European Network on New Sensing Technologies for Air Pollution Control and Environmental Sustainability - *EuNetAir*

COST Action TD1105

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AIR QUALITY IN SUBWAY SYSTEMS

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Background

- Citizens spend a considerable amount of daily time commuting
- Particulate matter (PM) in numerous subway systems generally higher than outdoor
- Exposure to ambient PM usually studied in outdoor stations
- Importance of personal exposure

Outline

- Exposure studied based on personal samples. Comparison with outdoor and indoor

- The Barcelona subway system
  - Platforms vs inside trains
  - Factors affecting air quality
  - Air conditioning effect

- Additional studies in Athens and Oporto subway systems

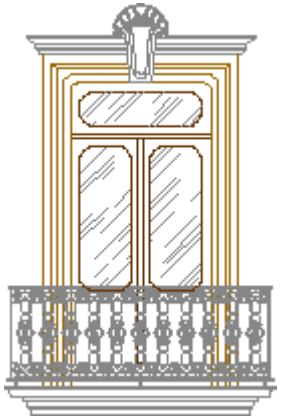
- General conclusions

Outdoor, indoor and personal exposure

- Barcelona, Spain
- 1 year measurements
- 54 pregnant women
- Rounds of two consecutive days
- $PM_{2.5}$
- Teflon and quartz filters
  - -- PAHs
  - -- Black smoke (BS)
  - -- Major and trace elements

indoor

outdoor



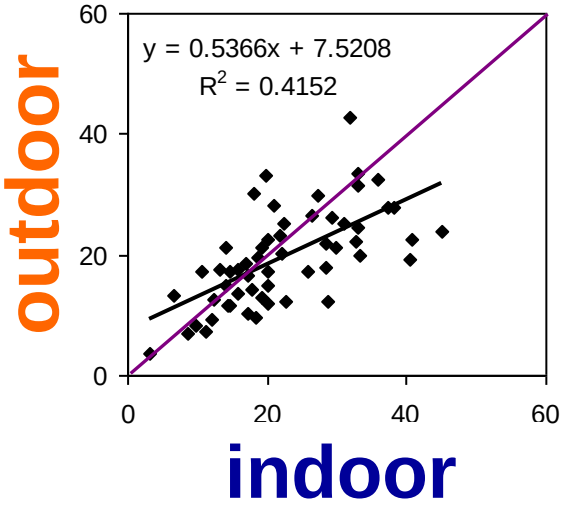
personal

Minguillón et al., 2012. Atmos. Environ.

