1ª Conferencia Latinoamericana sobre emisión de nanopartículas en motores de combustión interna

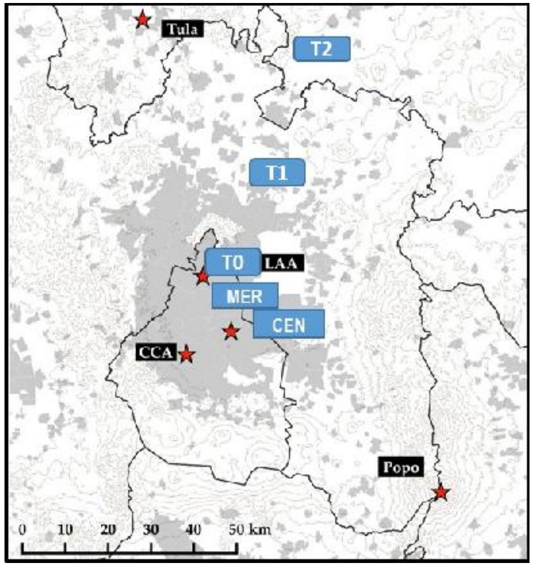
Tema: Calidad del aire: material particulado y nanopartículas

Estudios sobre partículas y calidad del aire y emisiones de vehículos diésel fuera de carretera

Luisa T. Molina

15 – 17/ octubre / 2019
Ciudad de México - México

PM studies conducted in the MCMA



Intensive field campaigns:

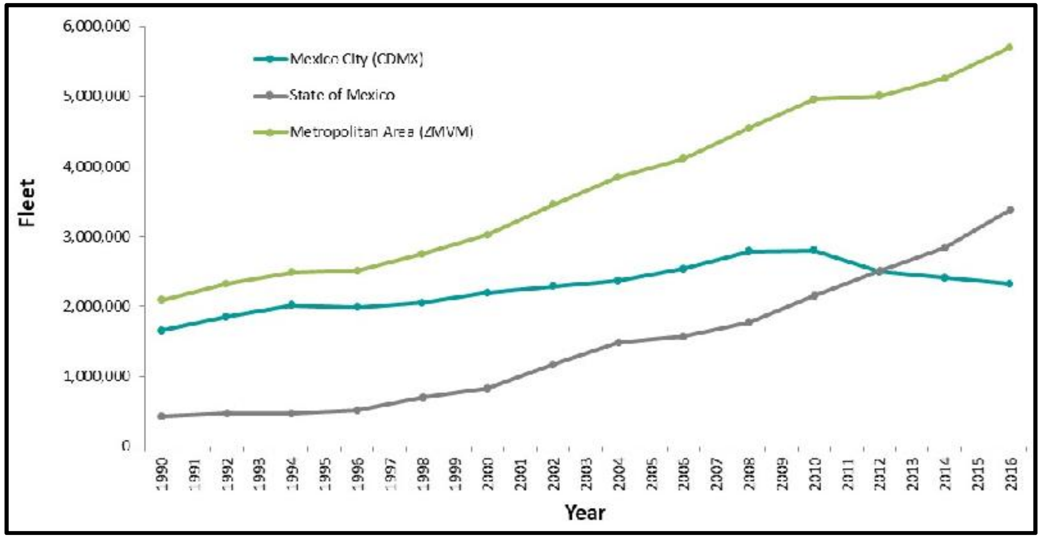
- **IMADA-AVER** (February 23 –March 22, 1997)
- **MCMA-2002/2003** (CENICA supersite and mobile lab)
  - February 2002
  - 31 March – 4 May, 2003
- **MILAGRO** (T0, T1, T2, Tula, mobile lab, aircraft)
  - 1 March – 4 April, 2006
- **SLCF-2013 Field Campaign** (2013- 2014)

On-going field studies

- **LAA** (SIMAT Laboratory): since 2013
- **UNAM- CCA:** On-going measurements
- **Plus other field measurements**

The studies provided extensive knowledge of the composition, size distribution and atmospheric mass loadings of both primary and secondary fine particles, and an improved understanding of the evolution and the radiative properties of aerosols.

