

TOWARDS A MEGACITY PROJECT IN SÃO PAULO BRAZIL

Maria de Fatima Andrade

Atmospheric Sciences Department

Instituto de Astronomia, Geofísica e Ciências Atmosféricas

Universidade de São Paulo

Collaborators

- University of São Paulo
 - Institute of Physics
 - Institute of Chemistry
 - Institute of Geosciences
 - Faculty of Medicine
- INPE (National Institute for Spacial Science)
- CETESB (Environmental State Agency)
- Federal University of São Paulo

São Paulo Air quality Project

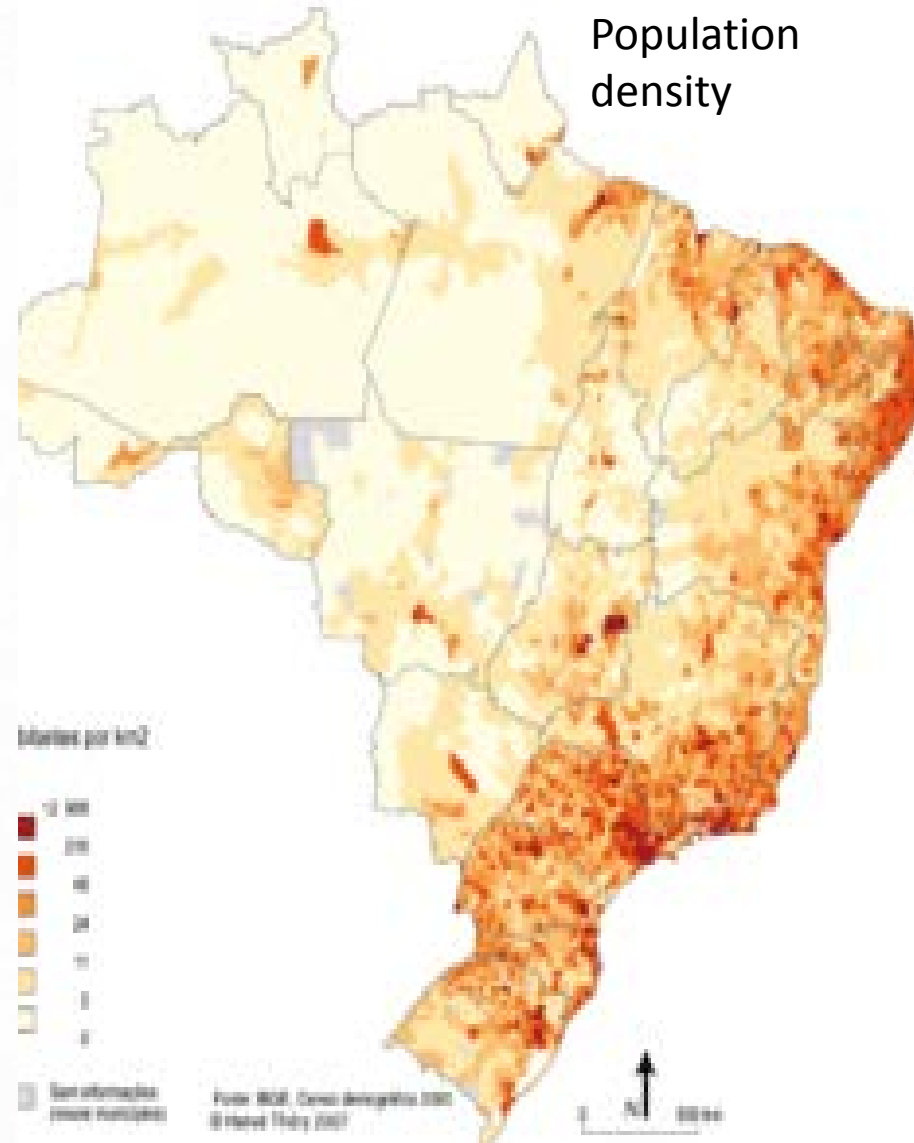
Outline

- Introduction: São Paulo + Brazil
- Projects for measurements of GHG and co-pollutants
- Example of results concerning particles and gaseous compounds
- Evaluation of Emission Factor + uncertainties
- Application tools for emission modeling
- Implementation of air quality modeling and health impacts
- Ongoing projects
- Measurements quality: Challenge

Brazil - Geography



Population density

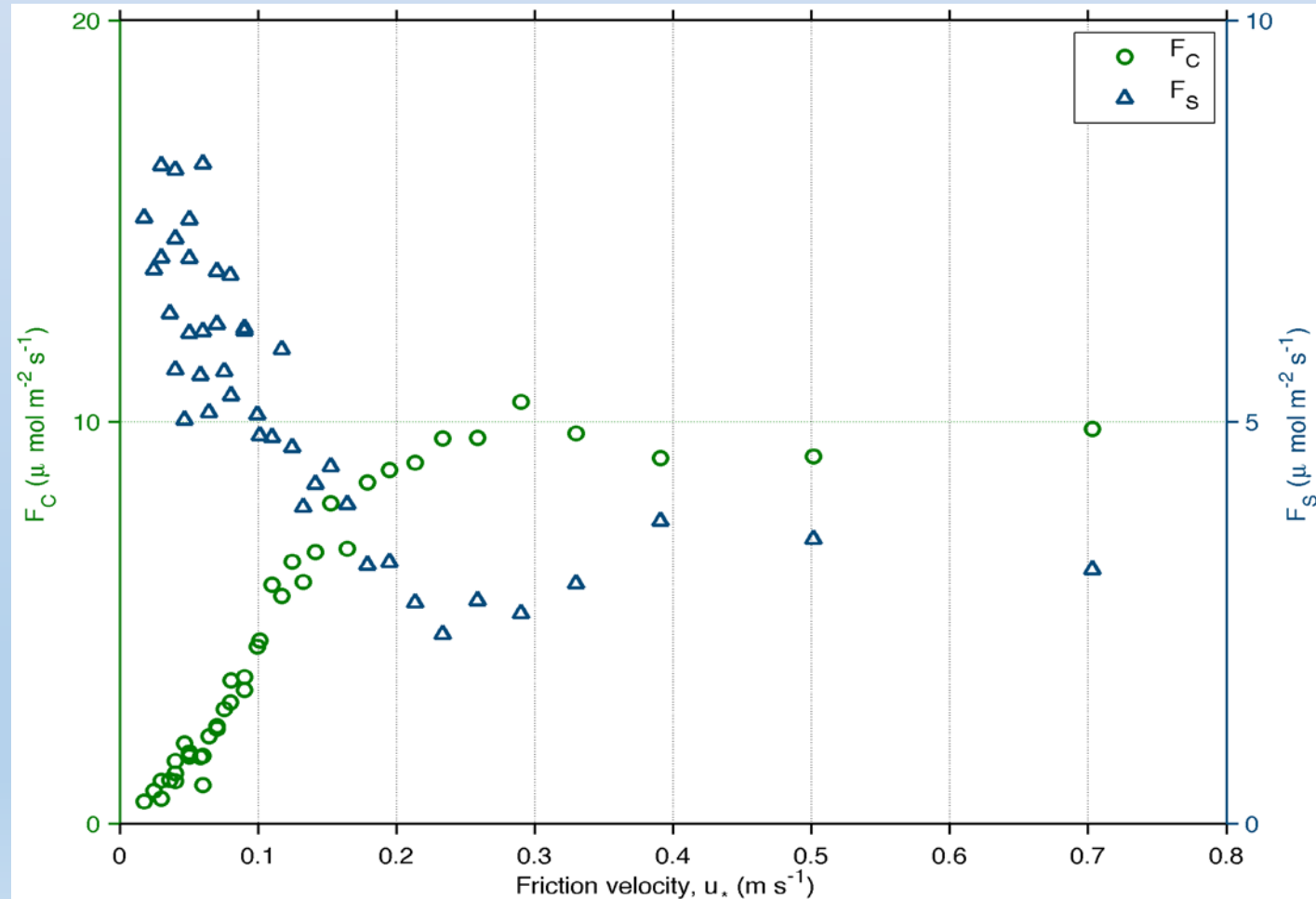


Population of Brazil 202.768.562

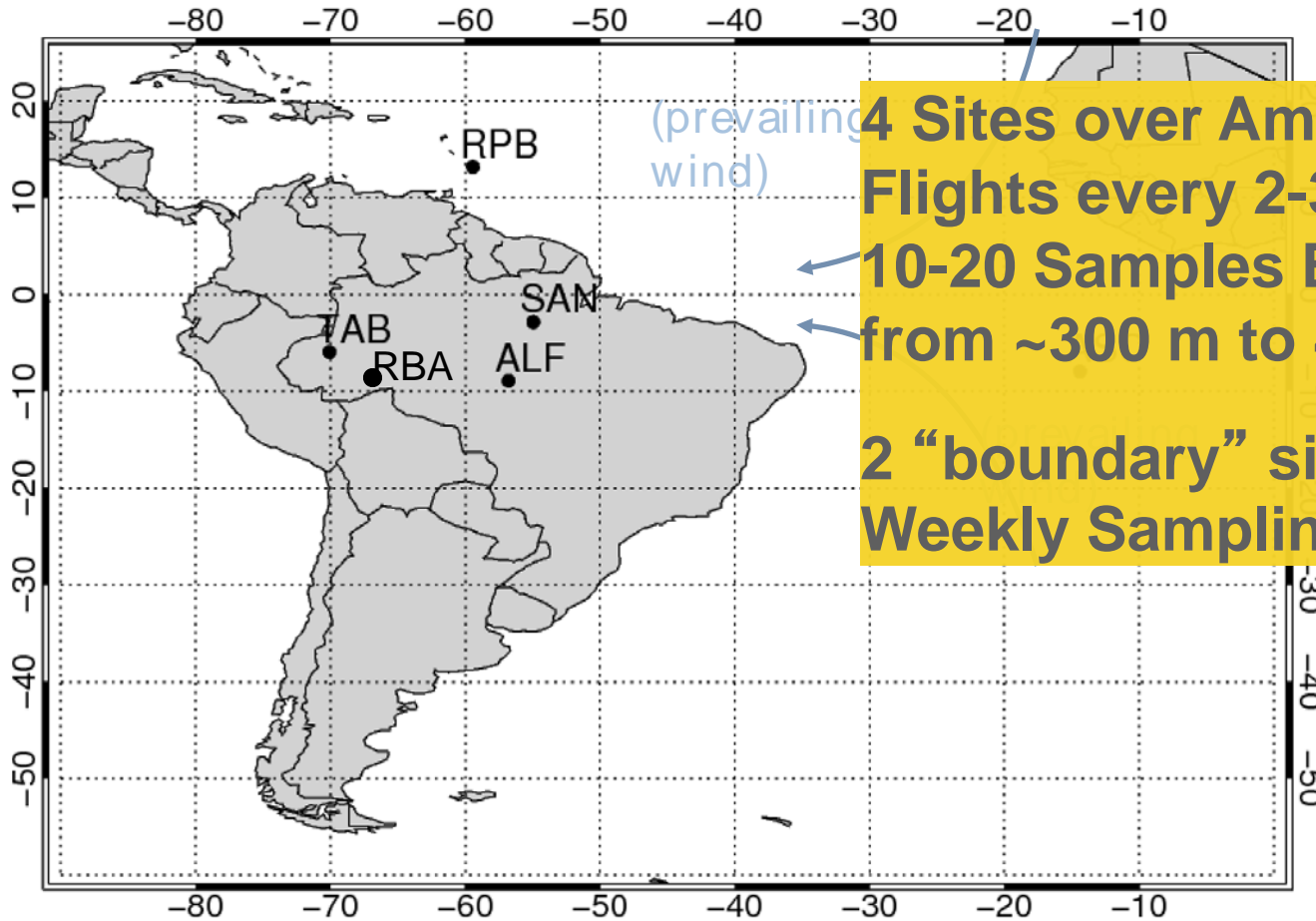
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Measurements of CO₂ have been conducted over Amazonia Forest and Cerrado

CO₂-flux (F_C) and storage (F_S) plotted versus classes of friction velocity – Rondonia site



Variability of Carbon and
Water Fluxes Following
Climate Extremes over a
Tropical Forest in
Southwestern Amazonia
Marcelo Zeri
Leonardo D. A. Sá
Antônio O. Manzi
Alessandro C. Araújo
Renata G. Aguiar
Celso von Randow
Gilvan Sampaio
Fernando L. Cardoso
Carlos A. Nobre
2014



4 Sites over Amazon Basin
Flights every 2-3 weeks

10-20 Samples Each Flight
from ~300 m to 4400 m

2 “boundary” sites
Weekly Sampling

L. V. Gatti, M. Gloor, J. B. Miller, C. E. Doughty, Y. Malhi, L. G. Domingues, L. S. Basso, A. Martinewski, C. S. C. Correia, V. F. Borges, S. Freitas, R. Braz, L. O. Anderson, H. Rocha, J. Grace, O. L. Phillips, and J. Lloyd, (February 2014): Drought sensitivity of Amazonian carbon balance revealed by atmospheric measurements *Nature*, **506**, 76-80. [doi:10.1038/nature12957](https://doi.org/10.1038/nature12957)

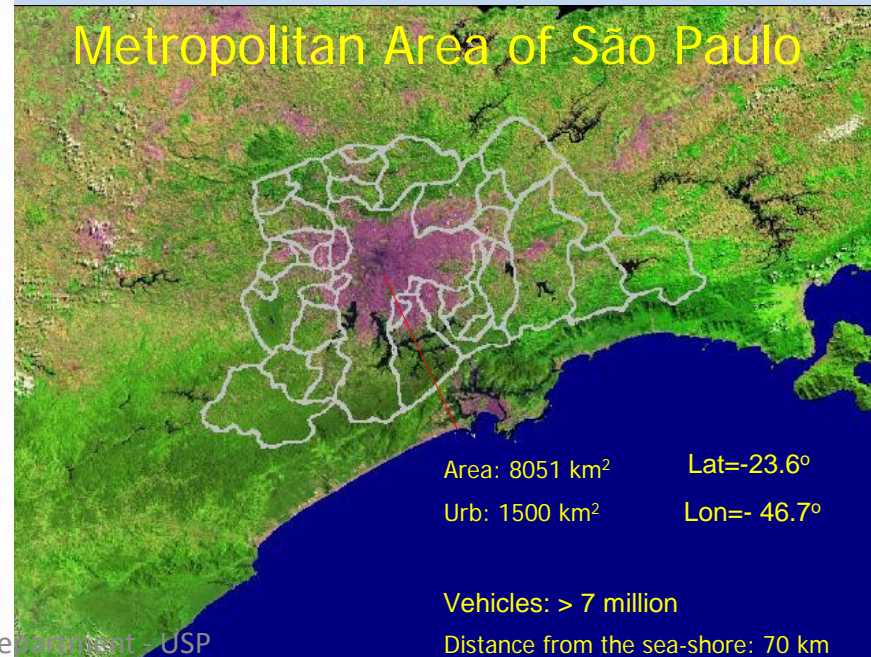
Metropolitan Area of São Paulo - MASP

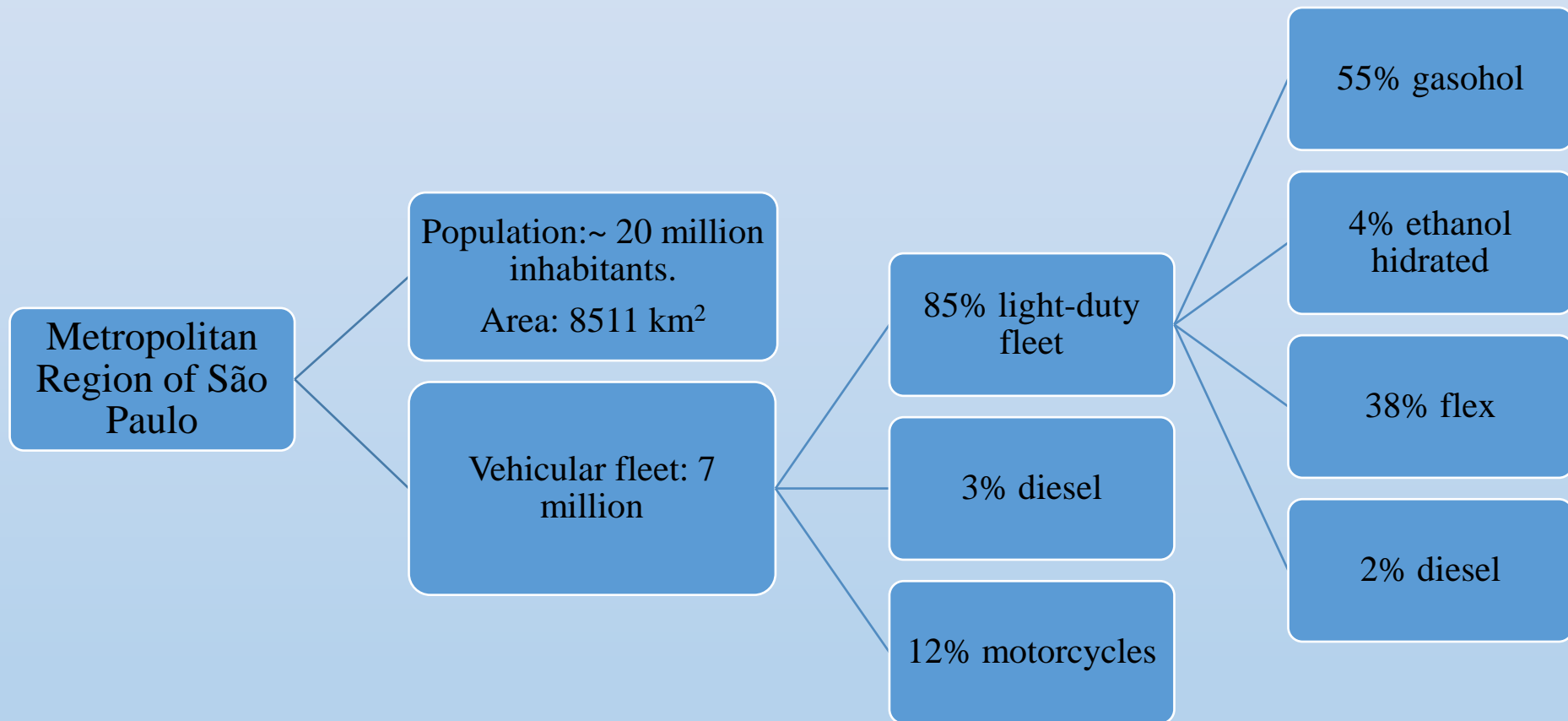
MASP= São Paulo city + 38 cities

- 19 million inhabitants
- 7,2 million vehicles
- 2000 significative industrial plants
- 8000 km²



