of Leeds, UK
(k.Ropkins@its.leeds.ac.uk)

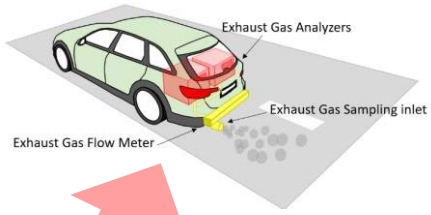
Background: PEMS, VERSS and Car Chasers

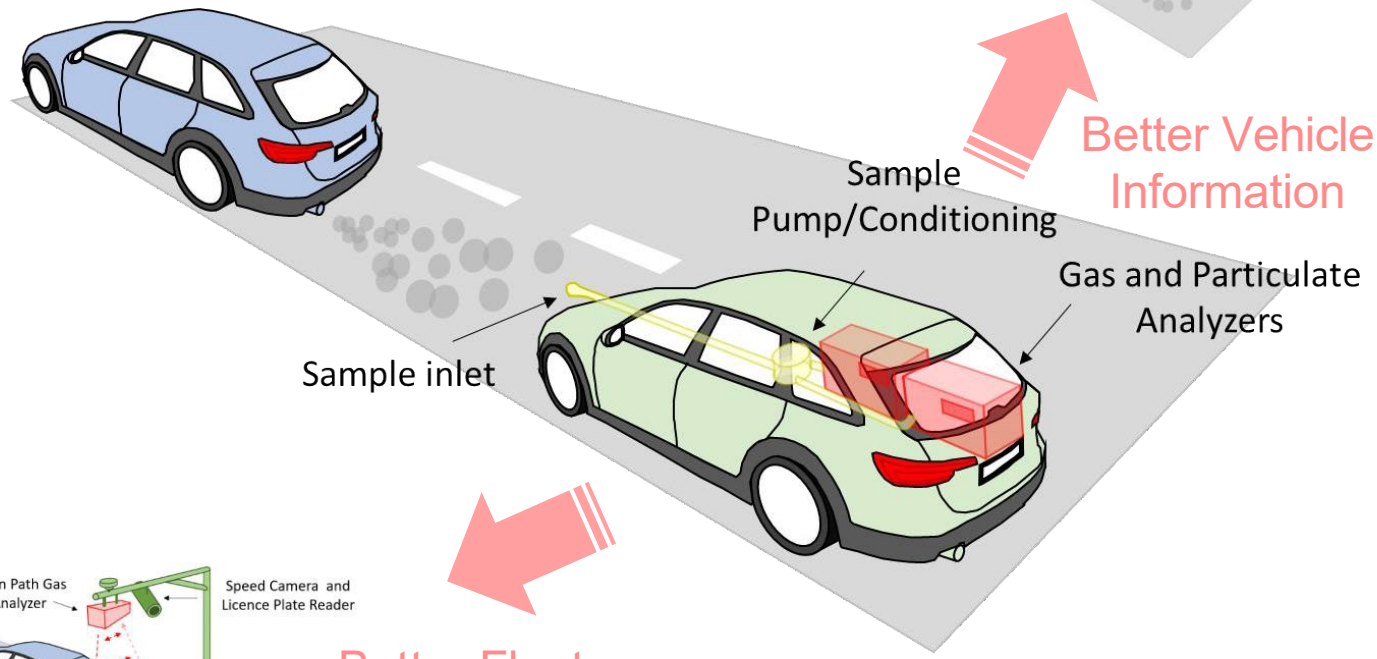
CAR CHASER
(Vehicle Chaser or Sniffer)

5-25 vehicles/day
500-1,000 measurements/vehicle

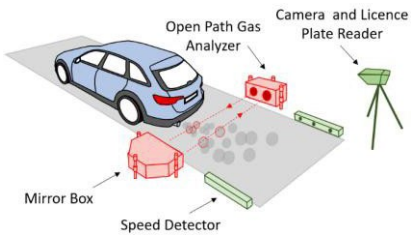
PEMS

1-2 vehicles/day
10,000 (plus) measurements/vehicle



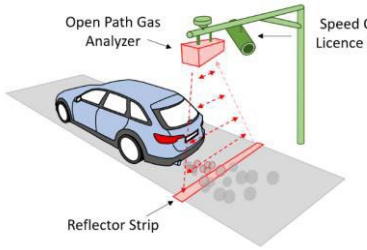


Better Vehicle Information



VERSS
(remote sensing)