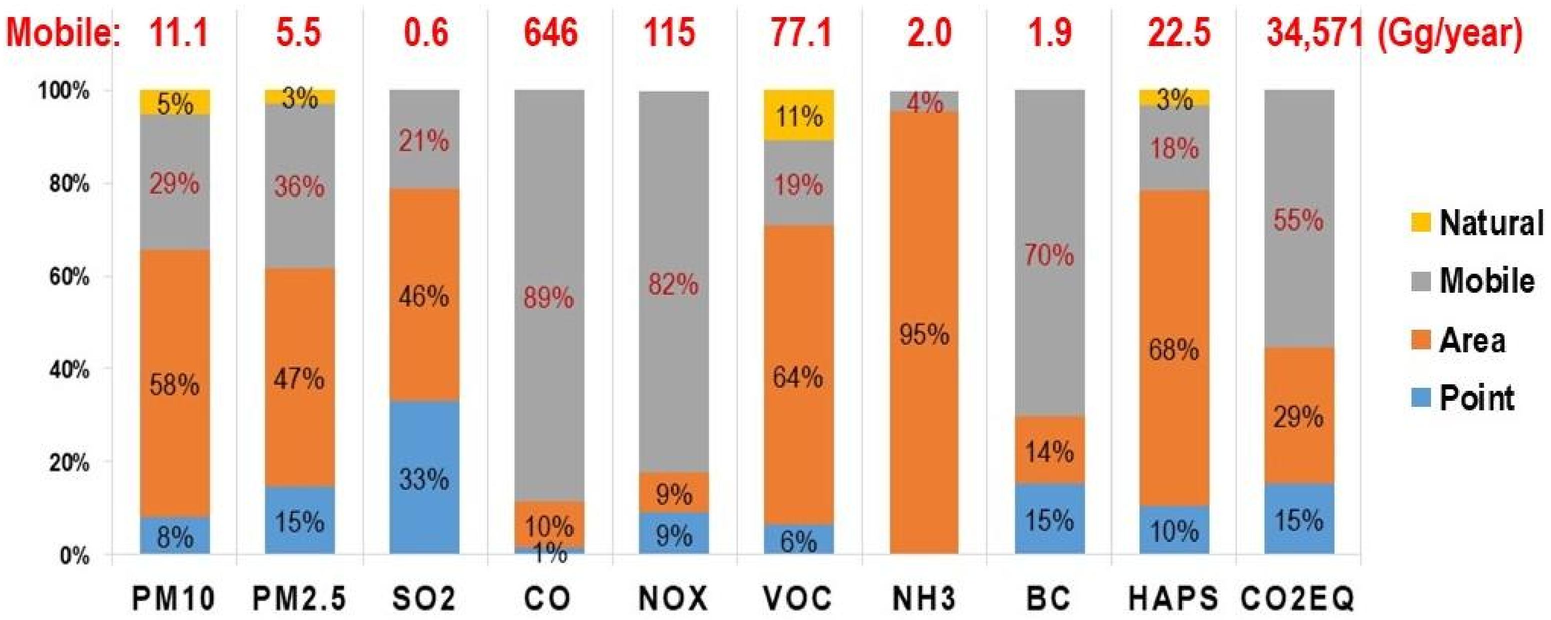
Emission Inventory and vehicle fleet of the MCMA