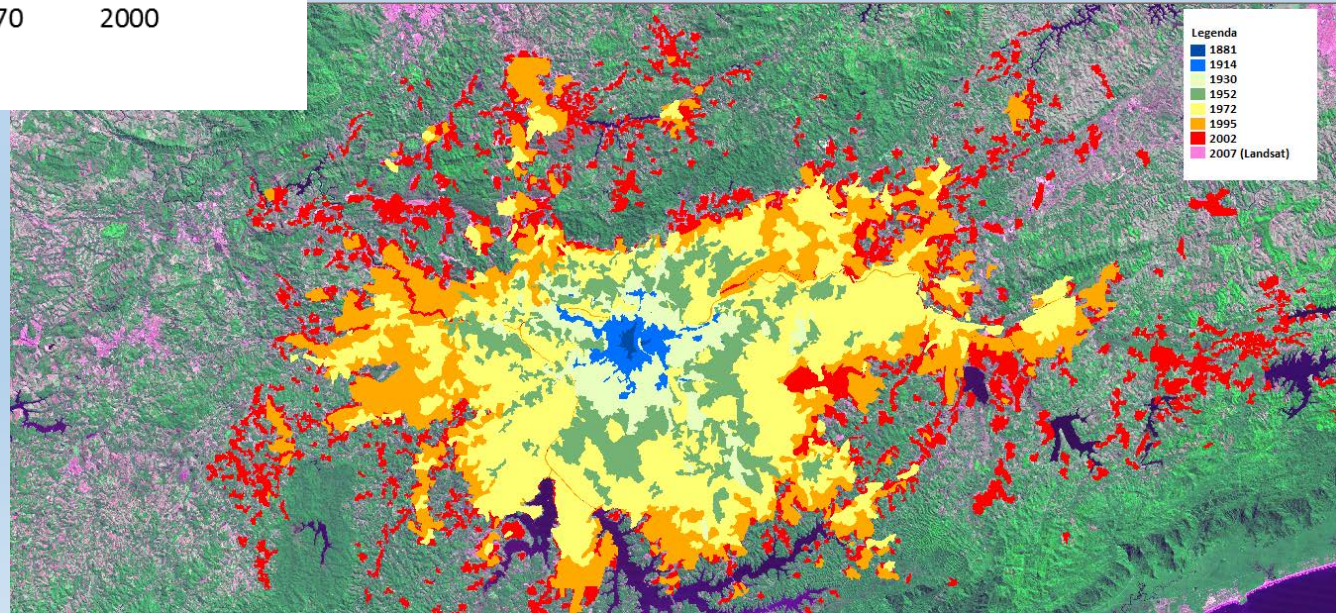
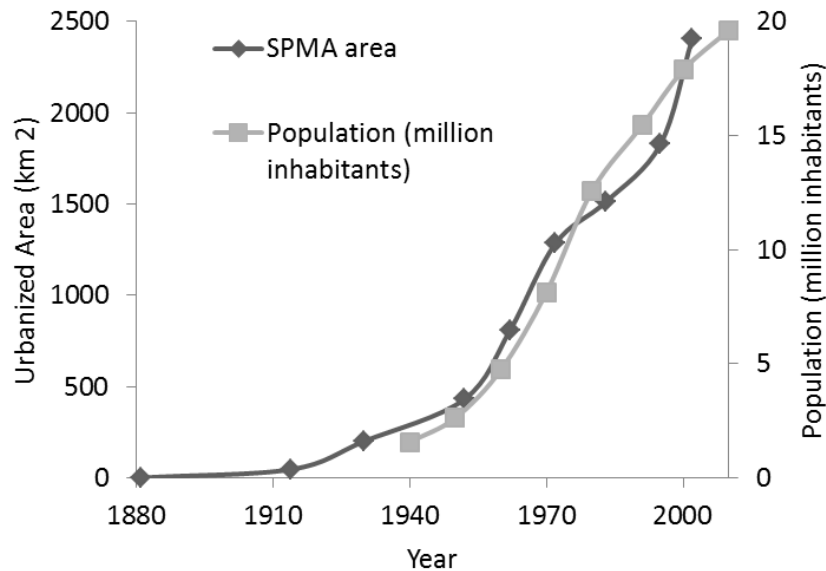
Metropolitan Area of São Paulo





Important questions

Expansion of urban areas and population growth





Very dense urban area

Contrast between urban
and suburban areas



On-Going Project

08/58104-8

Departamento de Ciências
Atmosféricas

Instituto de Astronomia,
Geofísica e Ciências
Atmosféricas-USP

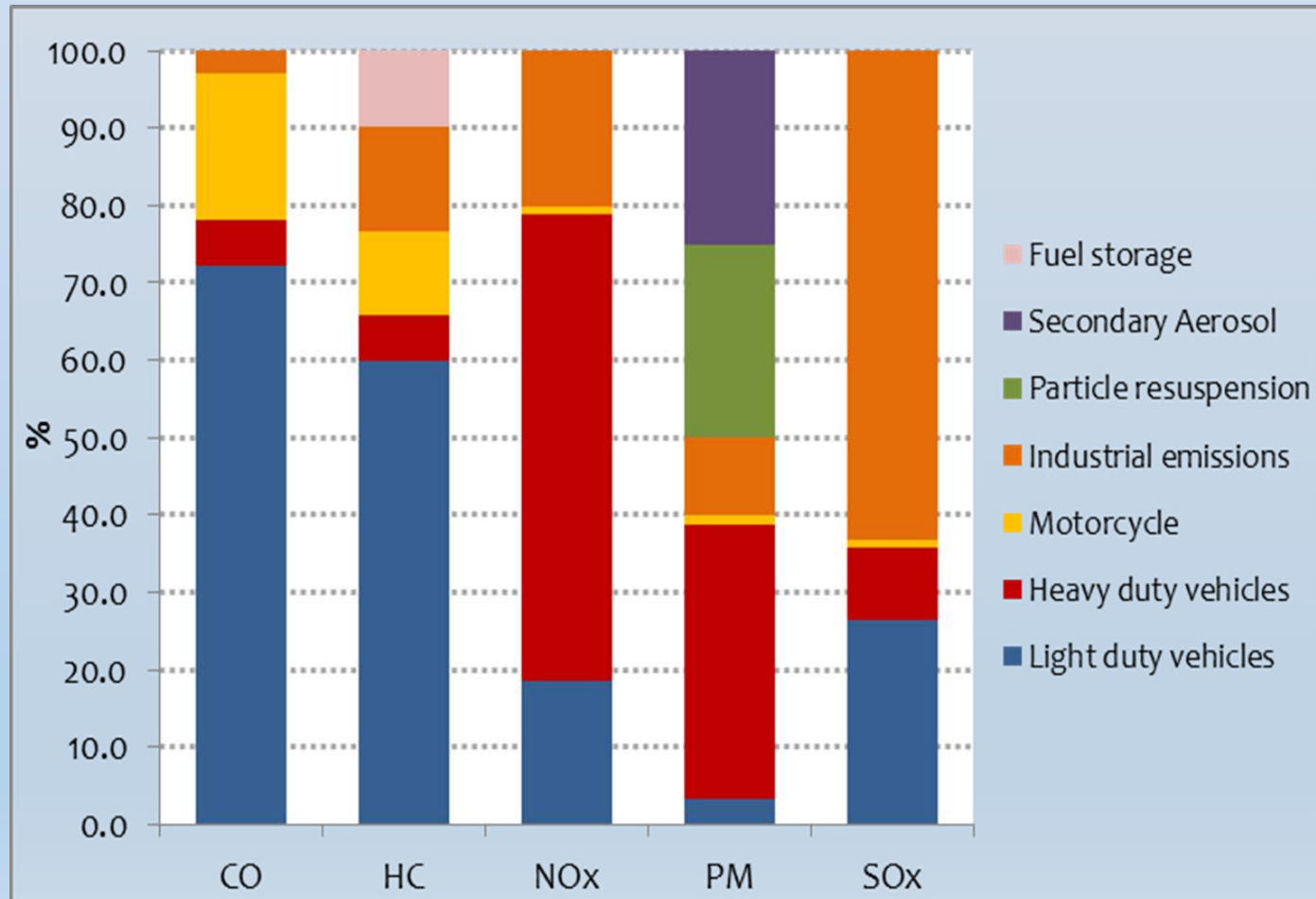
March 2011- december 2015

NARROWING THE UNCERTAINTIES ON AEROSOL AND CLIMATE CHANGES IN SAO PAULO STATE NUANCE-SPS

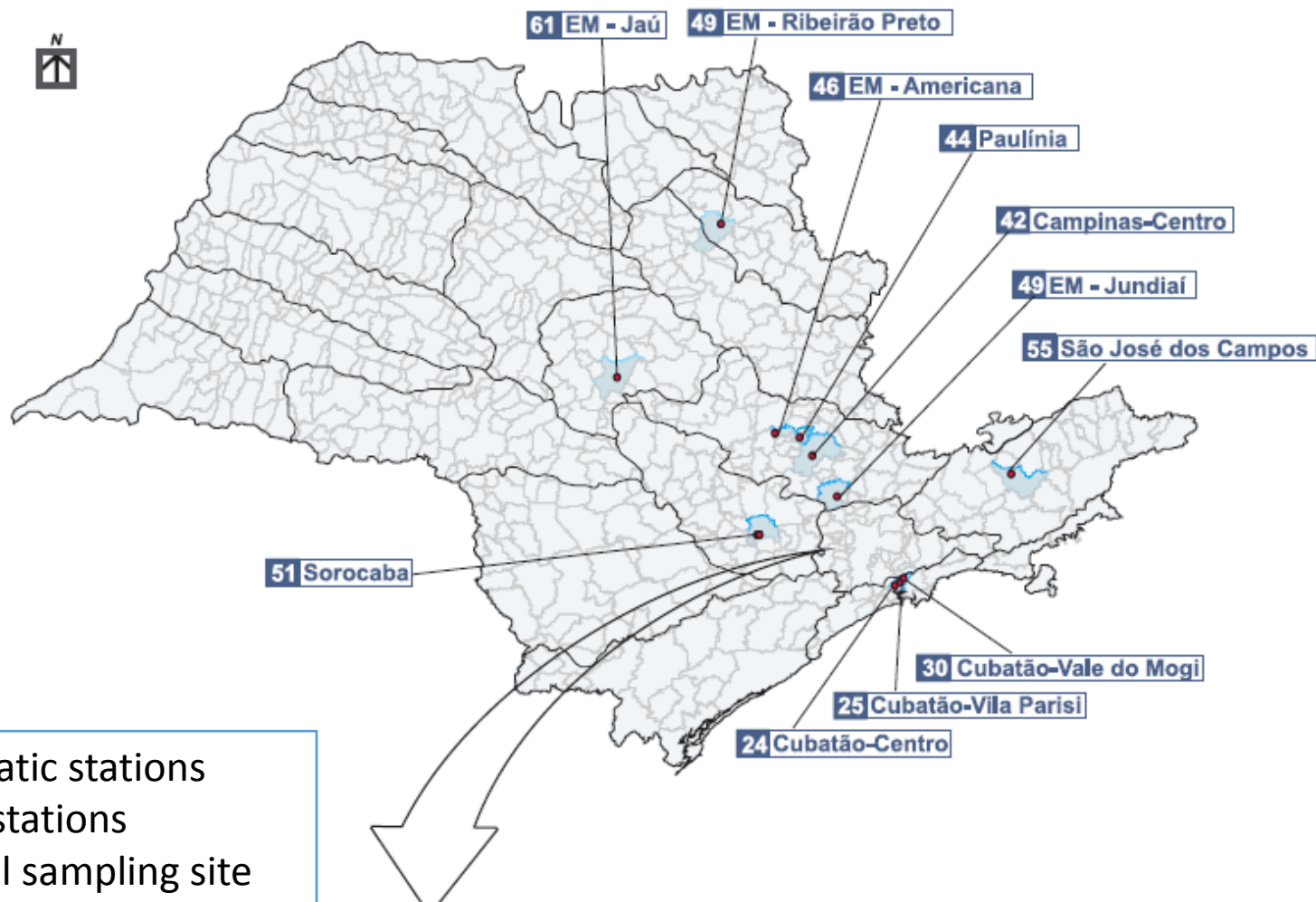
The project – approach

- *The megacity of São Paulo was considered as an example of integrated approach regarding evaluating of the impact of the climate change on its air quality. In this project, MASP was an observatory of the climate, with special attention to the variation of the meteorological characteristics due to the climate change.*
- *The objective of the project can be summarized as the implementation of a modeling system representing the chemical-physical process in the troposphere and the health impacts at the urban scale.*
- *Period: 2011-1015*

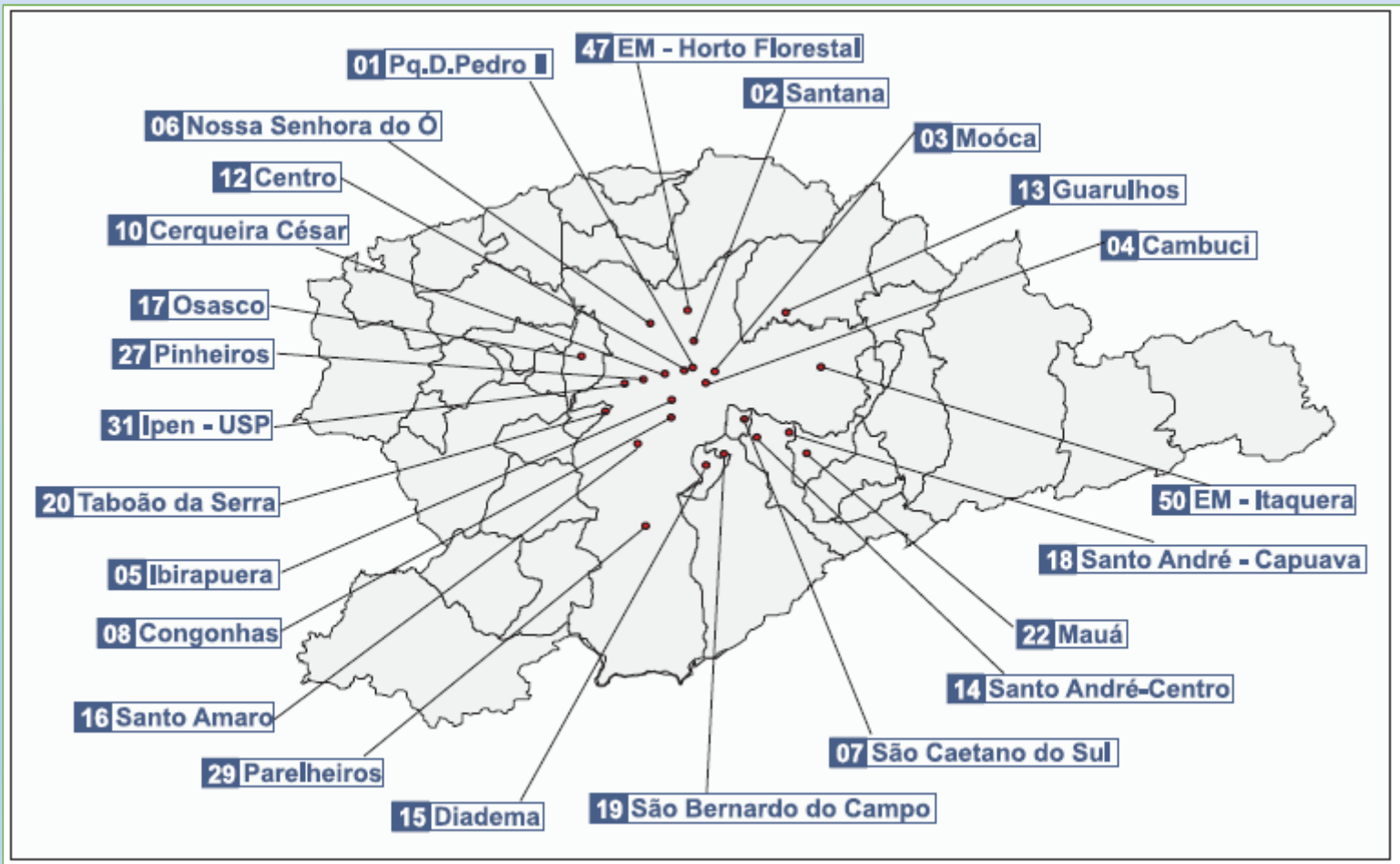
Official Data Emission Inventory in the Metropolitan Area of São Paulo for Regulated Pollutants

