



**INSTITUTO DE  
ASTRONOMIA,  
GEOFÍSICA  
E CIÊNCIAS  
ATMOSFÉRICAS**



Universidade de São Paulo

# What do we know about air pollution in Sao Paulo?

Maria de Fatima Andrade

Departamento de Ciências Atmosféricas



# Outline of the presentation

- Air Quality characterization of MASP (Metropolitan Area of Sao Paulo).
  - Sources
  - Time evolution in the last 30 years of regulated pollutants
  - Main Results

# Metropolitan Area of São Paulo - MASP



- MASP= São Paulo city + 38 cities
- 20 million inhabitants
  - 7,2 million vehicles
  - 2000 significative industrial plants
  - 8000 km<sup>2</sup>



Meteorological conditions: worst events in winter  
(dry season with radiative inversions)

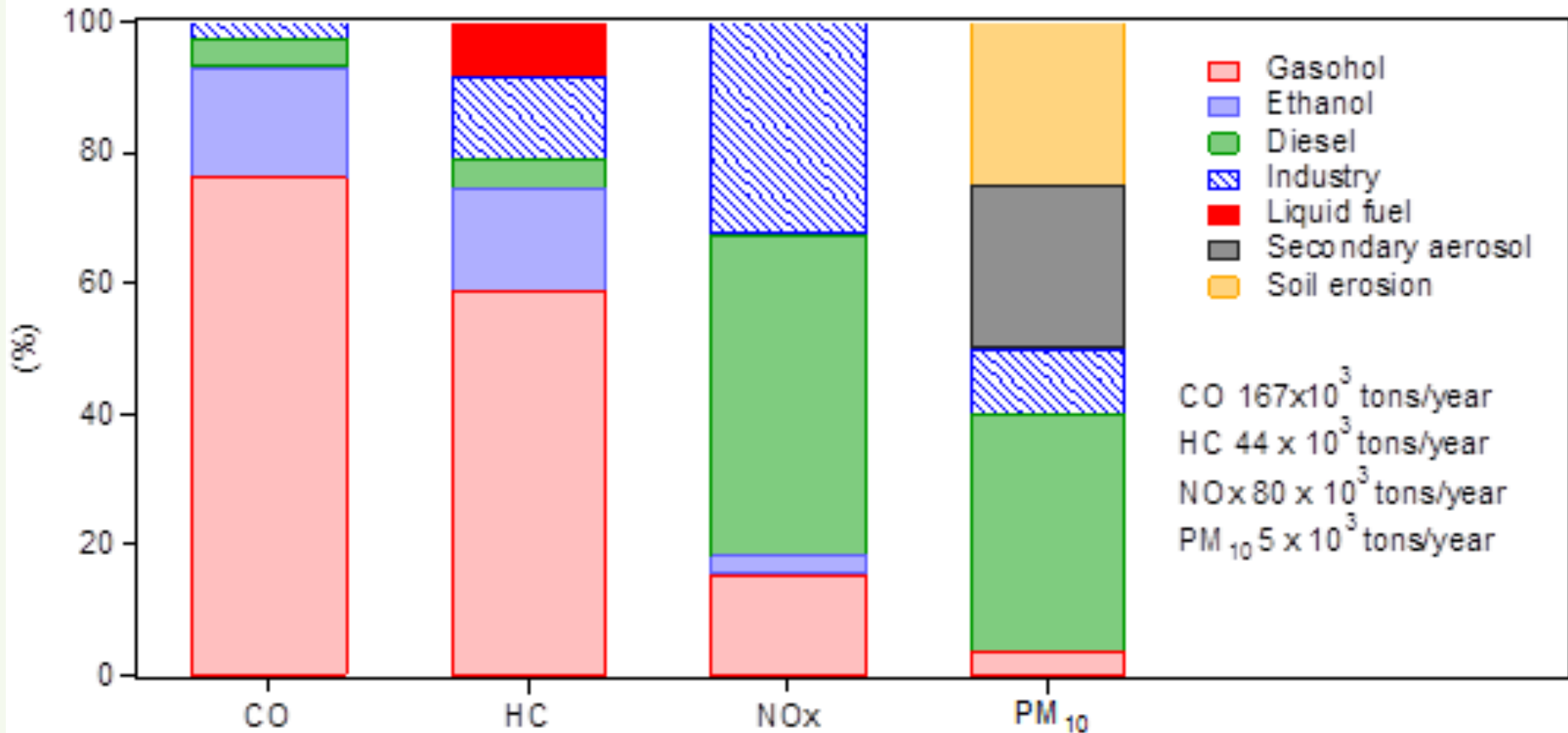


# Characterization of the air Pollution Problem



New Directions: from biofuels to wood stoves: the modern and ancient air quality challenges in the megacity of São Paulo. Atmos. Environ., 2016

State official source inventory for the year of 2016, in the Metropolitan Area of Sao Paulo, in tons/year (CETESB, 2017)



Source: Air quality in the megacity of Sao Paulo: evolution over the last 30 years and future perspectives. Atmos. Environ., 2017

MASP (Metropolitan Area of São Paulo )

Population:~ 20 million inhabitants.  
Area: 8511 km<sup>2</sup>

Vehicle fleet: 7 million passenger and commercial vehicles

85% light-duty vehicles (LDVs)

3% heavy-duty diesel vehicles (HDVs)

12% motorcycles

31 % of LDVs use gasohol (75% gasoline +25% ethanol)

2 % use hydrous ethanol (95% ethanol +5% water)

50 % are flex-fuel (any proportion of gasohol or ethanol)

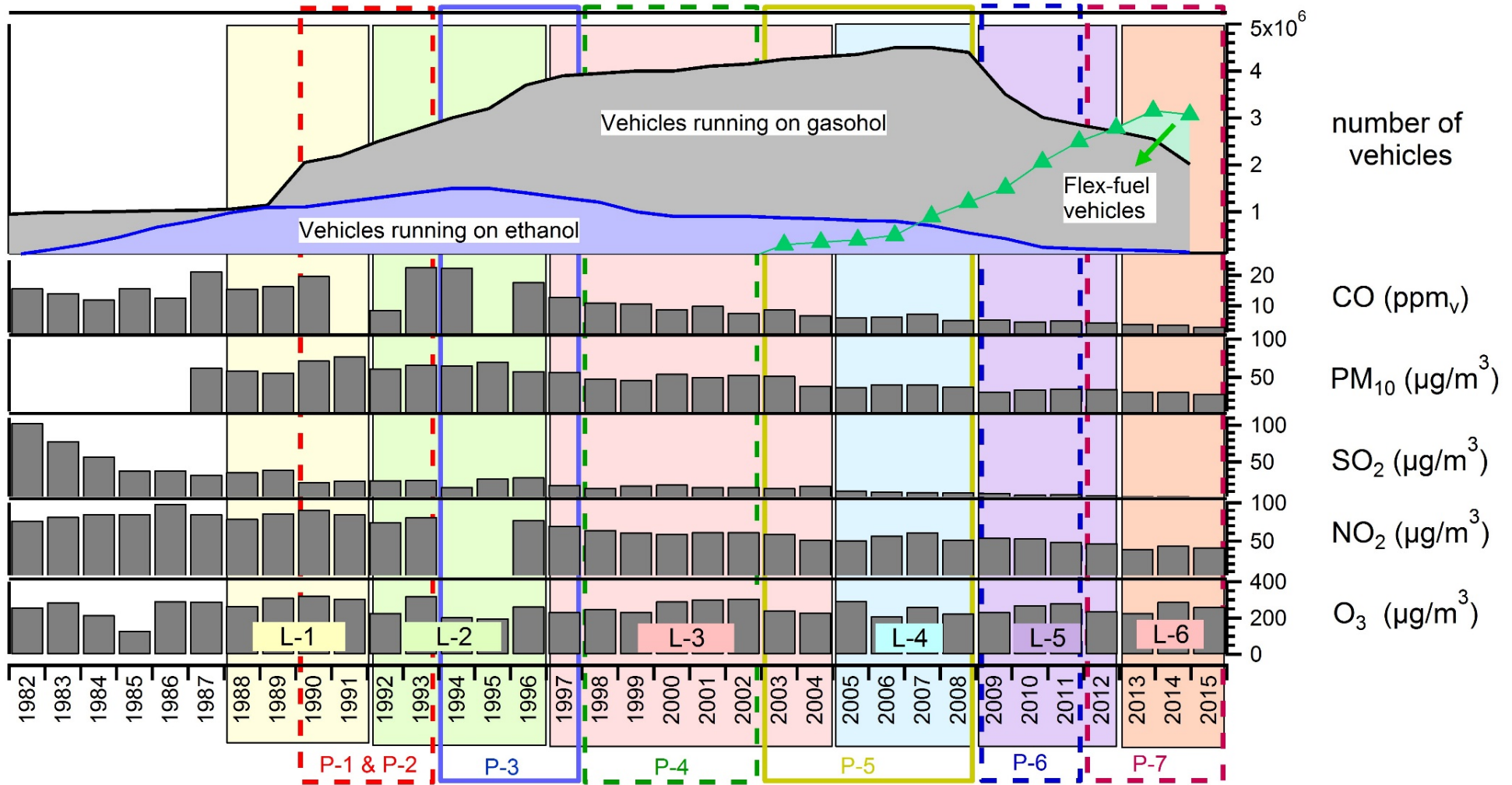
2% use diesel (diesel with 8% biofuel)



•Ethanol represents 55% of the burned fuel.

•50% of the cars have more than 10 years of use.

Evolution of the average values of CO, PM<sub>10</sub>, O<sub>3</sub>, SO<sub>2</sub> and NO<sub>2</sub> concentrations measured at the CETESB air quality monitoring stations in the MASP, number of vehicles by category (gasohol, ethanol and diesel) and the year of implementation of the PROCONVE (Program for the Control of Air Pollution Emissions by Motor Vehicles) phases.