2,000-8,000 vehicles/day
1-2 measurements/vehicle



Better Fleet Coverage

Source: Ropkins, Ibarra-Espinosa, Bernard, 2020. Chapter 4. Vehicle Emissions Measurement and Modeling. In: Khreis, Nieuwenhuijsen, Zietsman, Ramani, eds. Traffic-Related Air Pollution: Emissions, Human Exposures, and Health. Elsevier. ISBN: 9780128181225. https://www.elsevier.com/books/traffic-related-air-pollution/khreis/978-0-12-818122-5.

Vehicle Fleet Surveillance

High Emitter

A faulty, poorly maintained, or tampered vehicle

Regulatory Authority (Police, Highway Patrol)

- Trained to safely follow other vehicles and collect evidence, and
- Have authority to stop, inspect and (often) seize a vehicle

Car Chasers are already used for targeted vehicle fleet emissions studies but…

Automation of Analysis could Enhance Applications

For Regulatory Methods: A more user-friendly option for non-expert users/operators

For Car Chaser Studies: An option for ‘floating car’ emissions monitoring

Dataset and Simulation

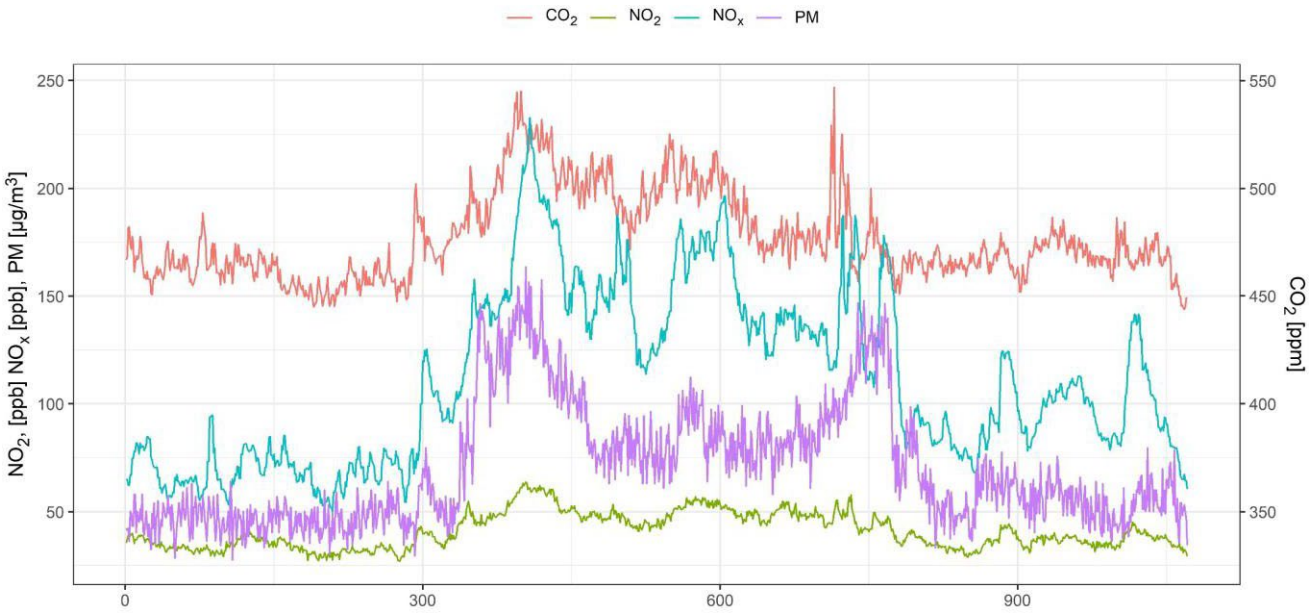
Dataset

CO_2	LI-850, LI-COR
$NO/NO_2/NO_x$	2100+2300, Gasboard
PM	eFilter, Dekati (Scielutions)

