DATA COLLECTION IN SUPPORT OF DEVELOPING A NOVEL MULTIPLEXED SENSOR-BASED APPROACH TO MOBILE PM MEASUREMENT

Andrew Burnette, infoWedge

Dr. Karl Ropkins, University of Leeds

Dr. Gurdas S. Sanhu, 3DATX

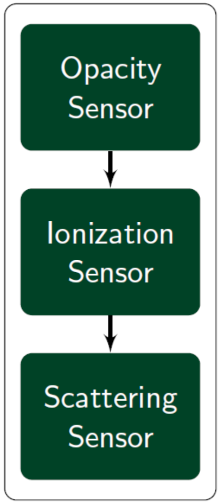
Outline of Presentation

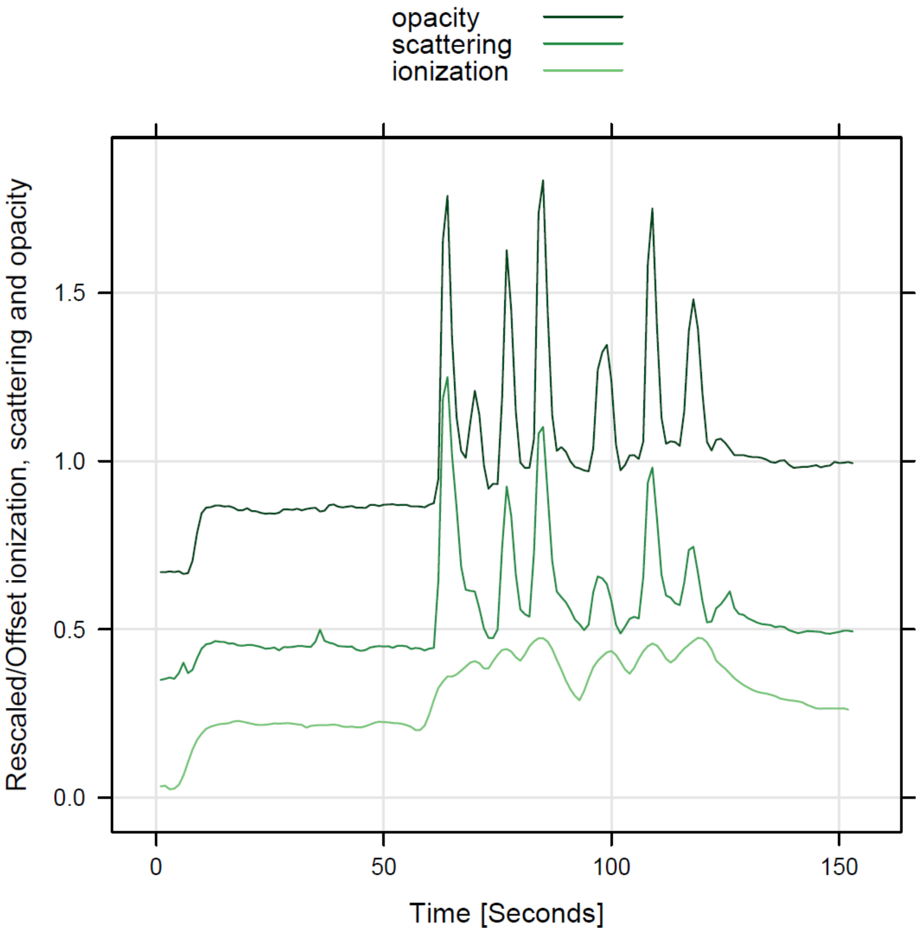
- Background
- Description of Technology
- Sample System Development Philosophy, Constraints, Approach
- Testing and Example Results
- Multiplex Correlation

Background

- The in-use emissions test industry continuously pushes for smaller, lighter, less power-hungry PEMS
- There is a natural tension/conflict between further measurement system downsizing and accuracy
- Leaps in capability, miniaturization, etc. will not come from incremental/generational improvements to existing systems

Description of parSYNC





infoWedge

Sample System Development Philosophy

- Given the parSYNC unit and its various possible uses (I/M, research, etc.), find the simplest sample system that works for each use.
  - I/M: sample times less than 5 minutes
  - Research: sample times from minutes to hours
- "Piggyback" on other projects to collect comparative PM data in parallel (with aim of developing correlations between PM systems).

parSYNC Test Plan

1. Start as simple, light, low-power as possible
   - Unconditioned sample, unheated components, etc.
2. Find the limits of the set-up during testing
   - Test in parallel with "accepted" PM systems until the data show obvious problems
3. Analyze the results to establish correlations
4. Incrementally improve the sample train for longer testing with acceptable results
5. Repeat steps 2, 3, & 4.

