Anthropogenic emissions in South America for air quality and climate modelling

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For **Nicolas Huneeus**
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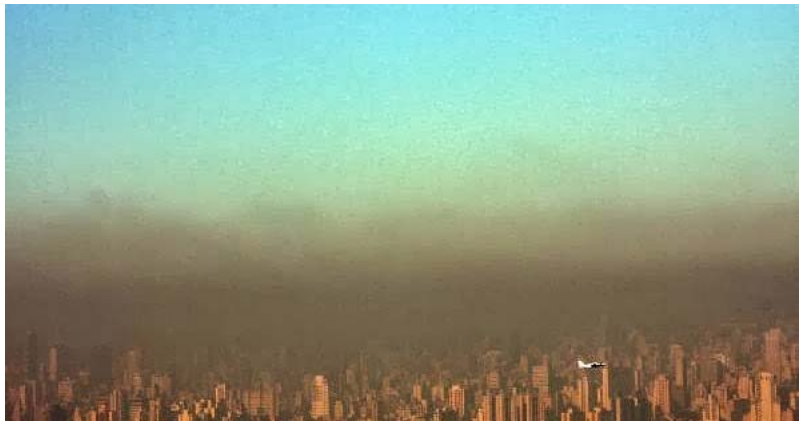
Air pollution has become a major issue in most countries of Latin America: example in Santiago, Chile

Orography plays an important role: mountains close to Santiago reach 5400m (17,800 feet)



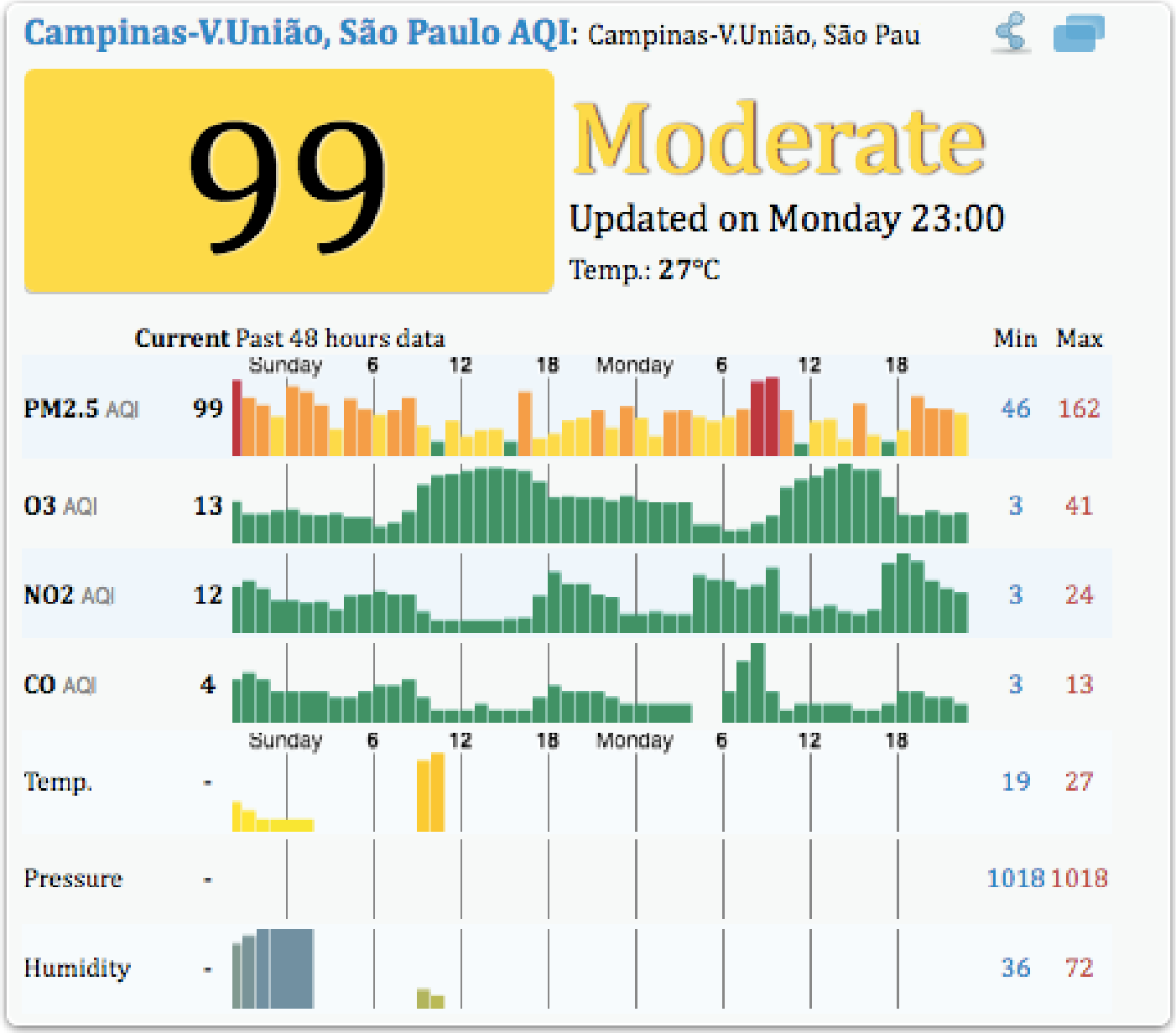
Sao Paulo, Brazil

Medellin, Colombia

La Paz, Bolivia

From the AQICN website (aqicn.org)

August 16, 2017



From the AQICN website (aqicn.org)

Sao Paulo, August 14, 2017

Forecast of air quality in South America:

- A lot of research in the past few years, on observations, modeling and emissions

- But no consistent inventory exist for South America providing anthropogenic emissions

- A workshop was organized in Chile in March 2017, to start a cooperation between South American groups, as well as US and European groups for the development of a consistent inventory

➔ EMISA project

EMISA

Emission Inventories in South America

Chile: Nicolas Huneeus, Laura Gallardo, Mauricio Osses, Sebastian Tolvett

Argentina: Laura Dawidowski, Melisa Diaz Resquin, Diaro Gomez, Paula Castesana, Enrique Puliafito

Brazil: Marcello Alonso, Maria de Fatima Andrade, Rita Ynoue

Colombia: Nestor Rojas

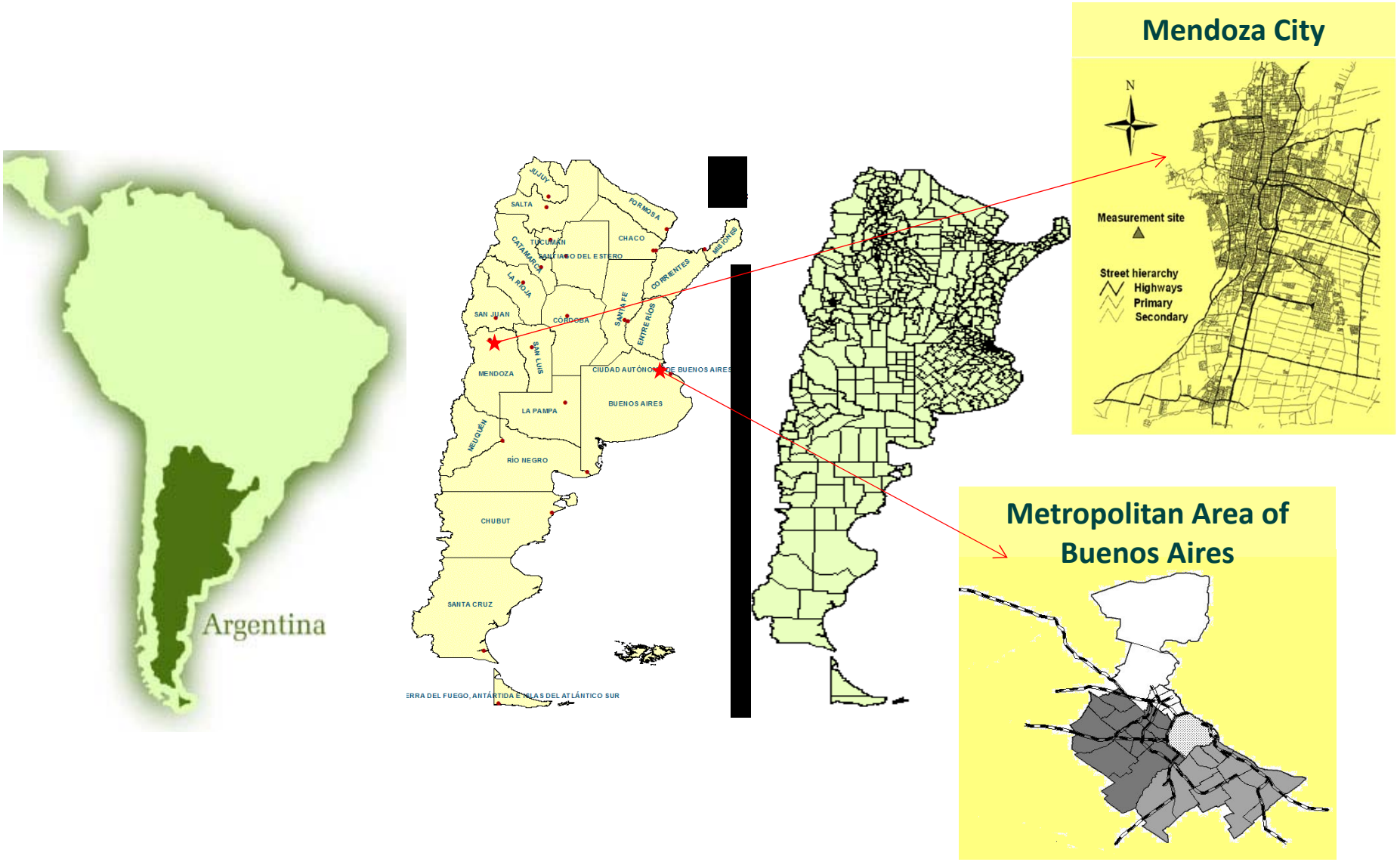
Peru: Odon Sanchez Ccoyllo

The Netherlands: Hugo Denier van der Gon, Jeroen Kuenen

USA: Greg Frost, Rachel Hoesly, Steven Smith, Megan Melamed

France: Claire Granier, Cathy Liousse, Sabine Darras, Louise Granier, Thierno Doumbia

Current work in Argentina



Argentina - Energy

● NC ● Researchers

● spatial disaggregated for modeling

Source categories	GHG		O3 precursors		PM related			
Energy	CO_2, CH_4, N_2O	F-gases	NOx, CO, VOCs	VOCs speciated	$PM_{10}/PM_{2.5}$	NH_3	SO_2	BC
Public electricity and heat production	● ●		● ●	●	●	●	● ●	●
Other Energy Industries	● ●		● ●	●	●	●	● ●	●
Manufacturing Industries and Construction	● ●		● ●	NE	●	●	● ●	NE
Domestic aviation	● ●		● ●	NE	●	●	● ●	●
Road transportation	● ●		● ●	NE	●	●	● ●	●
Rail transportation	● ●		● ●	NE	●	●	● ●	●
Inland navigation	● ●		● ●	NE	●	●	● ●	●
Other transportation	● ●		● ●	NE	●	●	● ●	●
Residential and other sectors	● ●		● ●	NE	●	●	● ●	●
Fugitive emissions from solid fuels	●		NE	NE	NE		NE	
Fugitive emissions from oil and gas	● ●		● ●	NE	●	●	● ●	●

Buenos Aires and Mendoza

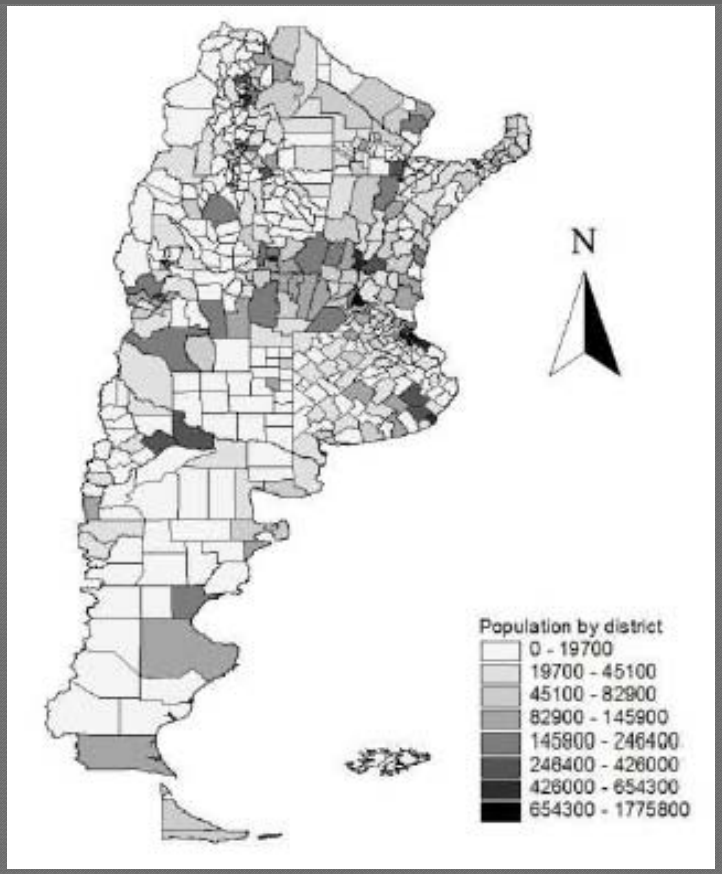
● Buenos Aires

● Mendoza City

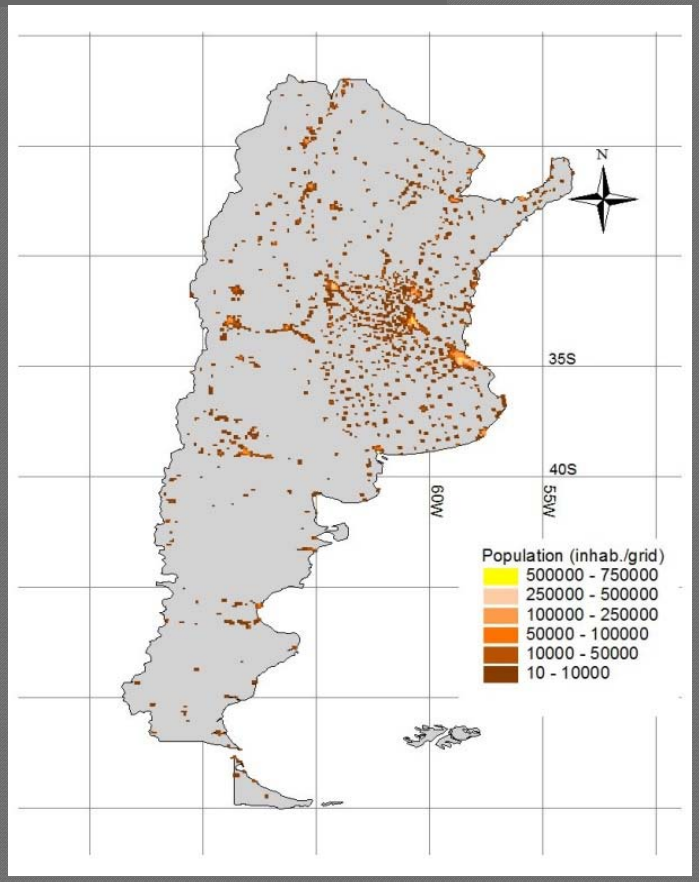
Source categories	GHG	O3 precursors		PM related				Others	
Megacities	CO_2, CH_4, N_2O	NOx, CO, VOCs	VOCs speciated	PM_{10}/$PM_{2.5}$	NH_3	SO_2	BC	Metals	POPs
Public electricity and heat production	●	●	NE	●	NE	●	●	●	●
Other Energy Industries	●	●	NE	●	NE	●	●	NE	
Manufacturing Industries and Construction	●	●	NE	NE		●	●	NE	
Domestic aviation	NE								
Road transportation	●	●	●	● ●	NE	●	●	●	● ●
Rail transportation	NE								
Residential and other sectors	●	●	NE	●	NE	●	●	●	●
Industrial sources	NE			●	NE			●	●
Wastes	NE							●	●
Natural sources (soils)	NE			●	NE			●	NE