All logged at 1Hz

Historic data
52 vehicle measurements
(Built Car Chaser project)

NOTE: Car chaser, so no exhaust flow measurement so emissions measurement by CO_2 ratio similar to remote sensing



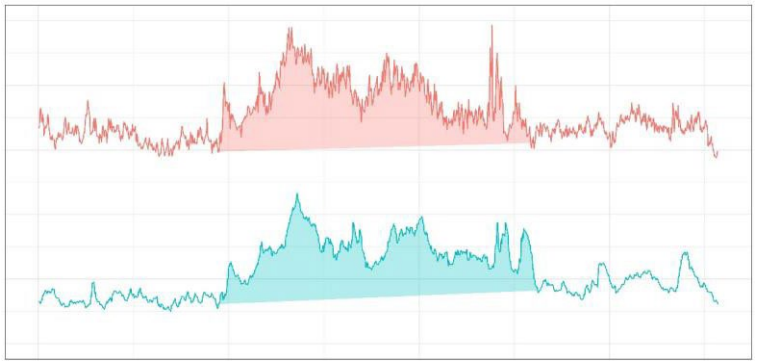
'2 System' Simulation

Computer 1 → **Computer 2**

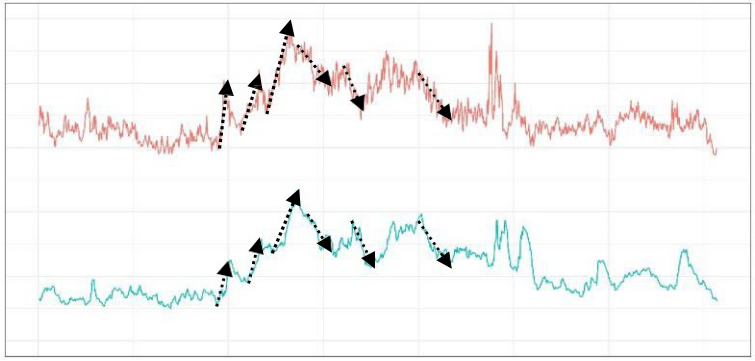
Holds data and acts as 'proxy' for the monitoring system by generating one signal per analyte, and updating this once per second to simulate a real-time output

Collects data and acts as 'proxy' for the logger/analysis software by collecting, processing, reporting and storing the proxy-monitor output to simulate real-time data handling

Example Manual and Automated Methods



versus



Manual Method

Peak Integration

As long as you focus on comparing 'like-with-like' regions/features of the plume profiles, the 'area under the profile' approach is relatively robust because you are looking at ratios

But the approach is labor-intensive and requires expert judgement

Automated Method

(Modified) Bentley Filter

1. Take a short segment (20-40 seconds)
2. Calculate linear regressions parameters for this:
   Assume y=mx+c for $[CO_2]$ ~ [analyte] but ignore c so just considering the local d[analyte]/d$[CO_2]$
3. Retain if linear regression correlation high (R>0.7)
4. Repeat steps 1 to 3, and compare m for multiple measurement segments

Source: Bentley, S.T., 2004. Graphical techniques for constraining estimates of aerosol emissions from motor vehicles using air monitoring network data. Atmospheric Environment, 38(10), pp.1491-1500. https://doi.org/10.1016/j.atmosenv.2003.11.033.