System Design Constraints

- Minimize particulate drop-out
  - Static
  - Cold spots (thermophoresis)
  - Liquid water
- Maximize simplicity
  - Ease & speed of installation
  - Ease of service

Initial Options for System Design

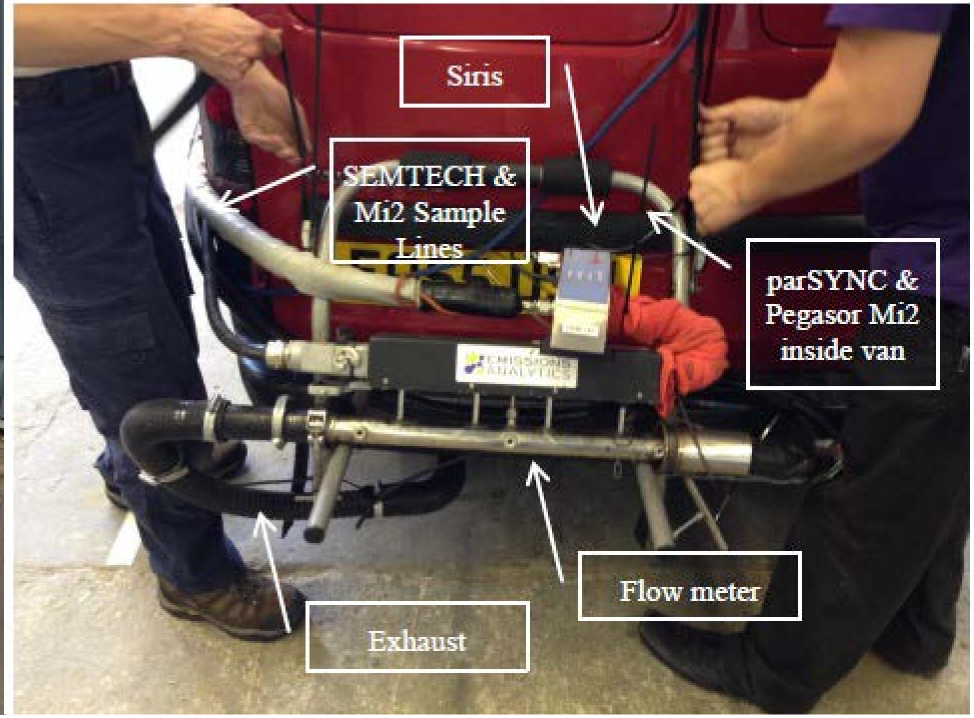
- Sample tubing materials
  - Flexible inert (e.g., PTFE, Tygon)
  - Flexible anti-static (e.g., conductive)
  - Stainless
- Sample conditioning
  - None
  - Temperature regulation
  - Gaseous water removal (Nafion system)
  - Dilution at sample site

Testing So Far

Vehicle Description	Aftertreatment	Parallel PM Measurement	Test Protocol
1. Water Truck: Ford L9000, diesel, Cummins M11, rebuilt 2007	None	MAHA MPM4 *(red scattering)*	Random snap idle
2. Fork Lift: Komatsu, LPG, 2003	Oxydation catalyst	Wager Opacimeter *(green opacity)* MAHA MPM4 *(red scattering)*	Random snap idle
3. Light-Duty Panel Truck: Vauxhall, diesel, 1.25 L, 2003	None	Process Metrix SIRIS *(red, dual-angle scattering)* Pegasor Oy Mi2 *(charge loss)*	In-use: urban short route
4. Class 8 Tractor-Trailer: Freightliner, diesel, Detriot Diesel DD15, 2014	DOC, DPF, SCR	Pegasor Oy Mi2 *(charge loss)* TSI DustTrak *(scattering)* TSI CPC *(condensation count)*	In-use: long-haul