Source: Air quality in the megacity of Sao Paulo: evolution over the last 30 years and future perspectives. Atmos. Environ., 2017



# Monthly variations in selected air pollutants in São Paulo.

Data are from the São Paulo Environmental Company CETESB, 2000–2013

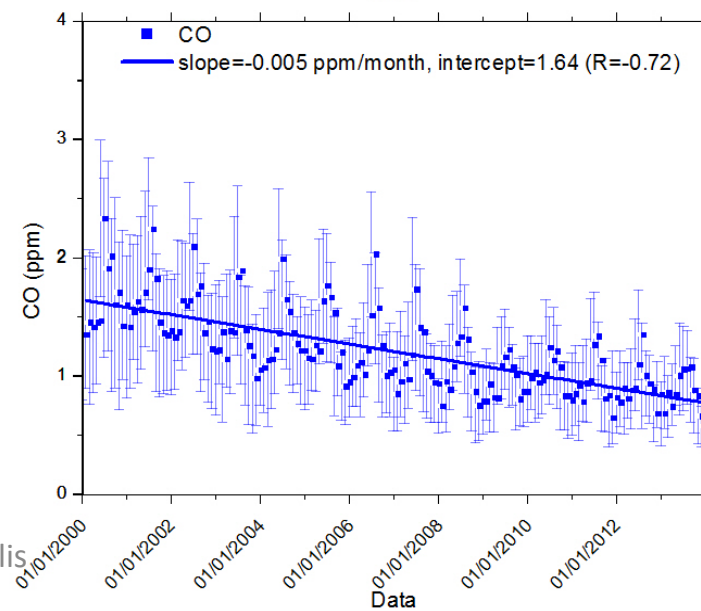
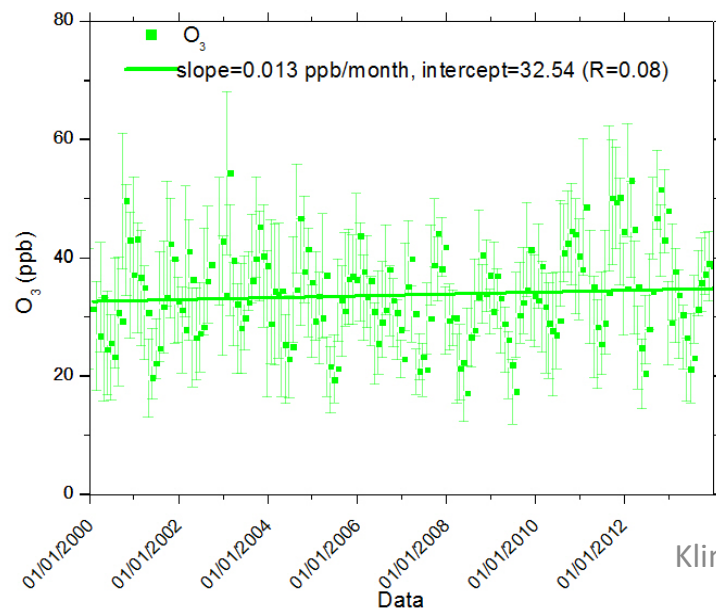
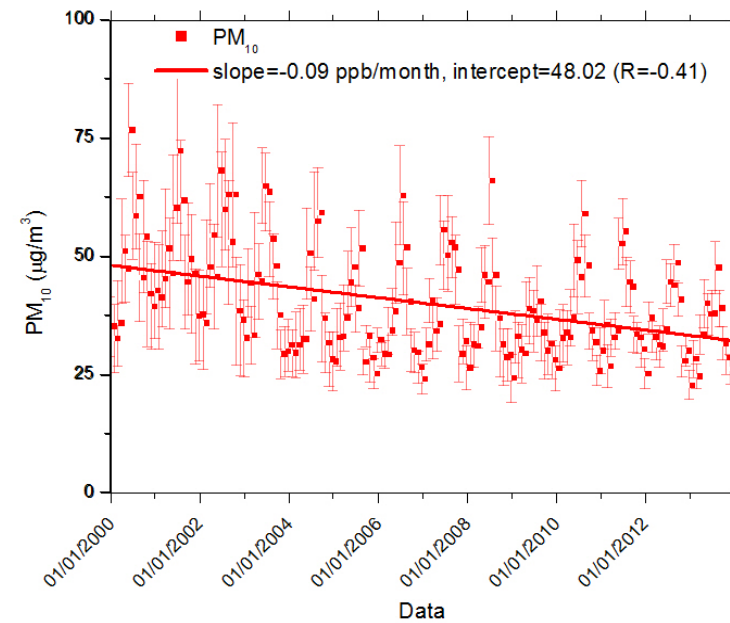
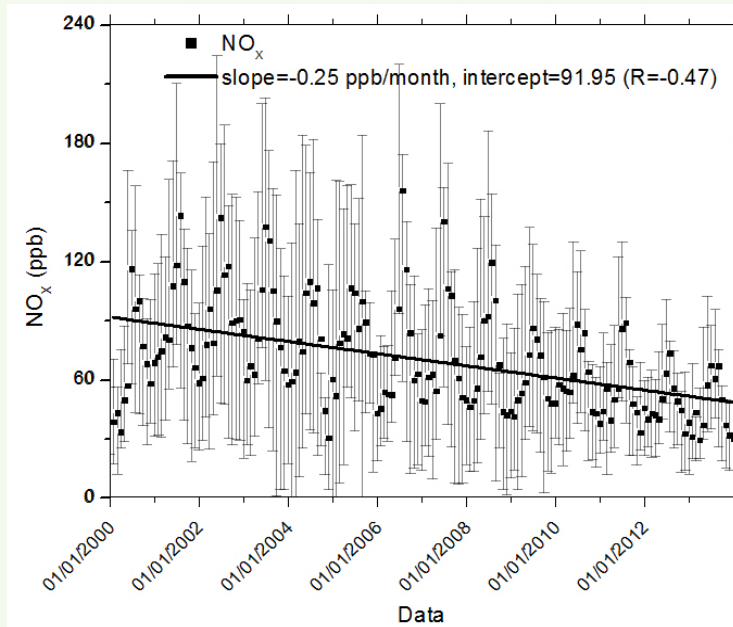
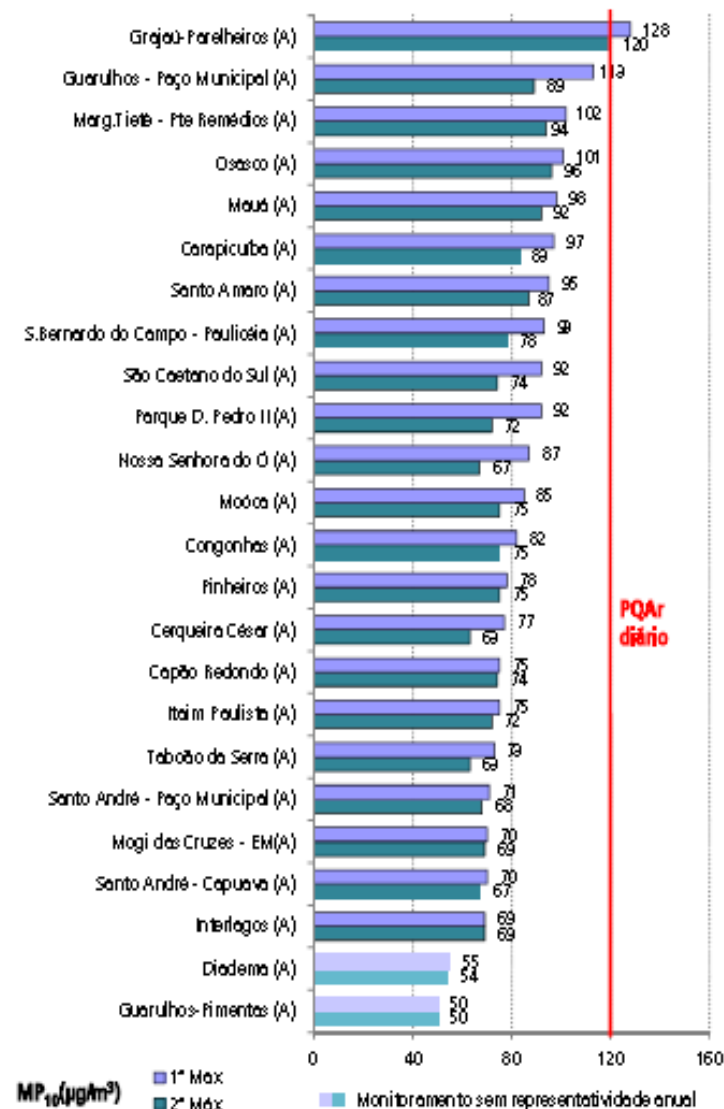


Gráfico 6 – MP<sub>10</sub> – Classificação das concentrações máximas diárias – RMSP – 2017

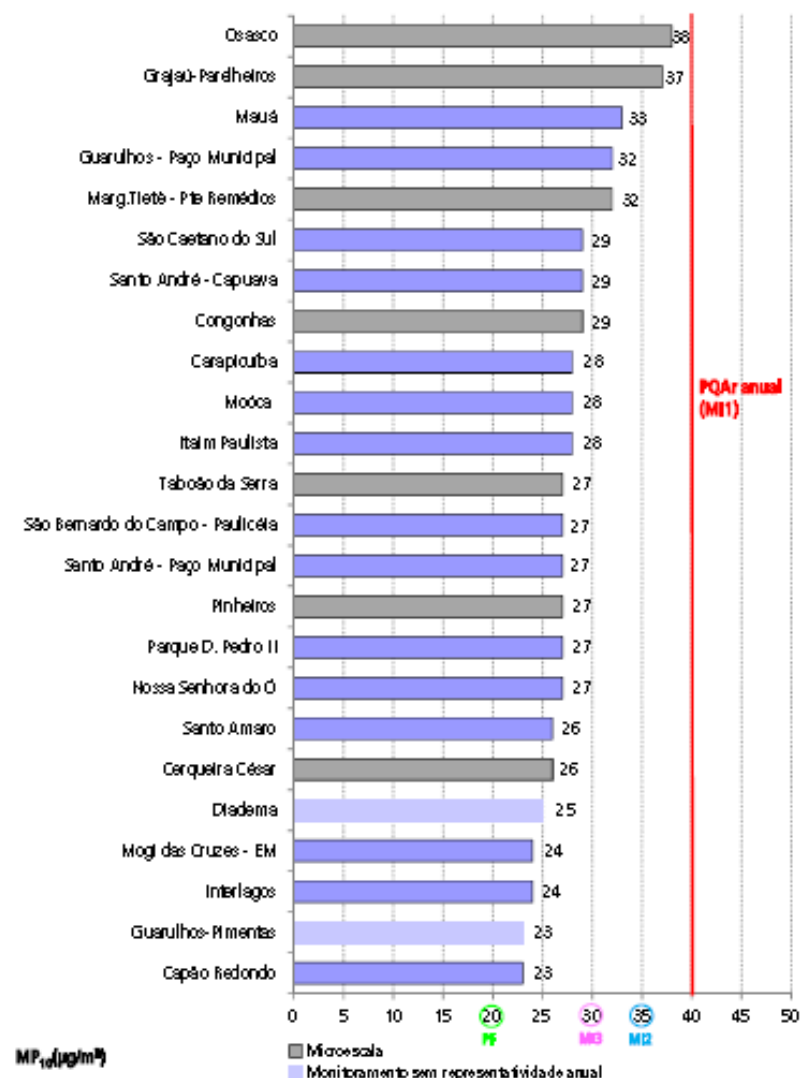


Fonte: CETESB (2018)

Nota:

Período de monitoramento: Diadema – de 01/01 a 13/08; Guarulhos-Rimentas – de 01/01 a 26/04.