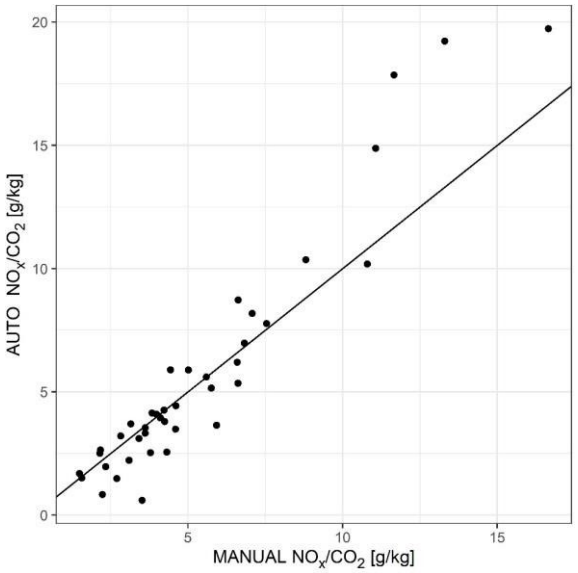
Example Filter Outputs

Manual and Automated Method Comparisons

NO_x/CO_2

Slope, m = 1.14
R^2 = 0.95

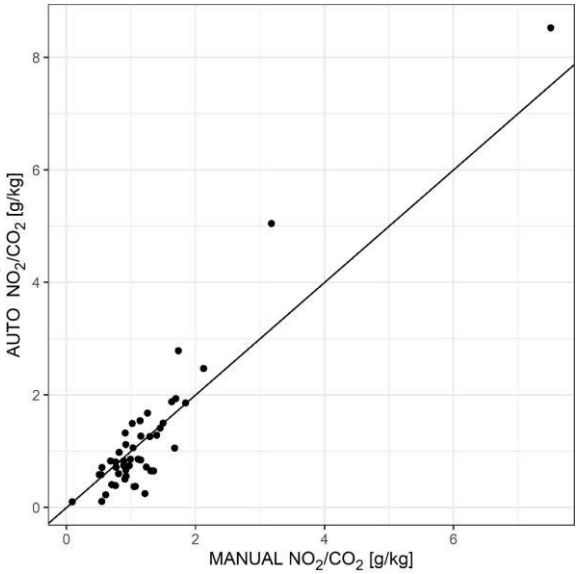
(41 vehicles)



NO_2/CO_2

Slope, m = 1.08
R^2 = 0.93

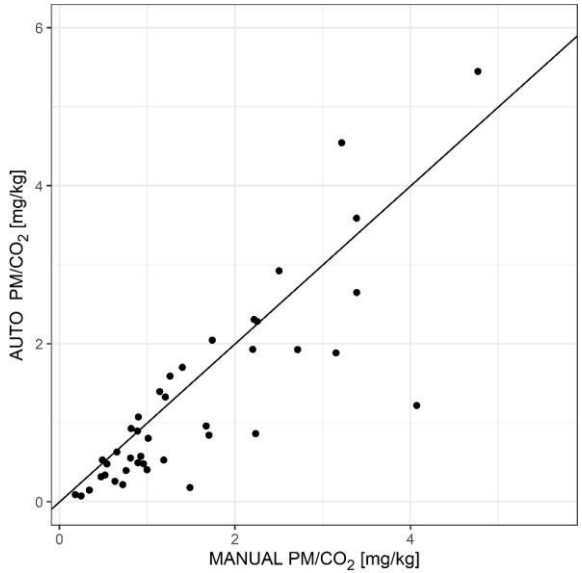
(48 vehicles)



PM/CO_2

Slope, m = 0.96
R^2 = 0.89

(44 vehicles)



Comments

Good agreement between manual (peak integration) and automated (Bentley Filter) methods: $R^2 > 0.85$, all slope *ca.* 1

Relatively poor agreement for PM/CO_2 (R^2 0.89 versus 0.93-0.95) possibly due to dissimilar gas and particulate dispersion and/or additional PM sources, like non-exhaust

Conclusions

This is a work in progress but:

- We have a provisional method that can be used to automatically report followed-vehicle emissions measurements in real-time
- We also have a '2 system' simulator we can use to refine methods and compare this and other methods using historic car-chaser datasets

Next steps:

- Look at other methods, using this and ideally other datasets
- Replace the proxy-logger/analysis software (computer 2) component of the '2 system' simulator with the real thing
- Work on analysis triggering: Currently using a standalone video system and manual assignment but obviously like to look at automating that (e.g. using OpenDataCam) but longer term aim is to replace with ANPR (like EU CARES already doing); also option to investigate CO_2 plume size
- (Also planning to open software release associated python code)