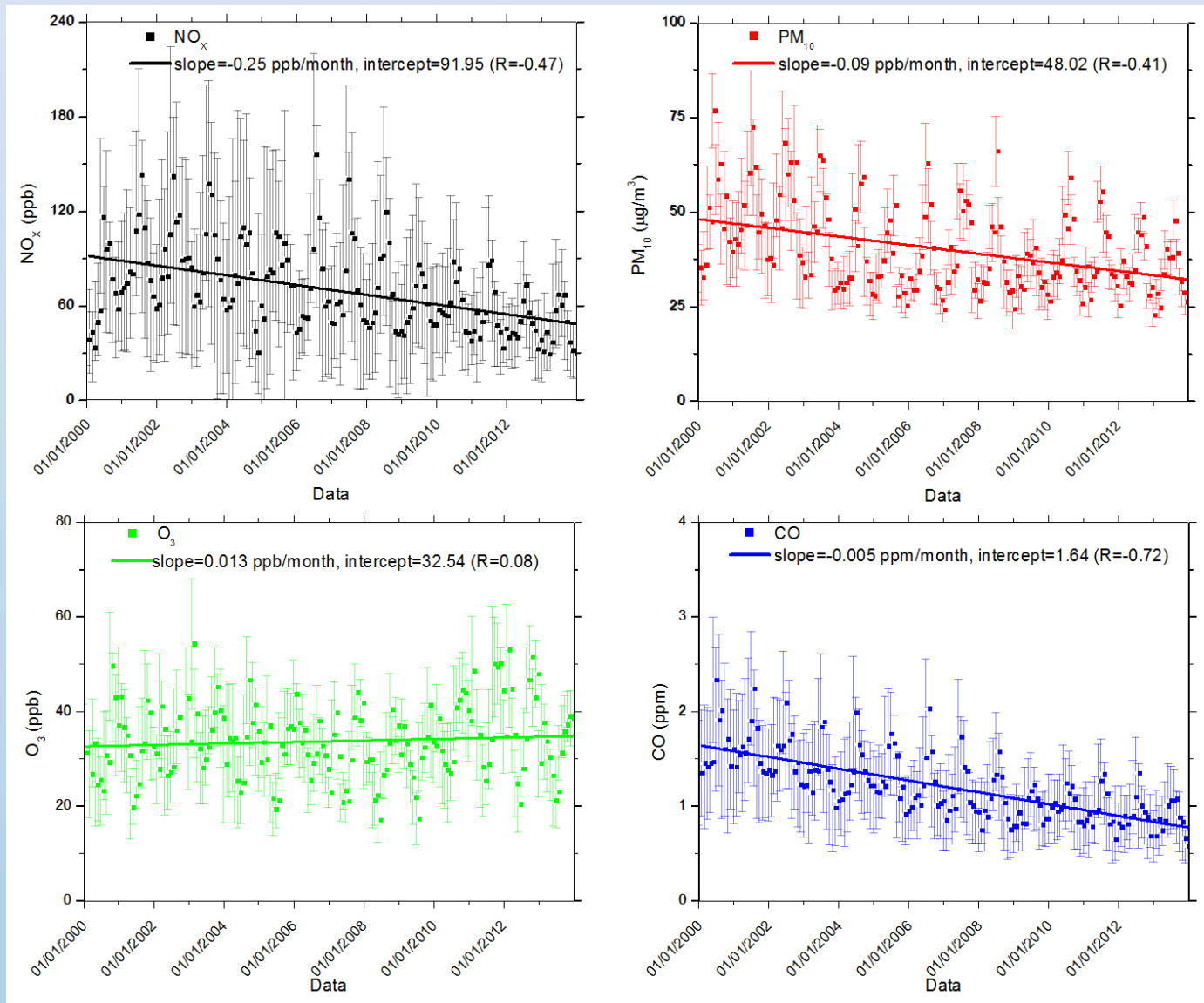


Air quality Monitoring Stations from CETESB Environmental Agency from São Paulo State



Air quality Monitoring Stations from CETESB – Metropolitan Area of Sao Paulo

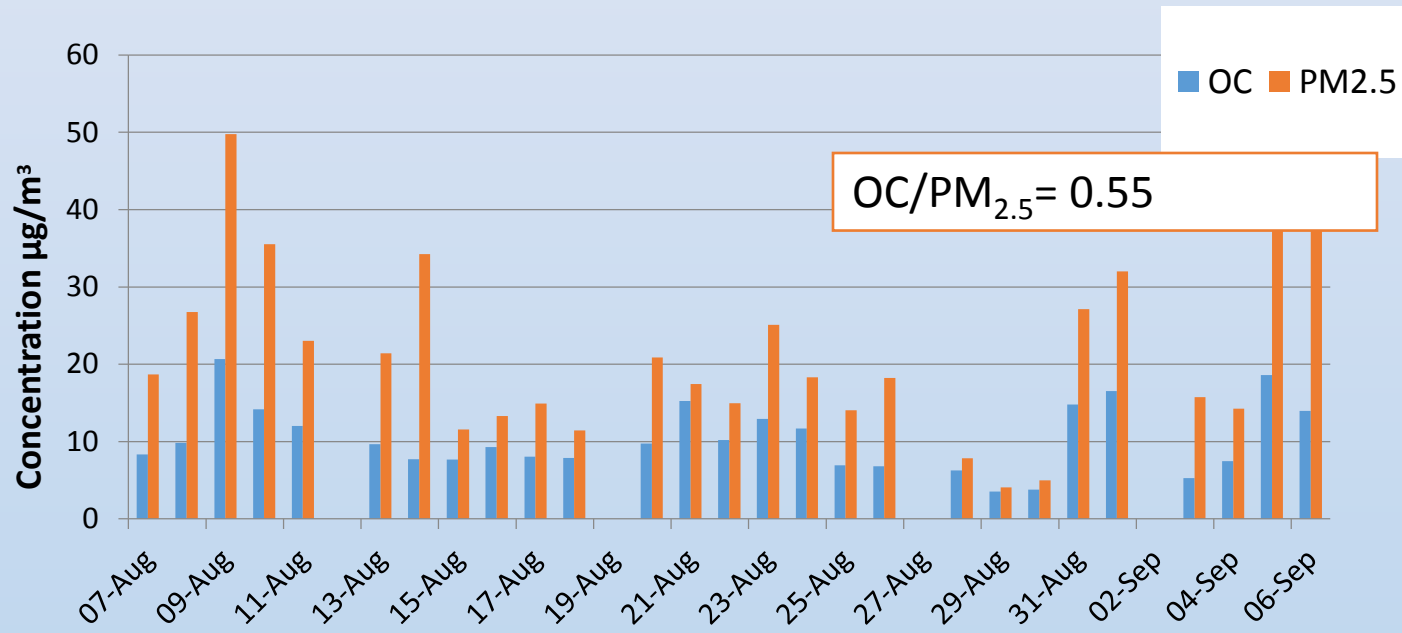




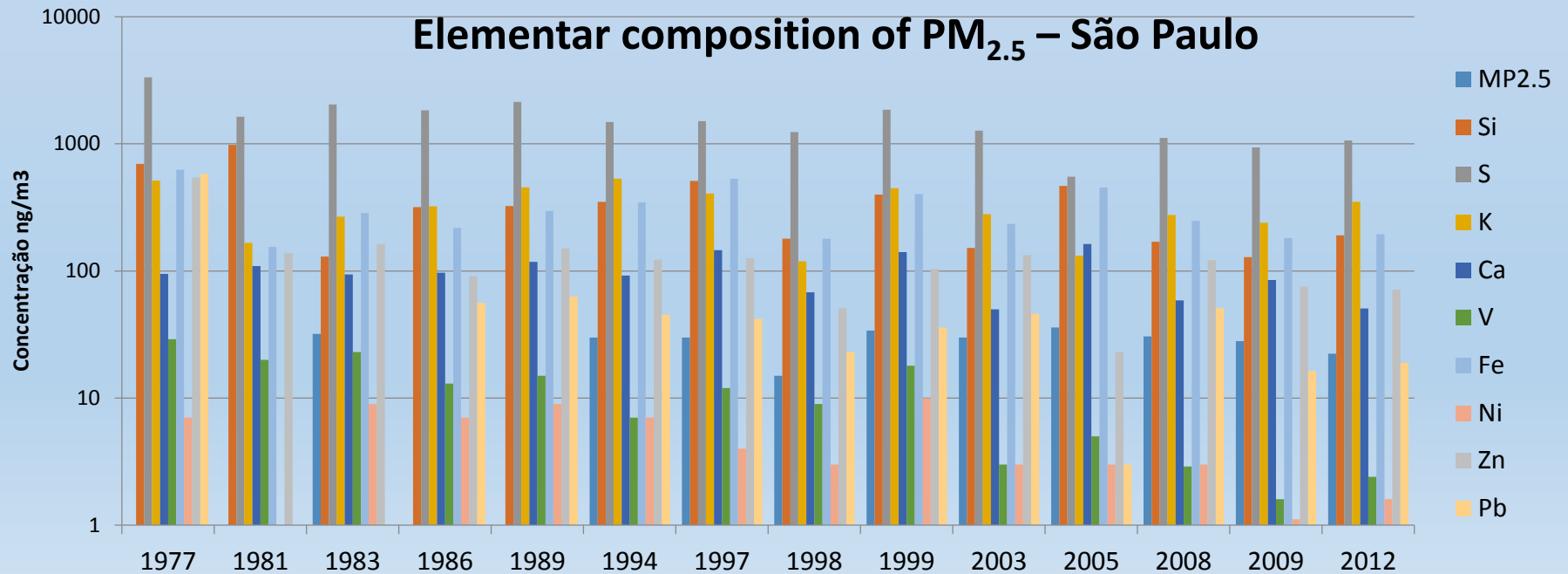
Monthly variations in selected air pollutants in São Paulo. Solid regression lines show monthly mean concentrations used in this paper. Error bars summarize the relative uncertainties in pollutant concentration measurements. Data are from the São Paulo Environmental Company CETESB, 2000–2013 (<http://www.cetesb.sp.gov.br/ar/qualidade-do-ar/32-qualar>)

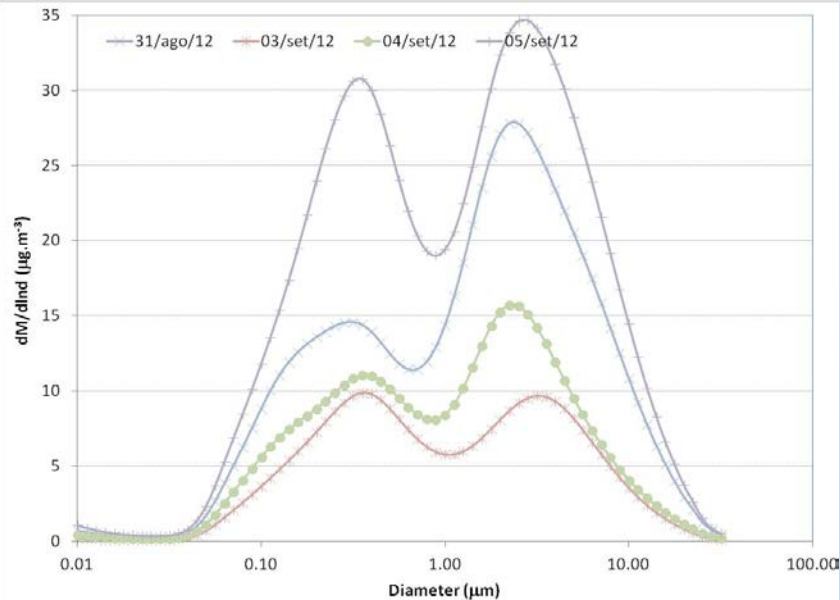
Perez et al., 2015, JGR

Ambient Data – OC and PM2.5



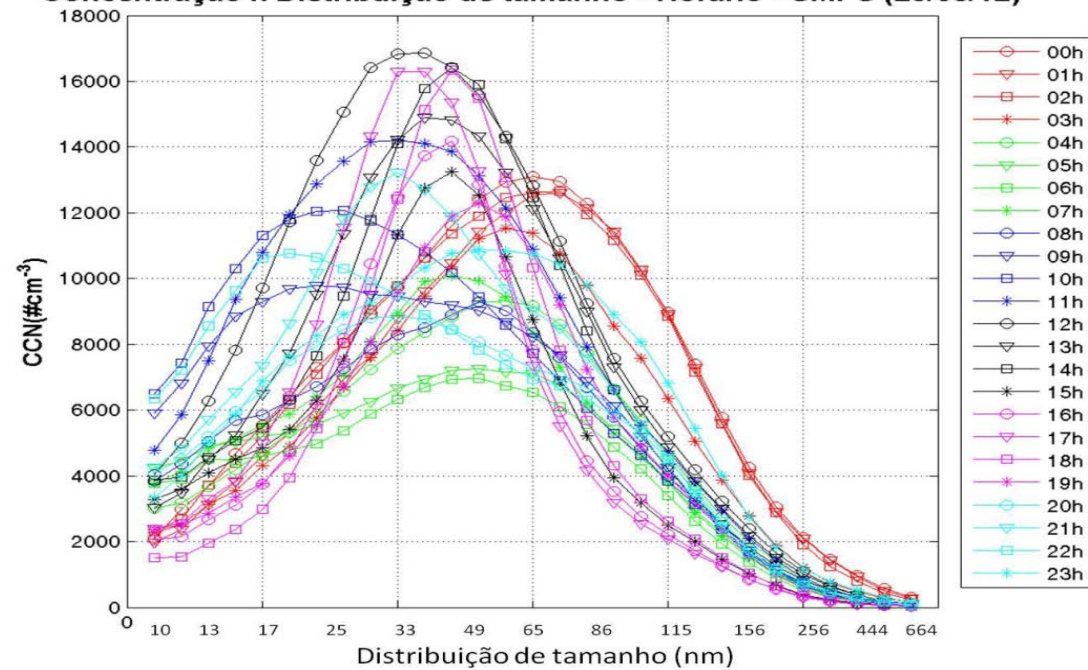
Elementar composition of PM_{2.5} – São Paulo





Mass Size Distribution

Concentração x Distribuição de tamanho - Horário - SMPS (25/08/12)



Number Size Distribution

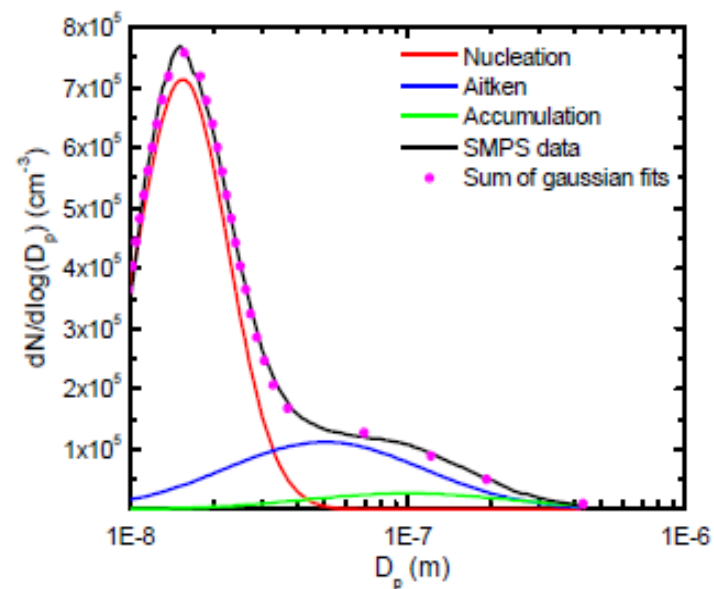
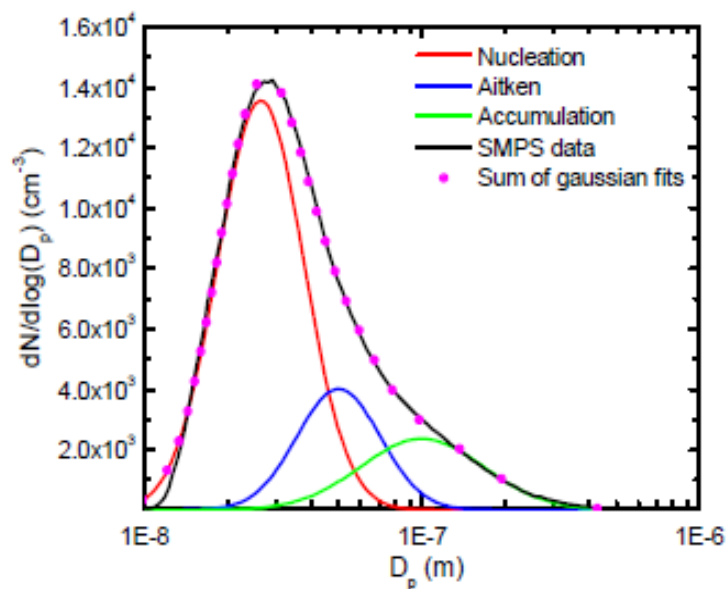
De 10 a 660 nm.