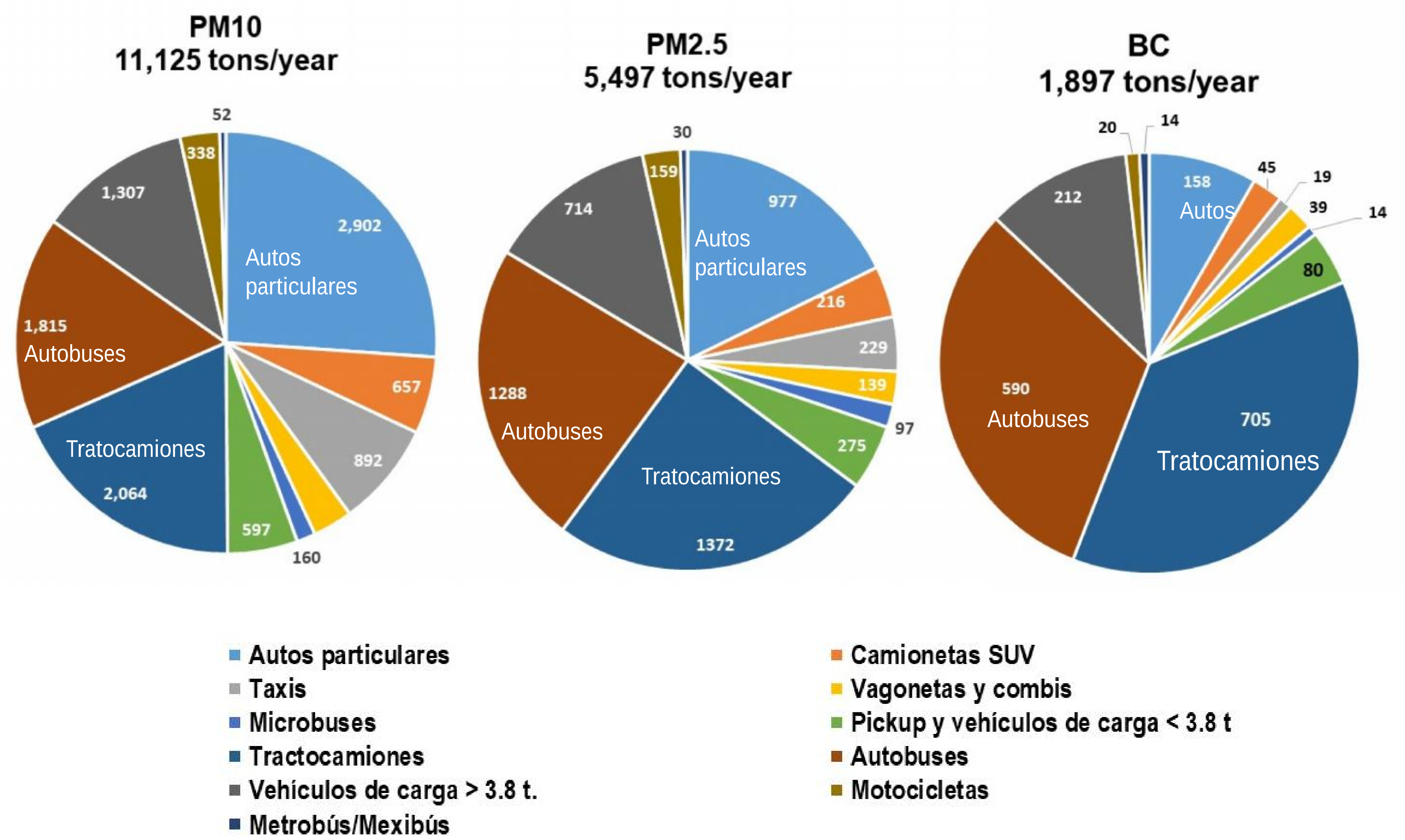
Vehicle fleet	ZMVM 2016 5,742,152	% contribución	CDMX 2,322,423 40%
Automóviles	3,341,324	58%	1,302,591
SUV	833,115	15%	351,180
Taxis	195,348	3%	133,956
Combis	55,643	1%	7,989
Microbuses	20,366	0.4%	14,019
Pick Up	440,643	8%	73,657
Vehículos ≤ 3.8 t	46,768	1%	13,576
Tractocamiones	89,625	2%	67,386
Autobuses	52,722	1%	38,465
Vehículos > 3.8 t	179,144	3%	51,578
Motocicletas	486,704	8%	267,441
Metrobús/Mexibús	750	0.01%	585

(Source: SEMAMA, EI-2016)