Spatial disaggregation

Model based on indicators and satellite imagery

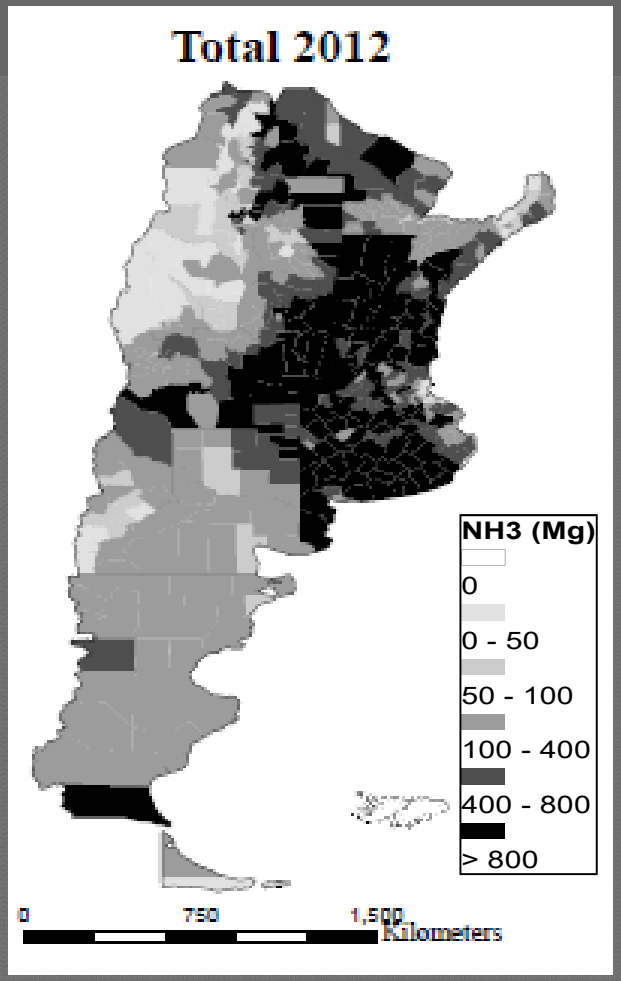


Population by district

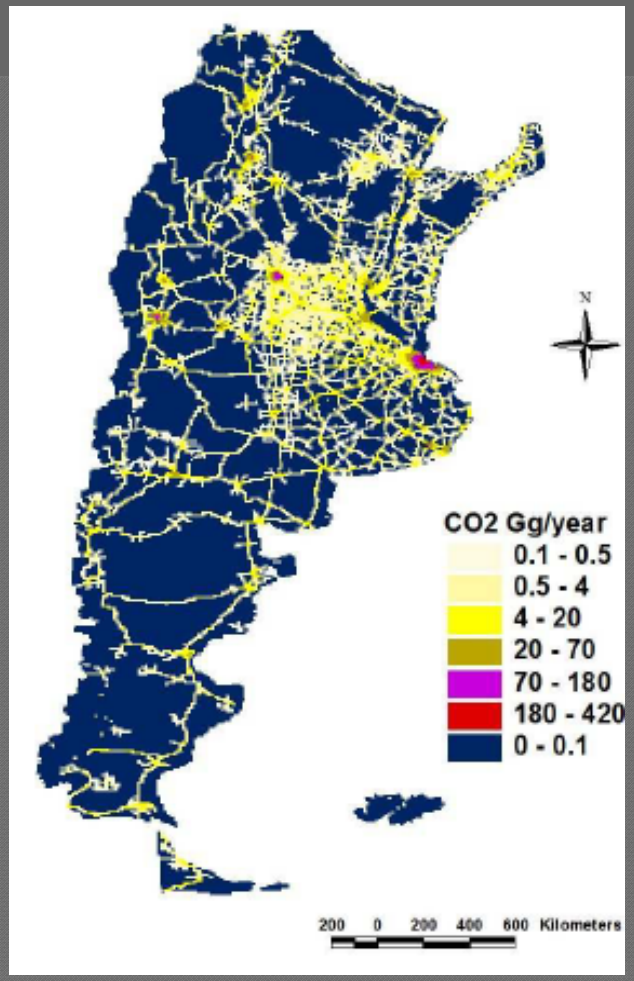


Population using Earth at night

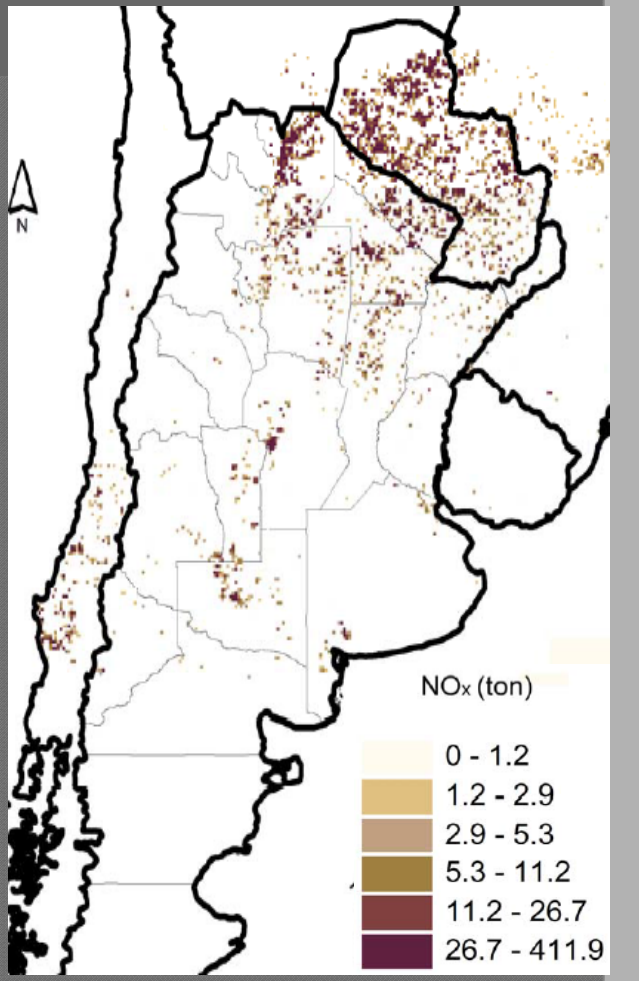
Spatial disaggregation



Direct disaggregation of activity data

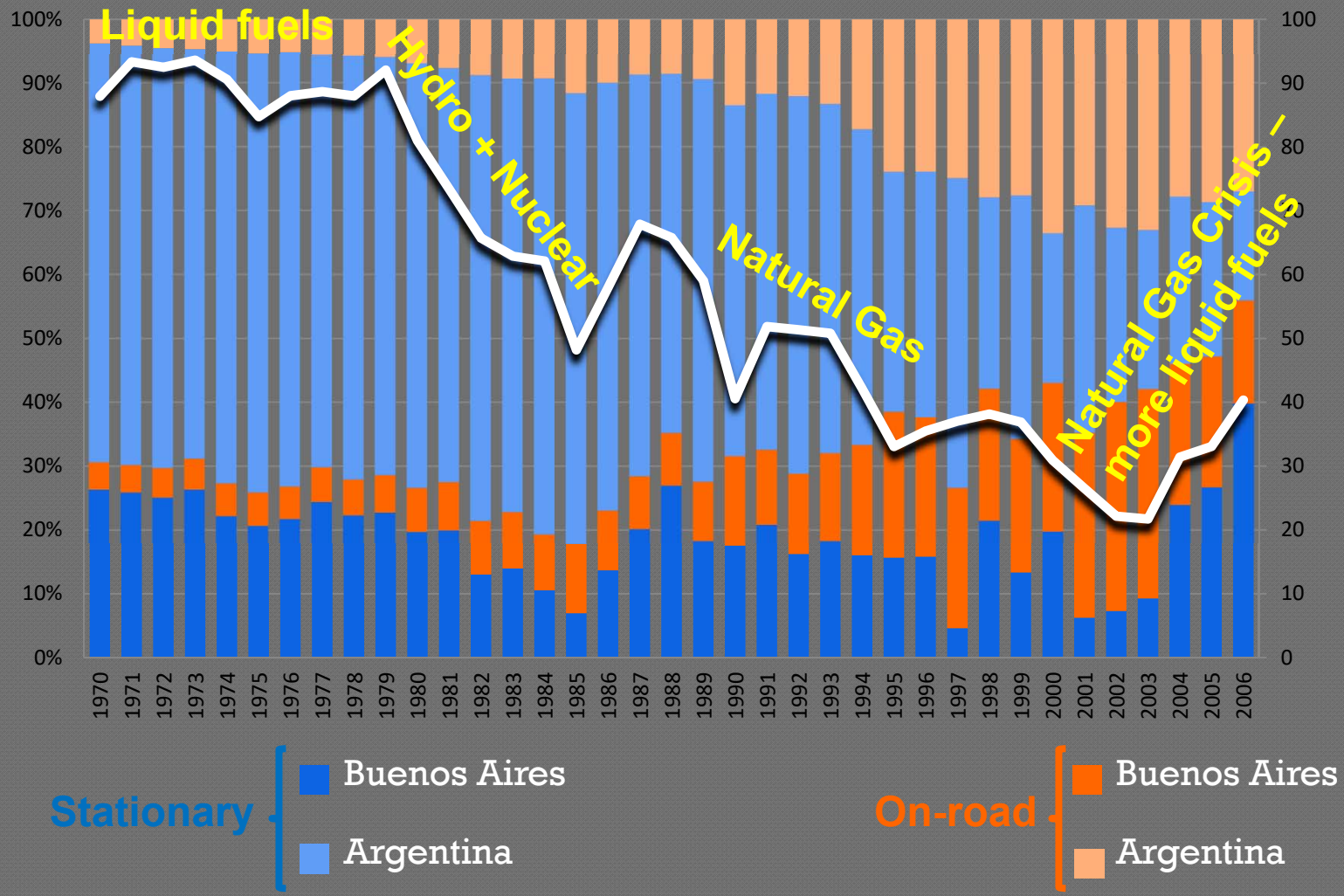


CO2 emissions from Road transportation, 2010

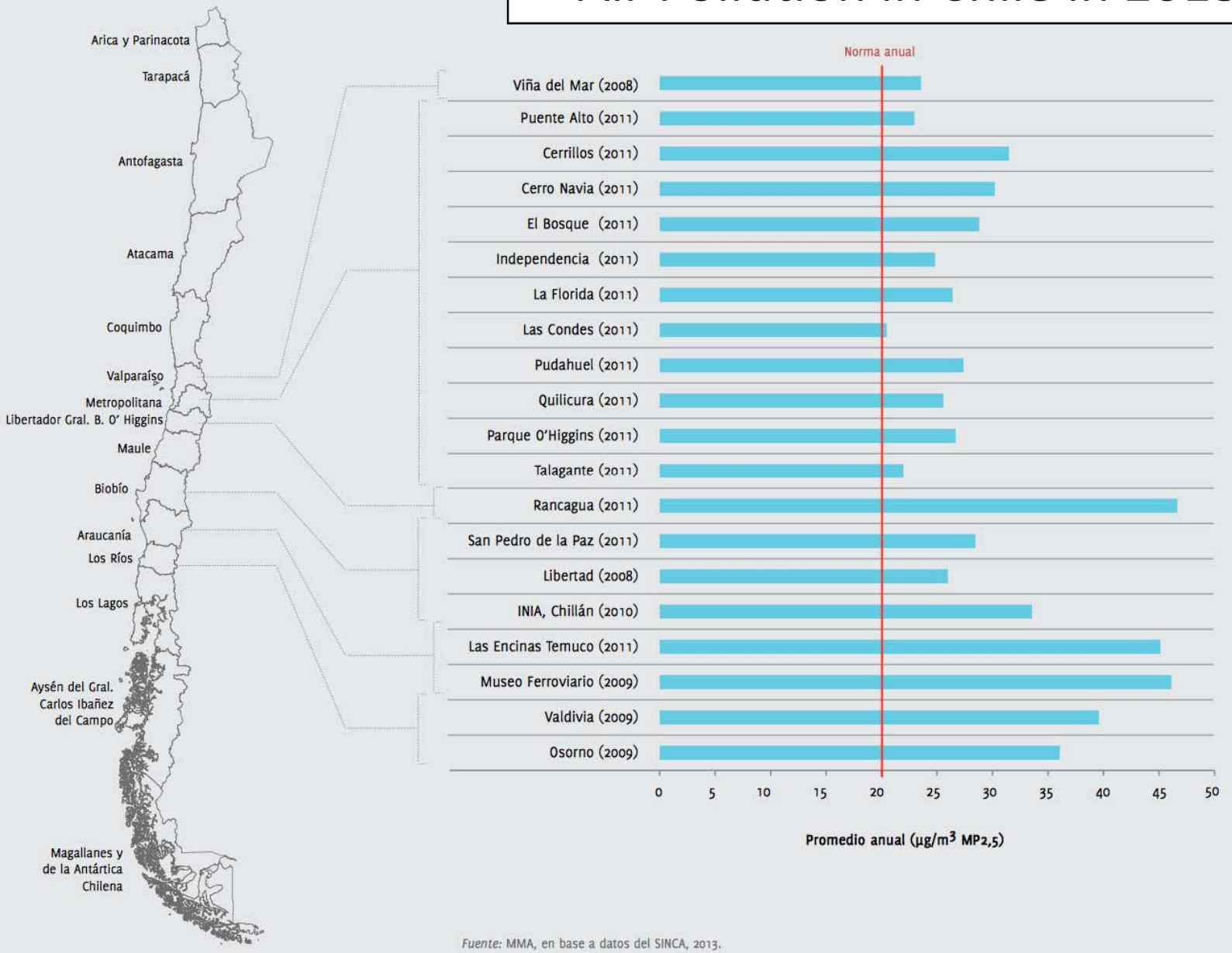


Fire detection algorithm

SO_2 National and local emission estimates: Buenos Aires and the *rest* of Argentina



Air Pollution in Chile in 2013



Fuente: MMA, en base a datos del SINCA, 2013.

Chilean Emissions Inventory

Chile: land use

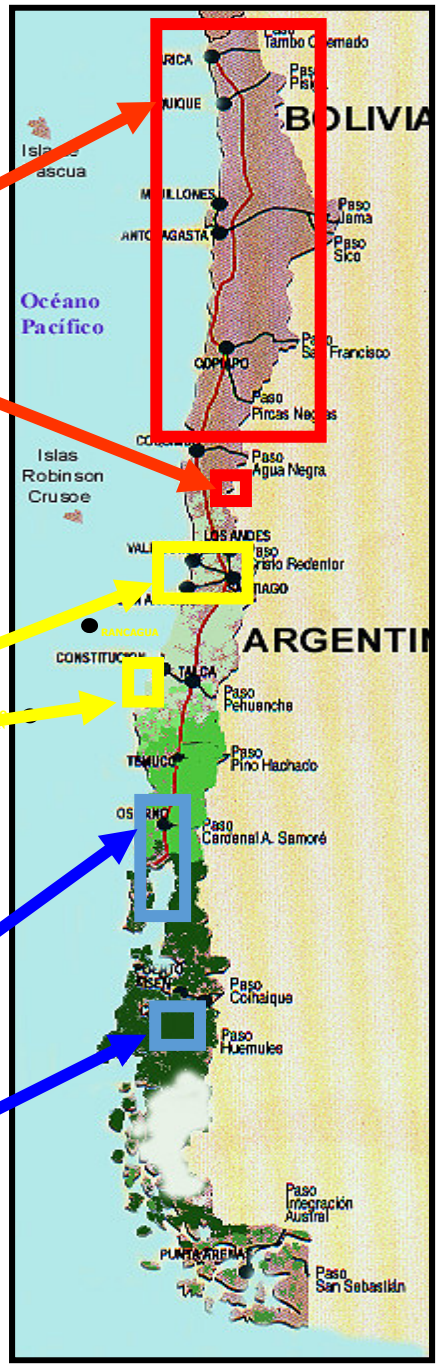
Total	Parameter	Value
Economic Activity and Social Development 18,191,884 Estimated 2016	GDP per capita 2015	22,316 USD
	Rural population 2013	12.7%
	Literacy rate 2012	98.9%
	Drinking water and treated waste water 2014	99.9%
	Population in extreme poverty 2015	3.5%
	Population in poverty 2015	11.7%
	Gini coefficient 2015	0.495
Energy Generation Electricity production capacity 2015 20,375 MW	Non-renewable sources 2015	55%
	Hydroelectricity 2015	34%
	Non Conventional Renewable Energy 2015	11%
	Projected NCRE 2050	60%
	National electric coverage 2015	99%
Land Use 756,102 km²	Urban and industrial areas	0.5%
	Forest plantations and mixed forests	4.2%
	Agricultural areas	4.4%
	Native forests	18.9%
	Meadows and thickets	27.1%
	Areas cleared of vegetation	32.5%

Areas with identified or probable air pollution problems

Areas with mega sources of PM10 and SO2: North and central Chile. Mining and power generation activities.