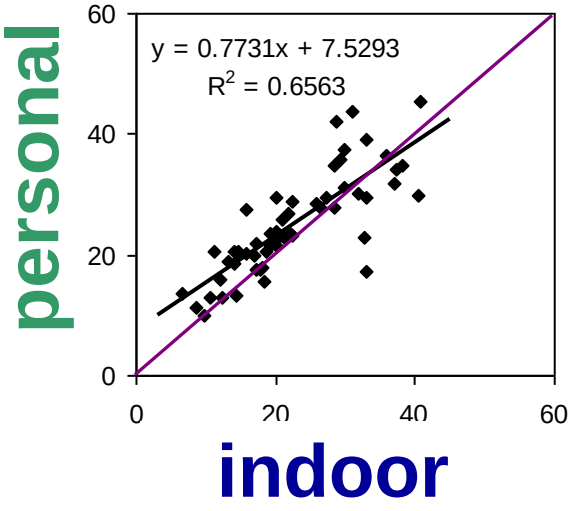
Indoor vs outdoor vs personal

- $PM_{2.5}$ (µg/m^3): personal > indoor > outdoor

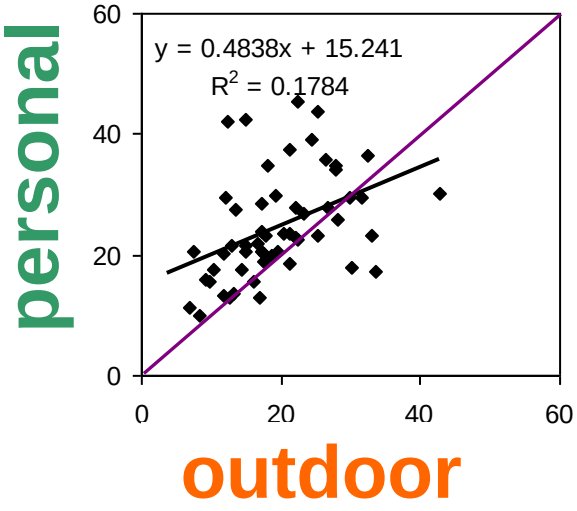
moderate



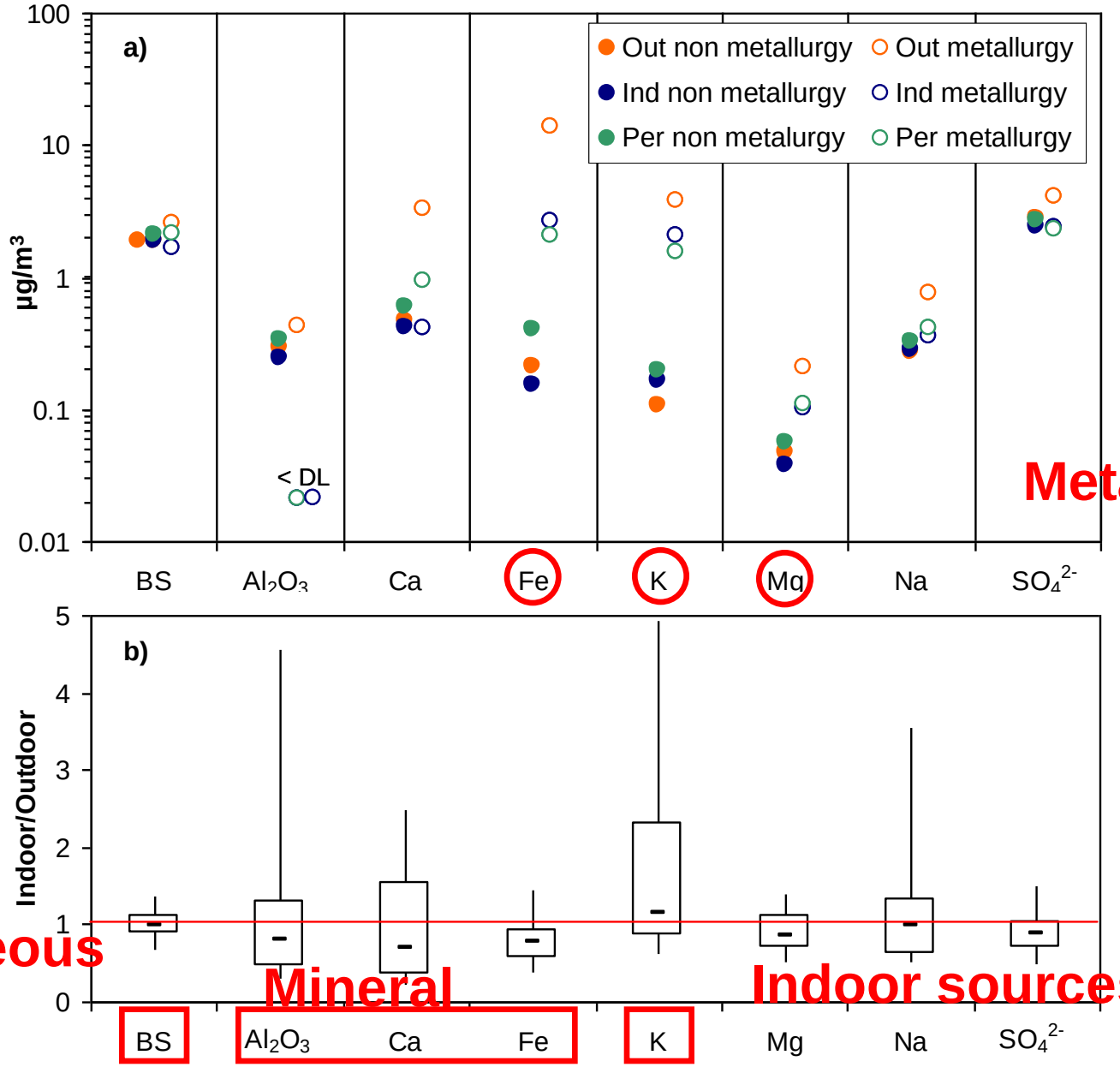
relatively strong



poor



Major components



Metallurgy

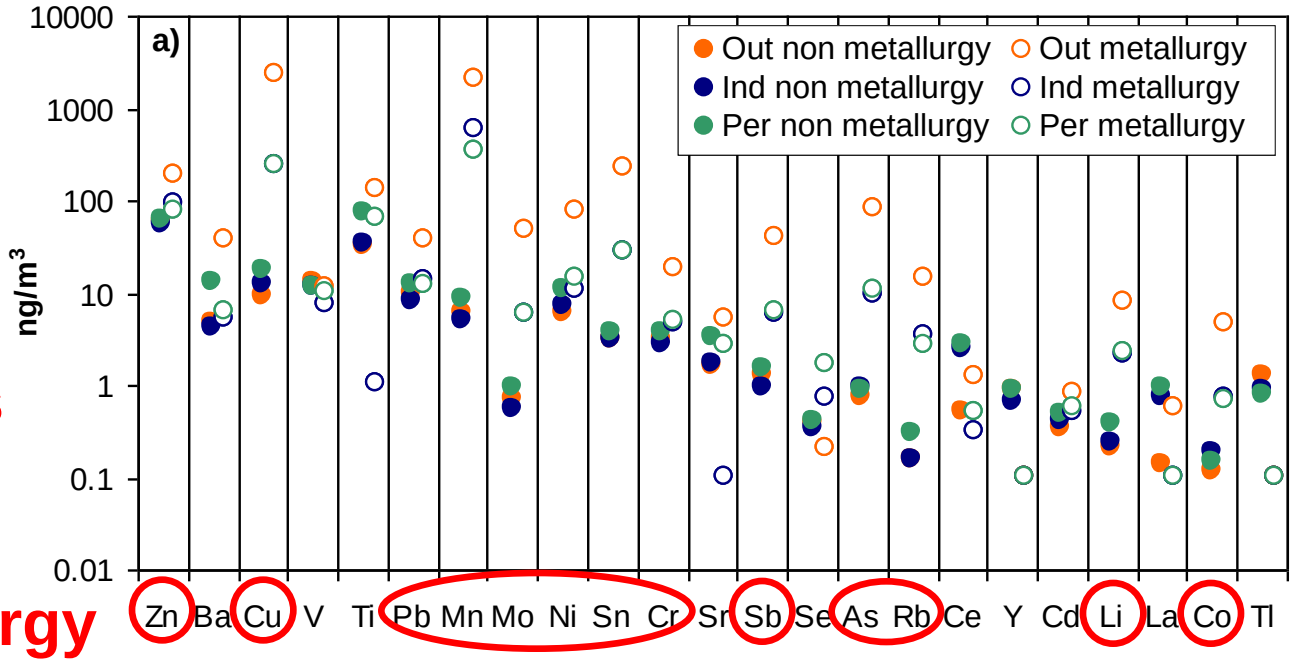
Very homogeneous

Mineral

Indoor sources