Gráfico 9 – MP<sub>10</sub> – Concentrações médias anuais – RMSP – 2017

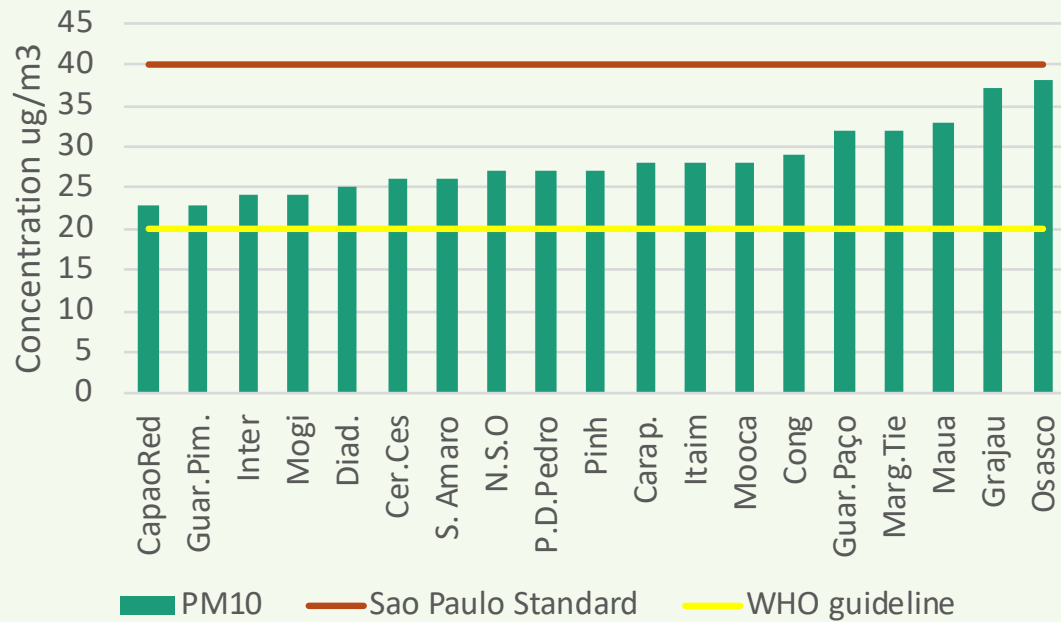


Fonte: CETESB (2018)

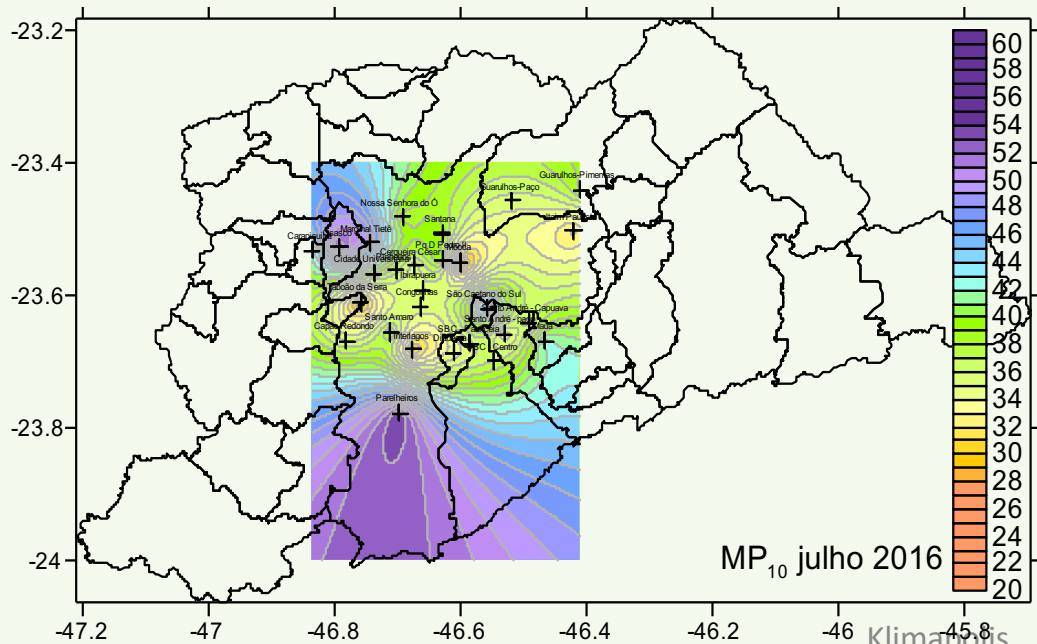
Nota:

MI1 = PQA; MI2 e MI3 = Metas Intermediárias; PF = Padrão Final, estabelecidos no Decreto Estadual nº 59.113/2013

Período de monitoramento: Diadema – de 01/01 a 13/08; Guarulhos-Rimentas – de 01/01 a 26/04.



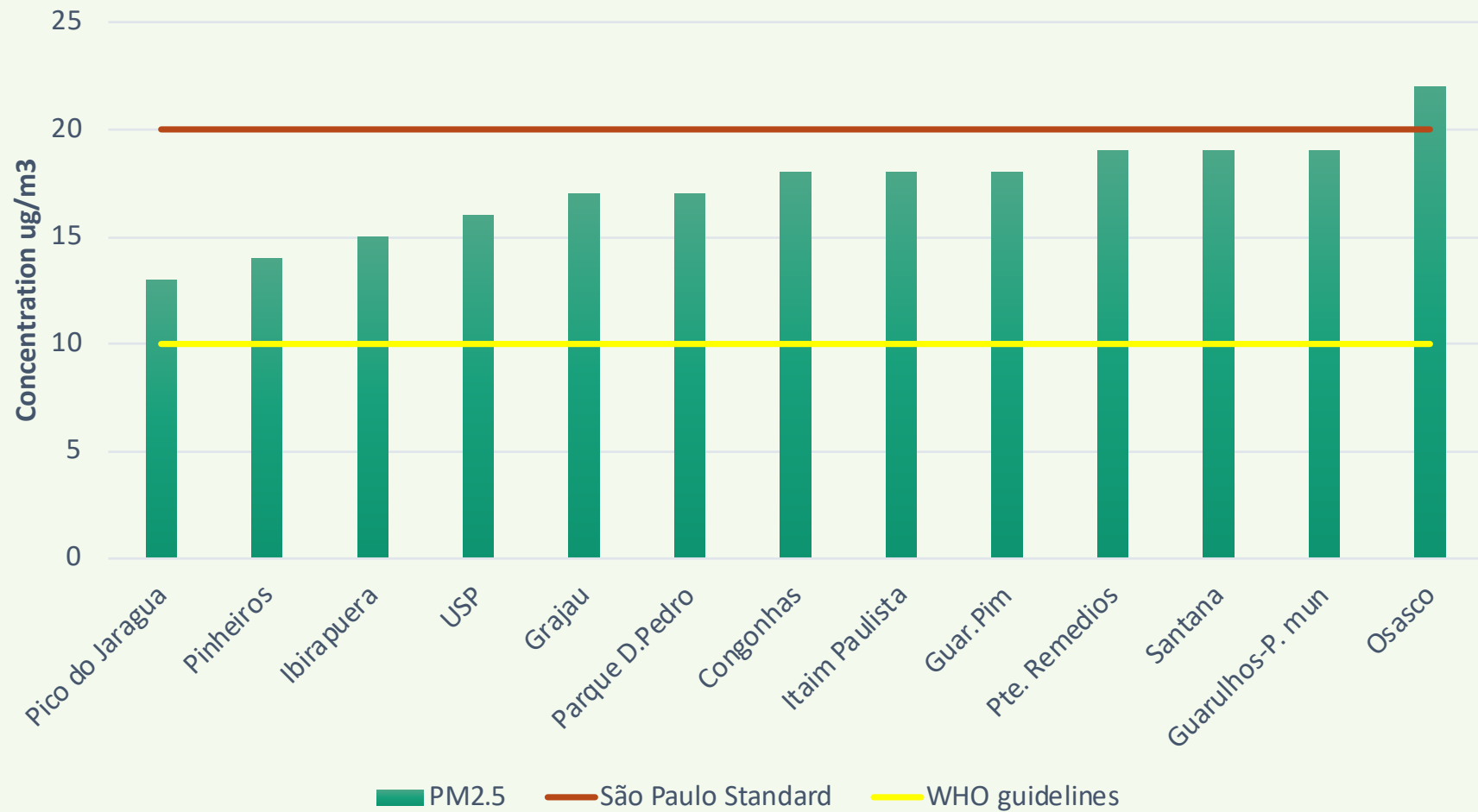
Average concentration of PM<sub>10</sub>, data from CETESB 2016



PM<sub>10</sub> concentration in São Paulo July 2016 (interpolation of data from CETESB stations).

Figure from Miranda R.

# Average concentration of PM<sub>2.5</sub> data from CETESB 2016



# Programs for Reduction of Emissions by Vehicular Fleet



## **PROCONVE: PROGRAM FOR CONTROLLING THE VEHICULAR EMISSIONS**

Established in 1983 for light and heavy-duty vehicles

## **PROMOT: PROGRAM FOR CONTROLLING THE EMISSIONS BY MOTORCYCLES**

Established in 2003 for regulation of motorcycles emission.