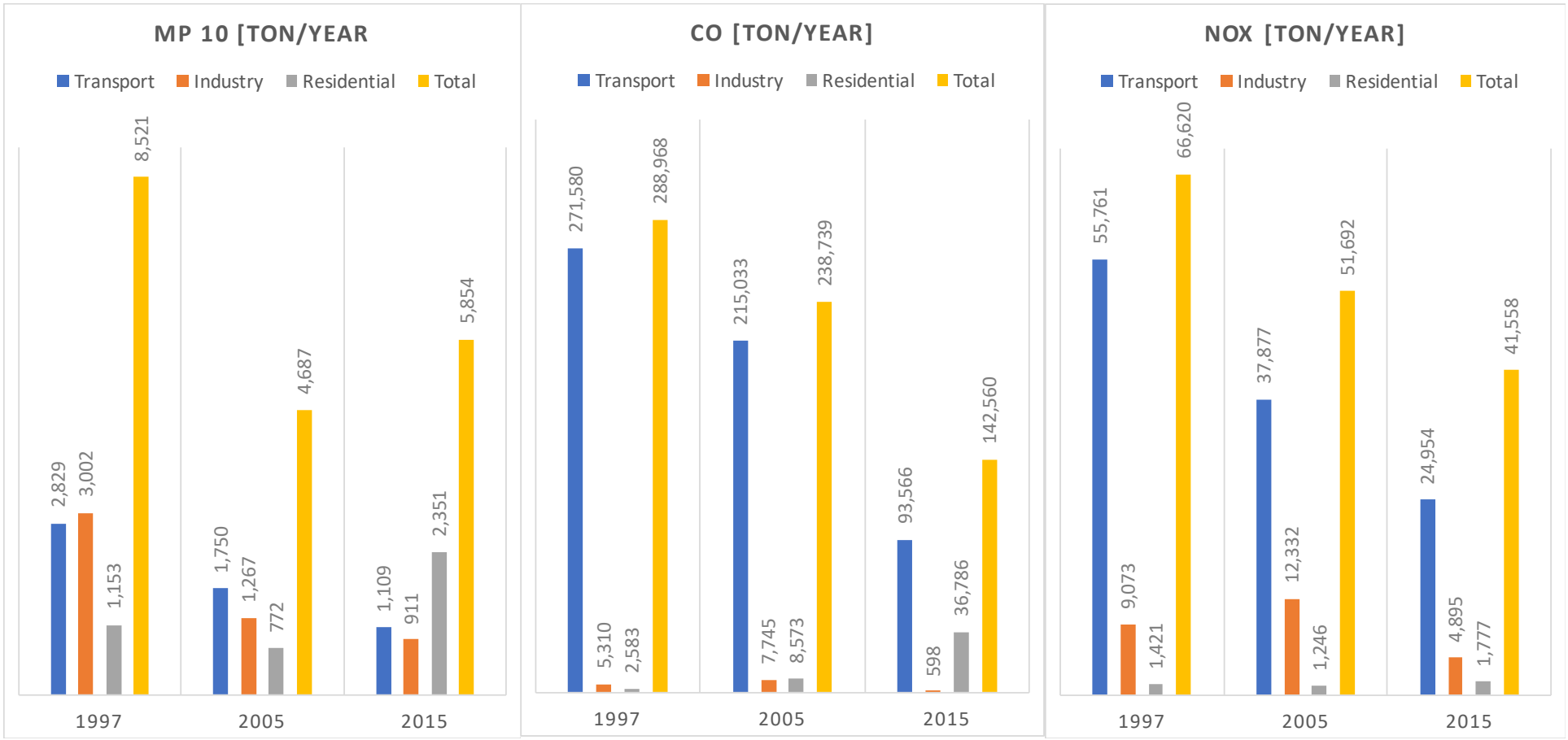
Large and medium urban areas, variety of sources: Santiago, Rancagua, Gran Valparaíso, Talcahuano-Concepción.

Areas of intensive use of firewood: Central depression of Southern Chile. Temuco, Father Las Casas, Osorno, Los Angeles ?, small towns?



Christian Santana O.

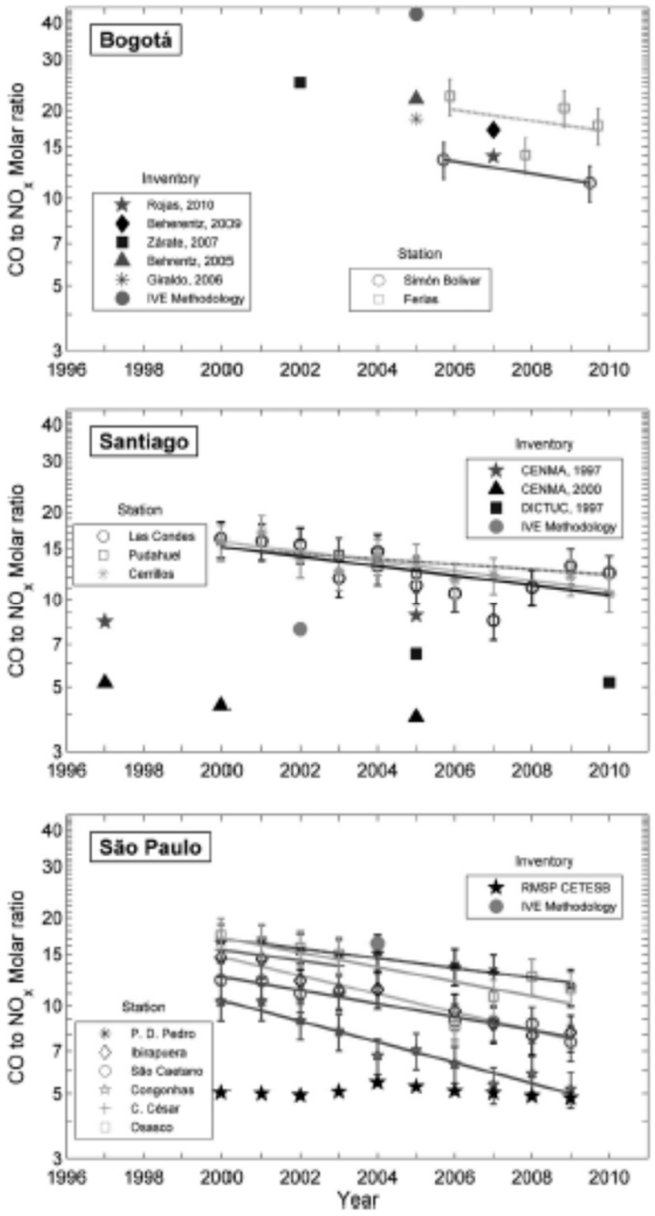
Comparison/Evolution MR Emissions Inventory Main Sectors 1997-2005-2015



Validation/Verification of emissions

CO/NO_x ratios

- Emission inventories for mobile sources are off
- Overestimate of NOx in Santiago and Sao Paulo by up to a factor of 3!!
- Major uncertainties linked to EF for CO and activity data for NOx
- Learning about VOCs unfeasible due to lack of measurements

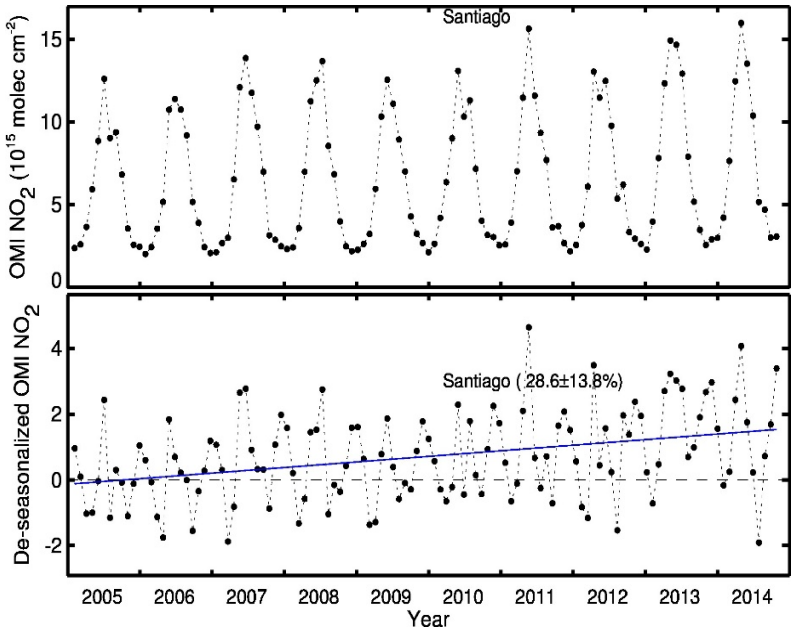


Gallardo, L., et al. (2012), Evaluation of vehicle emission inventories for carbon monoxide and nitrogen oxides for Bogotá, Buenos Aires, Santiago, and São Paulo, *Atmospheric Environment*, *47*, 12-19. doi: 10.1016/j.atmosenv.2011.11.051.

Validation/Verification of emissions

Satellite data

e.g., OMI NO_2
https://airquality.gsfc.nasa.gov/



City	Country	2014 Avg. NO2 *	Change (%)	Uncertainty (±%)
Bogota	Colombia	1.3	5	11.4
Buenos Aires	Argentina	4.6	-5.8	10.6
Caracas	Venezuela	2.1	10.2	10.4
Cordoba	Argentina	1.2	1.9	11.9
Iquique	Chile	0.6	-9	12.2
La Paz	**Bolivia**	**0.4**	**19.2**	**18.1**
Lima	**Peru**	**3.2**	**15.7**	**10.3**
Medellin	**Colombia**	**1**	**13.1**	**10**
Montevideo	Uruguay	1.2	11.2	14.6
Porto Alegre	**Brazil**	**1.6**	**-13.8**	**10.2**
Rio de Janeiro	Brazil	3.2	6.4	10.1
Salvador	**Brazil**	**0.7**	**32.2**	**12.5**
Santiago	**Chile**	**5.8**	**28.6**	**13.9**
Sao Paulo	Brazil	6	-8.4	10.4

Satellite retrievals are improving, however….Needs careful checking

- **PM…Notice reflectivity (Escribano et al, 2014)**
- **SO_2… South American Anomaly**
- **NO_2 …** ***to be explored further***

Current work in Colombia

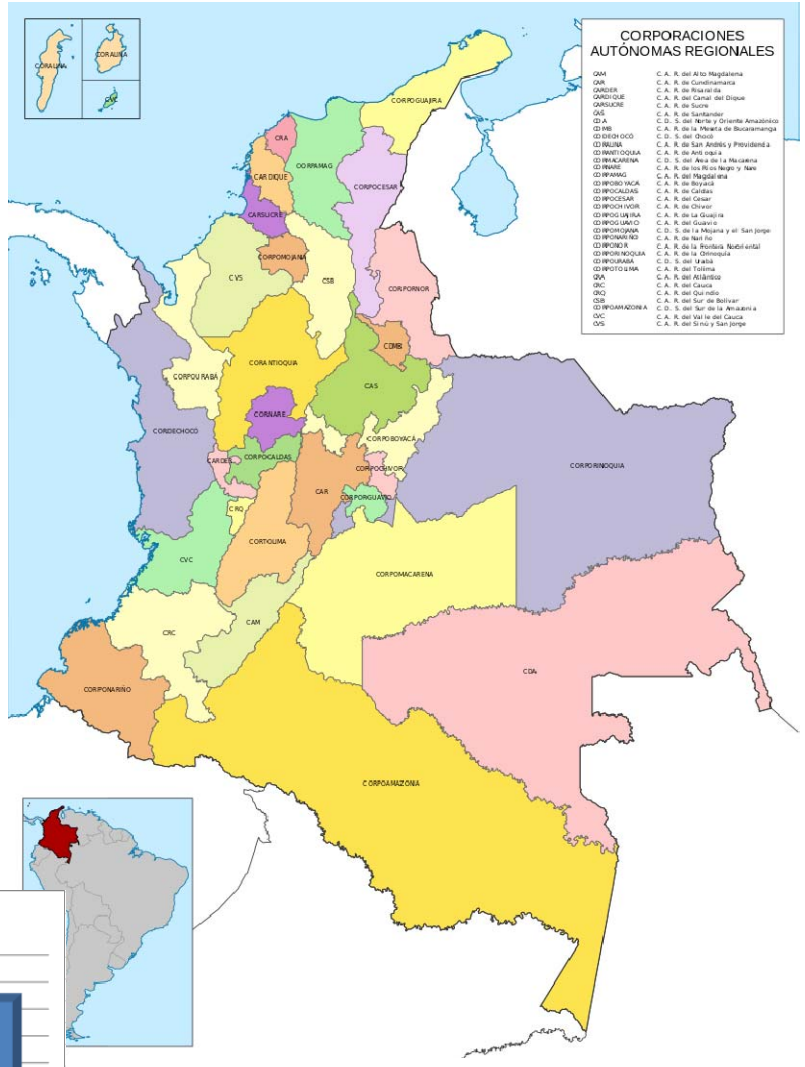
National emission inventories: GHGs

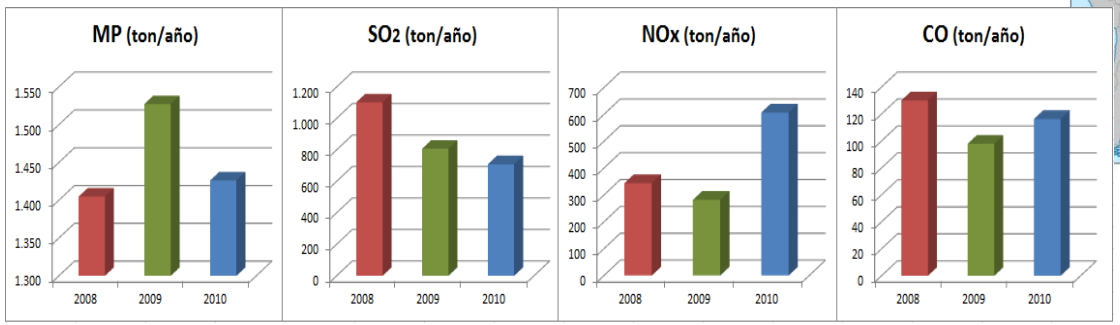
- 3 National communications (UNFCCC): 2001, 2008, 2016
- Species:
  - CO2
  - CH4
  - N2O
  - HFCs
  - SF6
- No national emission inventories for criteria pollutants (so far)

http://documentacion.ideam.gov.co/openbiblio/bvirtual/023634/INGEI.pdf

Local / sub-national (regional) inventories

- Responsibility of
  - Sub-national / “regional” agencies (Corporaciones Autónomas Regionales)
  - Urban agencies (Secretarías de Ambiente, Departamentos Administrativos)
- Species
  - PM, NOx, SO2, CO
- Supposed to be updated every two years. Actually, very irregularly
- Large differences among agencies (quality, completeness, transparency, consistency, …)