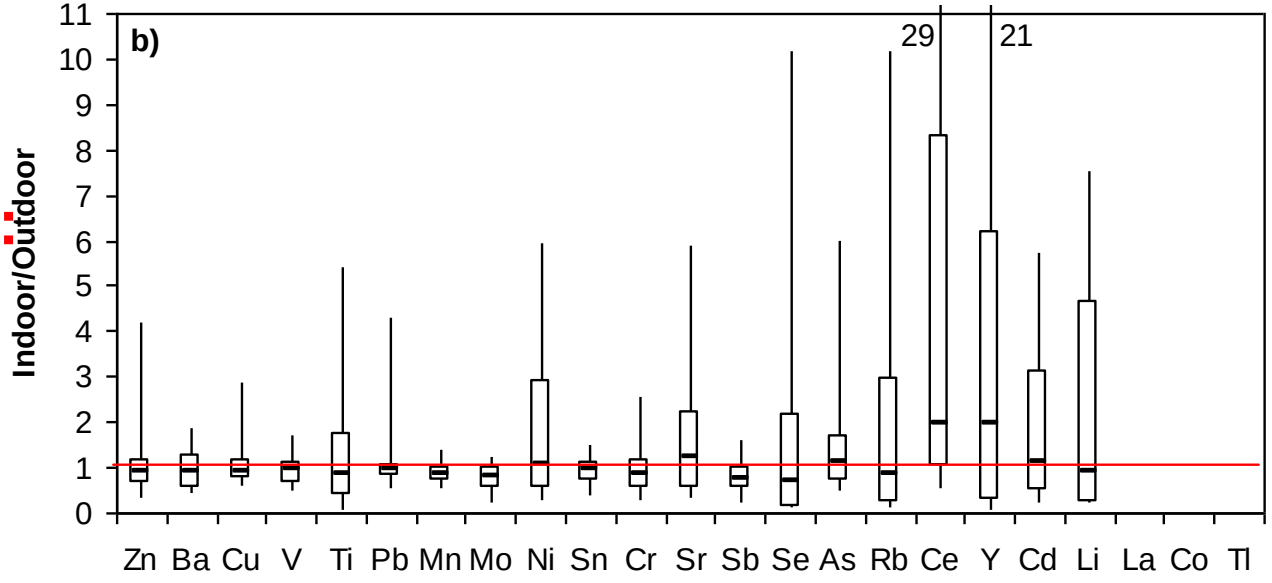
Trace elements

On average, similar indoor, outdoor and personal concentrations



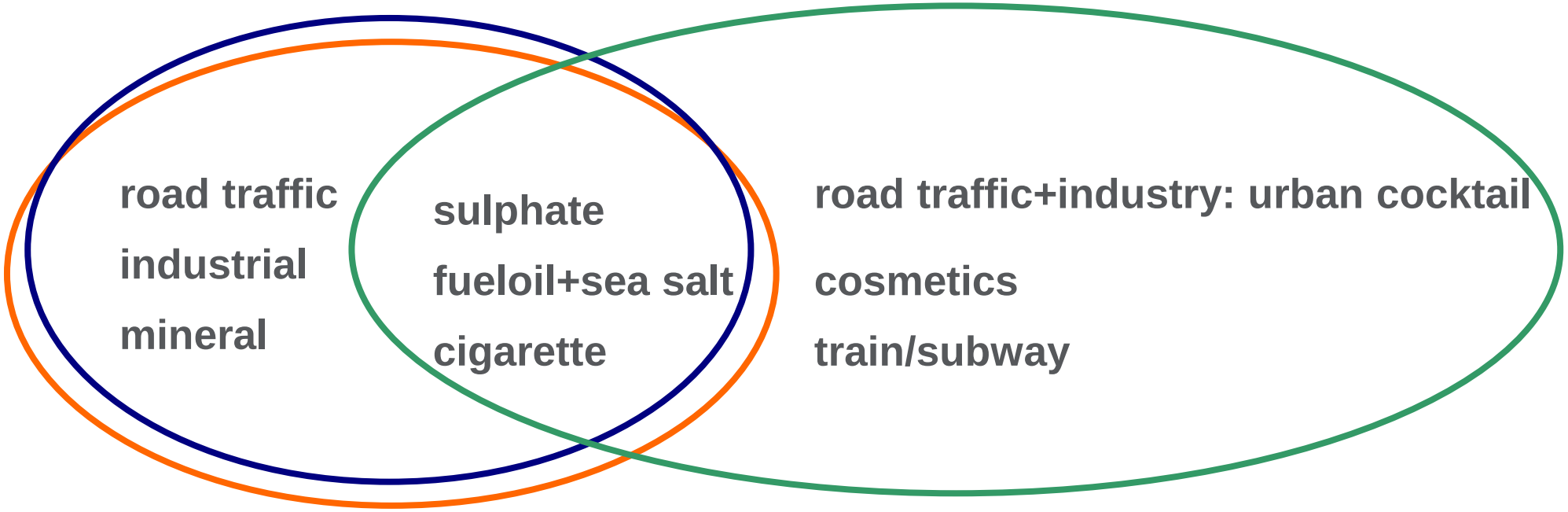
Metallurgy

Wide range indoor/outdoor: variable infiltration and sources



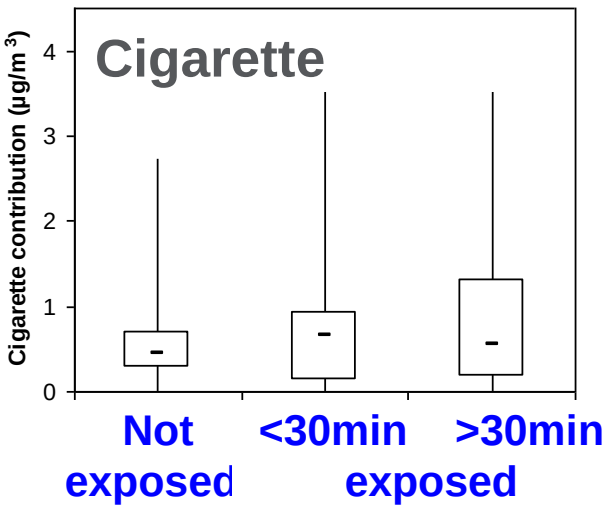
Source apportionment

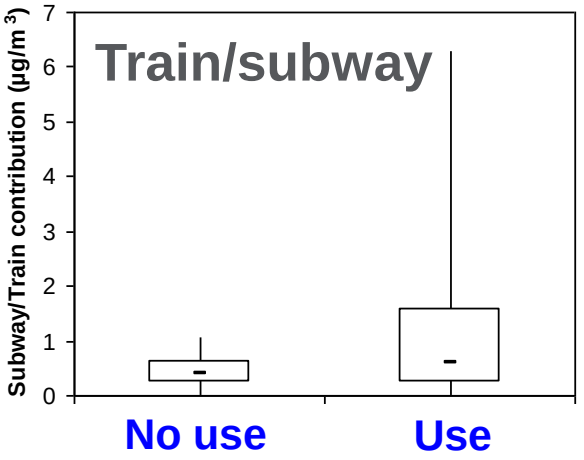
Positive Matrix Factorization (PMF)