# Main air pollution problems

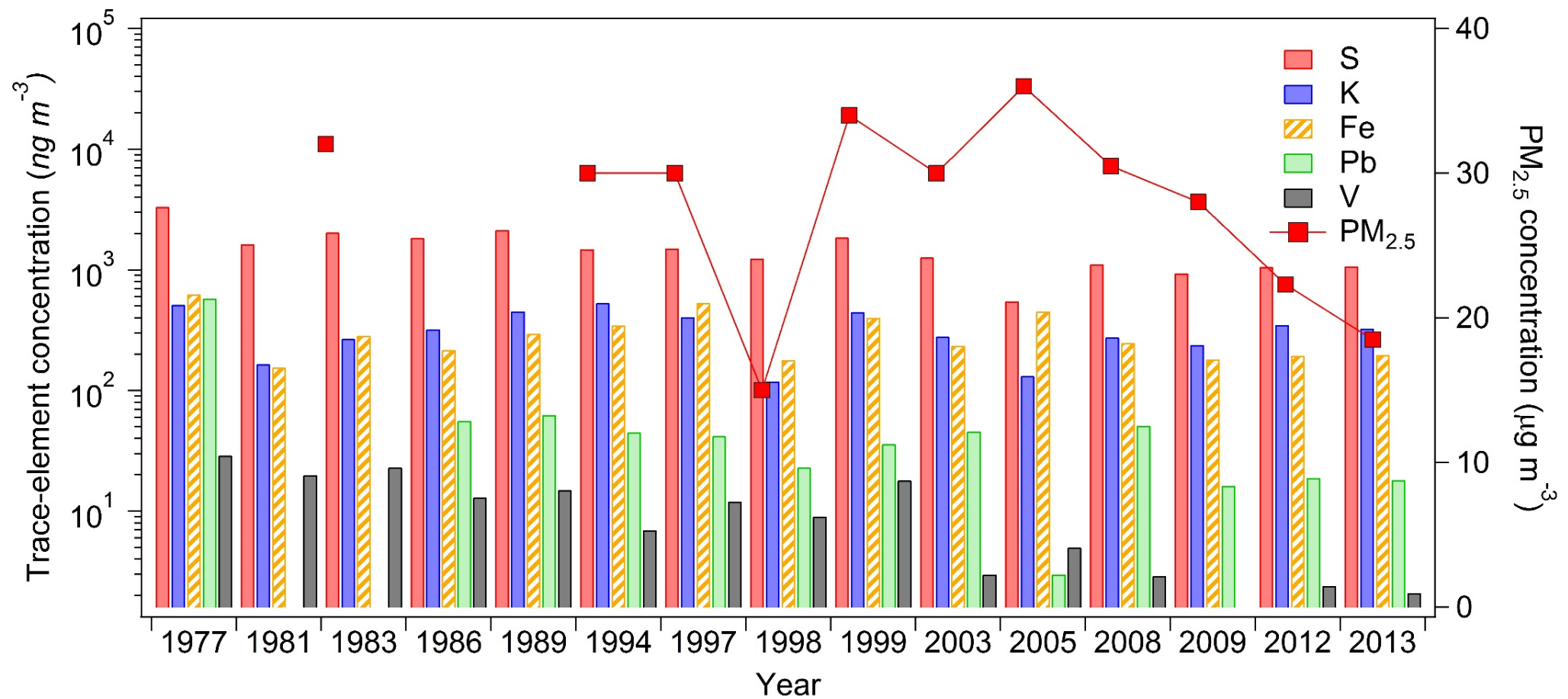
- **PM<sub>2.5</sub>**

- Secondary organic formation
- Secondary inorganic formation

- **OZONE**

- Contribution of ethanol fuel
- Contribution of gasohol
- Evaporative emissions

Mean annual concentrations of trace elements (in ng/m<sup>3</sup>) present in the PM<sub>2.5</sub> (in µg/m<sup>3</sup>). The measurements were performed during different experimental campaigns and at different locations in the MASP.



OC/PM<sub>2.5</sub> = 0.55  
 EC/PM<sub>2.5</sub> = 0.20

Air quality in the megacity of Sao Paulo: evolution over the last 30 years and future perspectives. Atmos. Environ., 2017

## CARBONACEOUS AEROSOL COMPOSITION IN PM<sub>2.5</sub>

EC

- 90 % Vehicular sources
- 10% Biomass Burning

OC

- Secondary Carbon from Vehicles
- Primary Organic Carbon (Biomass Burning, Vehicular)

Source: Vehicular emissions of organic particulate matter in Sao Paulo, Brazil



# Carbonaceous aerosols in MASP

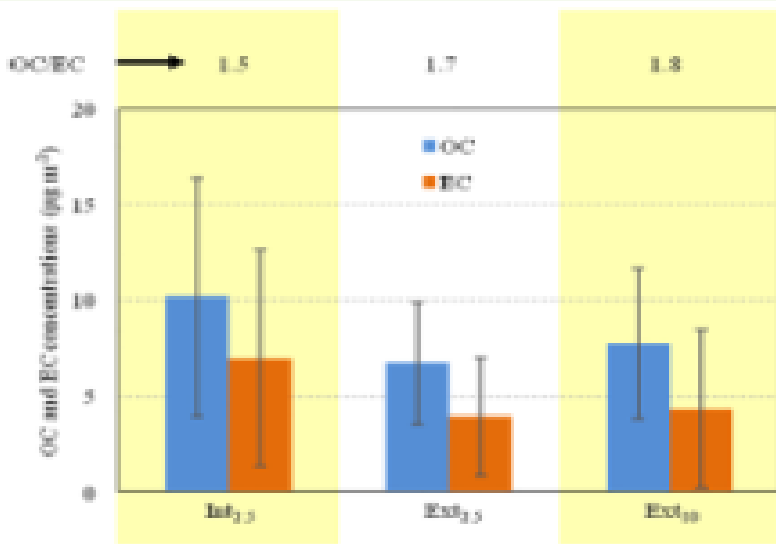
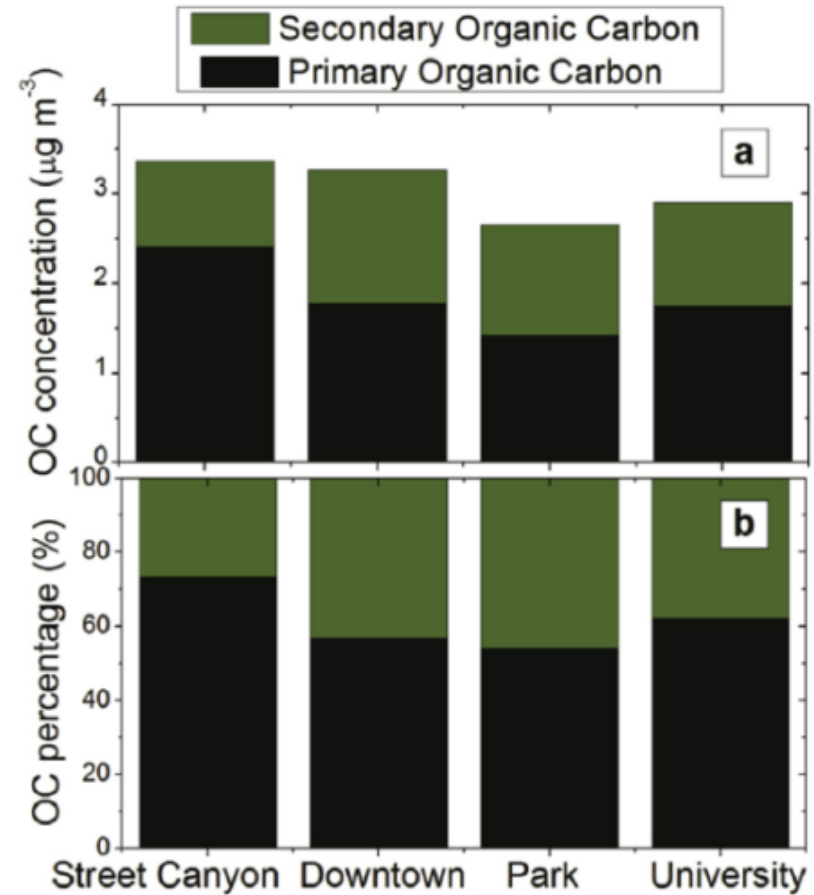
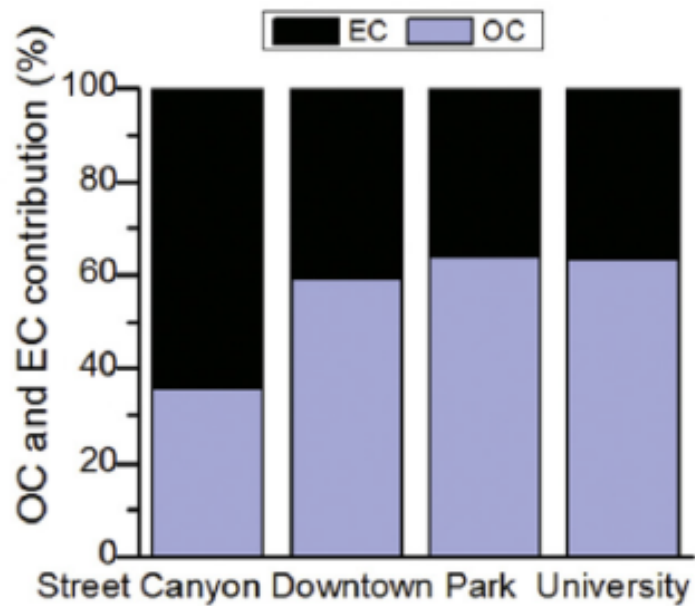


Figure 4. Carbonaceous species concentrations for all campaigns.

Fig. 4. Average concentration and percentage of total OC attributable to the estimated secondary and primary organic carbon at Street Canyon, Downtown, Park and University sites.