MCMA Emission Inventory for the year 2016

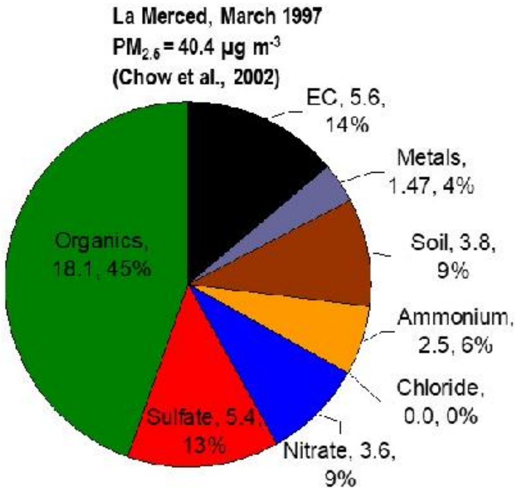


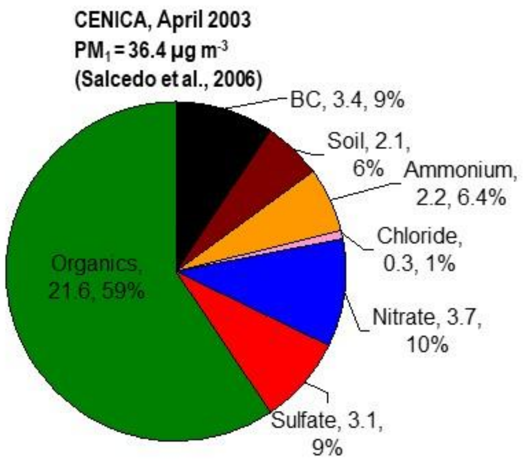
Mobile sources contribution to PM10, PM2.5, BC in the MCMA

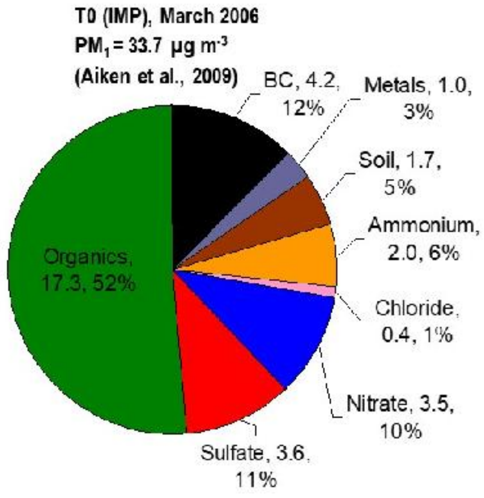


(Source: SEMAMA, Emissions Inventory-2016)

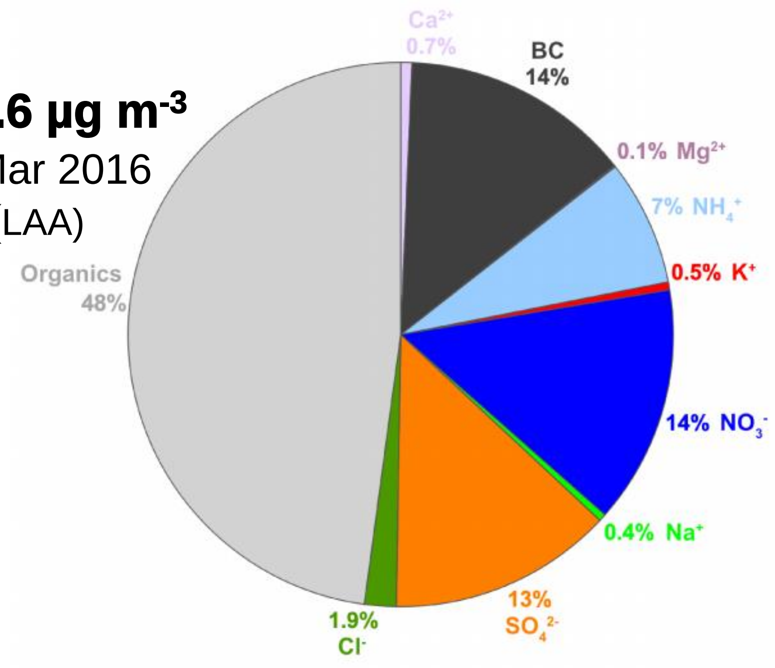
Average submicron-PM composition by mass and percent mass within the MCMA basin during different campaigns