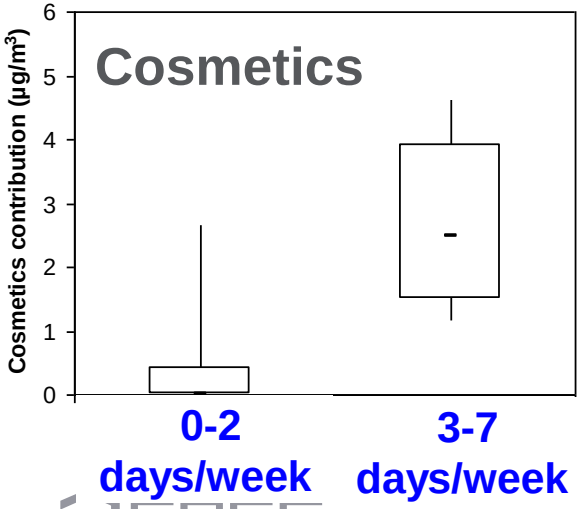


- Cosmetics: Ca, Li, Ti and Sr and absence of Al
- Train/subway: Fe, Mn, Cu and Ba

Contribution for personal samples







Not dependent on the time spent in train.

Highest exposure at the platforms

Barcelona subway campaign

- Four underground stations with different designs
- One month measurements at each station in two seasons




DustTrak (PM_{10}, $PM_{2.5}$ and PM_1)

High volume sampler PM2.5

Indoor Air Quality analyser (CO_2, CO, T, RH)

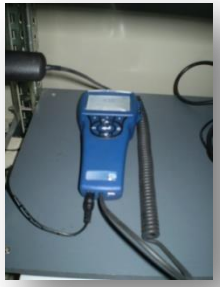
Martins et al., 2014. Sci. Total Environ.

Barcelona subway campaign

- Real-time measurements at 24 stations, from six subway lines (4 stations/line)

- Inside the trains measurements

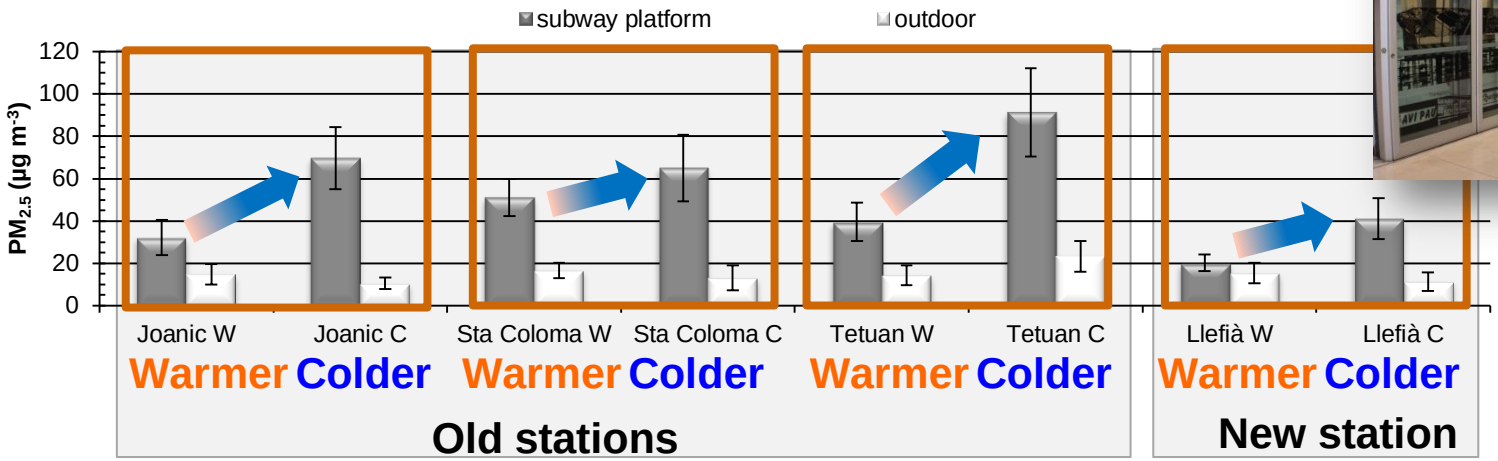
L2 L1 L10 L3 L4 L5



Indoor Air Quality analyser (CO_2, CO, T, RH)