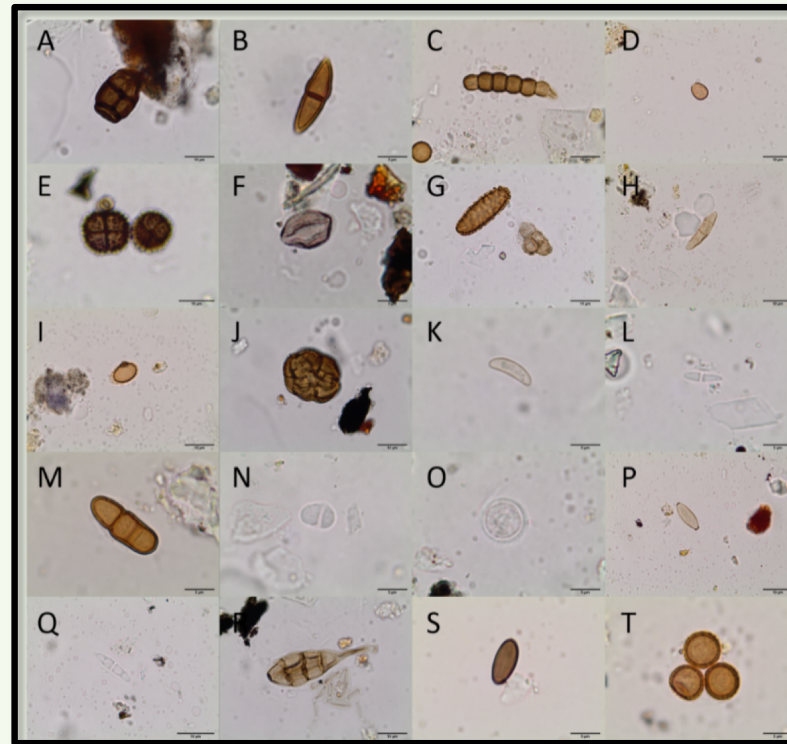
Santos et al., Atmos. Environ, 2016

Klimapolis

Pereira et al., ACP, 2017

# Pollen Spores in São Paulo

PM10 – Bioaerosols

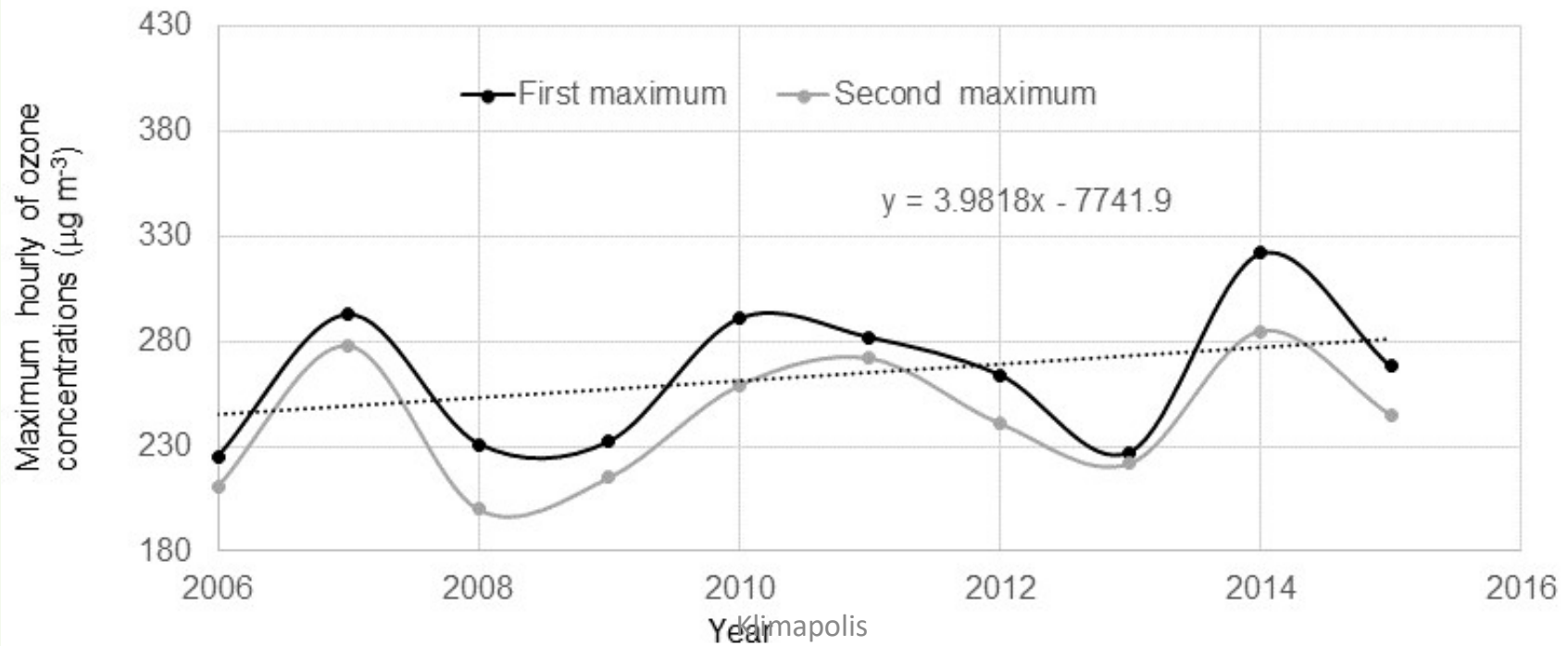
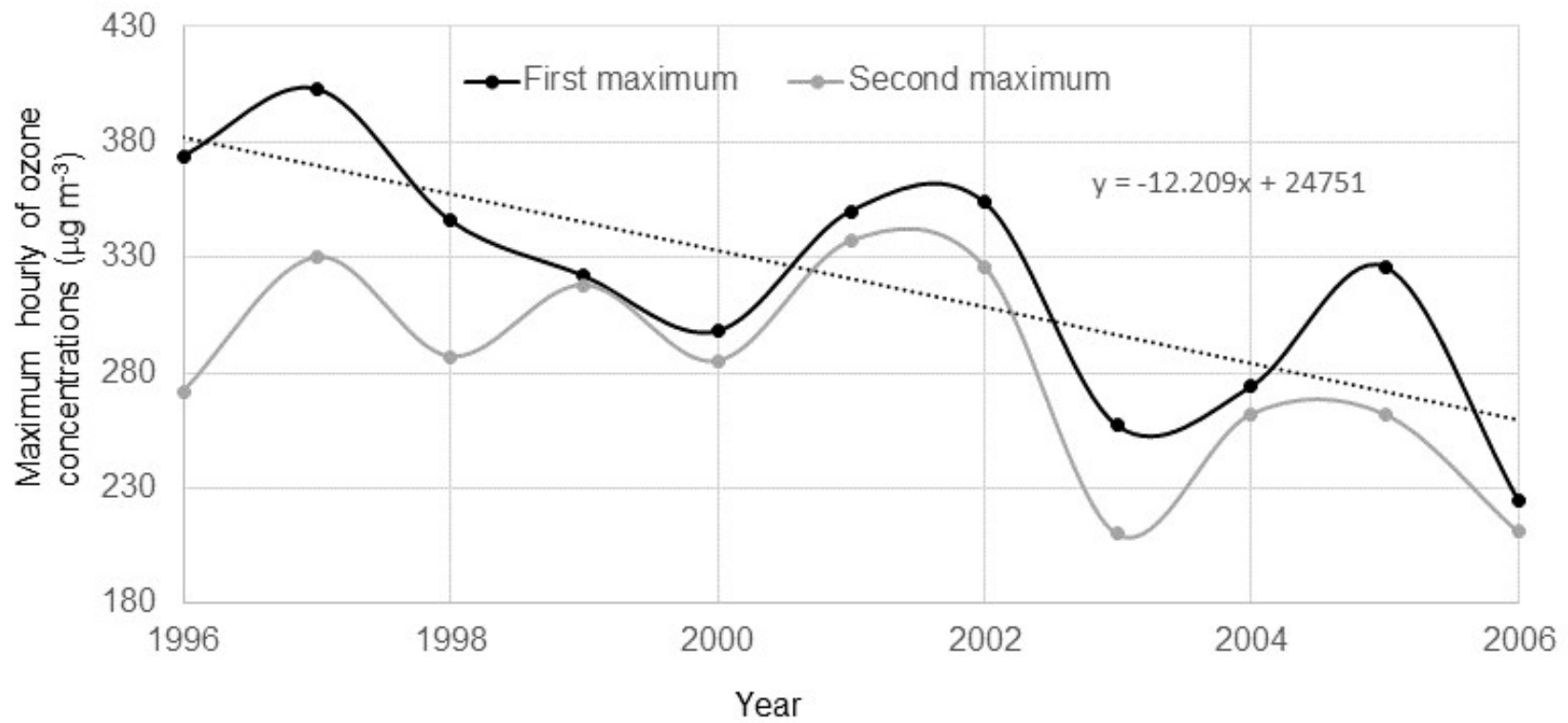


Mainly Analyzed Sporous. A: *Pithomyces* sp.; B: *Venturia* sp.; C: *Torula* sp.; D: Basidiósporo colorido indeterminado; E: *Spegazzinia* sp.; F: Myxomycota; G: *Gliomastix* sp.; H: Ascósporo de 4 células com cor; I: *Ganoderma* sp.; J: *Epicoccum* sp.; K: Diatrypaceae Grande; L: Ascósporo de 2 células sem cor; M: *Paraphaeosphaeria* sp.; N: Basidiósporos hialino grande; O: P: *Cladosporium* sp. sp.; Q: Ascósporo de 4 células sem cor R: *Drechslera*-like. S: Xylariaceae T: *Periconia* sp.

# Questions:

## Ozone

- Importance of gasohol and ethanol for the VOC emissions
- Identification of more reactive compounds to ozone formation
- Formation of secondary organic aerosol



# Formaldehyde and Acetaldehyde Concentrations in MASP

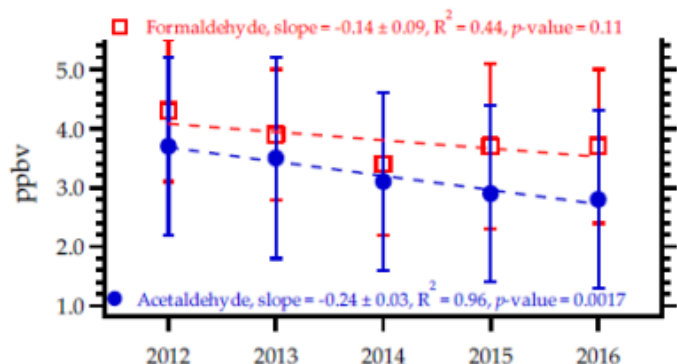


Figure 3. Annual trends in formaldehyde and acetaldehyde concentrations in the Metropolitan Area of São Paulo between 2012 and 2016. The dashed lines indicate the linear fit, and the bars indicate the standard deviation. Source: Pinheiros air quality monitoring station [24].