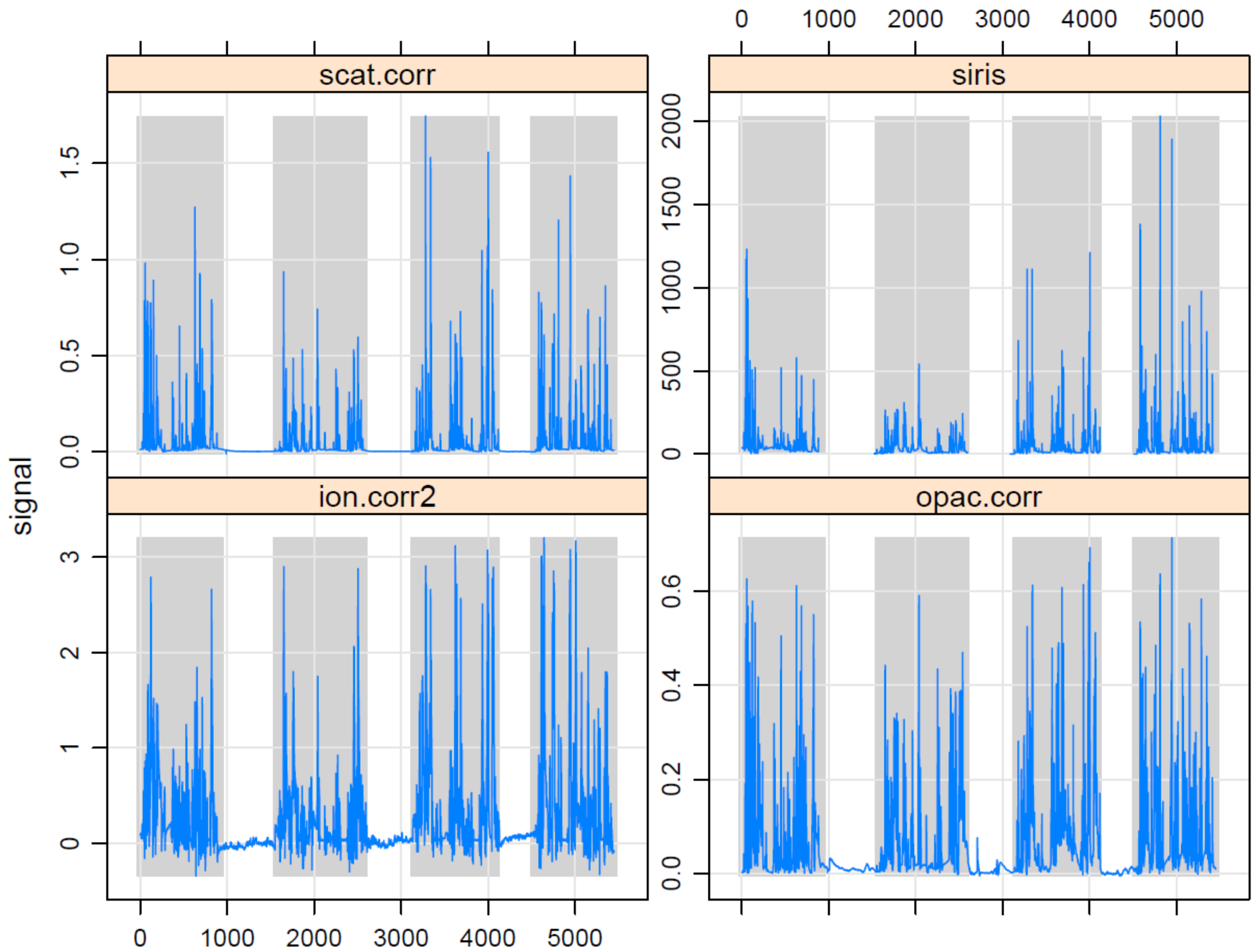
infoWedge

Vauxhall Combo Panel Truck Example



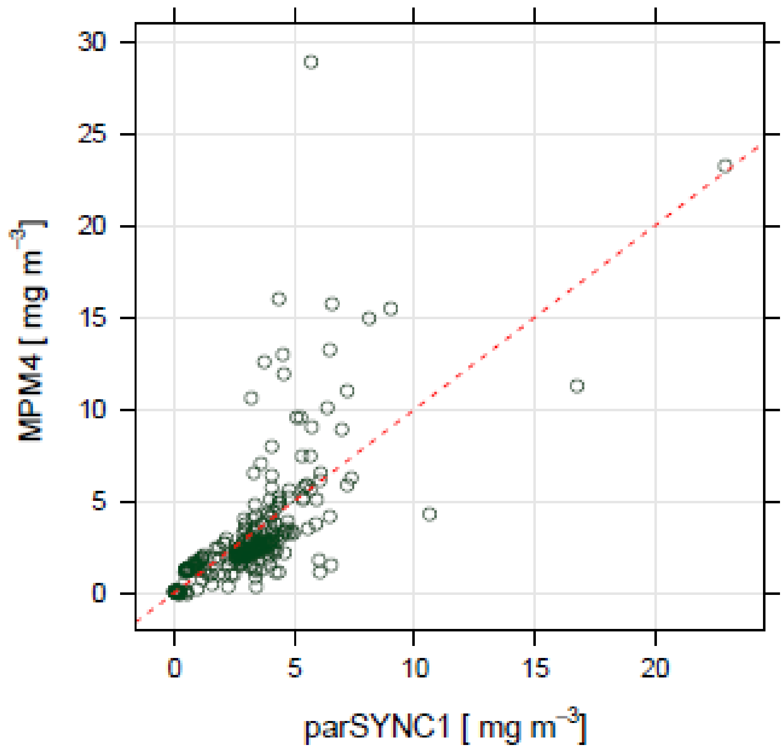
- 1.2 L diesel, no aftertreatment, >400 kg payload.
- Short, urban drive route (Banbury, UK) repeated 4 times with data & instrument check between each.

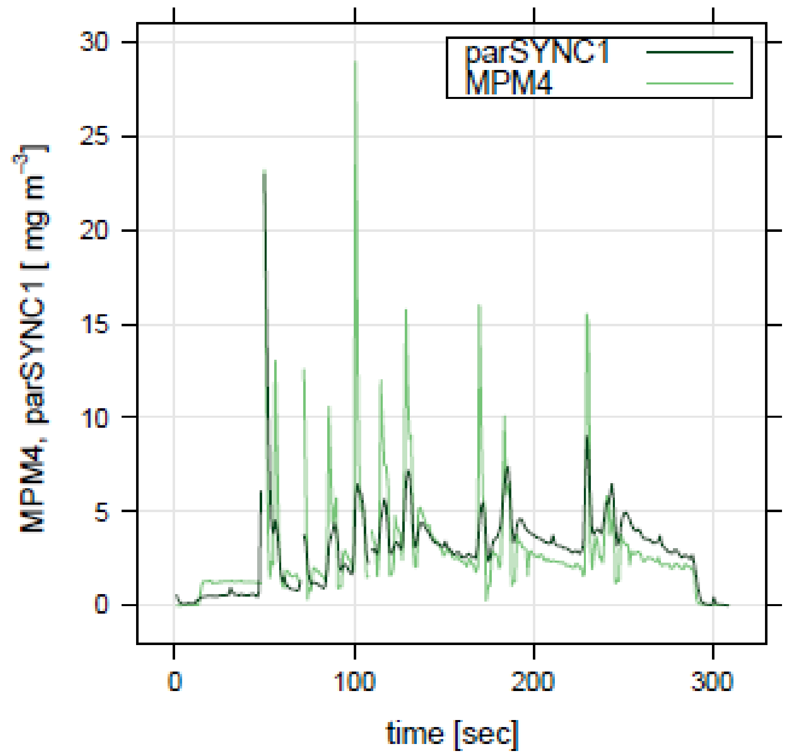
PM Signal Comparisons