Work by universities - examples

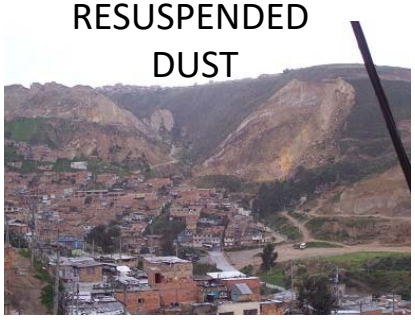
- Universidad Nacional de Colombia
  - Bogotá (1 km x 1km grid) – 2008 – PM, NOx, CO, SO2, VOCs
  - Cundinamarca (2km x 2 km) 2014 – PM, NOx, CO, SO2
  - Receptor modeling for Bogotá
- Universidad de La Salle
  - Bogotá (1 km x 1km grid) 2012, 2014
  - Receptor modeling for several cities
- Universidad de Los Andes
  - Bogotá (2 km x 2km grid) 2000
  - Receptor modeling for Bogotá
- Universidad de Cundinamarca
  - Bogotá – Biogenic VOCs – 2008
- Universidad Pontificia Bolivariana
  - Medellín + Metropolitan Area (1 km x 1km grid) – several years – PM, NOx, CO, SO2, VOCs

UPDATING EMISSION INVENTORIES

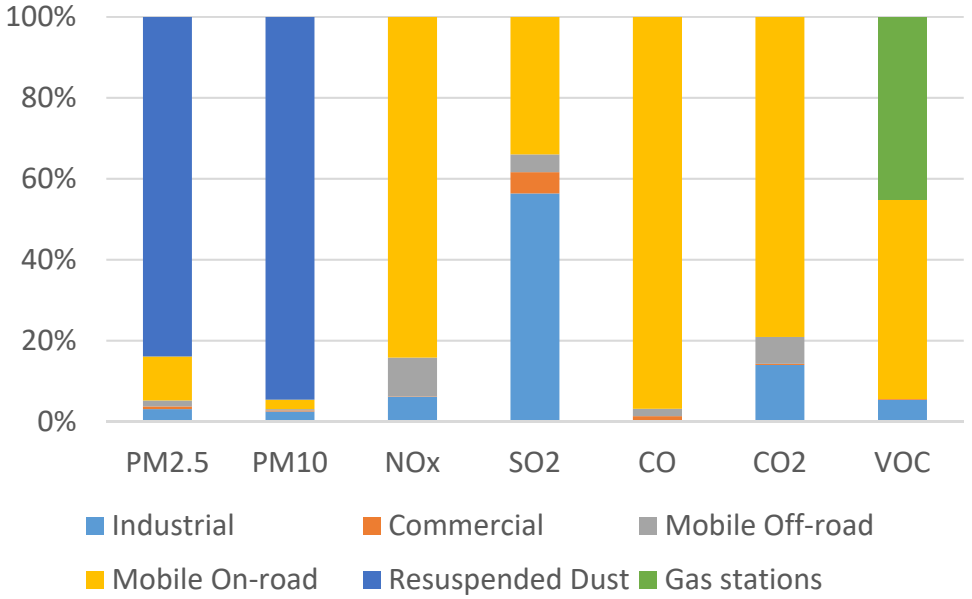
MOBILE

AREA

RESUSPENDED DUST



WILDFIRES

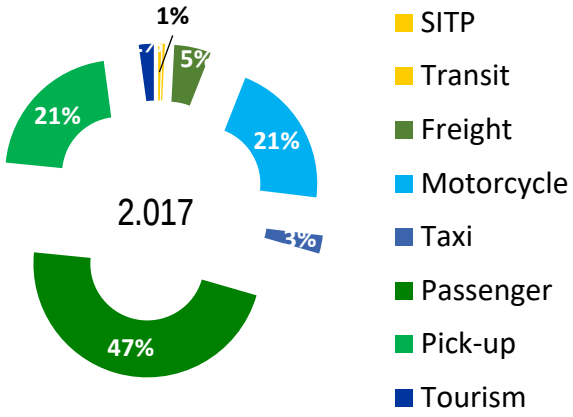


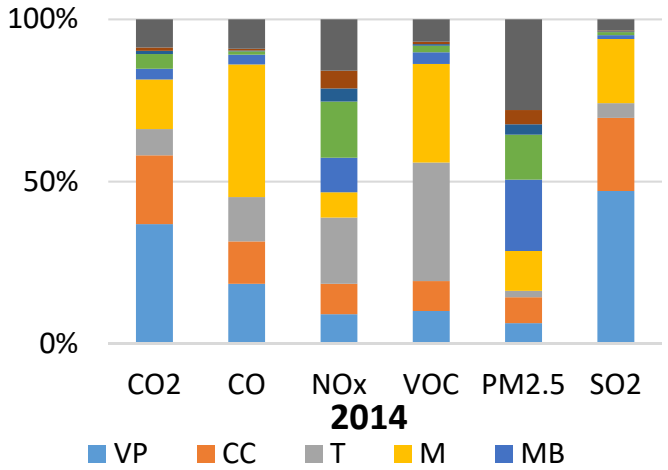
Emission Ton/yr 2014							
Source	**$PM_{2.5}$**	**PM_{10}**	**NOx**	**SO_2**	**CO**	**CO_2**	**VOC**
Industrial	307	1,281	3,275	2,036	812	1,619,573	2,828
Commercial	68	130	67	190	2,529	36,022	105
Mobile Off-road	149	157	5,159	159	4,520	769,623	0
Mobile On-road	1,087	1,202	45,297	1,228	241,527	9,164,014	26,096
Resuspended Dust	8,413	48,478	0	0	0	0	0
FGS	0	0	0	0	0	0	23,786
TOTAL	**10,024**	**51,248**	**53,798**	**3,613**	**249,388**	**11,589,232**	**52,815**

Mobile sources contribute with >90% of NOx, CO, CO_2 emissions and direct and indirect PM10 emissions.

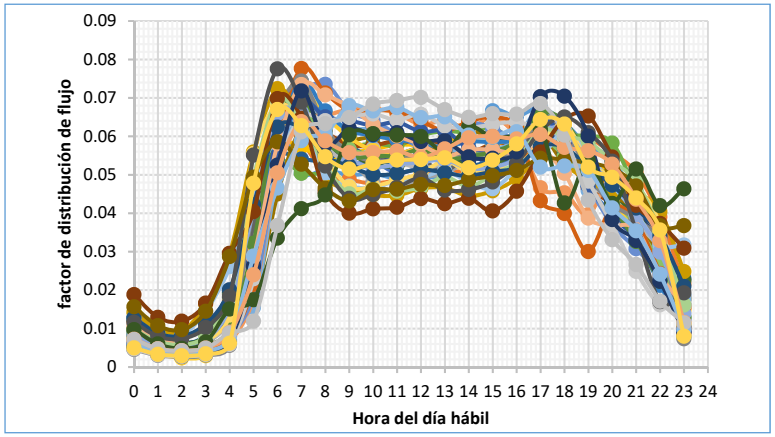
MOBILE SOURCE EMISSIONS

Buses and trucks contribute with more than 60% of PM emissions.

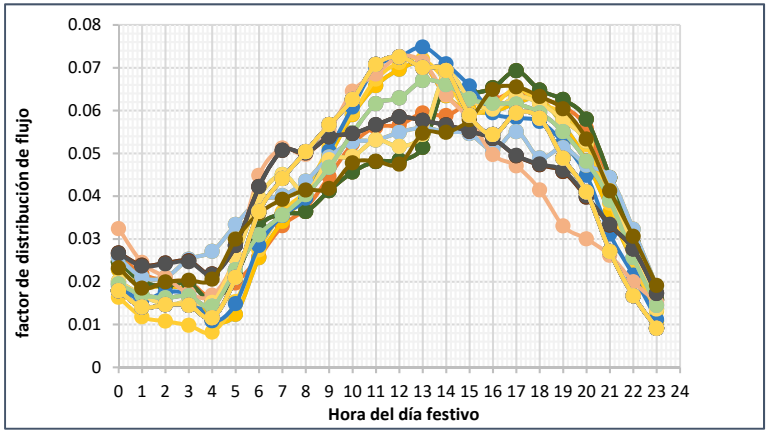




VP: passenger vehicles; CC: trucks and pick-ups; T: taxis; M: motorcycles; MB: microbus; B: bus; TM: Transmilenio (BRT); ESP: school and tourism buses; C: trucks



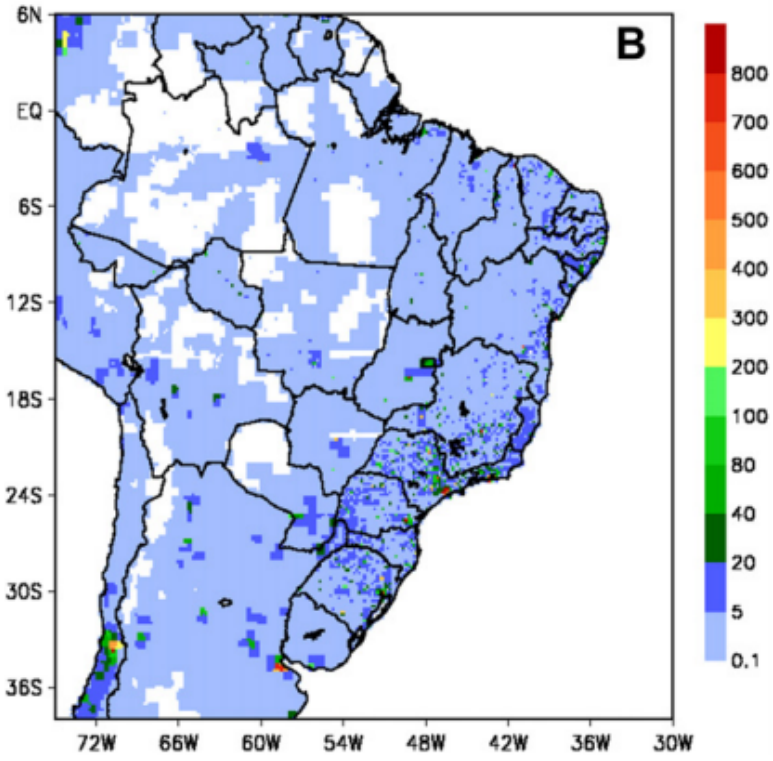
Temporal mobile profiles - weekday



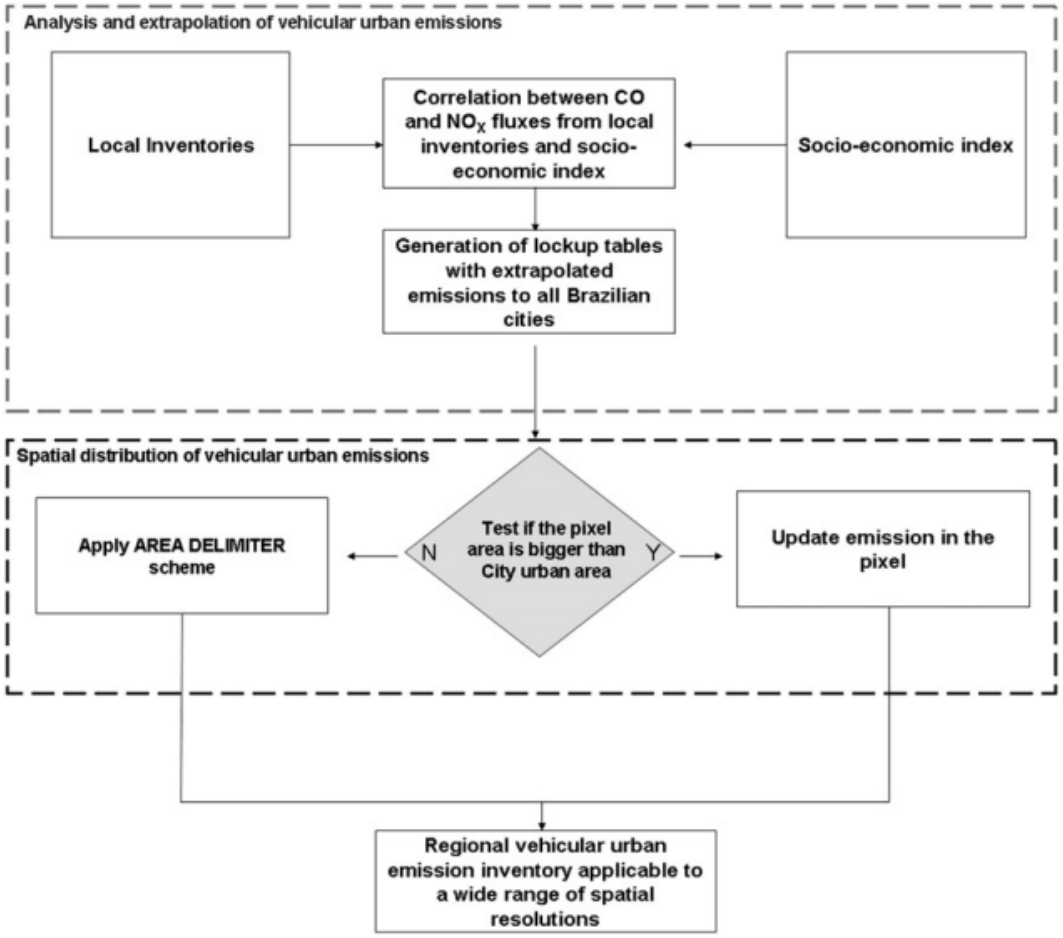
Temporal mobile profiles - weekend

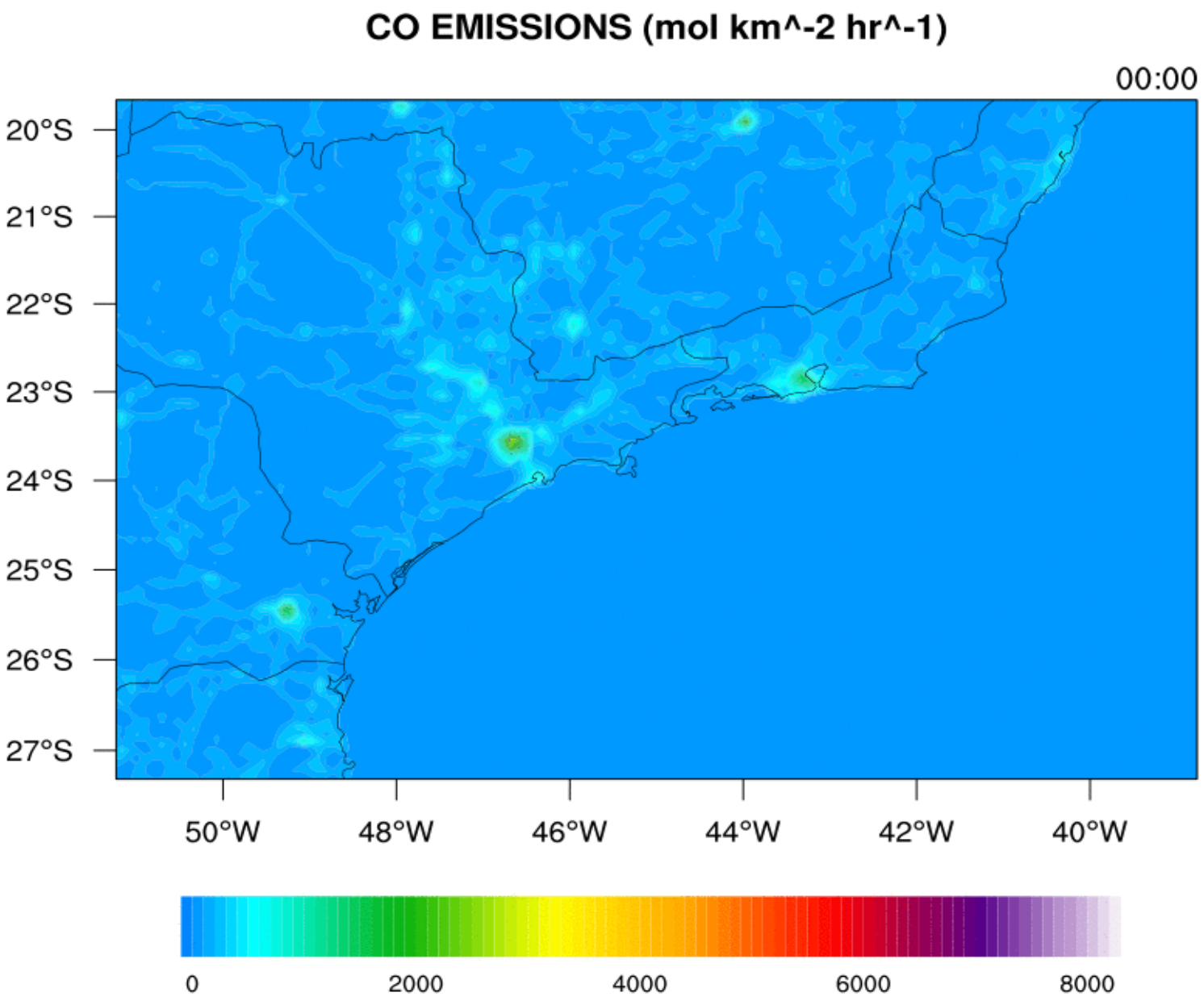
Current work in Brazil

An urban emissions inventory for South America and its application in numerical modeling of atmospheric chemical composition at local and regional scales