- The number of vehicles that can burn ethanol has increased (flex-fuel vehicles)
- The concentration of aldehydes has not increased (the use of ethanol has decreased)

## Aldehydes emission: São Paulo x California vehicles

California: Light-duty vehicles (10%ethanol+90%gasoline)

- Light-duty emission: formaldehyde and acetaldehyde 352% and 263% greater in São Paulo than California.
- Heavy-duty emission: Formaldehyde 33% greater in São Paulo
- 42% and 58% reduction in the formaldehyde and acetaldehyde emission between 2004 and 2011 in São Paulo.

Source: Formaldehyde and acetaldehyde measurements in urban atmosphere impacted by the use of ethanol biofuel: Metropolitan Area of Sao Paulo

Fuel, Nogueira et al., 2015

Klimapolis

# Sources not properly accounted

- Evaporative emissions during refuelling
- Solvents: painting and industries
- Biomass burning
  - Vegetation residues
  - Wood, charcoal

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## **Vehicle Emissions**

Combustion (Exhaust system)  
Evaporation (Fuel Storage and delivery system)

# Biomass burning

wood

May 19 – 22, 2016 – Active Data  
Fire, MODIS, 1 km - NASA



NOAA HYSPLIT, may 21, 2016

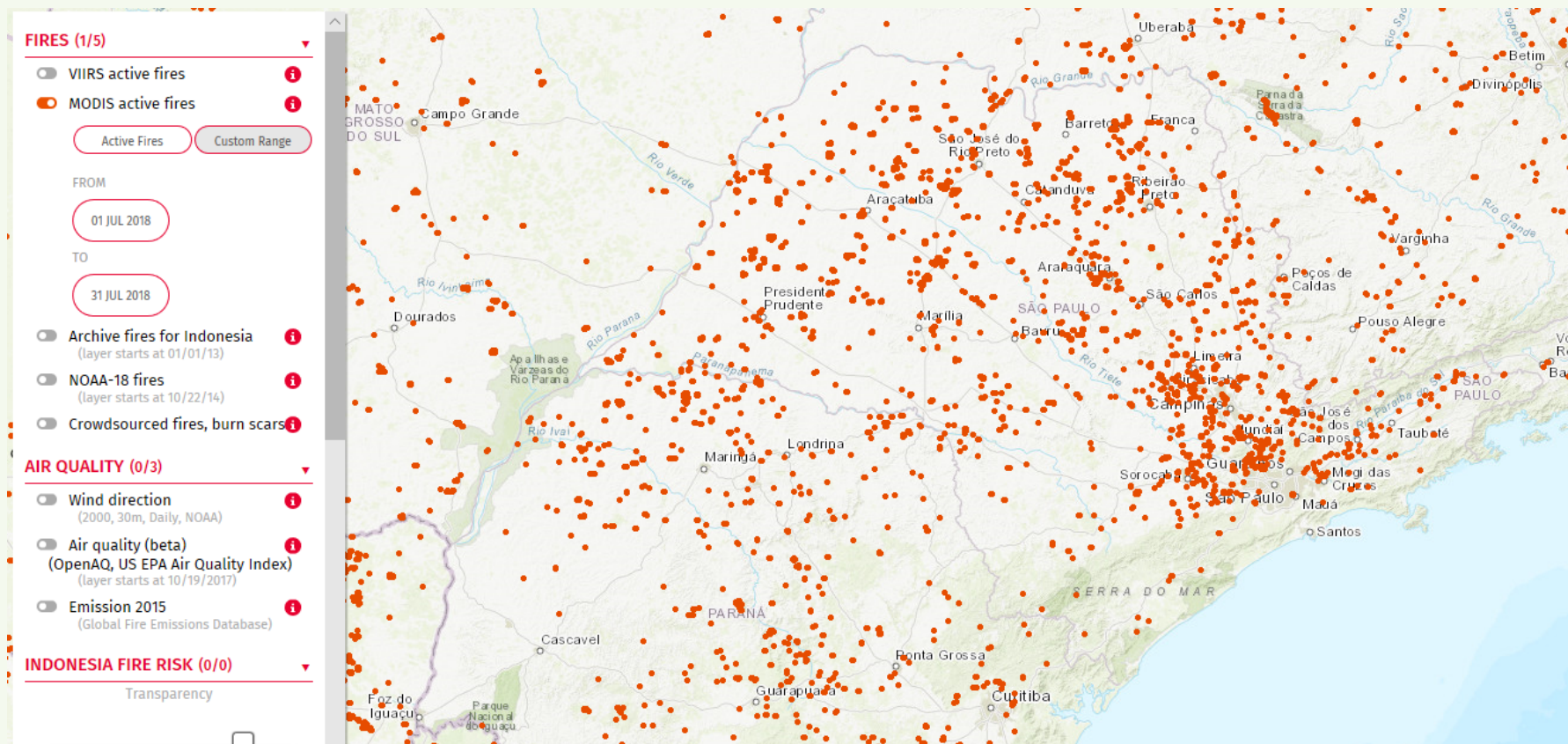


charcoal



# Active fires (July 1<sup>st</sup> to 31)

[fires.globalforestwatch.org.html](https://fires.globalforestwatch.org.html)



# Some conclusions

- The implementation of the Program to Control the Vehicular Emissions was effective in reducing the primary pollutants concentrations
- There are other sources that must be considered, biomass burning, evaporative emissions, painting, etc
- The contribution from remote sources and regional sources has impact in the number concentration of the particles
- The participation of carbonaceous aerosols is important and constitute the main fraction of the PM<sub>2.5</sub>
- With the reduction in the industrial activity, the vehicular source is the dominant for the primary emissions.

On-Going Project

# ASTRID - Project

- **Accessibility, Social Justice and Transport** emission impacts of Transit-Oriented **D**evelopment Strategies (FAPESP-ESRC-NWO)
- This proposal seeks to investigate the causal mechanisms underlying disparity and social injustice in job accessibility and air quality in metropolitan areas, and the potential of transit-oriented development to promote social justice.
- The study regions in this project are London (8 million inhabitants), São Paulo (11.3 million inhabitants) and Randstad South (3 million inhabitants)

# ASTRID PROJECT

[Home Page](#)[About ASTRID](#)[ASTRID Team](#)[Events](#)[Contact Us](#)

## ASTRID

**A**ccessibility, **S**ocial justice and **T**Ransport emission **I**mpacts of **T**OD strategies

This project seeks to investigate the causal mechanisms underlying disparity and social injustice in job accessibility and air quality in metropolitan areas, and the potential of transit-oriented development to promote social justice. [More Info.](#)

## Research Focus Themes



### Emission-exposure and social justice

This Theme is led by the University of São Paulo (BR).

[More Info](#) ▶



### Land use, housing and social justice

This theme is led by the University of Surrey (UK)

[More Info](#) ▶



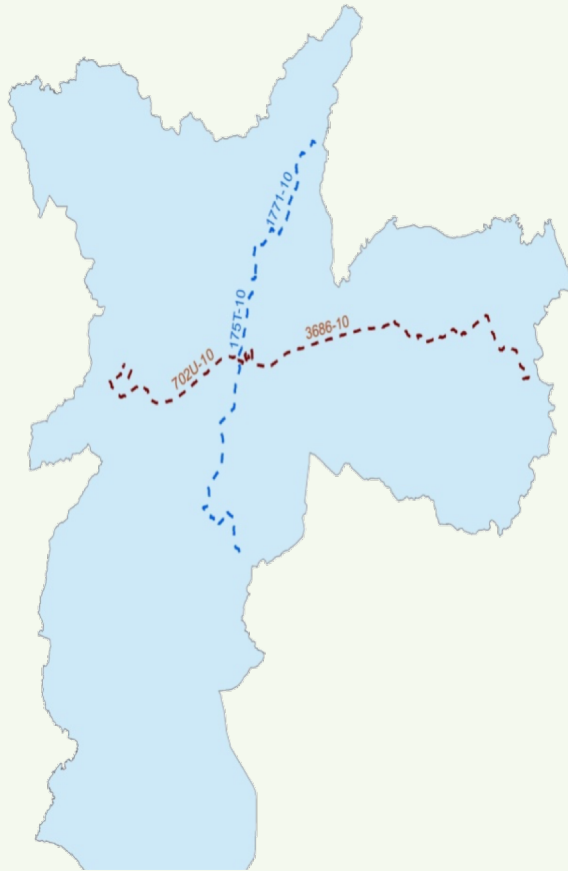
### Transit-oriented development, accessibility and social justice

This theme is led by the University of Twente (NL).