Almeida et al., 2014

Light duty fleet

Diesel

Aerosol size distribution



Average particle number concentration
 73000 cm^{-3} and $d=48.4 \text{ nm}$

Average particle number concentration
 366000 cm^{-3} and $d=38.7 \text{ nm}$

Biologic Aerosol Particles

Tipo

Mitosporos
 Alternaria sp
 Cercospora sp
 Cladosporium sp
 Dreschlera/Bipolaris
 Pen/Asp
 Spegazzinia sp
 Torula sp
 Smuts
 Agaricaceae
 Agrocybe-like
 Coprinus-like
 Cortinariaceae
 Ganoderma sp
 Panaeolus/Psathyrella
 Russula/Laccaria
 Emigydio A. P.,
 Tomentella-like
 mestrado

Visão geral de um campo do microscópio



Basidiósporo *Ganoderma* sp



Ascoporos



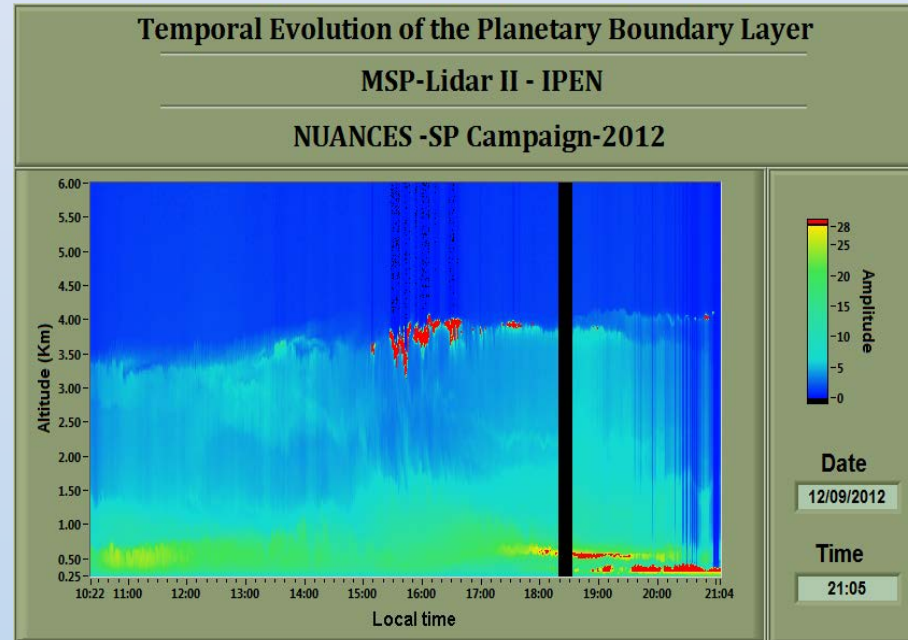
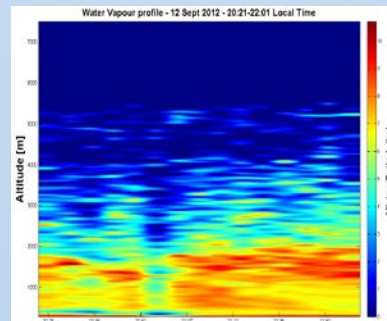
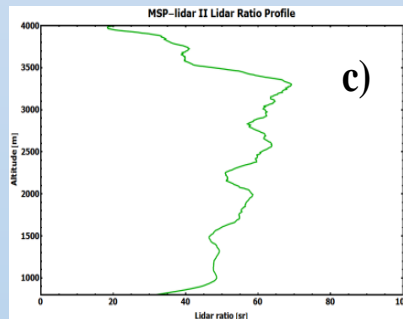
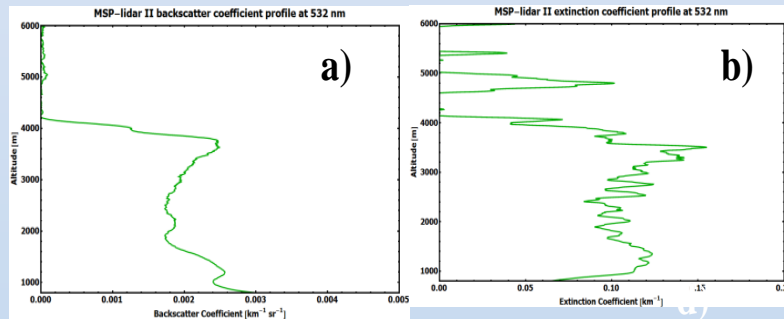
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Polens

Alchornea sp
 Amaranthaceae
 Arecaceae
 Cedrela (Meliaceae)
 Cyperaceae
 Eugenia sp (Myrtaceae)
 Machaerium
 Maytrenus (C
 Monolete



Lidar Measurements and AOD



LIDAR – Retroscatering,
September 12, 2012

Vertical Profile – Setembro 12, 2012

AOD – July-September, 2012

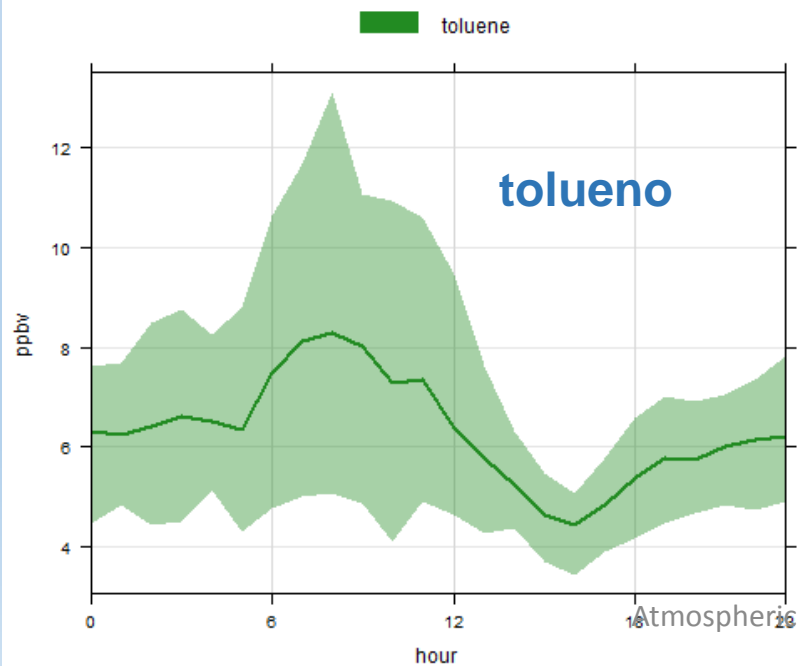
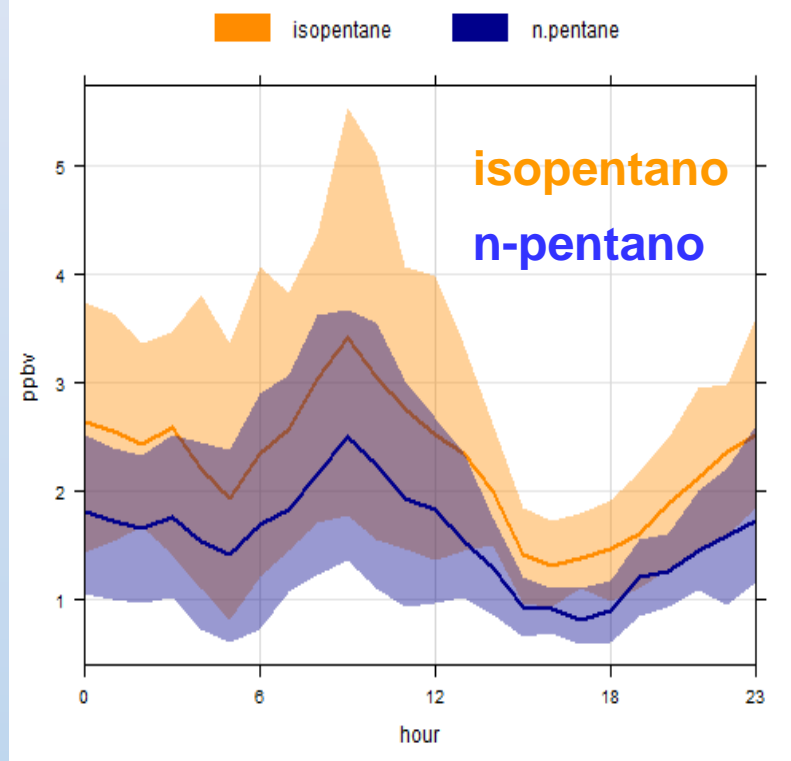
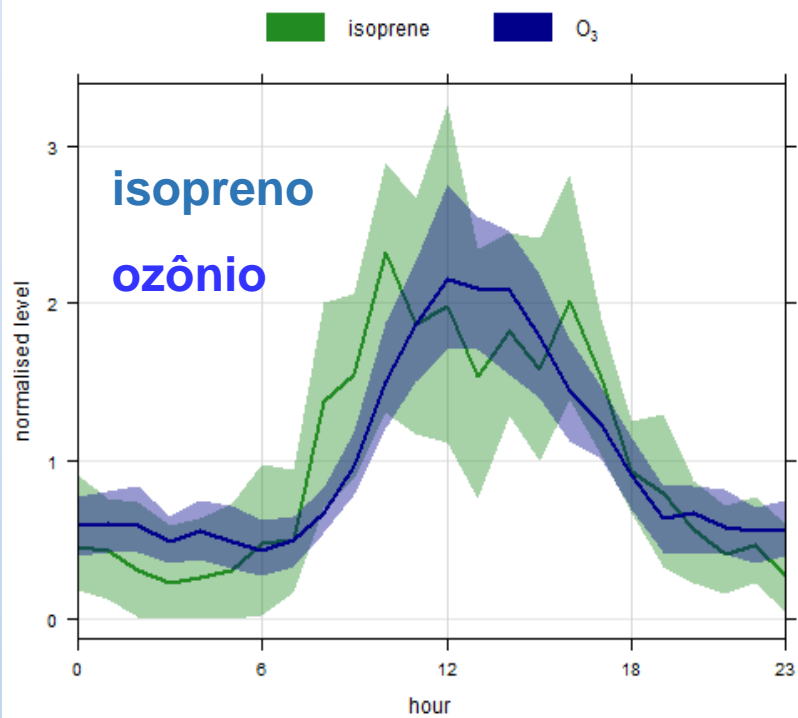
	AOD mean	AOD maximum	AOD minimum
Aqua Satellite	$0,316 \pm 0,215$	$0,927 \pm 0,201$	$0,049 \pm 0,005$
Terra Satellite	$0,187 \pm 0,174$	$0,915 \pm 0,024$	$0,005 \pm 0,005$



Hydrocarbons, HC
⇒C2-C12

- ❖CG-FID (Perkin Elmer, model Clarus 500, with automatic sampling and thermal desorption)
- ❖> 55 HCs (hourly resolution)
- ❖4000 hours of sampling since March 2014

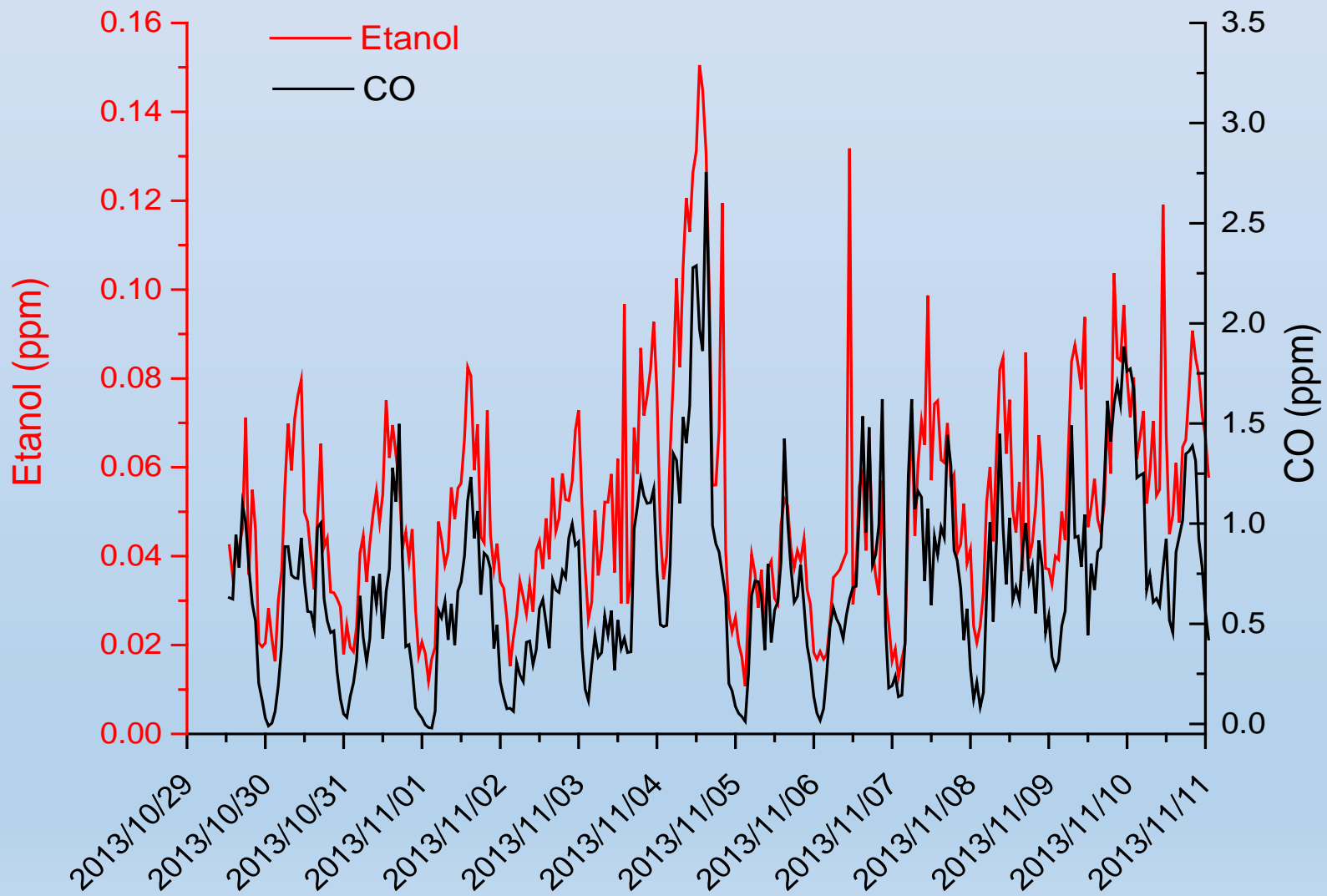
Gaseous compounds



Mean Hourly Variation

Dominucci P. & Nogueira T.