infoWedge

parSYNC Correlation to Green Opacity (1/3)





Agreement MPM4 / parSYNC® scattering (parSYNC1) R ≈ 0.75

(MPM4 / Opacity (parSYNC2) R ≈ 0.75)

(MPM4 / Ionization (parSYNC3) R ≈ 0.42)

infoWedge

parSYNC Correlation to Green Opacity (2/3)

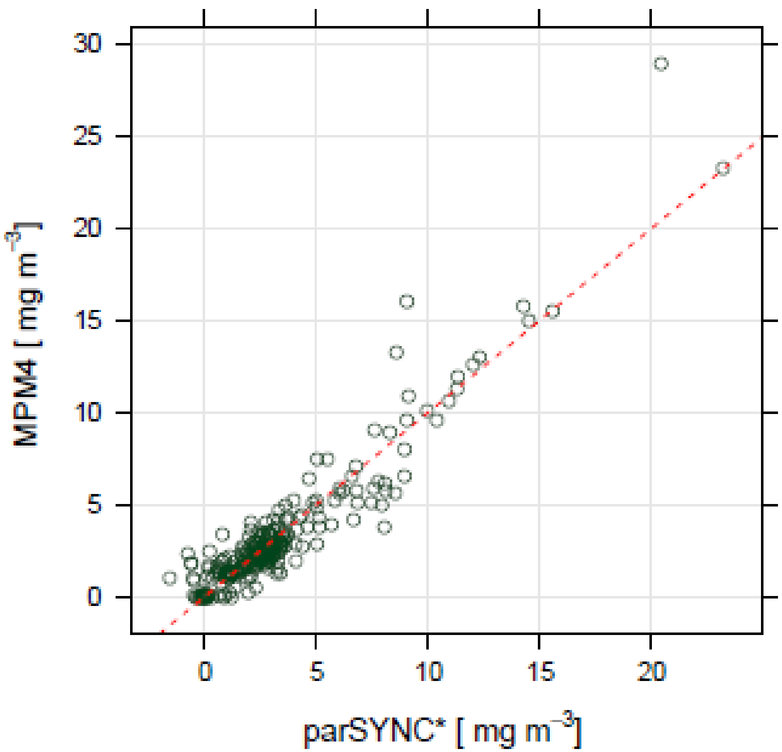
The current multiplex function (parSYNC*) attempts to