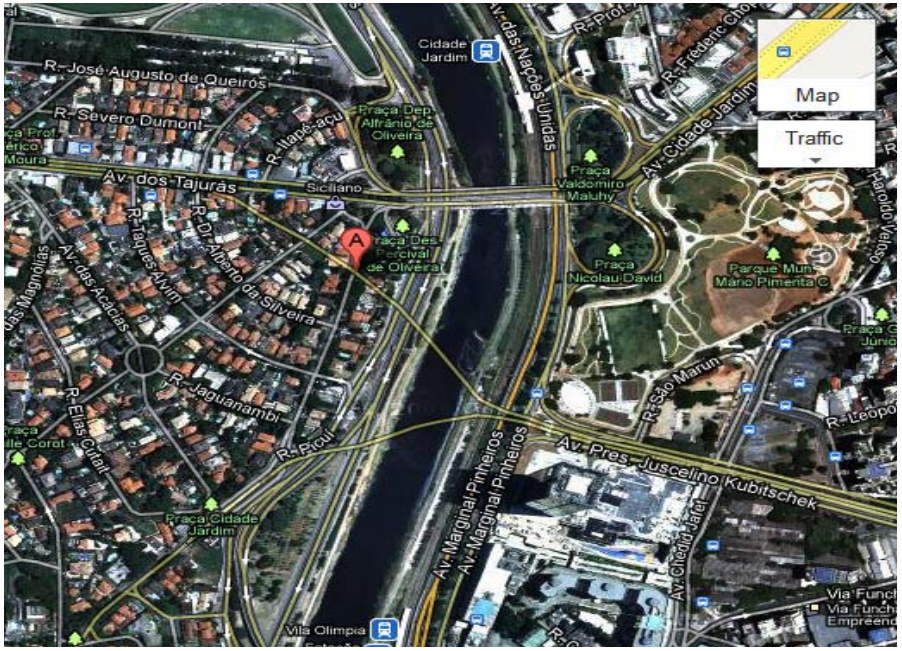


Emissions of CO (x 10^6 kg m^2 day) on a 20 km grid cover South America





www.lapat.iag.usp.br



Measurements of emission factors: TUNNEL JANIO QUADROS

MASP (Metropolitan Area of São Paulo)

Population:~ 20 million inhabitants.

Area: 8511 km^2

Vehicle fleet: 7 million passenger and commercial vehicles

85% light-duty vehicles (LDVs)

3% heavy-duty diesel vehicles (HDVs)

12% motorcycles

55% of LDVs use gasohol

4% use hydrous ethanol

38% are flex-fuel

2% use diesel

- **Alcohol represents 55% of the fuel burned.**
- **50% of the cars are older than 1997.**

Contents lists available at ScienceDirect

Fuel

journal homepage: www.elsevier.com/locate/fuel

Formaldehyde and acetaldehyde measurements in urban atmosphere impacted by the use of ethanol biofuel: Metropolitan Area of Sao Paulo (MASP), 2012–2013

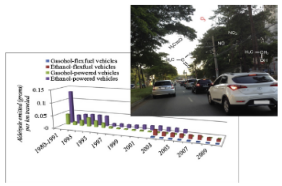
Thiago Nogueira [a,*], Pamela Alejandra Dominutti [a], Lilian Rothschild Franco de Carvalho [b], Adalgiza Fornaro [a], Maria de Fatima Andrade [a]

[a] Department of Atmospheric Sciences, Institute of Astronomy, Geophysics and Atmospheric Sciences, University of São Paulo (IAG/USP), Brazil
[b] Department of Fundamental Chemistry, Institute of Chemistry, University of São Paulo (IQ/USP), Brazil

HIGHLIGHTS

- Reduction of aldehyde vehicular emissions resulting from public policy implementation.
- Vehicular emissions on formaldehyde and acetaldehyde atmospheric concentrations vs. meteorological effects.
- Formaldehyde/acetaldehyde ratio has been increasing in recent decades.

GRAPHICAL ABSTRACT



- Although 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).

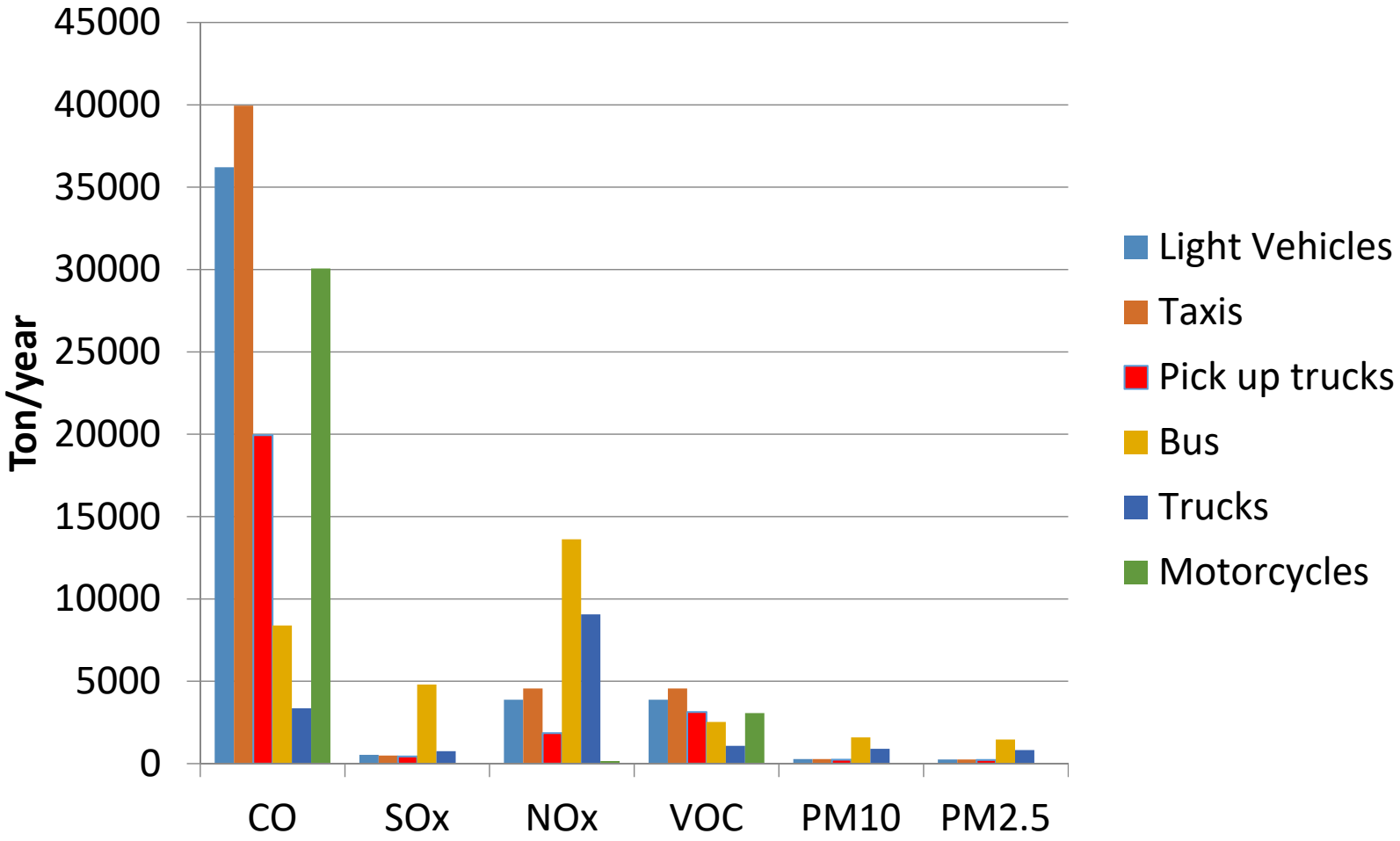
Table 1
Environmental concentrations of formaldehyde and acetaldehyde in the MASP over the last 30 years.

Year	Formaldehyde (ppbv)	Acetaldehyde (ppbv)	F/A ratio	References
1986[a]	5.4	16.1	0.34	[52]
1989[a]	10.8	22.3	0.48	[21]
1990[a]	15.2	22.6	0.68	[21]
1993[a]	6.4	9.3	0.69	[21]
1996[a]	3.35	5.1	0.65	[21]
1997[a]	5.6	10.4	0.54	[21]
1998[a]	5.0	5.4	0.9	[53]
1999[b]	1.0–46	11.9	1.2	[54]
2000[a]	4.2		n.a.	[24]
2001[b]	1.0–46.3	1.2–56.6	n.a.	[47]
2002[a]	4.0		n.a.	[24]
2003[a]	2.0–8.2	1.0–9.2	0.9–3.2	[23]
2004[a]	18.1	15.4	1.18	[21]
2006[a]	5.7	5.6	1.02	[55]
2007[a]	13.5		n.a.	[24]
2011[a]	5.0	4.0	0.8–1.7	[22]
2012/ 2013	8.6 ± 6.7[c] 4.7[d]–6.9[e]–9.8[f]	5.4 ± 5.2[c] 2.3[d]–3.2[e]–6.5[f]	2.1 ± 1.3[c] 1.2[d]–1.8[e]–2.8[f]	Present study

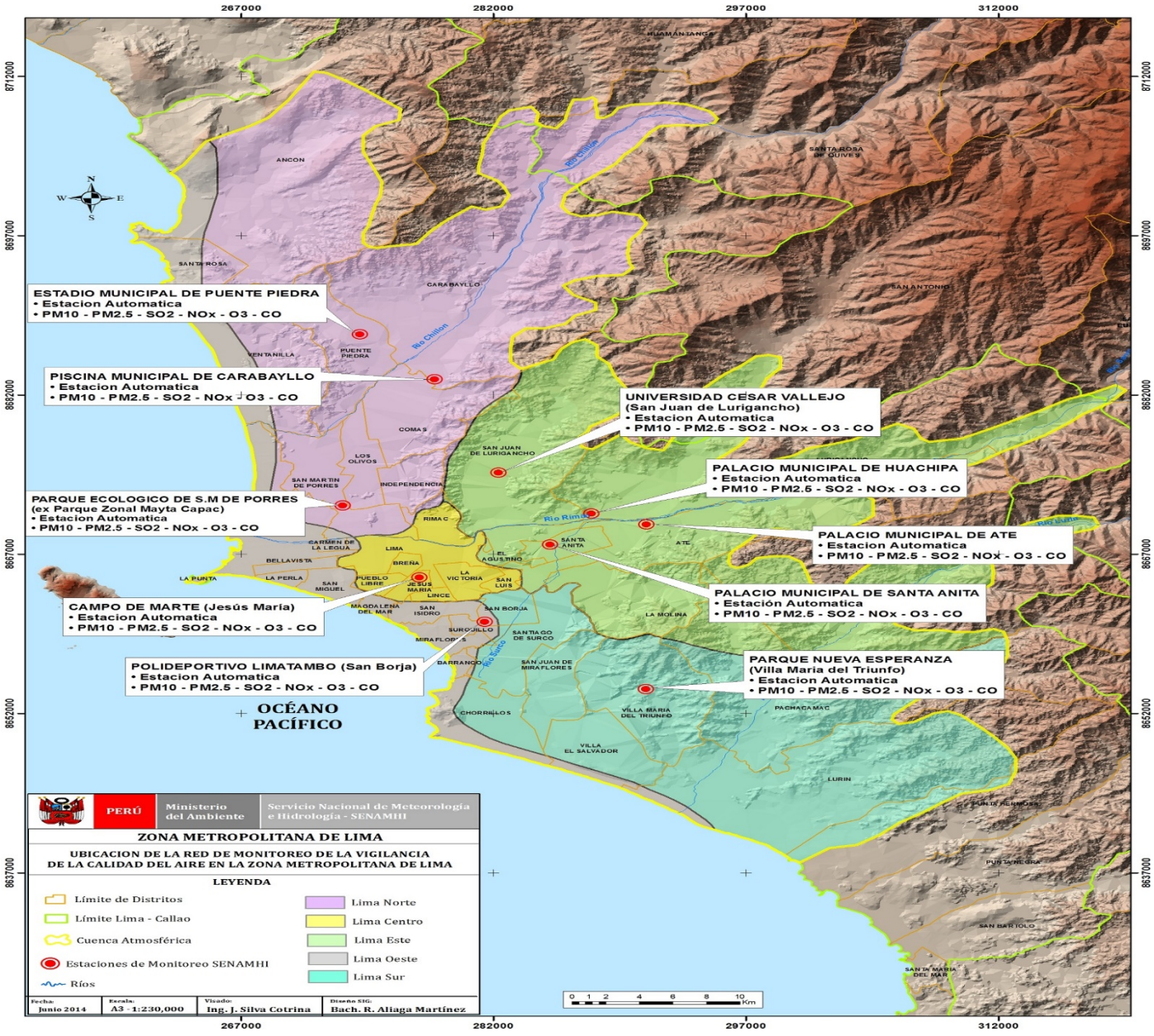
[a] Mean values.
[b] Maximum and minimum values.
[c] Mean ± SD.
[d] 25th percentile.
[e] 50th percentile.
[f] 75th percentile.