Hourly variation of Ethanol and CO in a street level



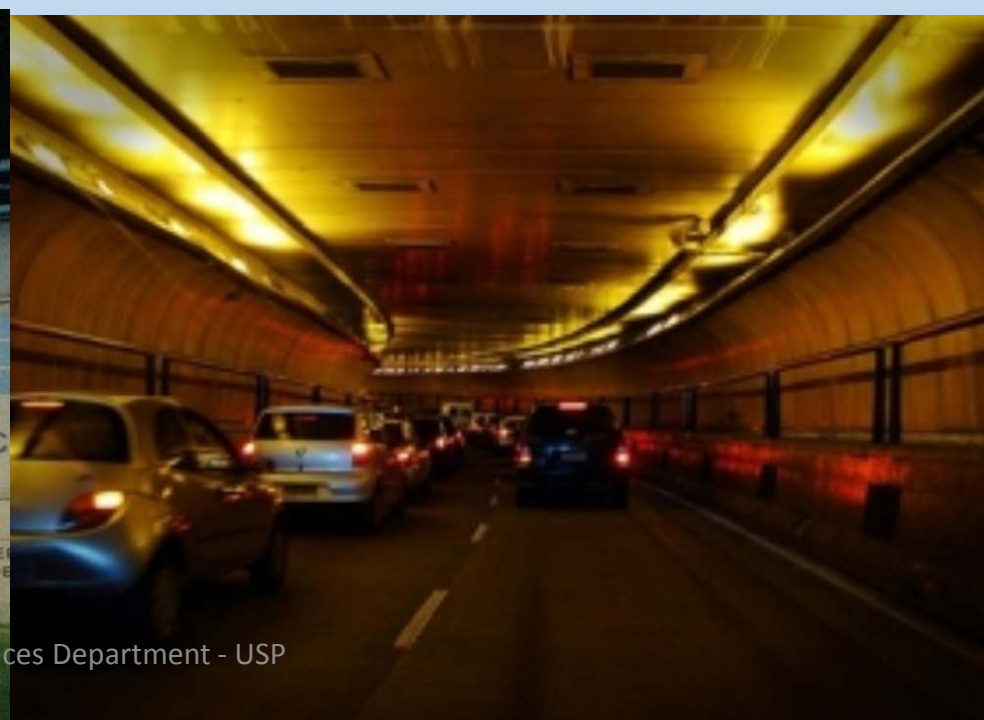
Nogueira T.

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Emission characterization

Emission Factor Evaluations

Tunnel Measurements

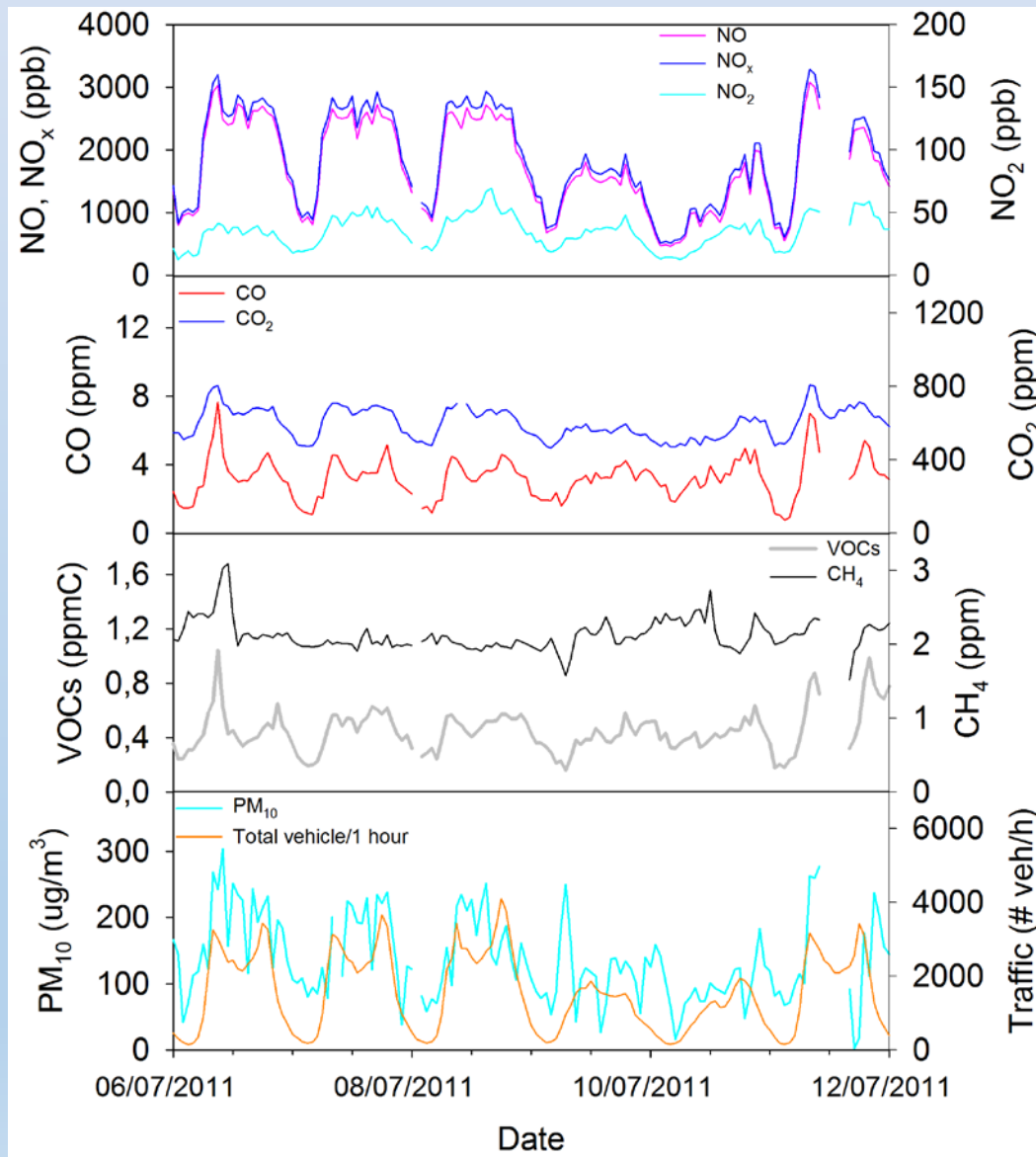


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	TRA (Normal/cong.)	TJQ (Normal/cong.)
Length, l (m)	1.150	850
Cross-sectional area, s (m ²)	100.5	80.6
Perimeter, P (m)	50.3	45.1
Natural flow velocity, u₀ (m s ⁻¹)	4.9/1.0	6.1/1.0
Inlet ventilation rate, a_i (min ⁻¹)	0.3/0.2	0.3/0.2
Outlet ventilation rate, a_o (min ⁻¹)	0.3/0.2	0.3/0.2
Concentration in inlet air, C_i (μg CO m ⁻³)	2.5/5.0	2.6/5.2
Concentration in outlet air, C_o (μg CO m ⁻³)	3.9/7.6	3.7/7.4
Traffic volume, V (#vehicles h ⁻¹)	3.000/1.600	2.000/1.500
Vehicle speed, v (km h ⁻¹)	83/12	72/10
Percentage HDV, f_D (no units)	0.3/0.0	0.0/0.0
Vehicle emission factor (g NO _x kg ⁻¹)	12/48	8/32

Pollutant	PM₁₀	NO_x	CO	CO₂
Method	Beta radiation	Chemi-luminescence	Non Dispersive Infrared Analysis	Infrared Analysis
Analyzer	5014i - Beta	Thermo electron (42i-HL)	Thermo electron (48B)	LI COR-6262 Picarro-G1301
Accuracy	±5%	±1.5%	±1-2.5%	±1%
Resolution	1 min	5 min	5 min	1 min
Units	μg m ⁻³	ppb	ppm/mg m ³	ppm

Time variation of the gas and particulate compounds Inside tunnel – Light and Heavy duty



Emission factors (g km^{-1} , g/kg of fuel burned) from 2011 in comparison with values calculated in 2004 study (mean \pm standard deviation).

Veh.	Local measured	Fuel (km kg^{-1})	CO (g km^{-1}) (g kg^{-1})	NO_x (g km^{-1}) (g kg^{-1})	PM₁₀ (g km^{-1}) ($\mu\text{g kg}^{-1}$)	CO₂ (g km^{-1}) (g kg^{-1})
LDV	TJQ (2011)	13.7 \pm 18.4	5.8 \pm 3.8 78.9 \pm 25.3	0.3 \pm 0.2 4.2 \pm 2.6	0.178 \pm 0.143 2,441 \pm 44	219 \pm 165 3,001 \pm 85
HDV	TRA (2011)	2.24 \pm 2.71	3.5 \pm 1.5 7.8 \pm 4.3	9.2 \pm 2.7 25.5 \pm 8.1	0.290 \pm 0.248 692 \pm 663	1,427 \pm 1,178 3,177 \pm 90
LDV	TJQ (2004)[12]	n.d.	14.6 \pm 2.3 n.d.	1.6 \pm 0.3 n.d.	n.d. n.d.	n.d. n.d.
HDV	TMM ¹ (2004) [12]	n.d.	20.6 \pm 4.7 n.d.	22.3 \pm 9.8 n.d.	n.d. n.d.	n.d. n.d.

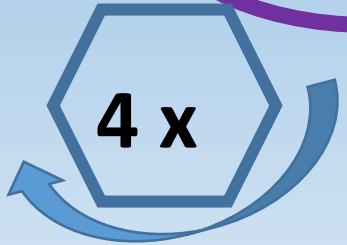
Notes: ¹Tunnel Maríá Maluf, São Paulo (2004).

Comparison between official inventory and Tunnel measurements

	Emission (Gg/year) in 2011 calculated from Tunnel Data Measurements			
	CO	NOx	PM ₁₀	CO ₂
Gasohol/ Ethanol	478	25	13	18029
Diesel	81	207	38	31911
MOTO	247	13	7	9332
Total Mobile	805.4	244	58	59273

Official Inventory
15327 Gg/year

4 x



Modeling emission

2 Approaches

Source distribution Noturn Light DMSP-OLS

Source distribution

Grid points with 30 seconds resolution
from -180° to 180° longitude and -65°
to 65° latitude



Image and data from NOAA's National
Geophysical Data Center.

II Approach

Spatial Distribution of Sources

Geographic information from Open Street Maps

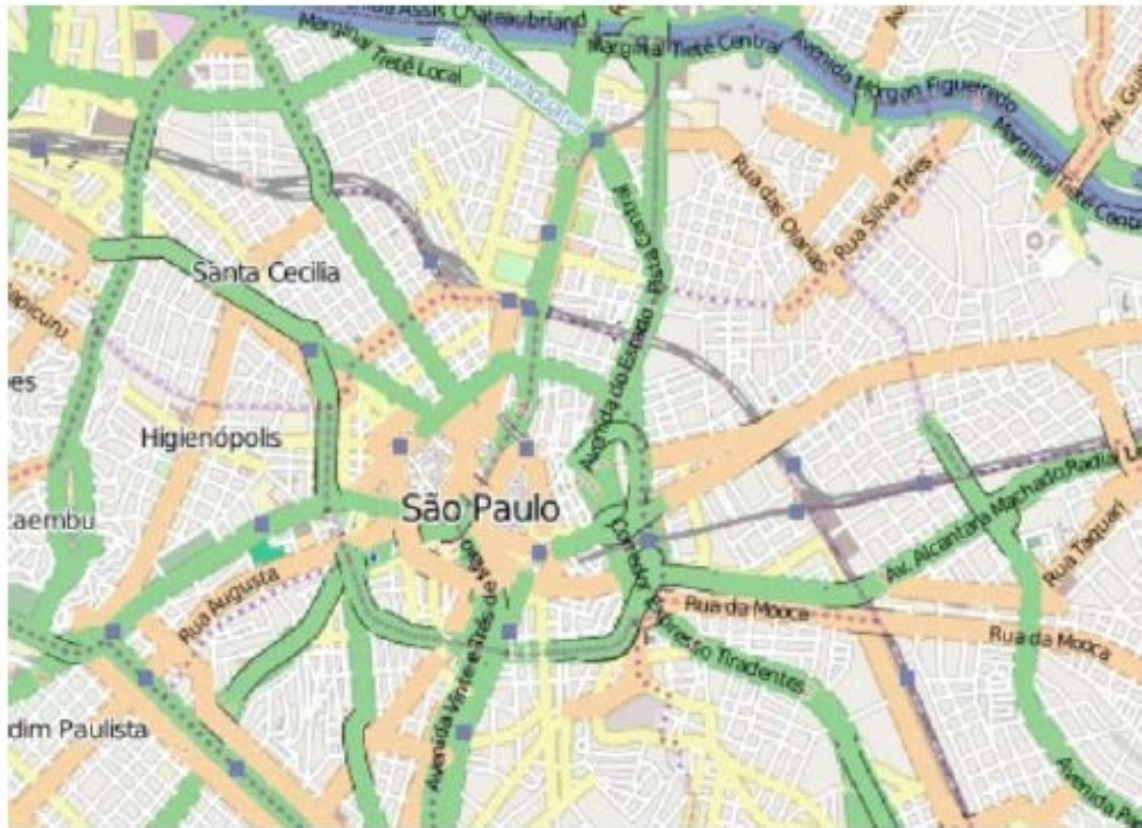
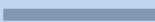
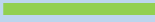