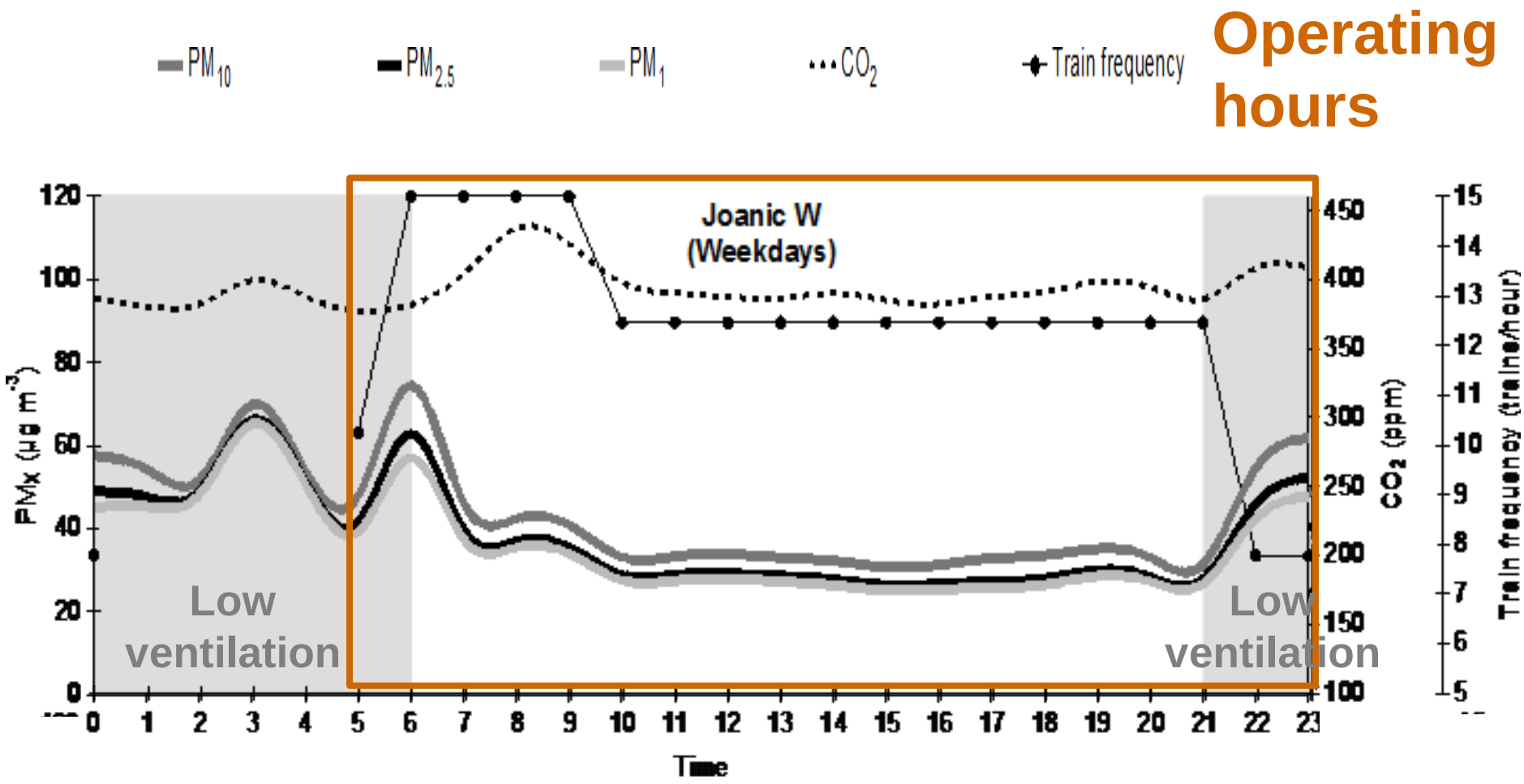
DustTrak (PM_{10}, $PM_{2.5}$ and PM_1)

Barcelona subway campaign

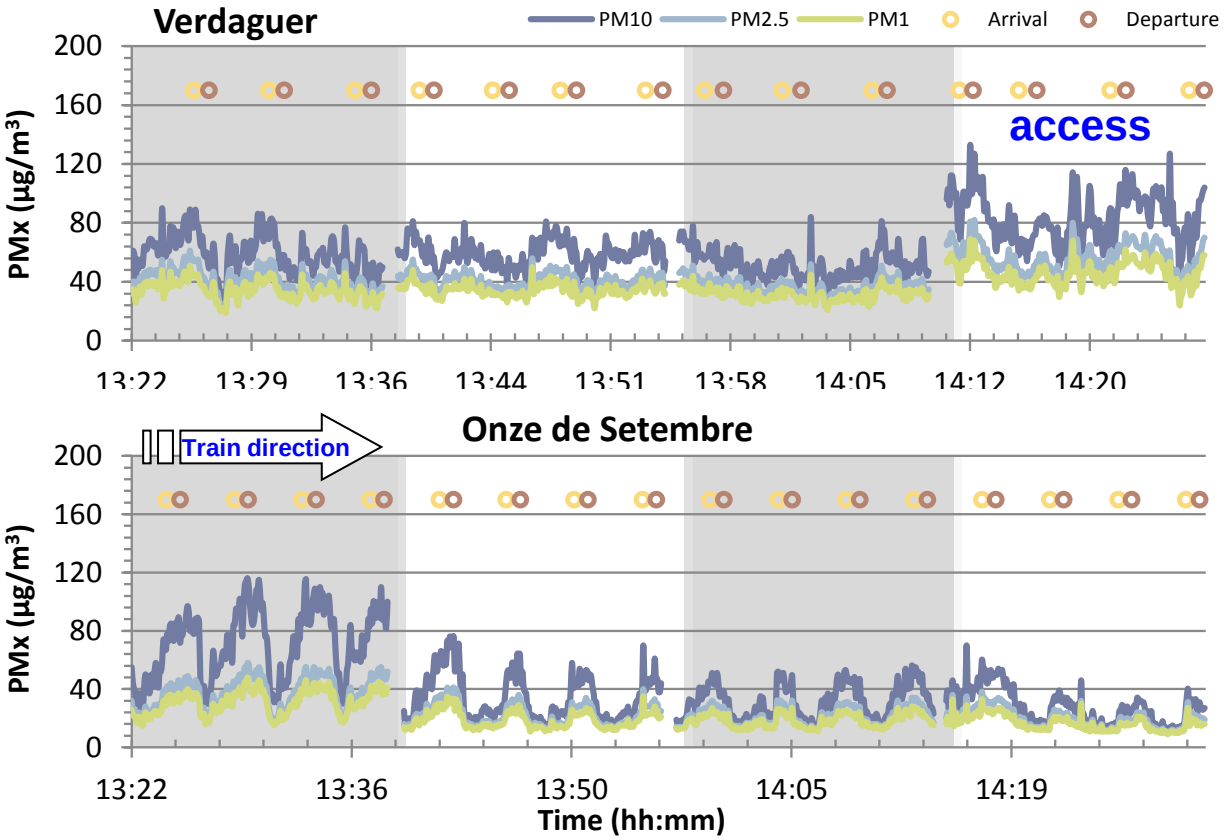


- $PM_{2.5}$ concentrations were 1.3 – 6.7 times higher on the platforms than outdoors.
- PM generated within subway system (abrasion and wear of rail tracks, wheels and braking systems).
- PM lower in the warmer period (strong ventilation) than in the colder (weak ventilation).
- PM concentrations lower in the new station than the old stations (due to platform screen doors, less train frequency, better ventilation).
- Old stations: 18-154 µg/m^3
- New stations: 13-61 µg/m^3

Intra-day variation



Variation along the platform



- Higher PM near passenger's access due to turbulence (created by commuters and by air flow into and out of the station)