Current work in Peru

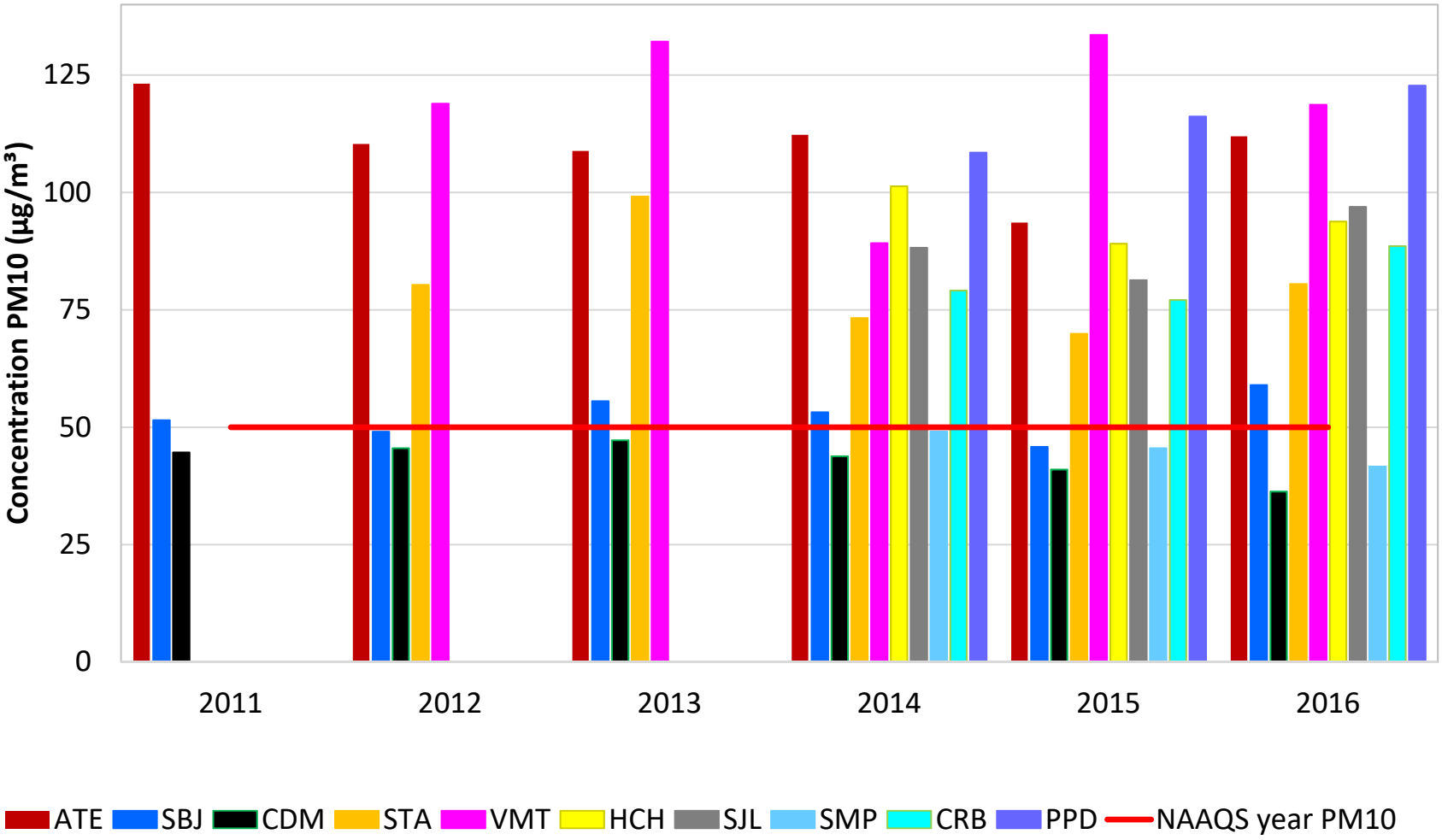
Motor vehicles emissions inventory in the metropolitan area of Lima (Tons/year)



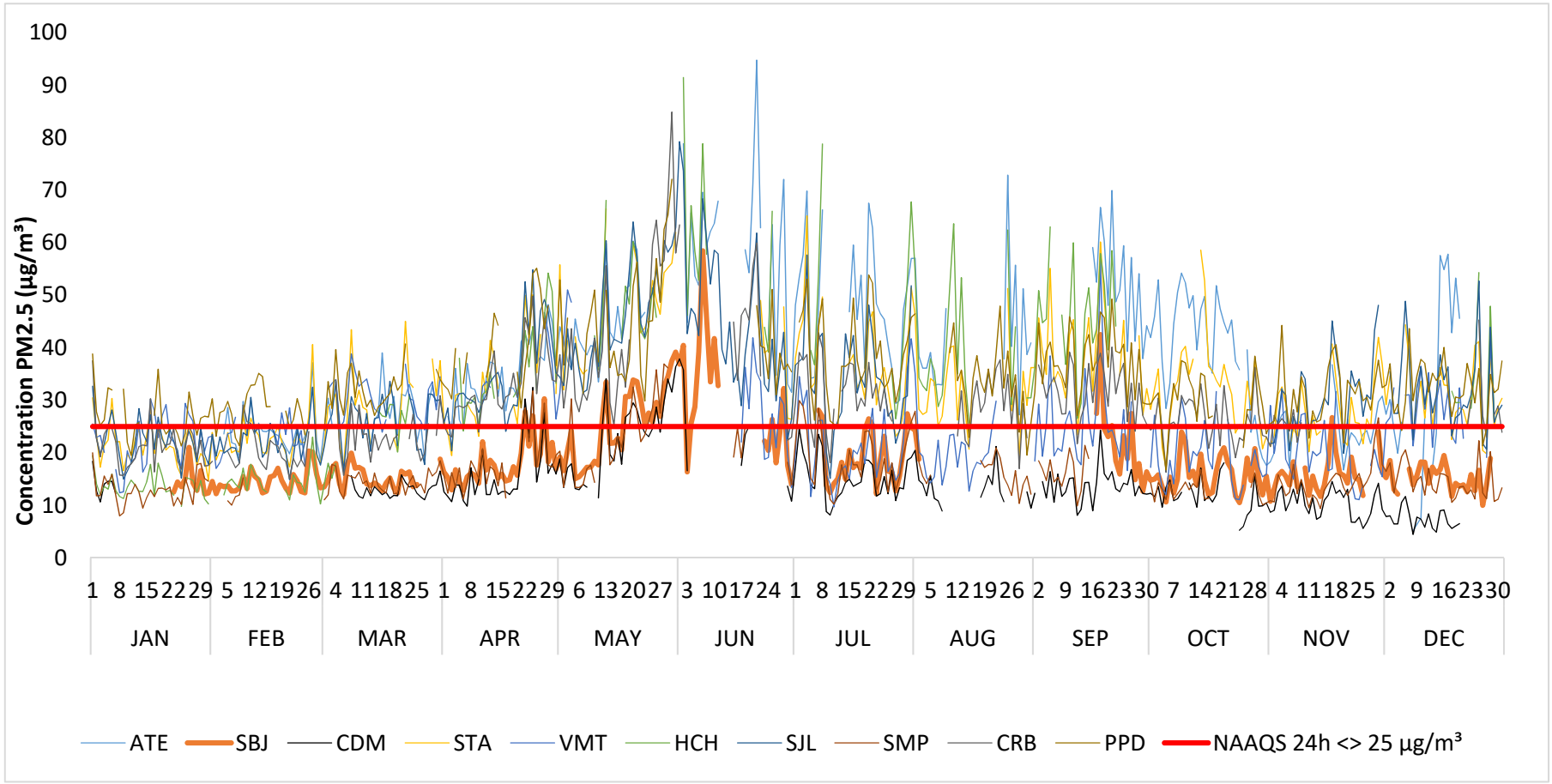
Source Newman & Wash, 2005



Monitoring sites in Lima Peru (SENAMHI, 2017)

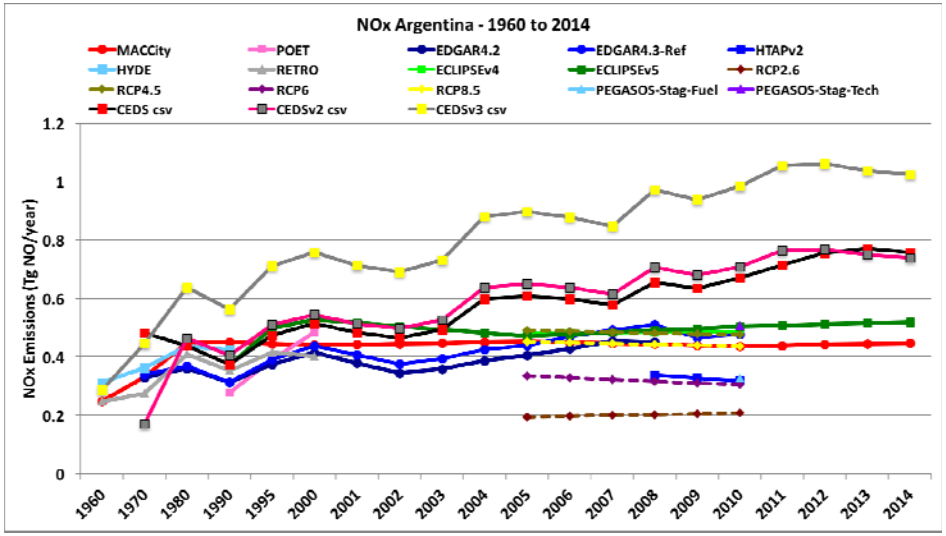


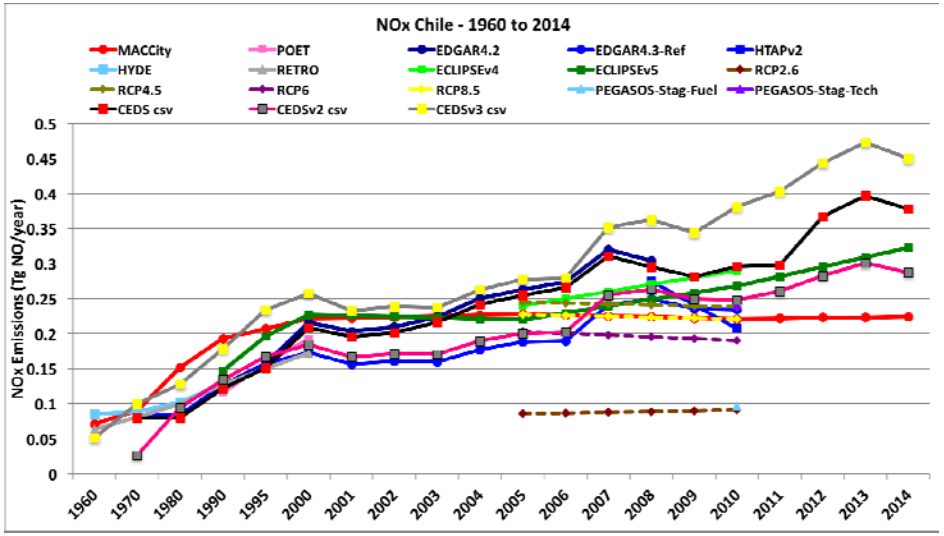
PM10 annual (µg / m³) in Lima

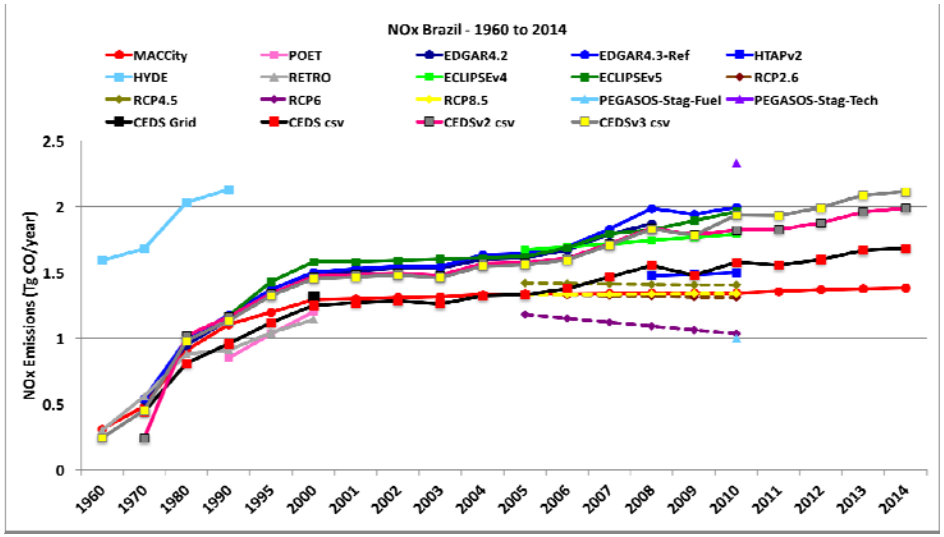


Average daily PM2.5 (µg / m3) in 2016

A few results of the comparison of global inventories for South America

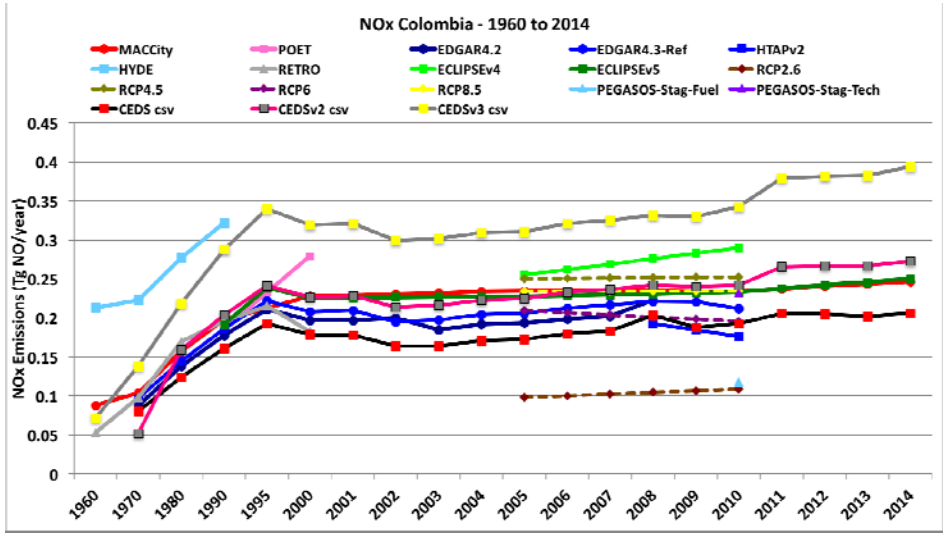


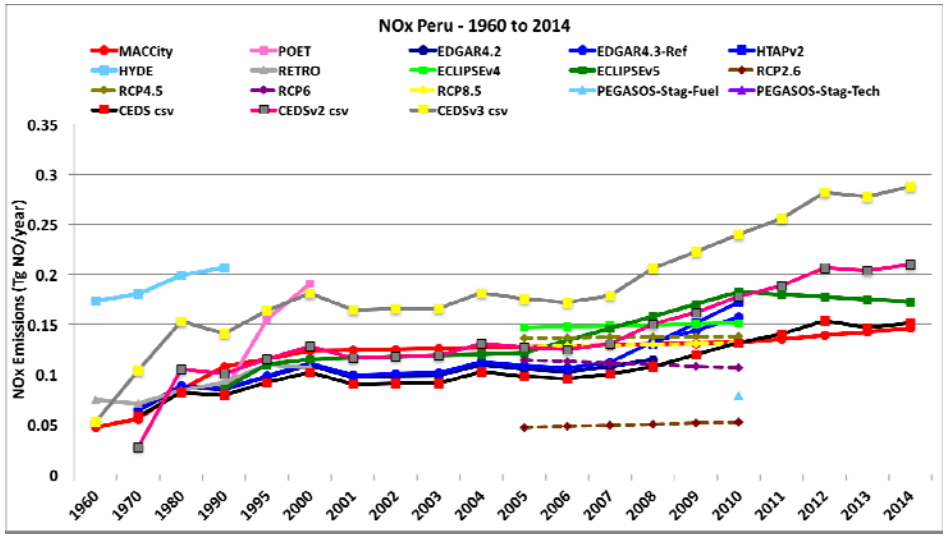




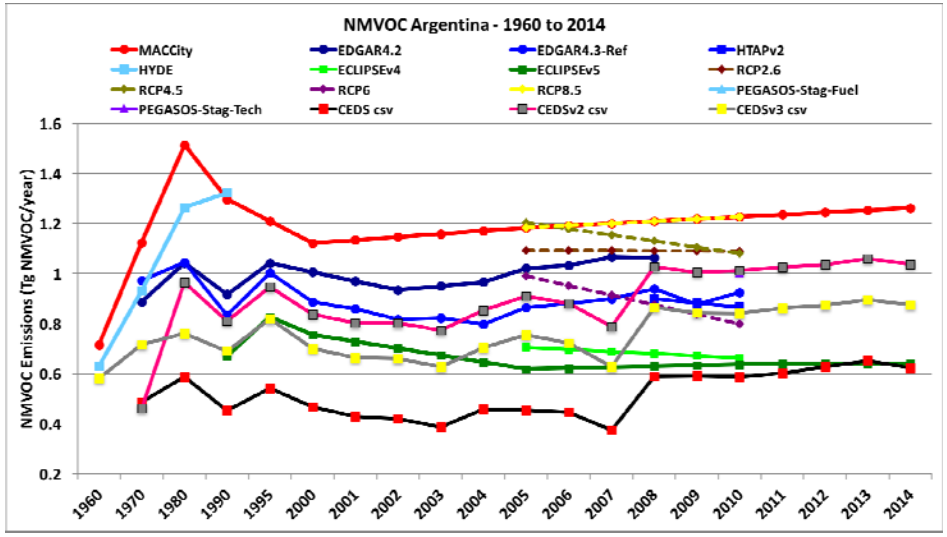
NOx (in Tg NO/year): Argentina, Chile, and Brazil