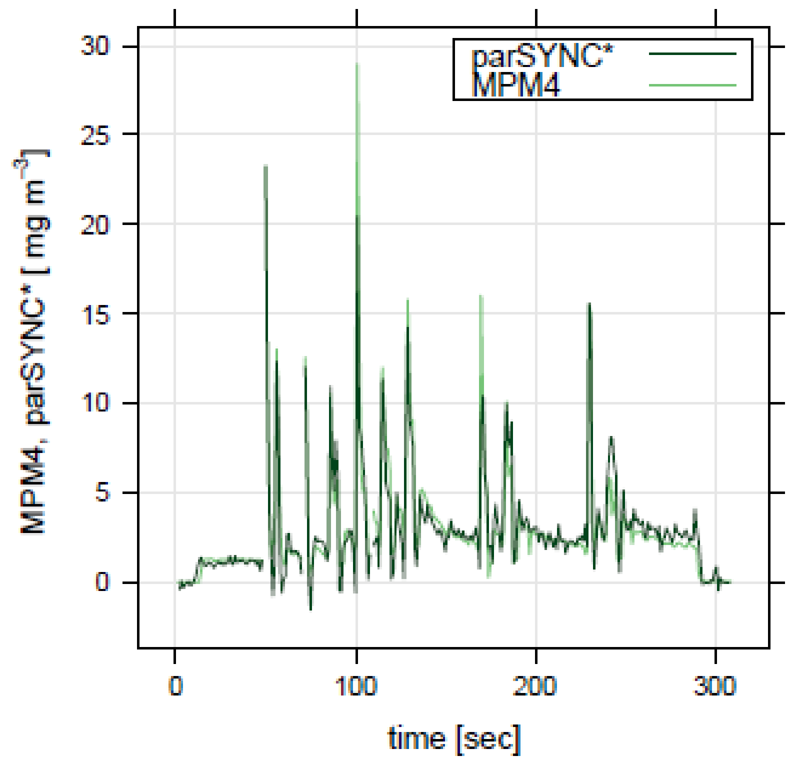
- Map the cross/non-cross correlation behavior of individual sensors onto the reference method *robustly*
- Correct for the different time resolutions of the sensors and reference method

Three Sensor Fit

$$\begin{aligned} \text{parSYNC*} = [\text{MPM4}] = \; & f(\text{parSYNC1}_{t=-1,0,1}) + \\ & f(\text{parSYNC2}_{t=-1,0,1}) + \\ & f(\text{parSYNC3}_{t=-1,0,1}) \end{aligned}$$

parSYNC Correlation to Green Opacity (3/3)





Agreement MPM4 / parSYNC® multiplex sensor $R \approx 0.92$
(two sensor, scattering and opacity, parSYNC* model)

infoWedge

Going Forward

- Continue the iterative process of sample train improvement and parallel data collection
  - develop robust sample handling systems for each end use
  - Develop multiplex correlations with other PM measurement system, both mass and number

The Authors Thank

3DATX: for supplying equipment, operation training and fast responses to questions

Emissions Analytics: for extensive support during the UK tests

Comptech Racing Engines and Buckeye Union ISD: for supplying test vehicles

Many others: who anonymously supplied vehicles, expertise, labor, and parallel data.

infoWedge

Q? ➔ A!

Contact:

Andrew Burnette
andrew.burnette@infowedge.com
916.760.8474

Dr. Karl Ropkins
k.ropkins@its.leeds.ac.uk

Dr. Gurdas S. Sandhu
gurdas@3datx.com