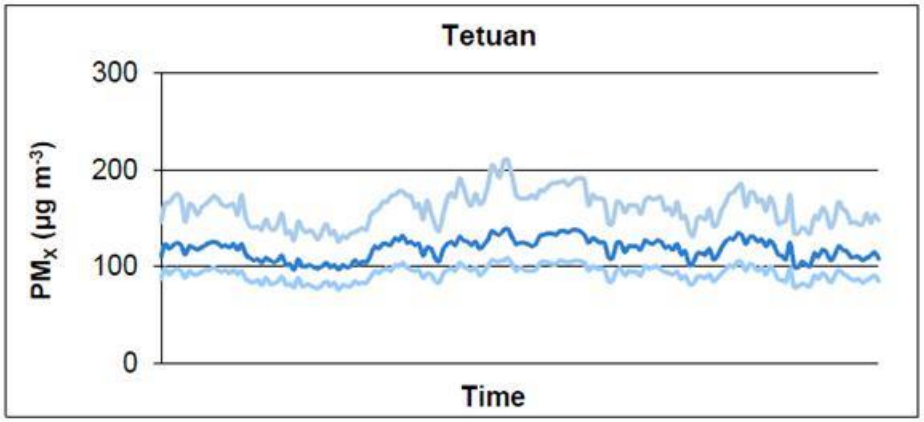
- PM increase when the train enters (pushes polluted air from tunnel), and decrease when it departs.

- Higher PM near the train entry point due to turbulence caused by the trains.

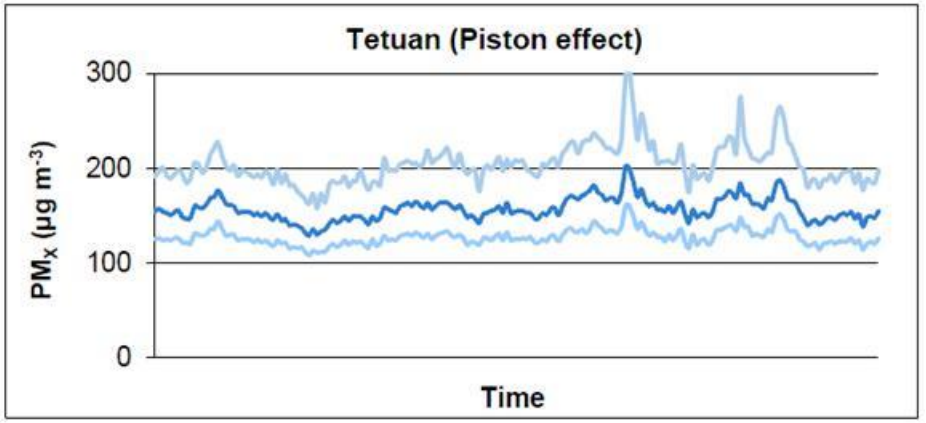
- PM decrease with train direction.