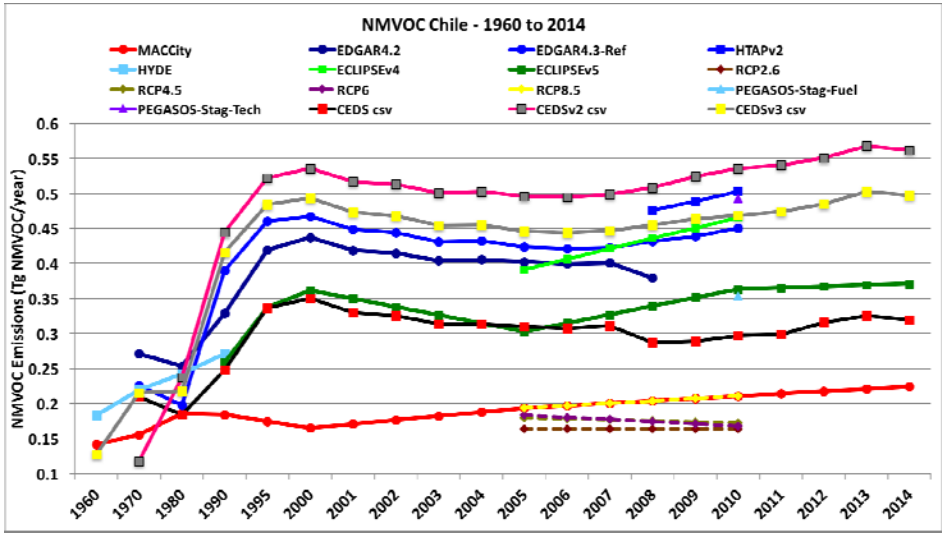
NOx: Colombia and Peru

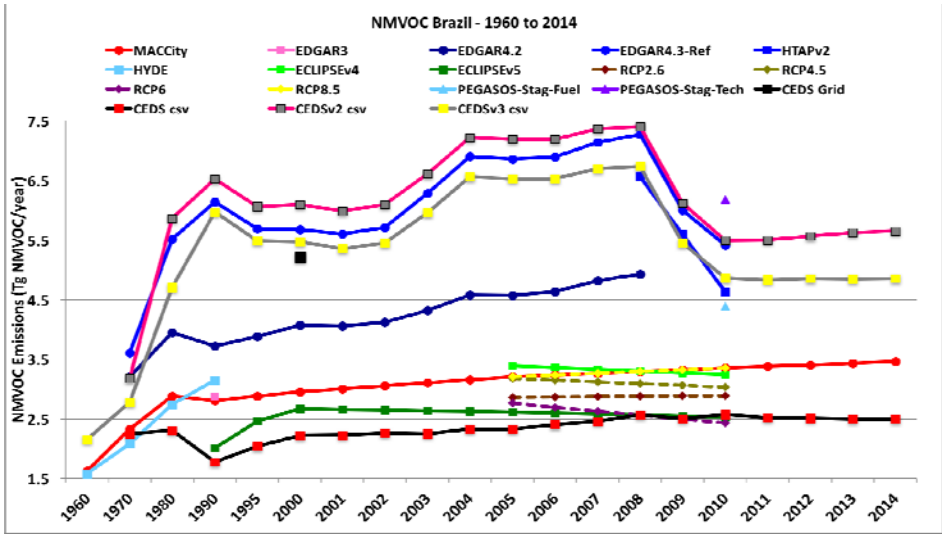




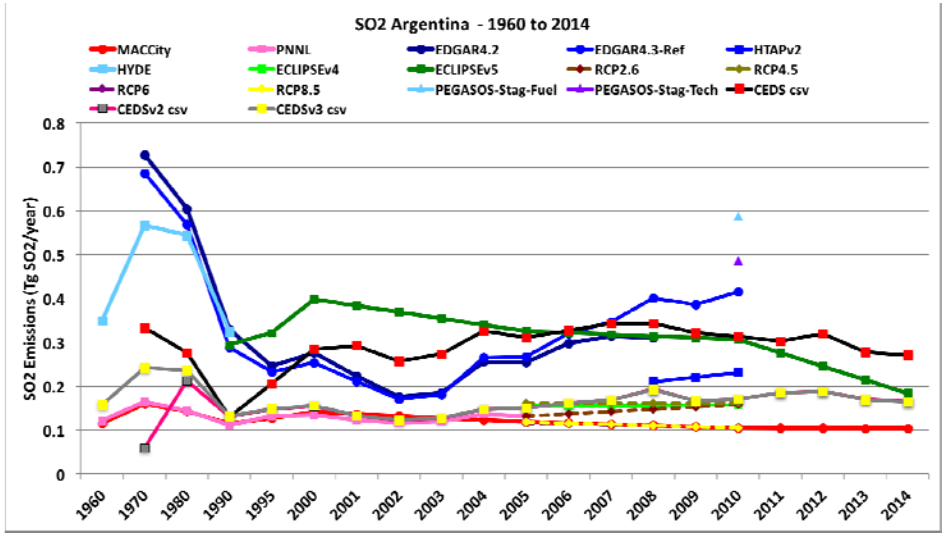
NMVOC: Argentina, Chile, and Brazil

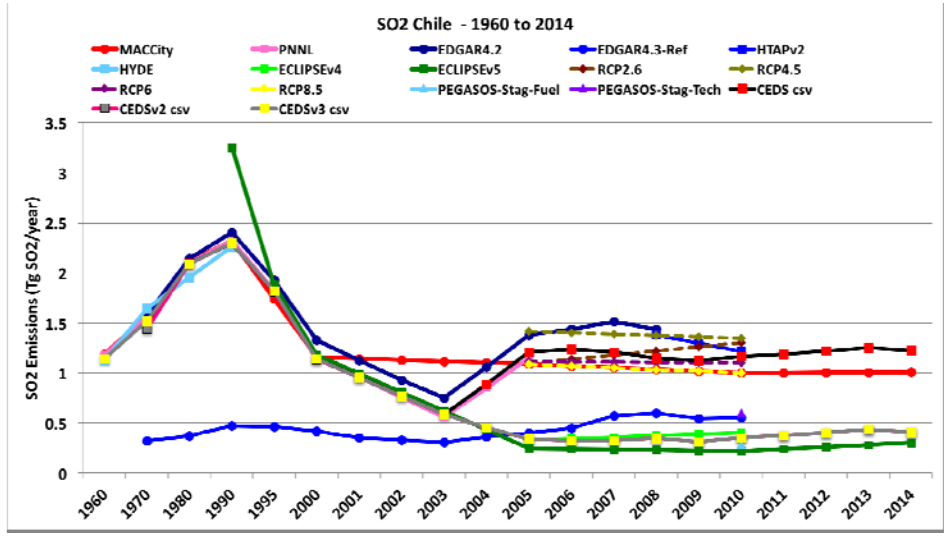


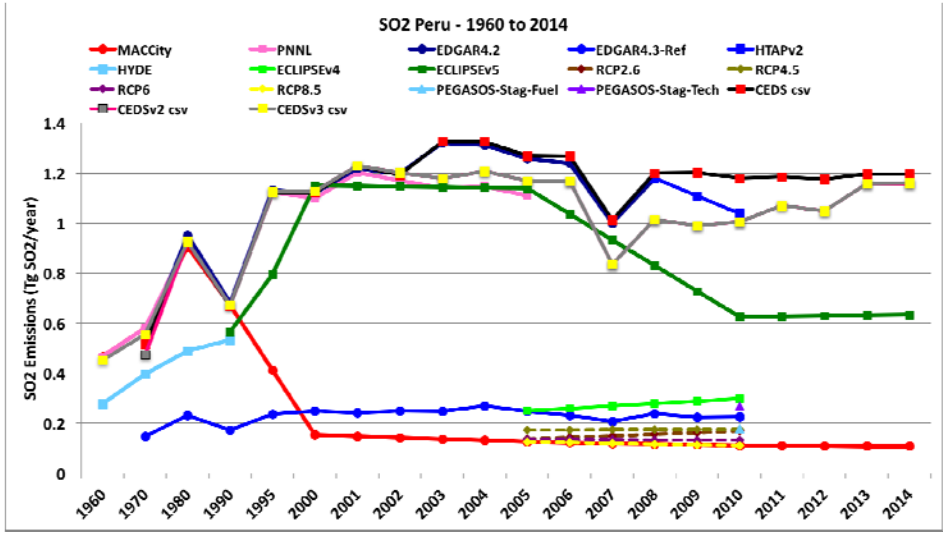




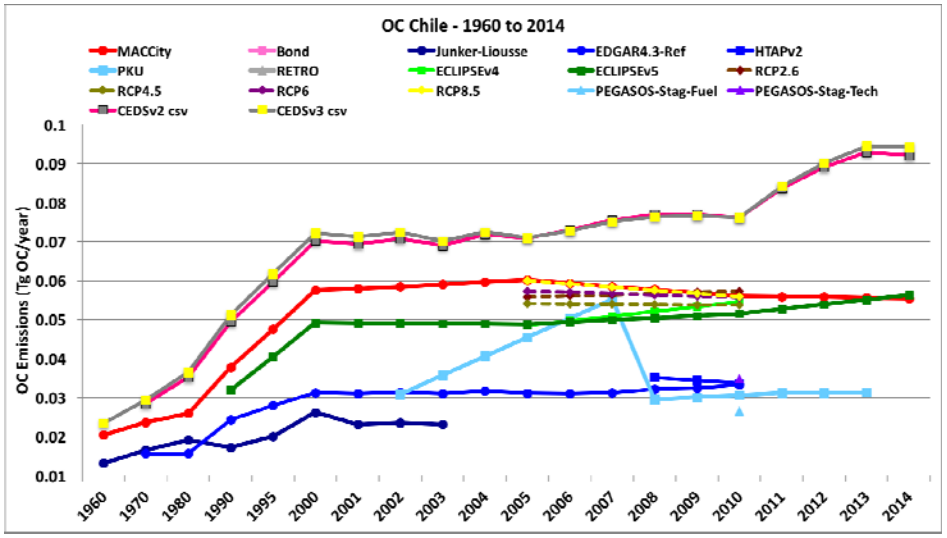
SO2: Argentina, Chile, and Peru

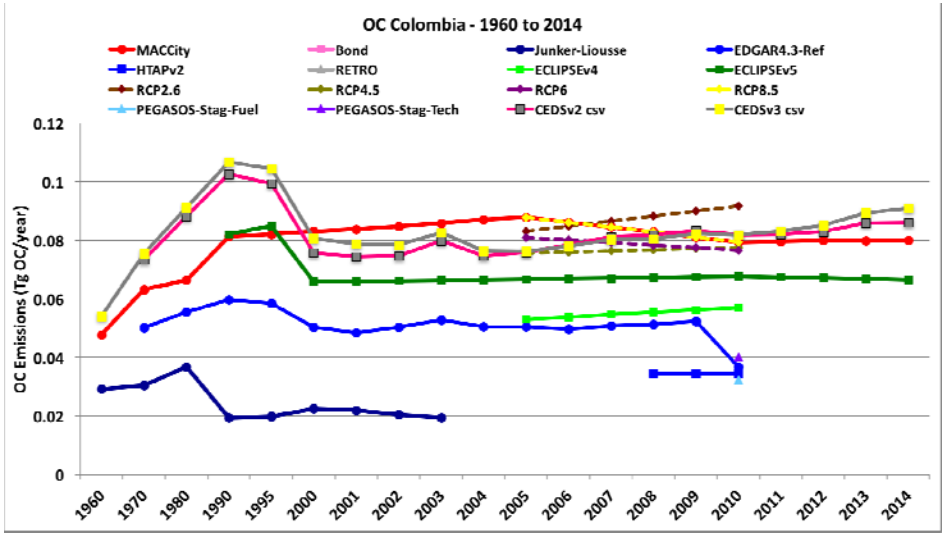


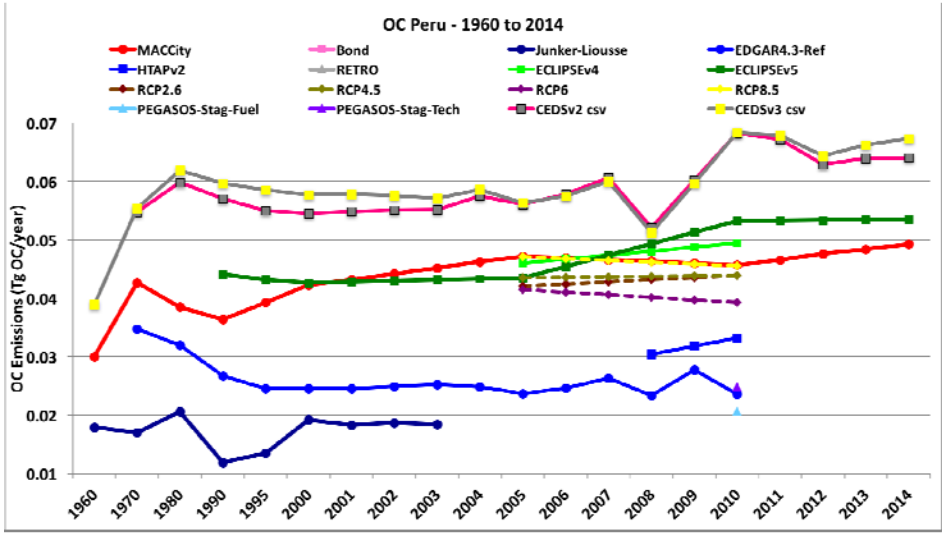


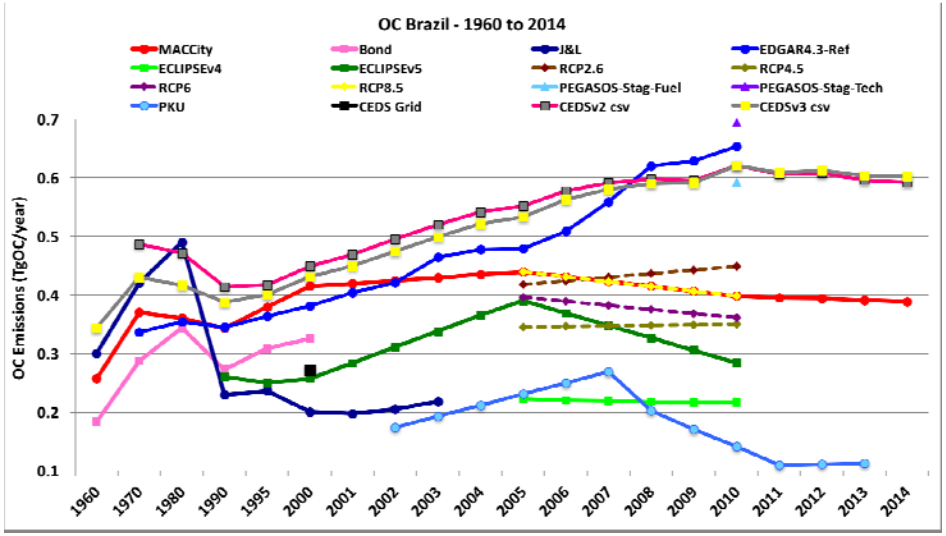


OC: Chile, Colombia, Peru and Brazil









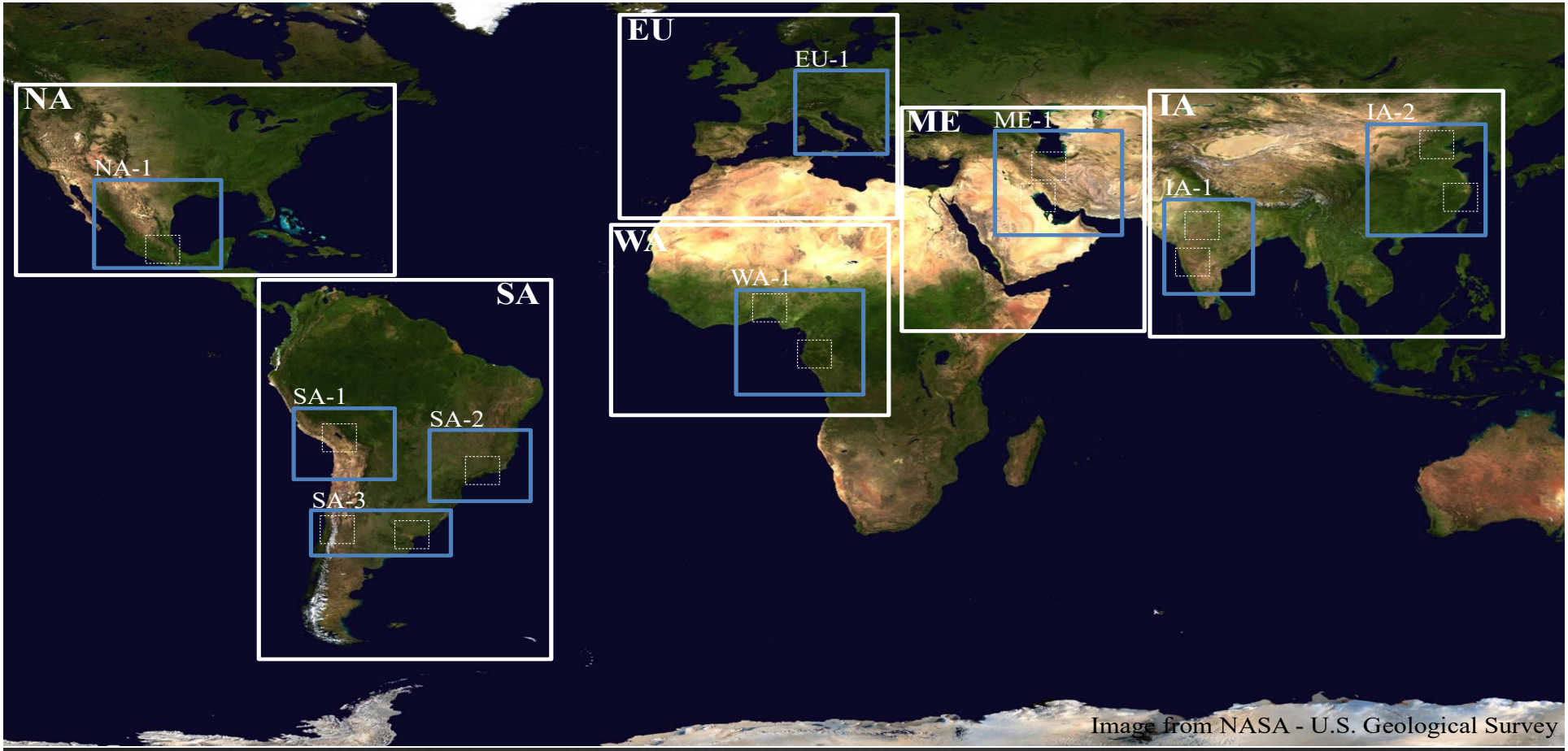
EMISA project and international activities