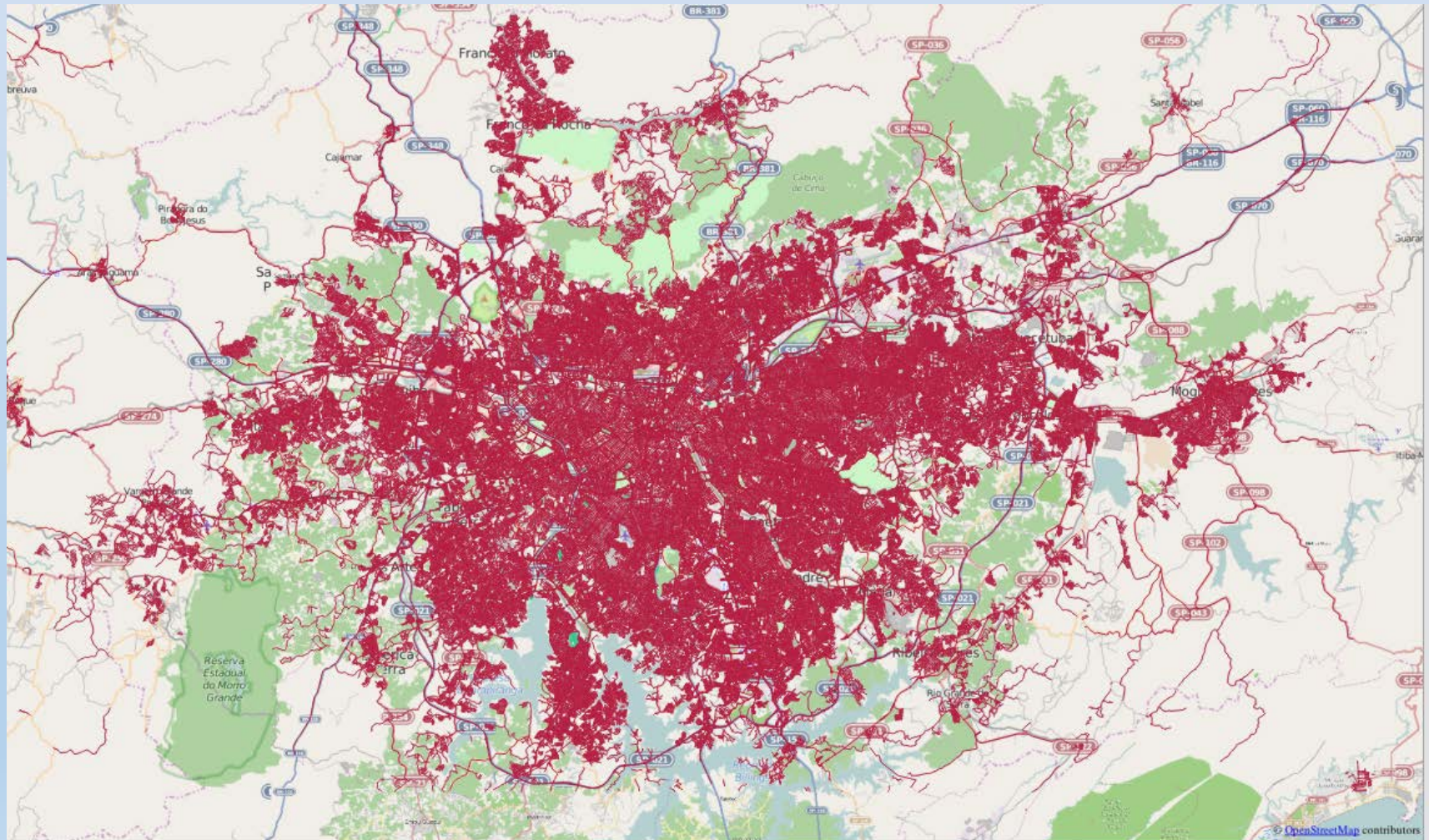
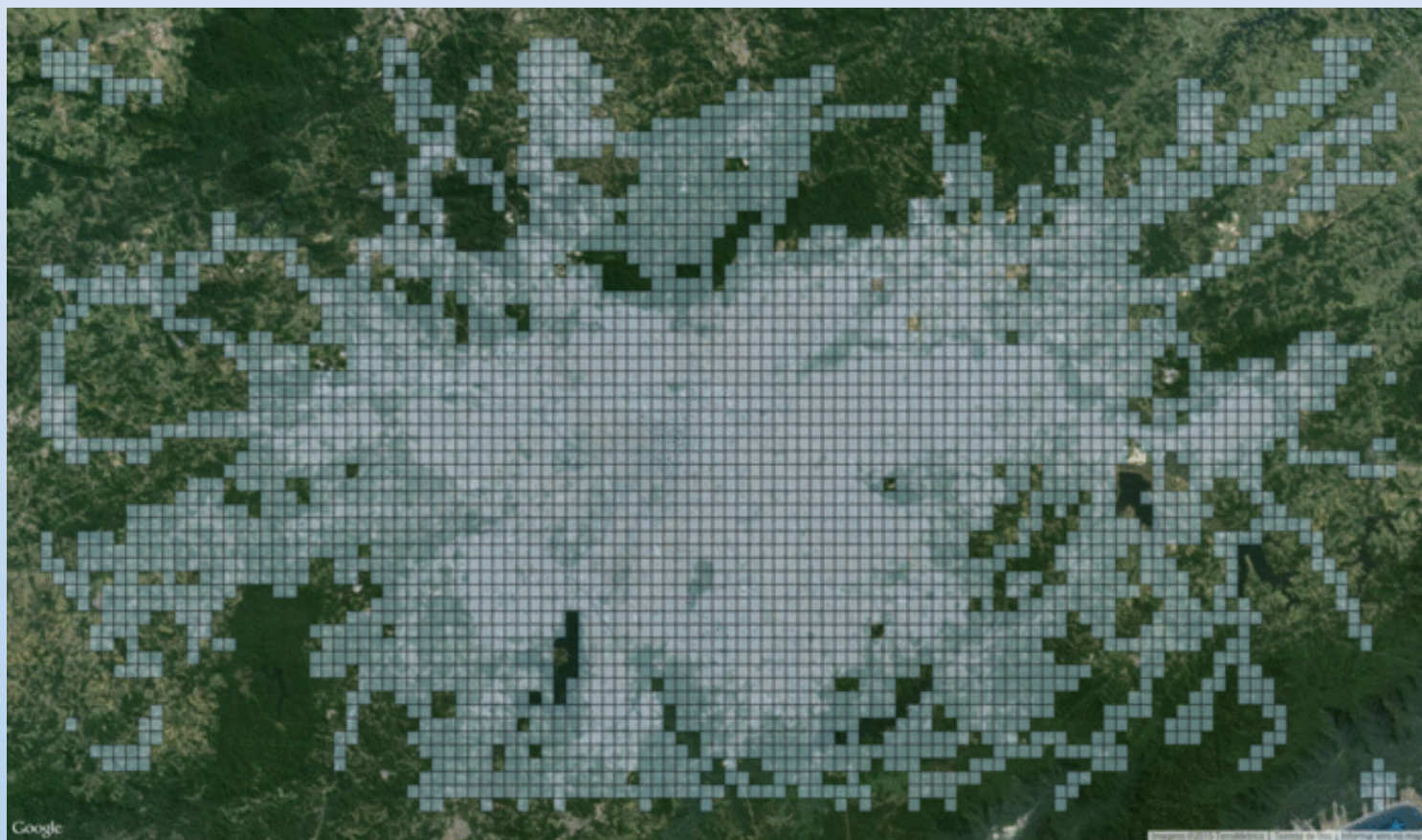


Figura 4. Informação geográfica no open Street Maps

-  Road
-  Main street
-  Primary street
-  Secondary street
-  street

Geographic information from Open Street Maps





CO2 Emissions in MASP

S. Ibarra & R.
Ynoue, 2015

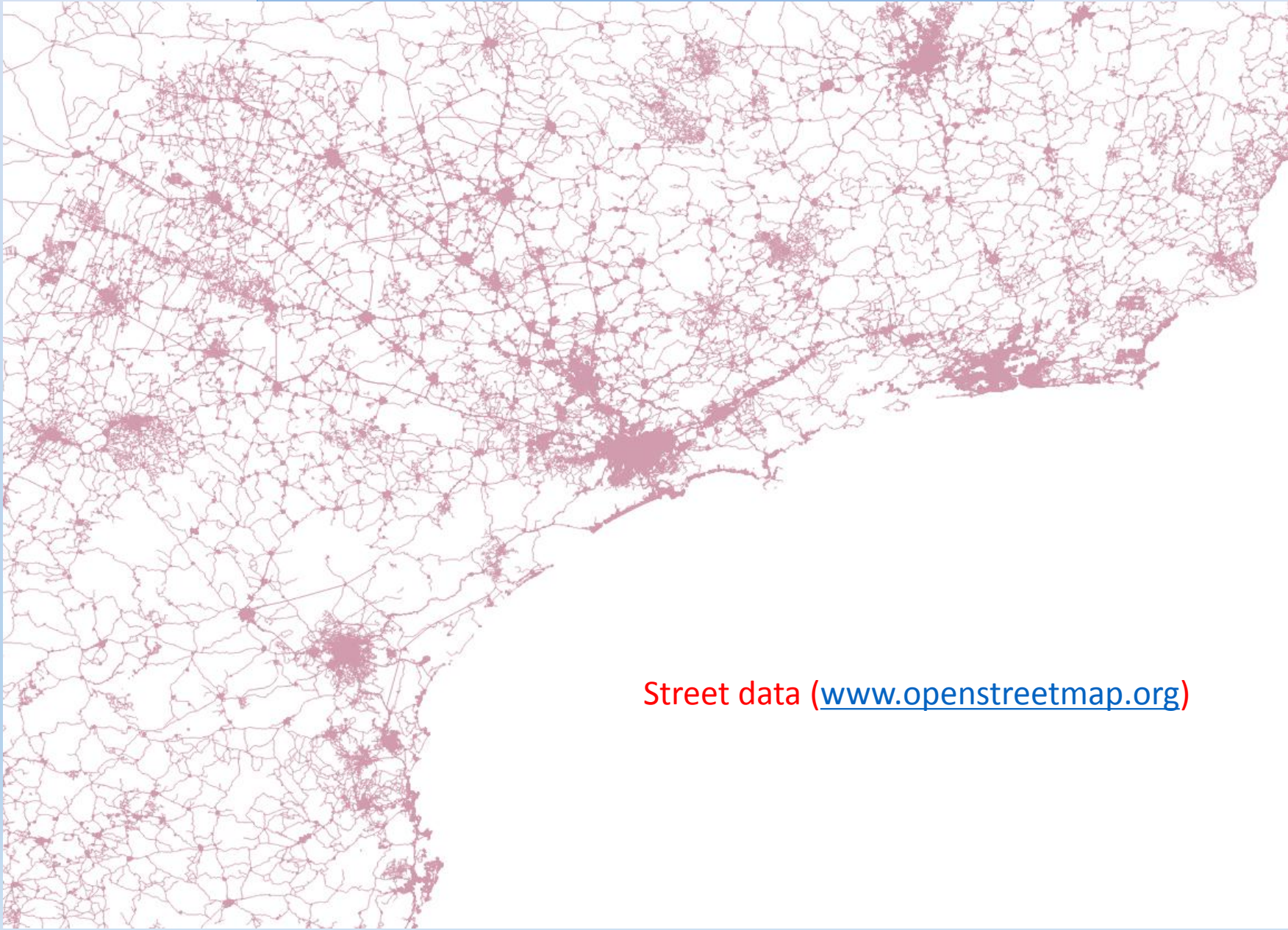
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Modeling Air Quality

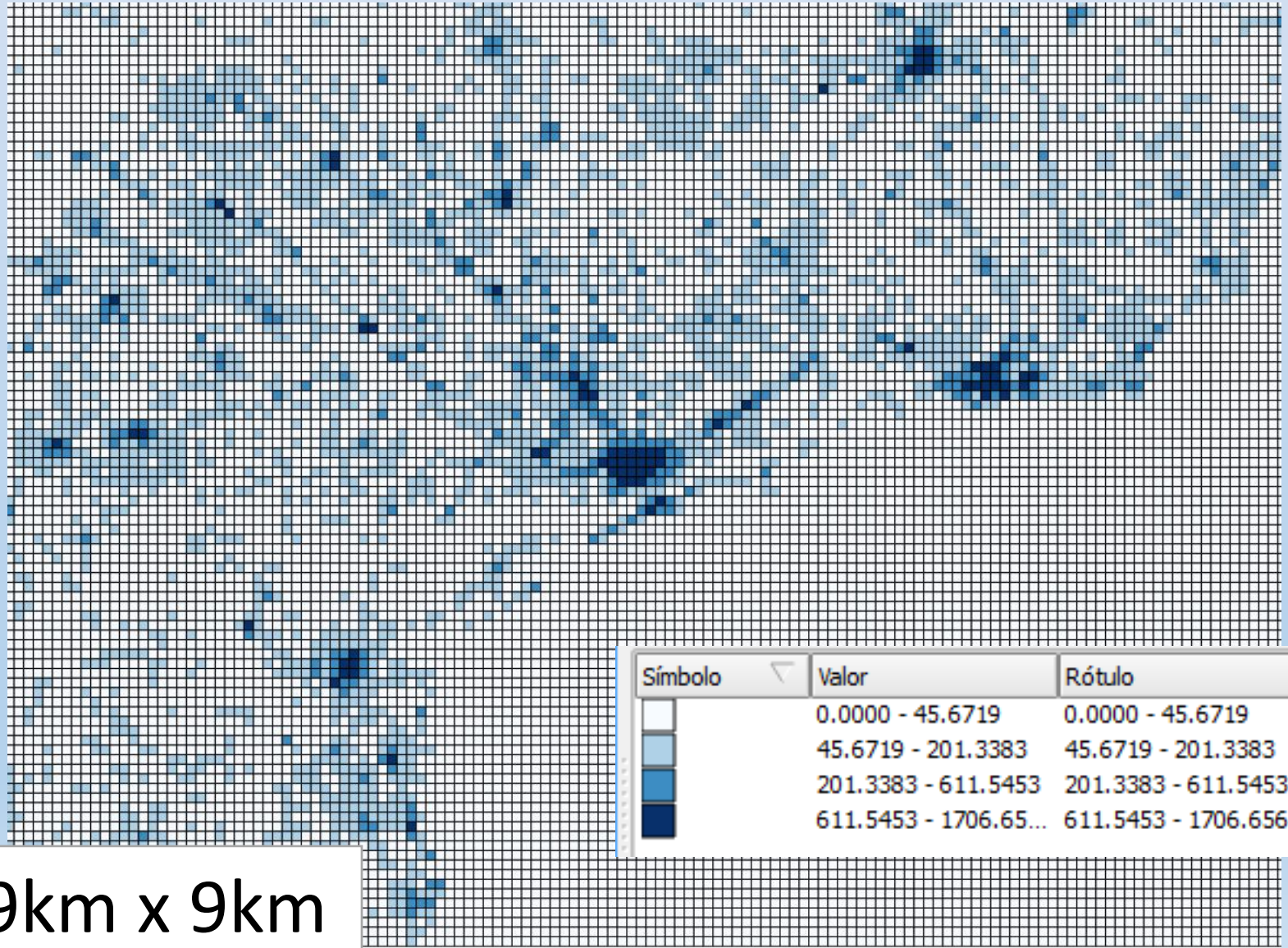
WRF/chem

Spatial distribution of emissions



Street data (www.openstreetmap.org)

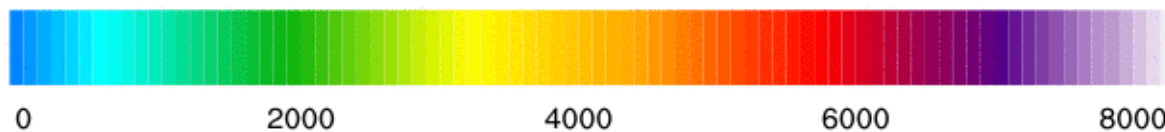
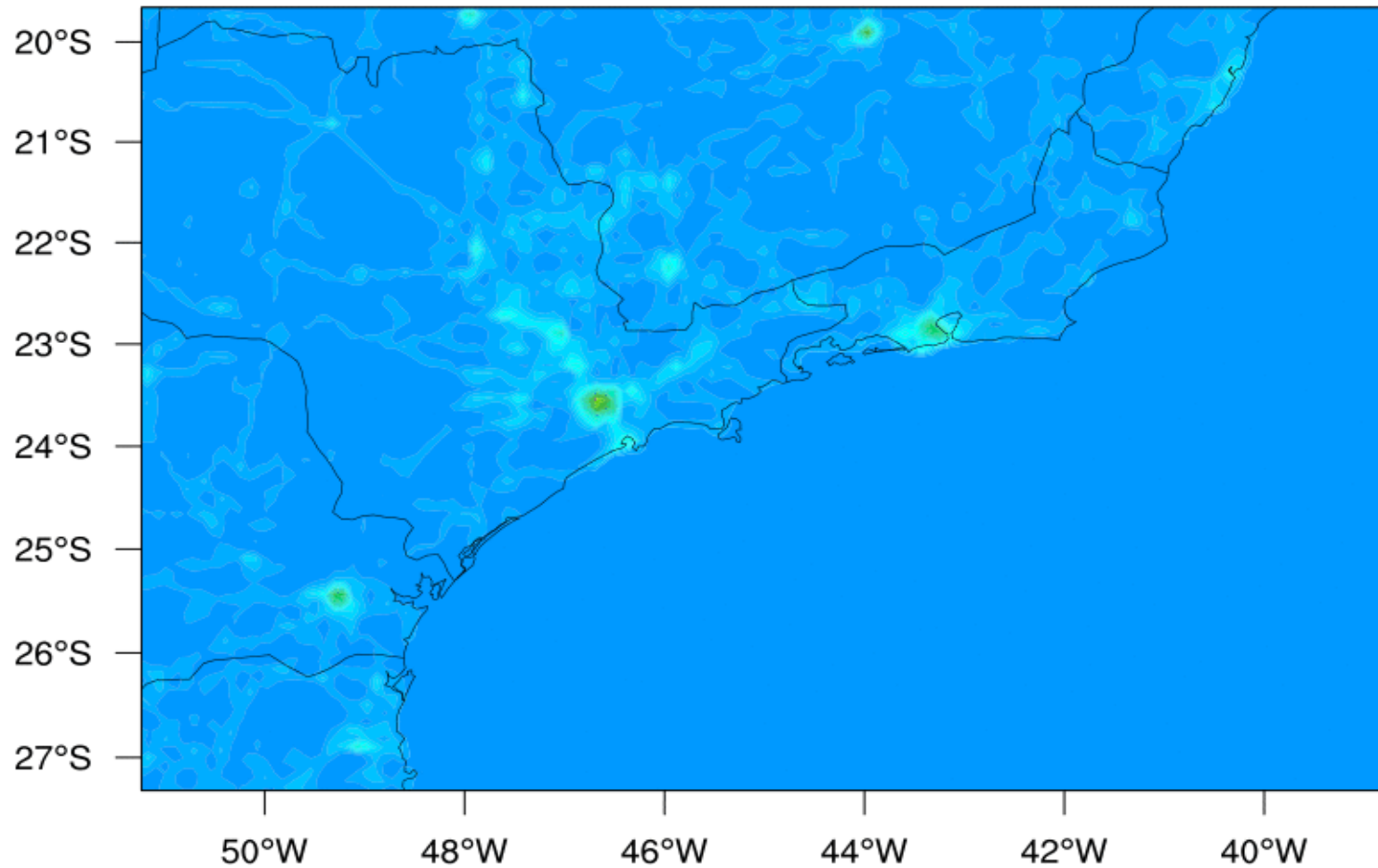
Density (km of street\grid)
number of vehicles proportional to the density