Tunnel ventilation effect

Normal conditions

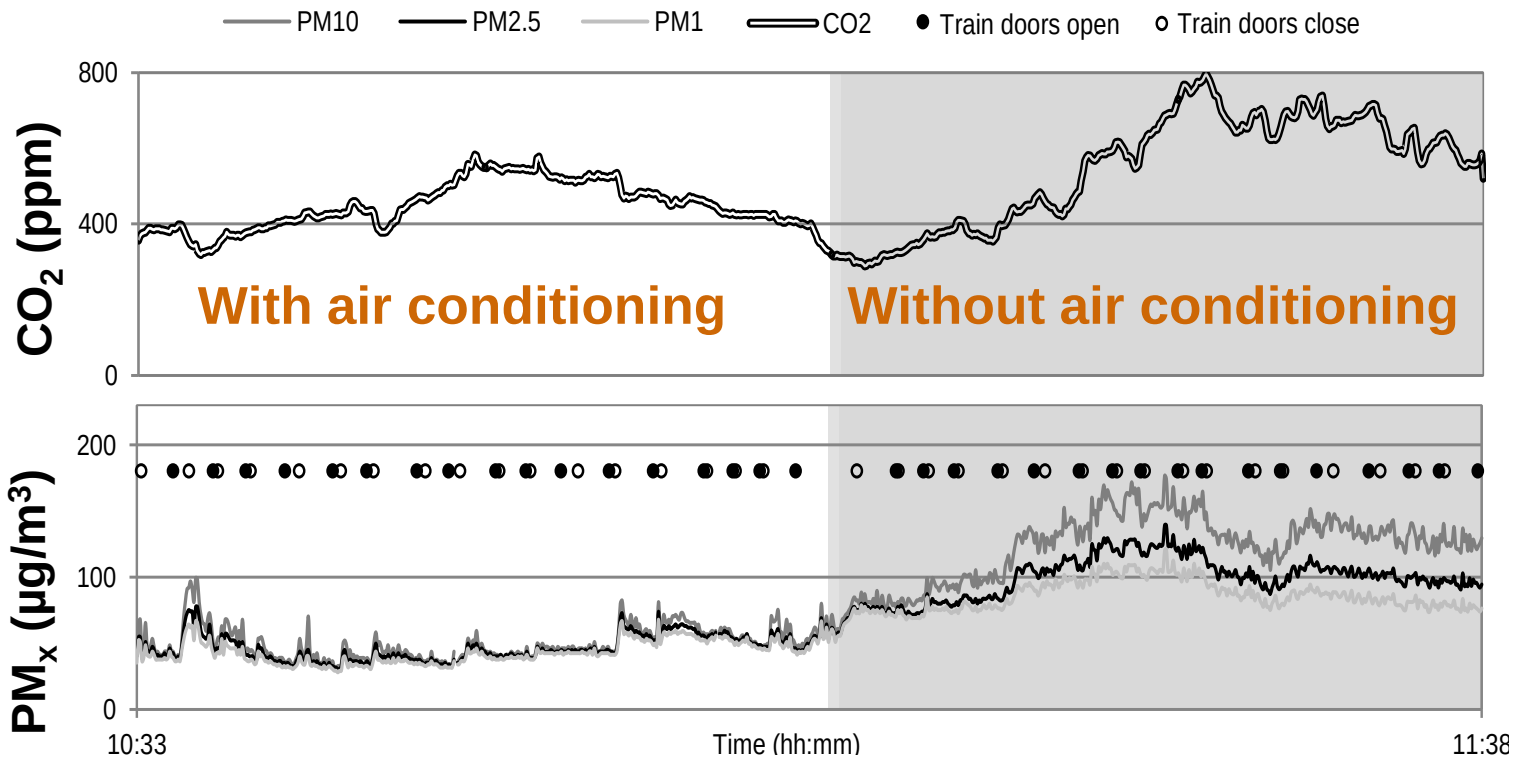


Tunnel ventilation off



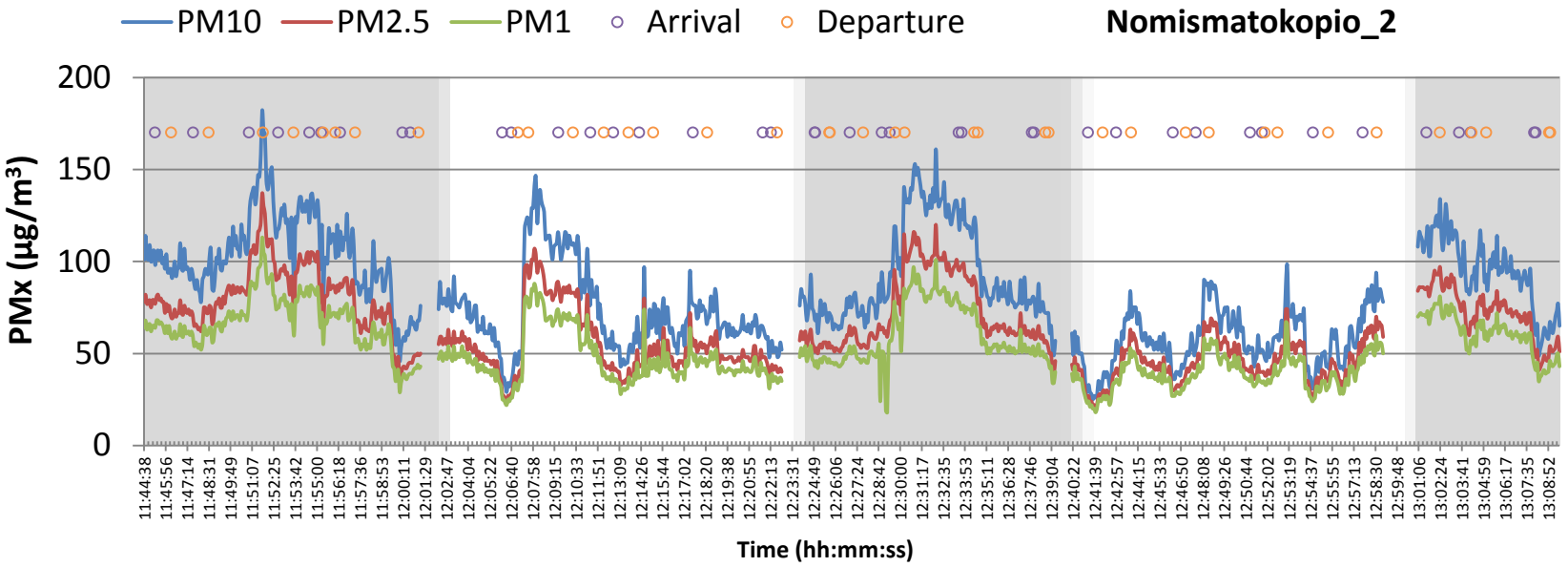
- Higher PM concentration

Inside the trains



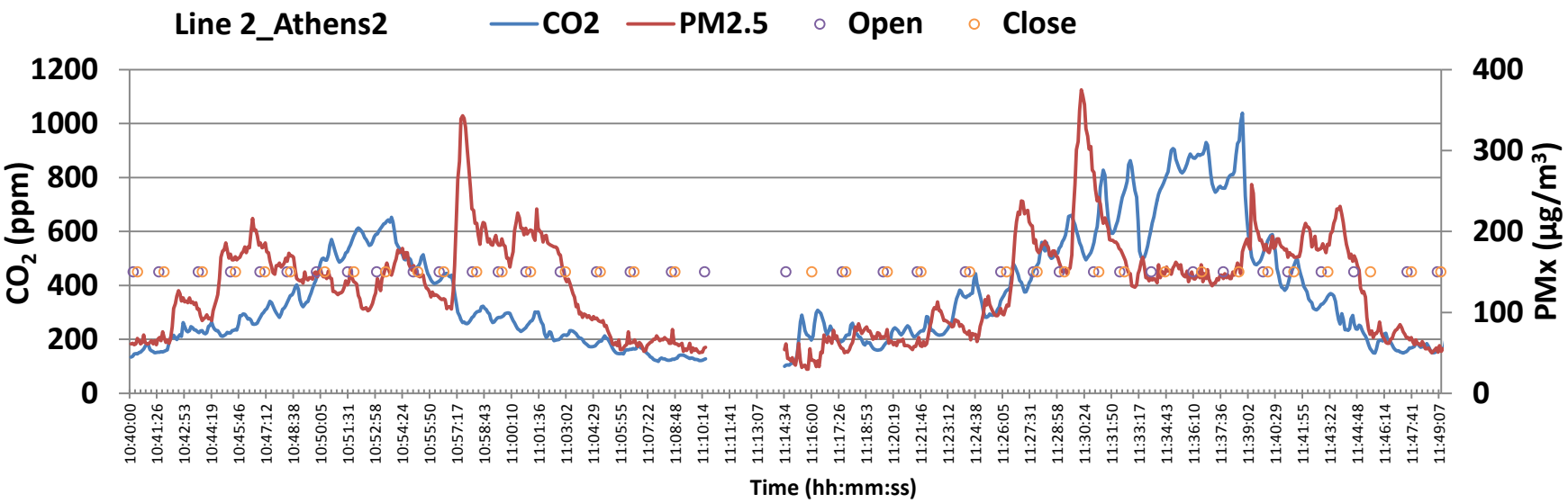
- CO_2 shows max number of people in the middle of the line with and without air conditioning
- Lower PM concentration (-47%)
- Finer PM