[More Info](#) ▶



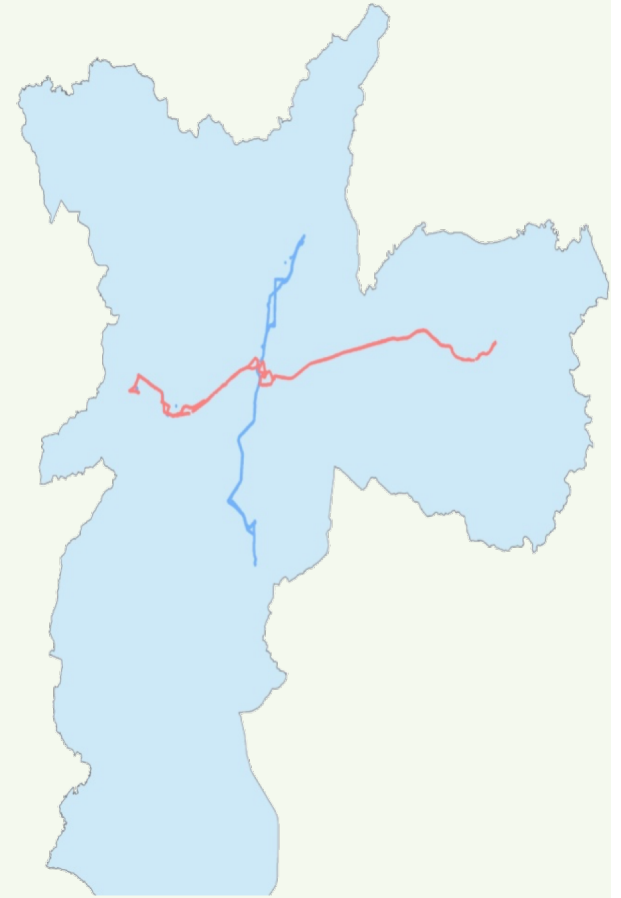
# Route Selection



Bus



Subway

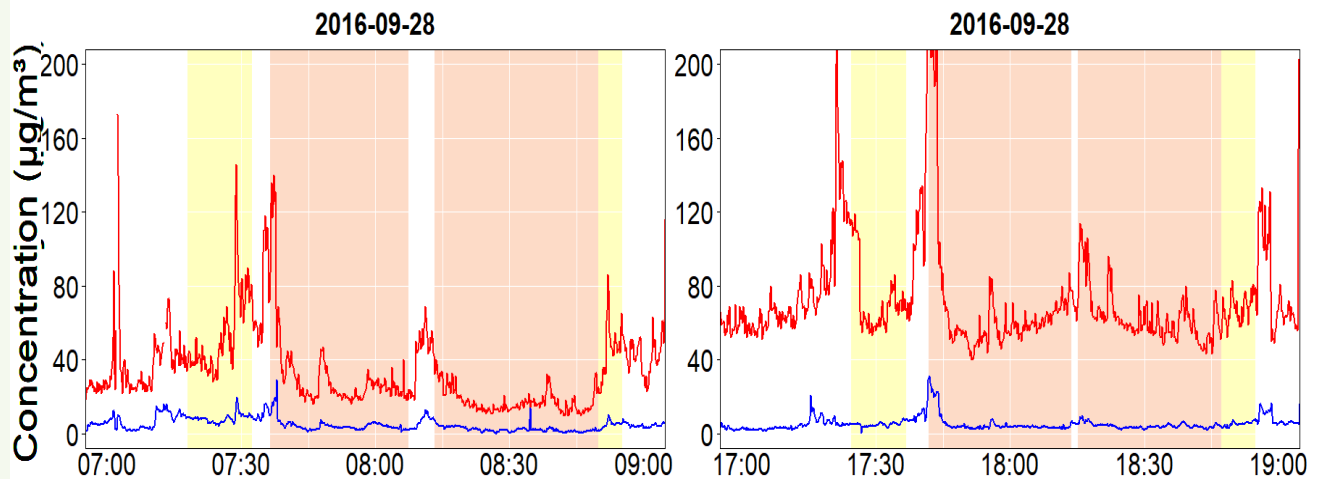
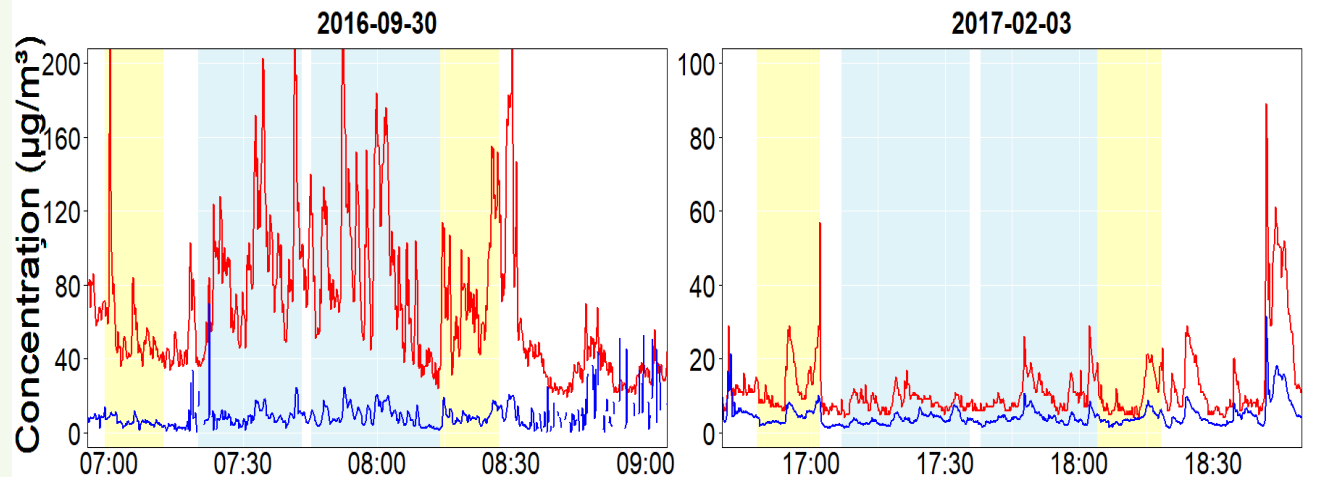


Car

# Subway

- The background color indicates the Subway Line that was being sampled;
- The morning samples showed higher peaks
- The Red Line had substantially lower concentrations than the Blue Line;

North-South route



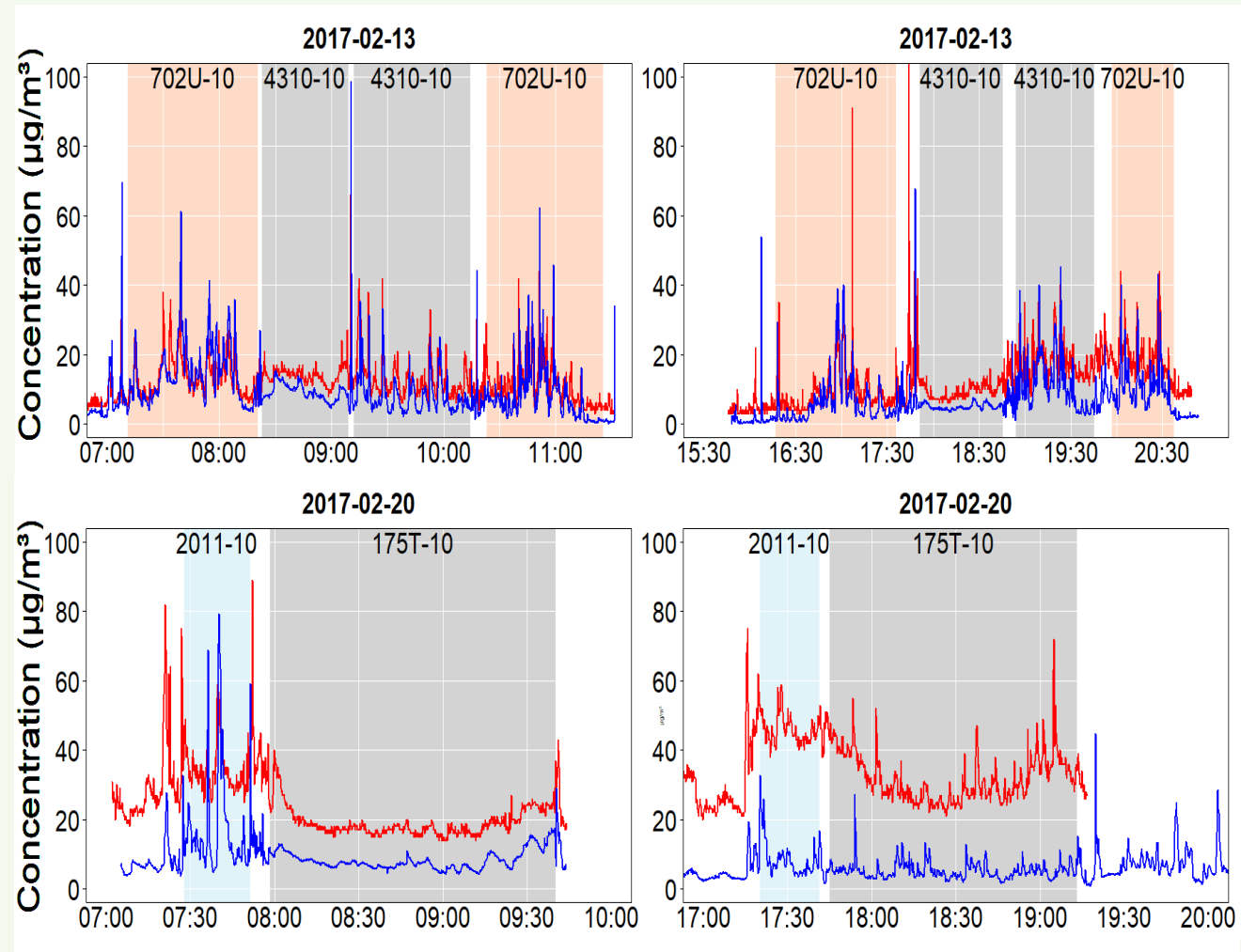
East-West route

— MP<sub>2.5</sub> — BC

# BUS

- The colors on the background indicate different buses;
- In the morning period the concentrations had higher peaks;