- Link with the MAP-AQ project of IGAC

IGAC = International Global Atmospheric Chemistry Project (igacproject.org)

- Link with the European project PAPILA

A Mozaic of Regional Approaches: The MAP-AQ Initiative

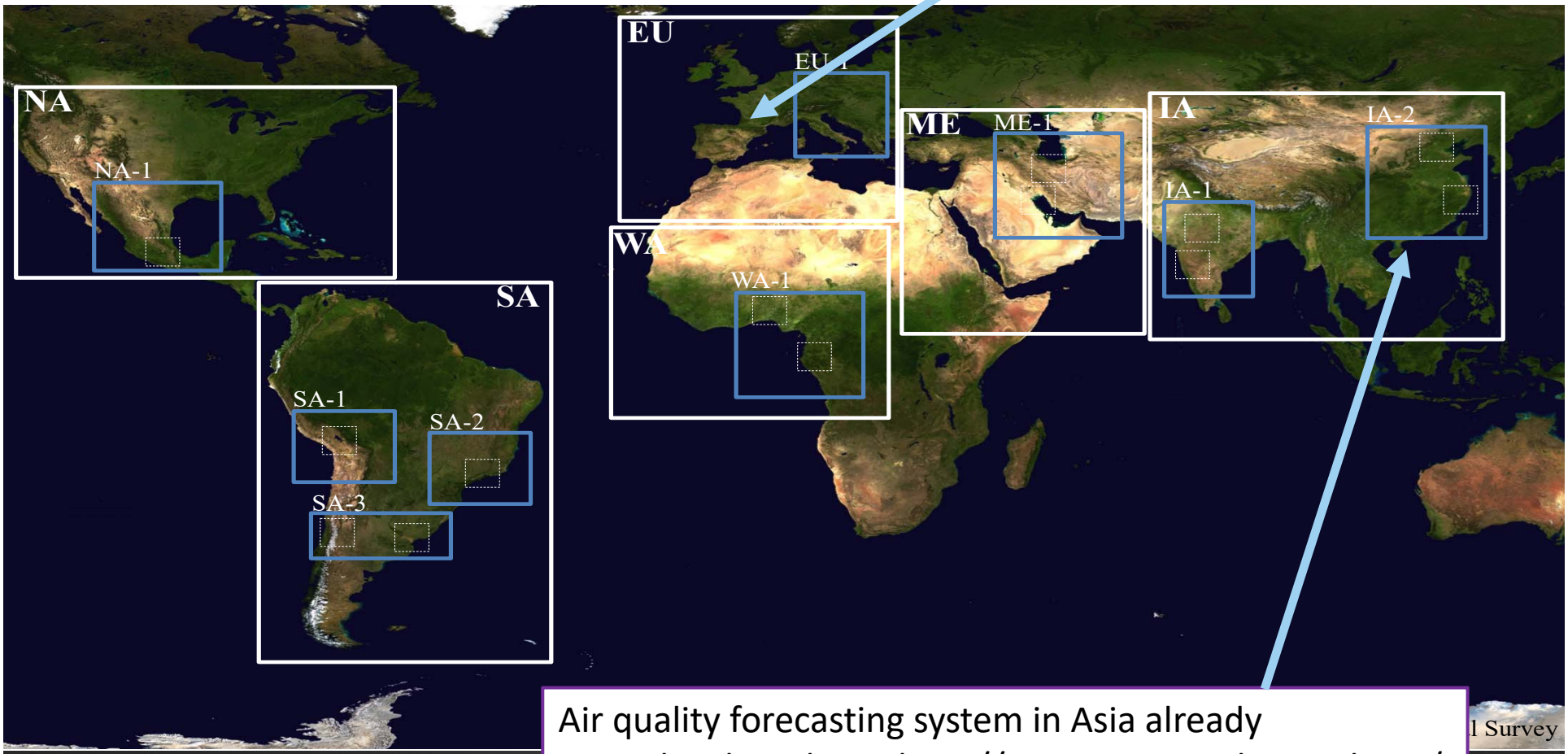


Objectives of MAP-AQ

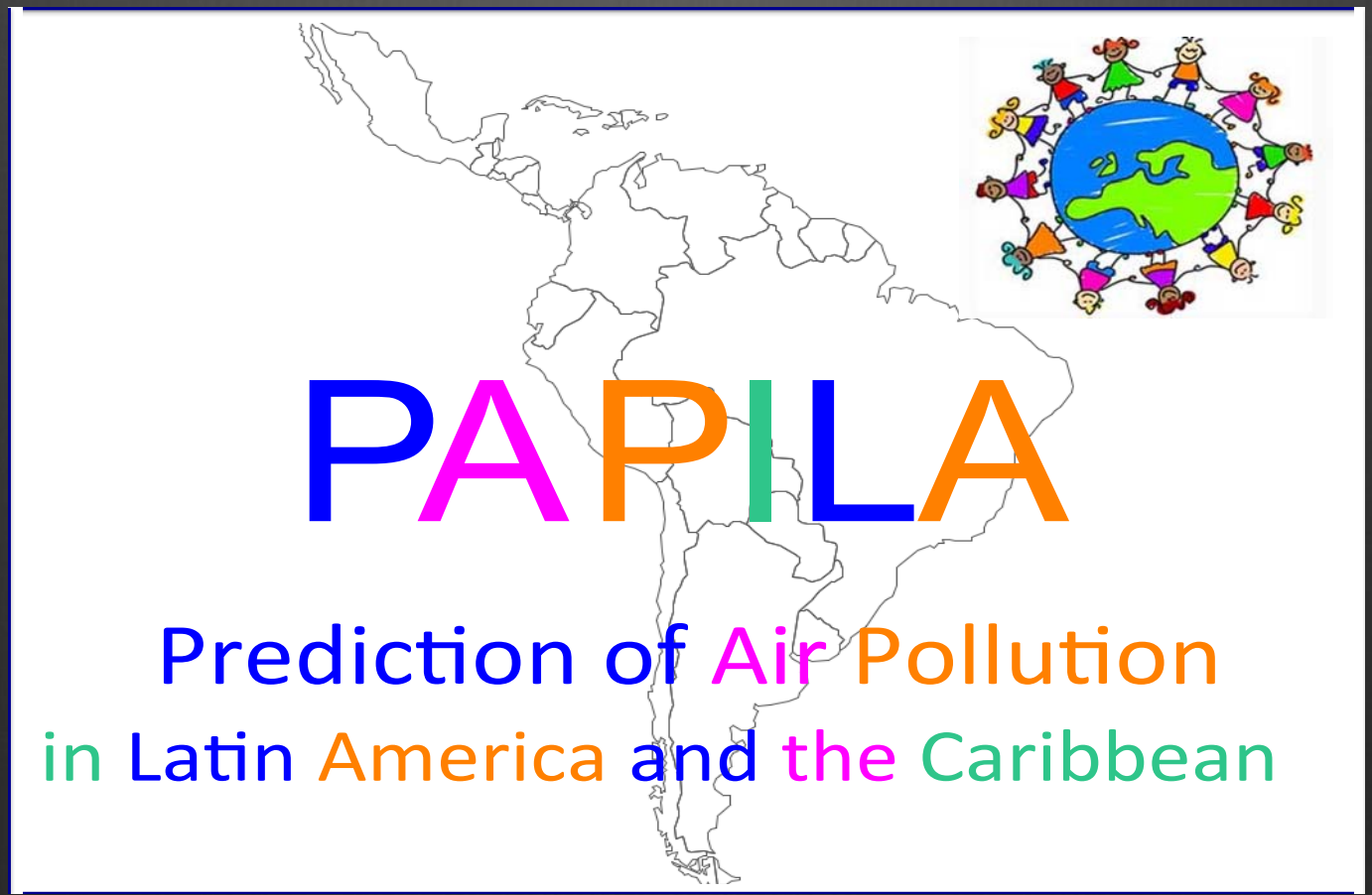
- To **develop a consortium of expert groups** that coordinates and enhances research and services with the purpose of mitigating air pollution, specifically in regions of the world with high concentrations of pollutants.
- To assimilate information provided by monitoring systems, specifically spacecraft, ground instruments and small sensor devices.
- To combine an ensemble of state-of-the-art multi-scale chemical transport models, high-resolution emission inventories, space observations and surface measurements to provide near-real-time forecasts of air pollution and its effects at the global to regional and local scales.

MAP-AQ status

European air quality forecasting system = Copernicus Atmosphere : http://copernicus-atmosphere.eu/



Air quality forecasting system in Asia already Been developed: see http://www.marcopolo-panda.eu/



PAPILA

Prediction of Air Pollution in Latin America and the Caribbean

A contribution to the MAP-AQ Project

Overall objective of PAPILA

- To establish a sustained **network of partners** with complementary expertise that develops and implements an **analysis and forecast system** for air quality with **downscaling capability** for Latin America and the Caribbean region (LAC region).
- To assess the **impact of air pollution** (background and peaks) on health and on the economy.
- To help decision-makers
  - improve air quality and **public health**,
  - avoid the occurrence of **acute air pollution** episodes, particularly in urban areas

Papila Consortium

MPG Germany (Coordination)

CNRS France

MET Norway

FMI Finland

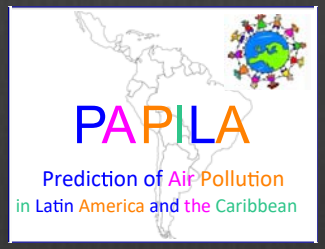
INERIS France

KNMI Netherlands

SU Sweden

UGA France

TROPOS Germany



UCL Chile

USP Brazil

UNAL Colombia

CNEA Argentina

UMSA Bolivia

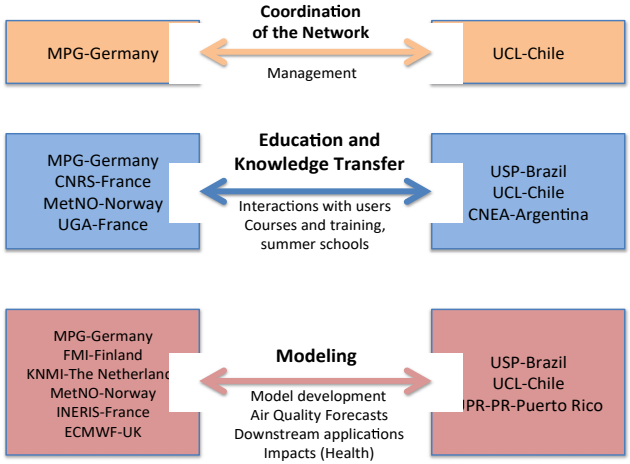
USM Chile

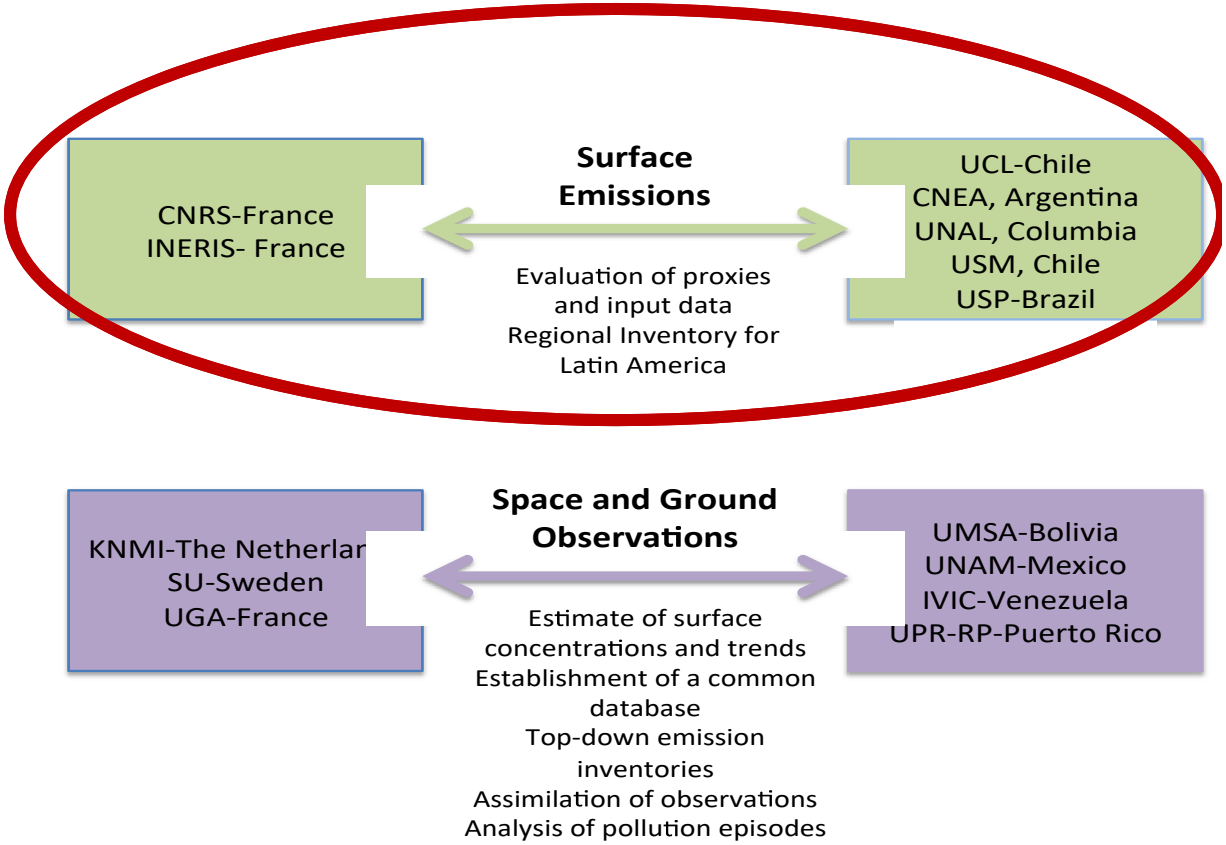
IVIC Venezuela

UNAM Mexico

UPR-RP Puerto Rico

Partnerships in the Papila project.





Thank you for your attention