Grid 9km x 9km

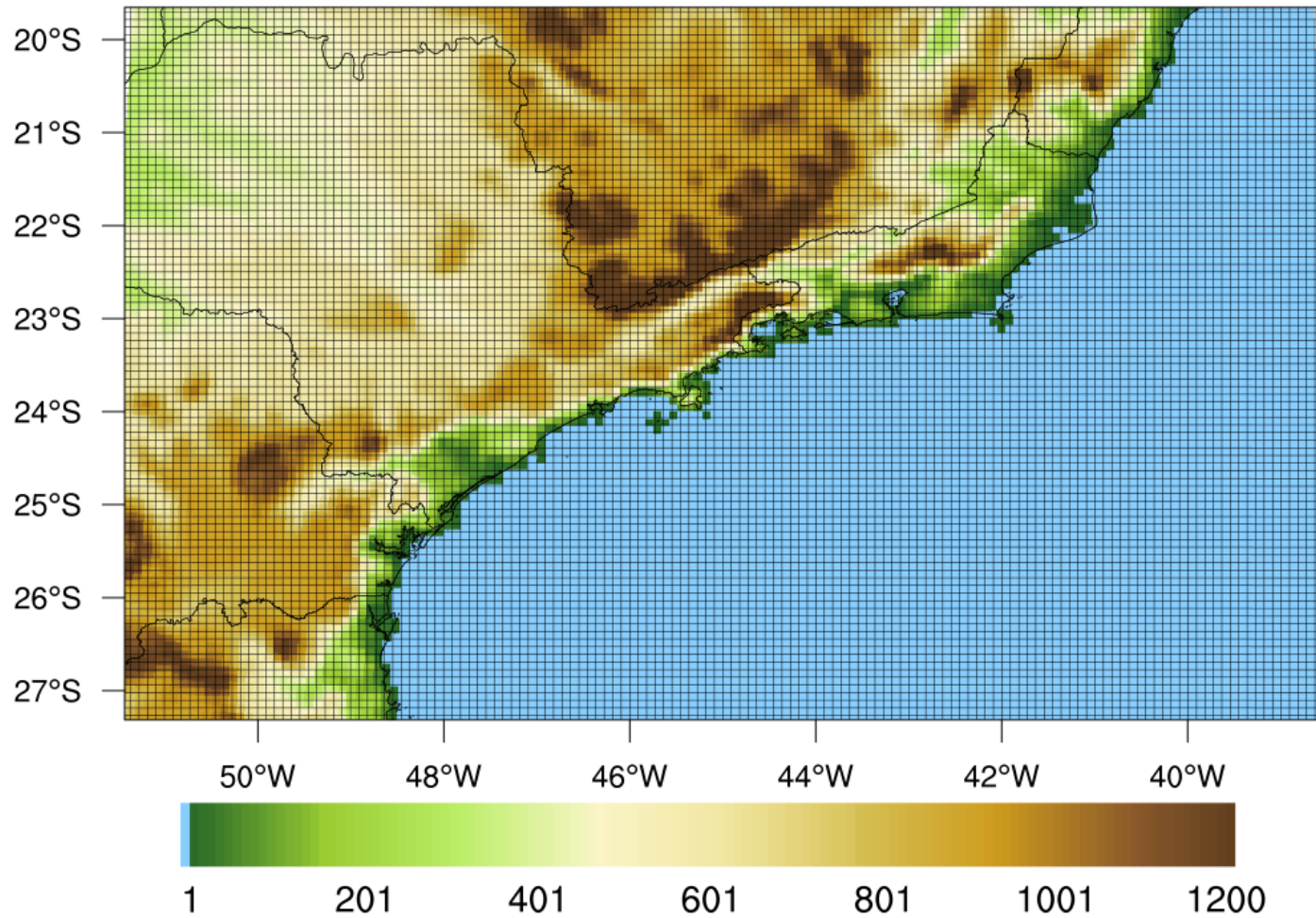
CO EMISSIONS (mol km⁻² hr⁻¹)

00:00

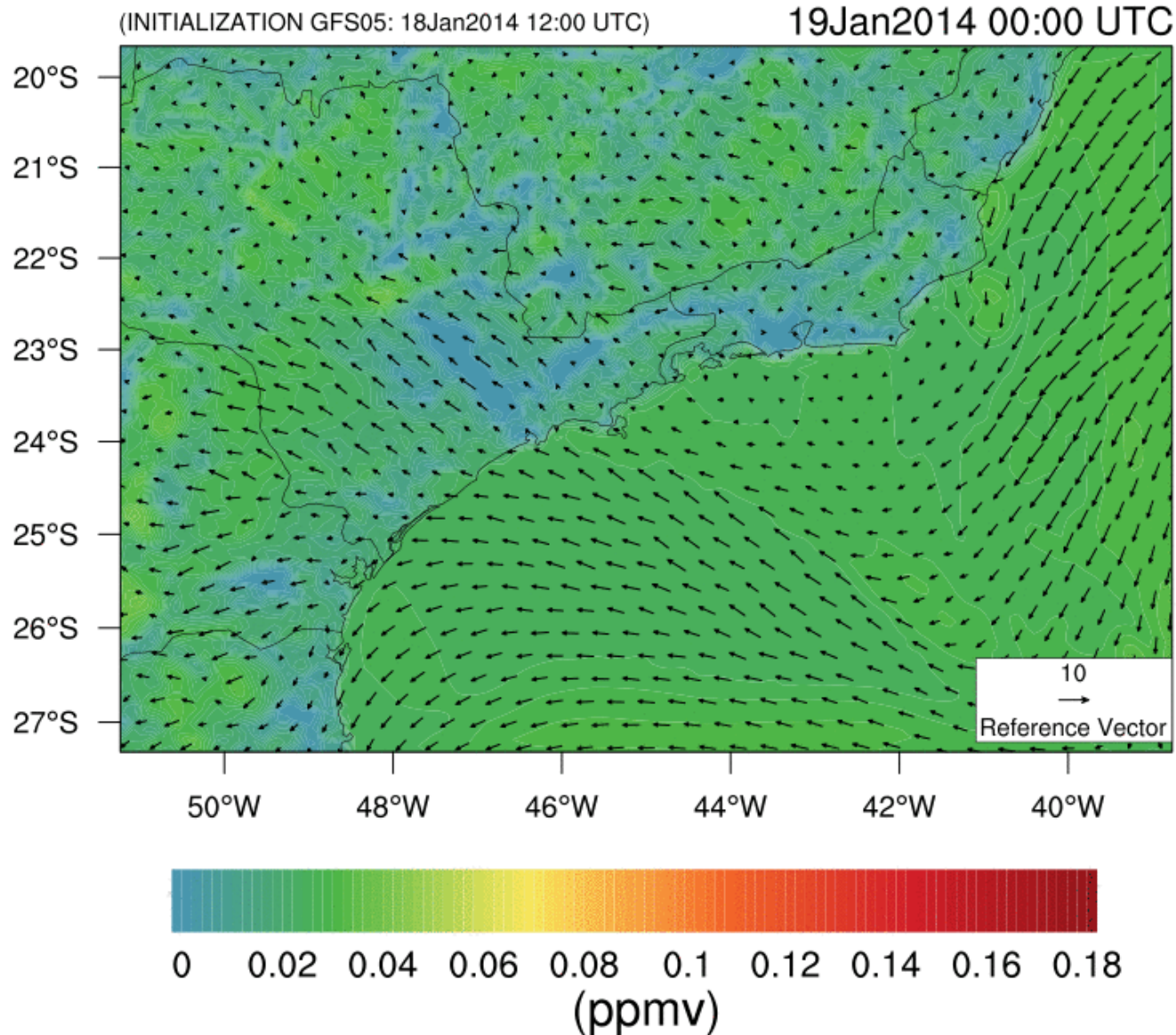


GRID - Sao Paulo/Rio de Janeiro

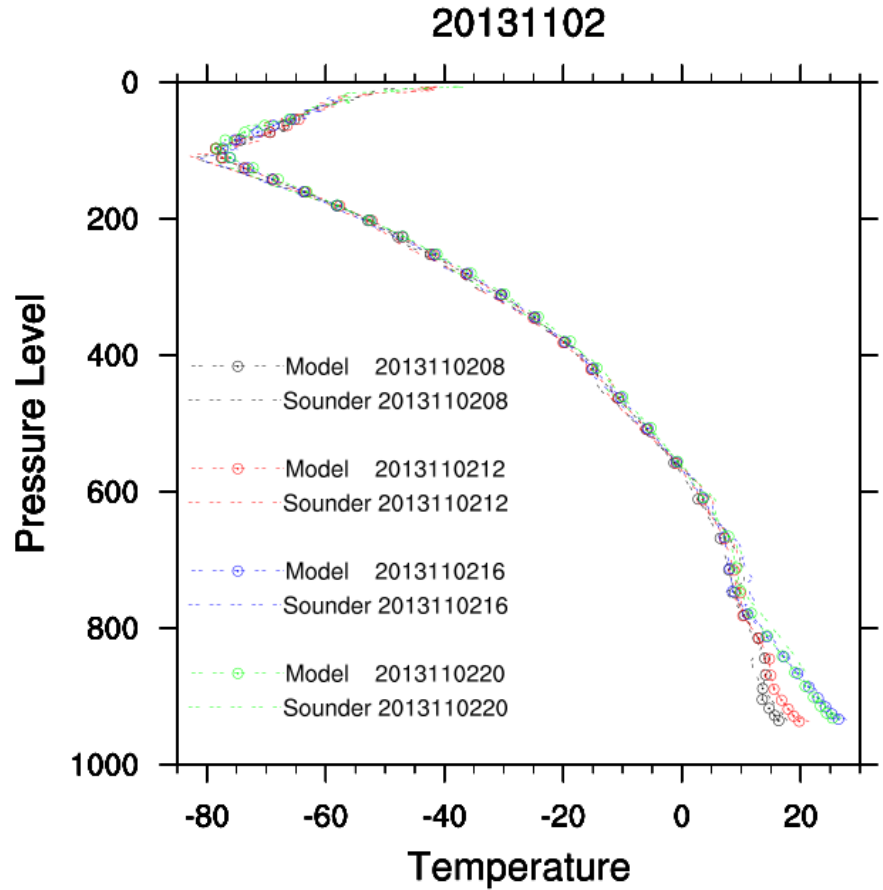
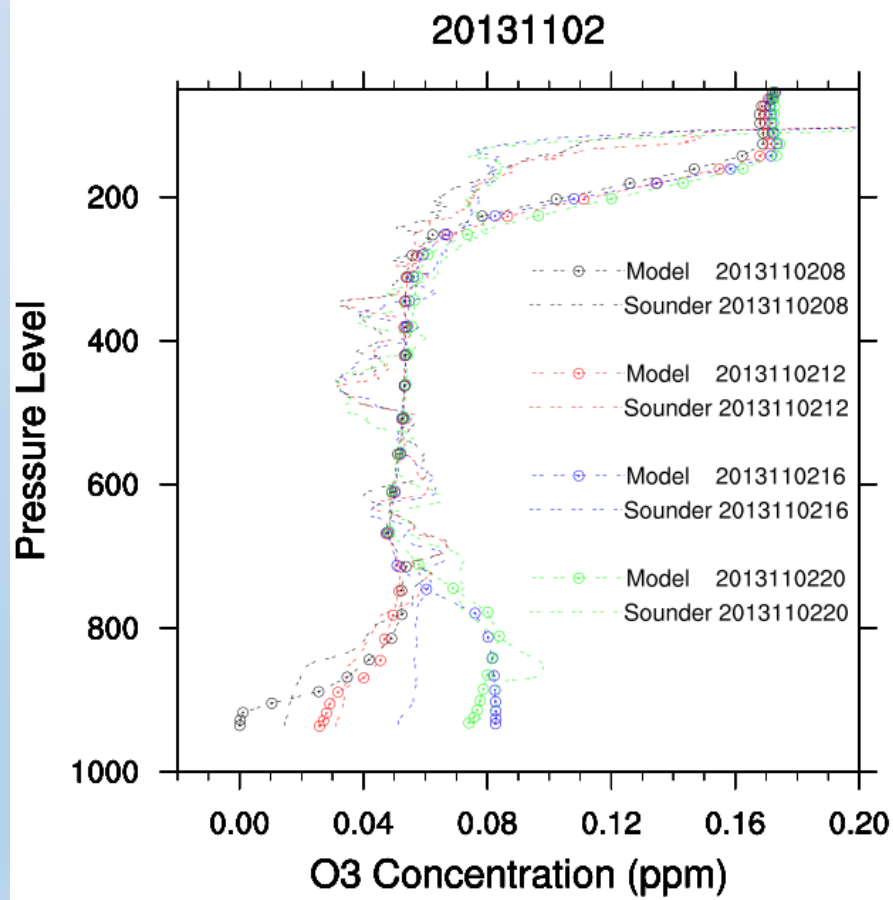
Topography (m)



OZONE CONCENTRATION and SURFACE WIND



Ozone sounding & modeling



Follow Up Project - Main objectives of the METROCLIMA-SPS:

- 1. Evaluate the contribution of the Metropolitan Areas of São Paulo State (MASPS) to the emission of greenhouse gases and co-pollutants, characterizing the “hot-spots” of emission. This objective is in accordance to the research effort in improving the emission inventory for the metropolitan areas of the State. The construction of the emission inventory will be based on top-down and bottom-up approach;**
- 2. Assess the impacts of the MASPS emission to the air quality and contribution to the greenhouse emissions and feedback between emissions, air quality and climate;**
- 3. Integrate the models capability to describe the transport and chemical transformation at different spatial and temporal scales, going from local to regional scales, using regional/urban modelling system.**
- 4. Develop integrated tools to evaluate the impacts of the MASPS to regional climate, and analysis of future scenarios. The scenarios that will be considered are related to the expected changes in the emissions by the transport and agricultural areas, and expansion of urban areas;**

Experimental SITES

Topography (m)