## East-West route



## North-South route

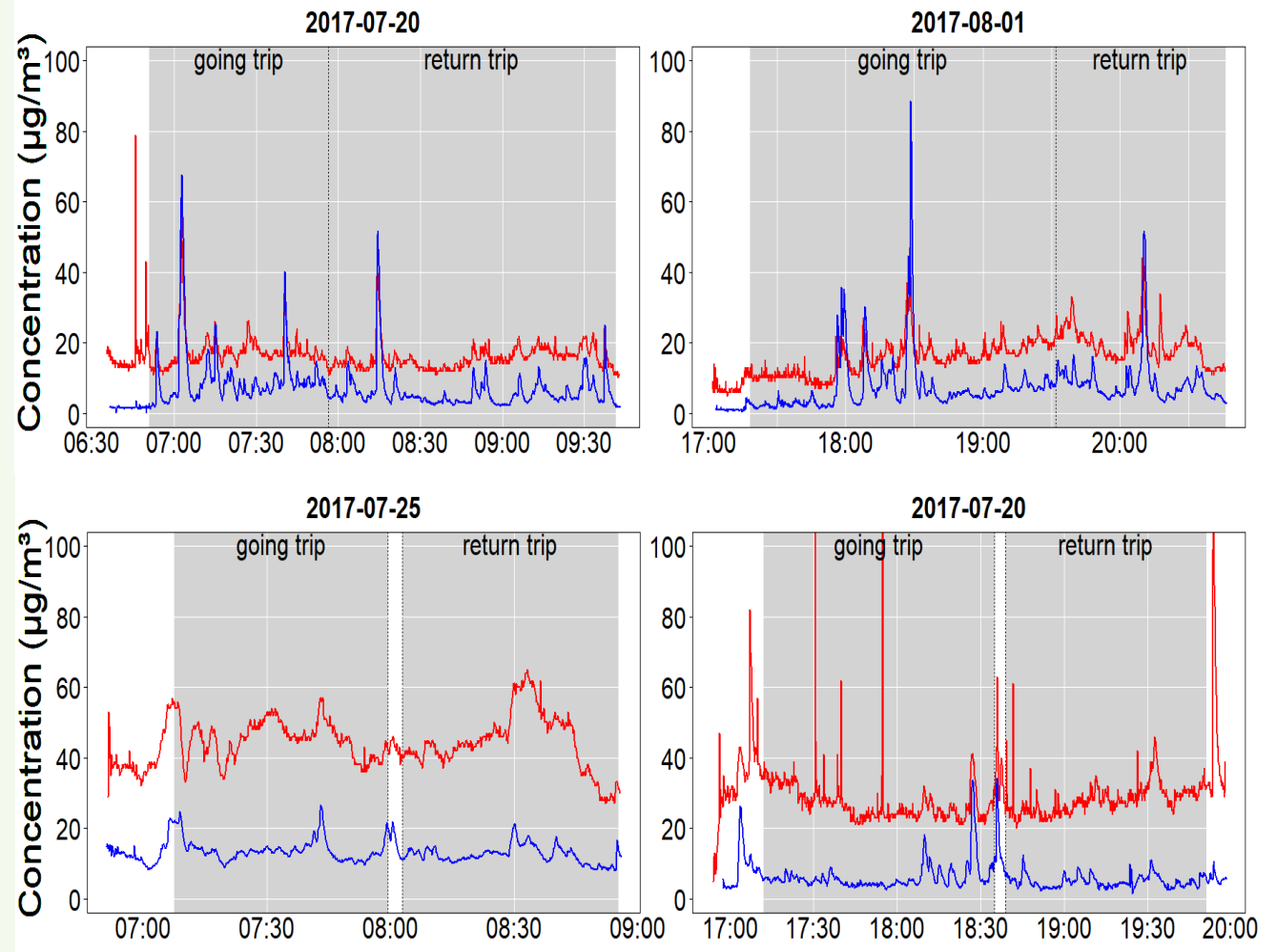
—  $MP_{2.5}$  — BC

Brand et al., 2018

# Car

- The gray background indicates the time inside the vehicle in route;
- In the morning the concentrations were slightly higher;

## East-West route



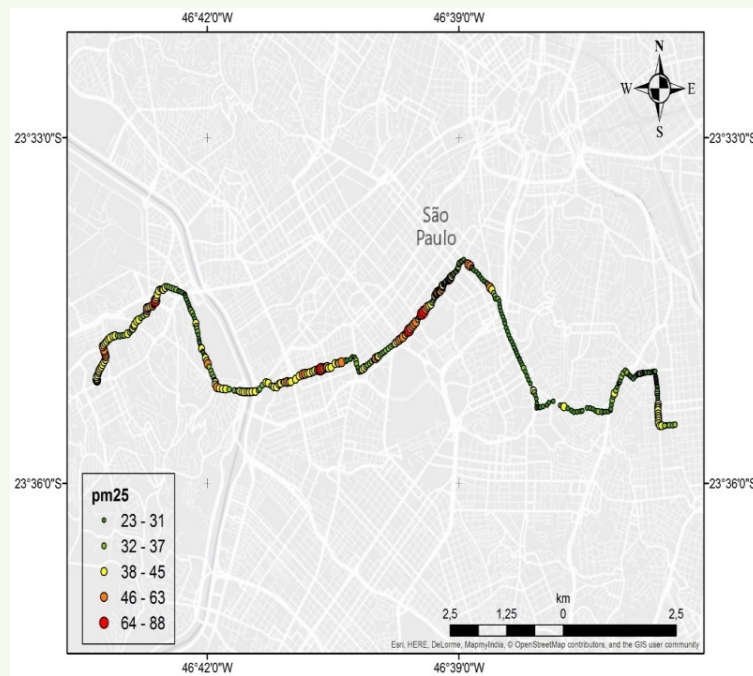
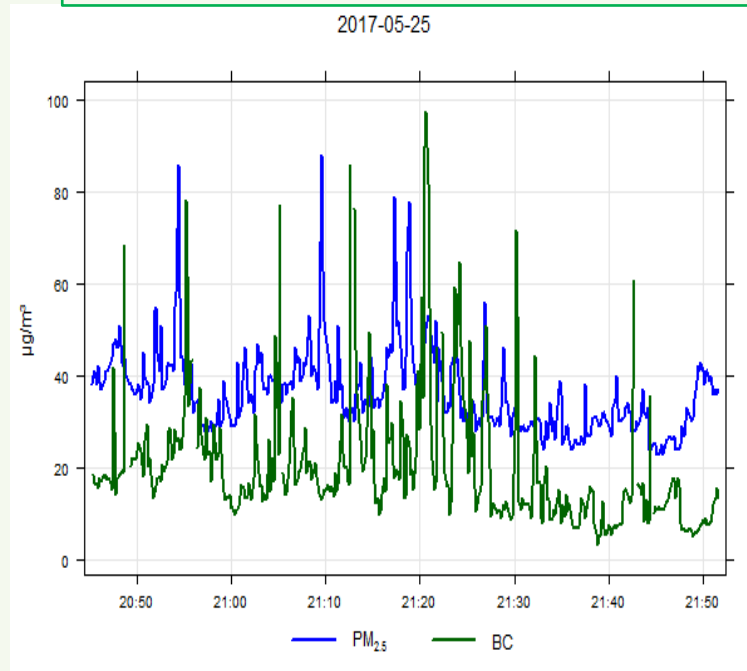
## North-South route

—  $MP_{2.5}$  —  $BC$

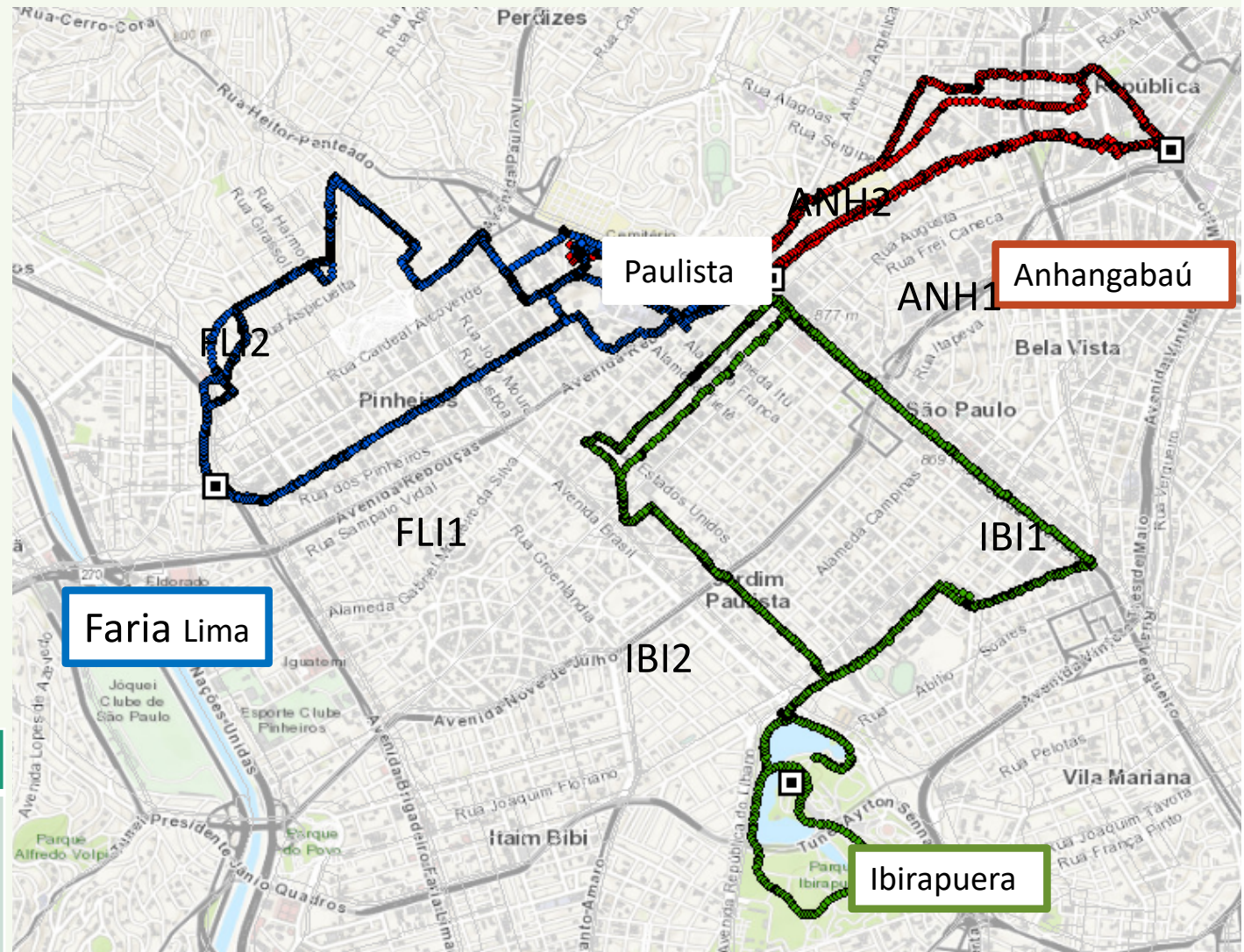
Brand et al., 2018



# PEDALS: Bicycle user exposure to air pollution



# Byke



ID	Origem	Destino
FLI	Faria Lima	Paulista
IBI	Ibirapuera	
ANH	Anhangabaú	

# Thank You!

## Muito Obrigada!



The logo of the Universidade de São Paulo (USP), consisting of the letters "USP" in a stylized, outlined font.