Athens metro



Platform average 61 µg/m³

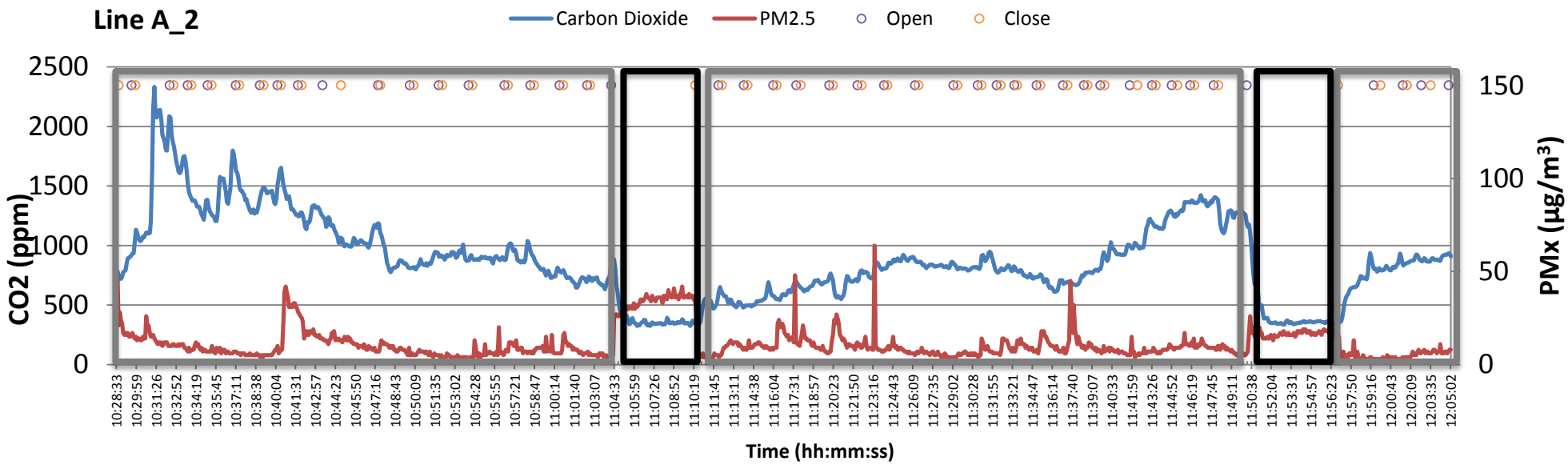
Athens metro



Inside train average 125 µg/m^3

Concentrations higher between stations, due to influence of tunnel air (open windows)

Oporto metro



Inside trains

Platform

Inside trains

Platform

Conclusions

- $PM_{2.5}$ concentrations: personal > indoor > outdoor
- $PM_{2.5}$ correlations: outdoor-indoor moderate, outdoor-personal poor and indoor-personal relatively strong
- The wide range of indoor/outdoor ratios: variations in infiltration efficiencies and sources among homes
- Sources: secondary sulphate, fueloil+sea salt, mineral (only indoor and outdoor), cigarette, road traffic, and industrial
- Two specific personal sources: cosmetics and train/subway

Conclusions

- PM concentrations on platforms higher than outdoor
- PM concentrations 50% lower with platform screen doors than the conventional system
- Tunnel ventilation affects platform air quality
- Concentrations inside the trains lower than in the platforms
- The use of air conditioning reduced PM concentrations in 47%
- Athens: PM concentrations inside the trains increase considerably when windows are open (Athens)
- Oporto: low PM inside the trains due to good isolation

THANK YOU FOR YOUR ATTENTION

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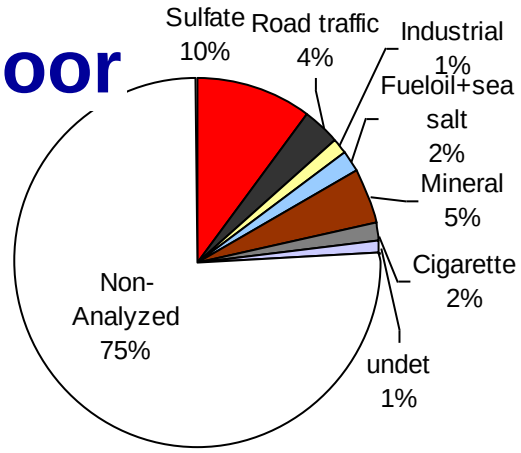
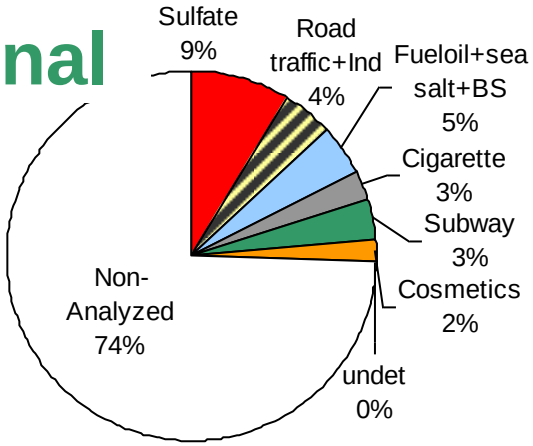
Source apportionment

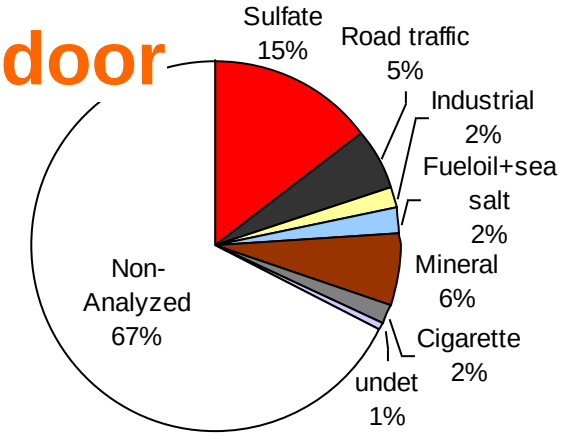
Indoor



Personal



Outdoor



Outdoor completed