23°20'S

23°30'S

23°40'S

23°50'S

Jaraguá

IAG

45°W

46°30'W

46°15'W

46°W

400

675

800

1200

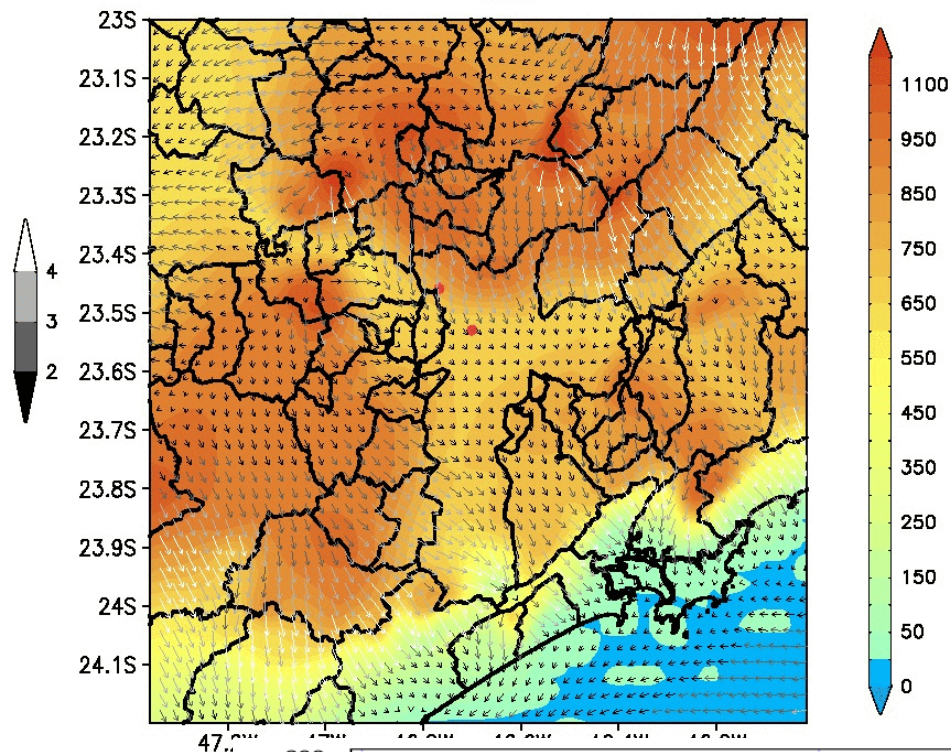


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CO₂ and CH₄ sites

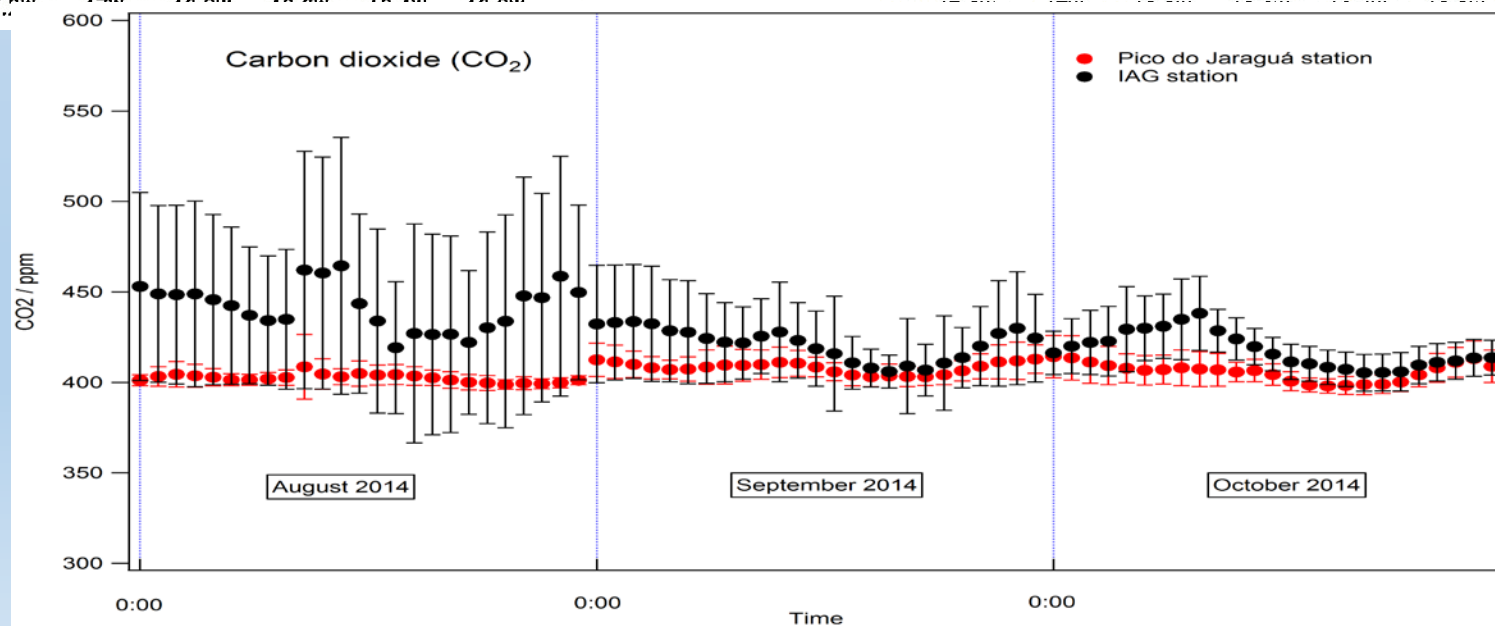
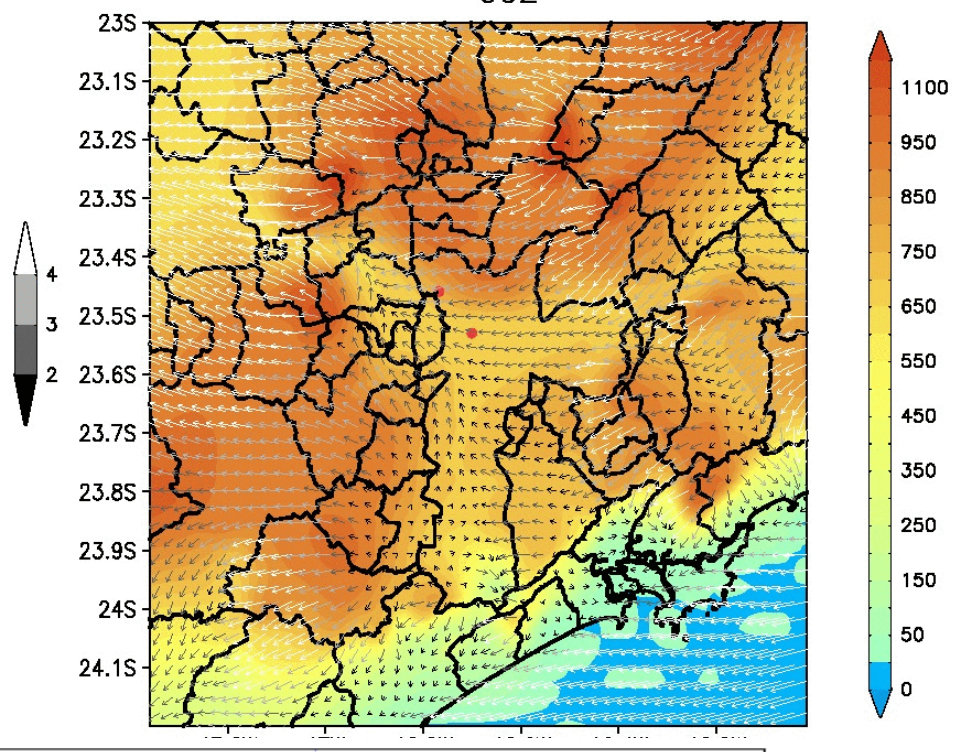
00Z01JUL2012 – 23Z31JUL2012

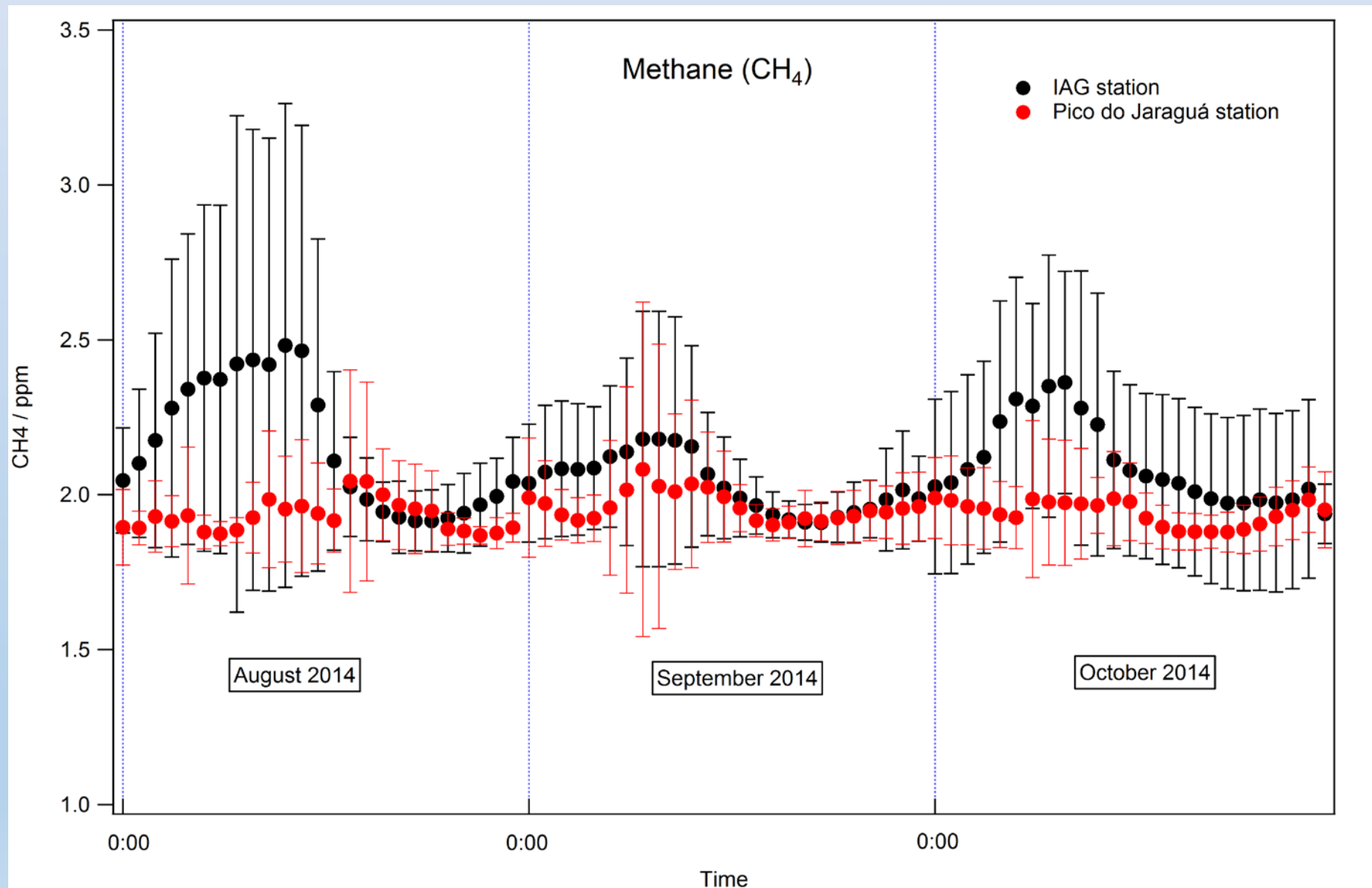
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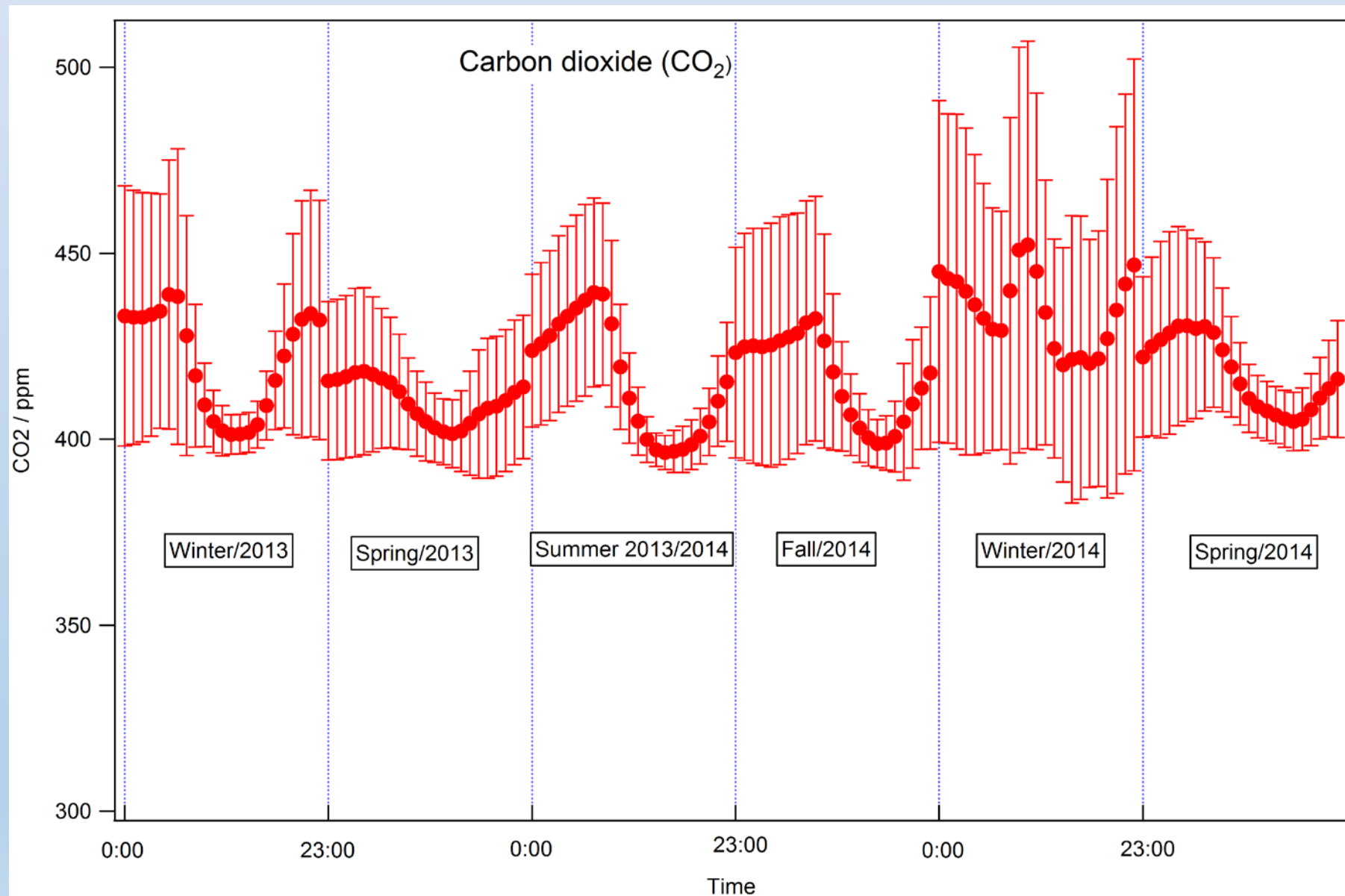


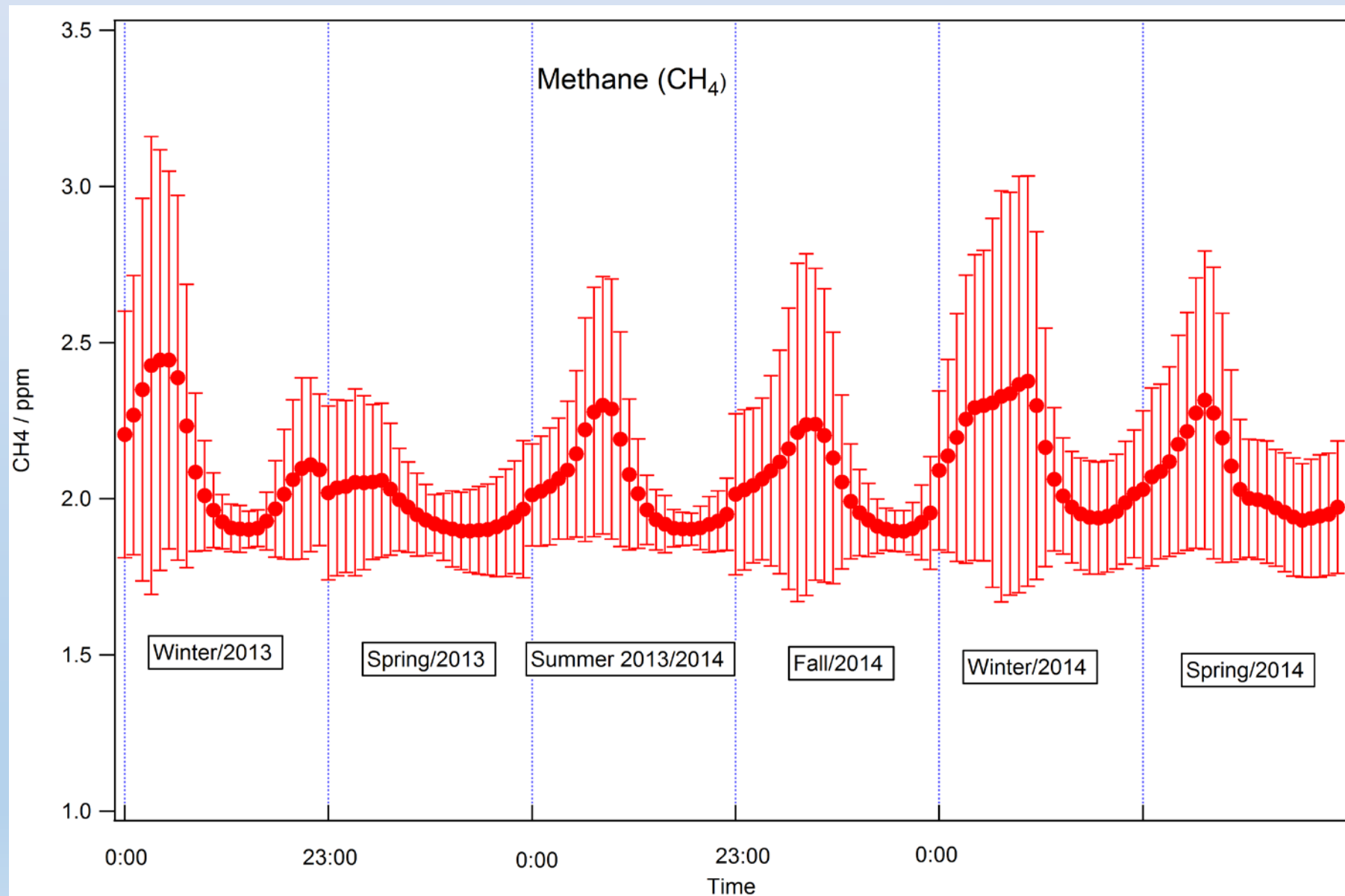
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Summary and Challenges

- How to connect air quality emissions to emissions of greenhouse gases?
 - The quality of measurements considering all the São Paulo State
- How to consider the improvement of both air quality and global warming mitigation?
- The accuracy and reproducibility of measurements
- Perspective 
- Work with INMETRO (Instituto Nacional de Metrologia, qualidade e tecnologia)

**MERCI
THANK YOU
OBRIGADA**

Acknowledgements