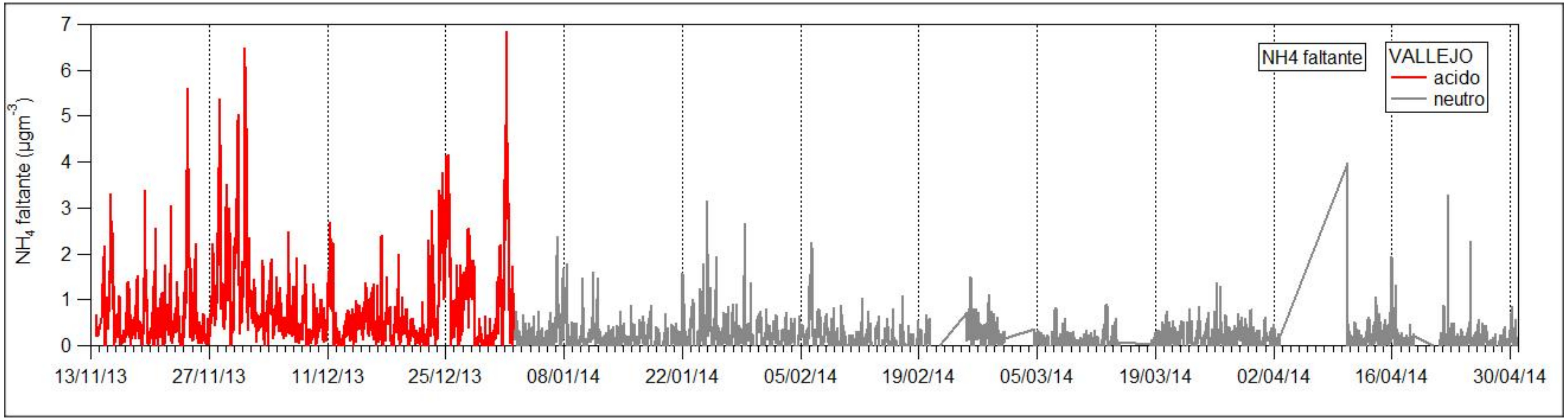
PM_1 = 25.6 µg m^{-3}
Nov 2015–Mar 2016
SIMAT Lab (LAA)

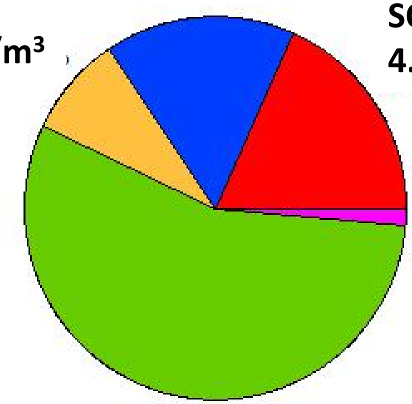


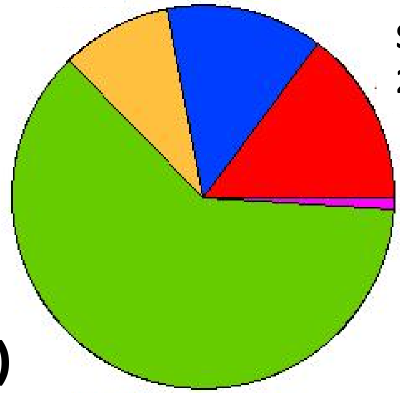
- PM_1 contributes ~70% to $PM_{2.5}$
- Organic aerosols dominate PM_1
- BC & organics contribute > 60% to PM_1
- Nitrate, sulfate and ammonium dominate the inorganic fraction
- 3/4 of sulfate has a regional origin

(Source: Retama et al., 2019, In preparation)

Seasonal changes in PM1 composition north of CDMX





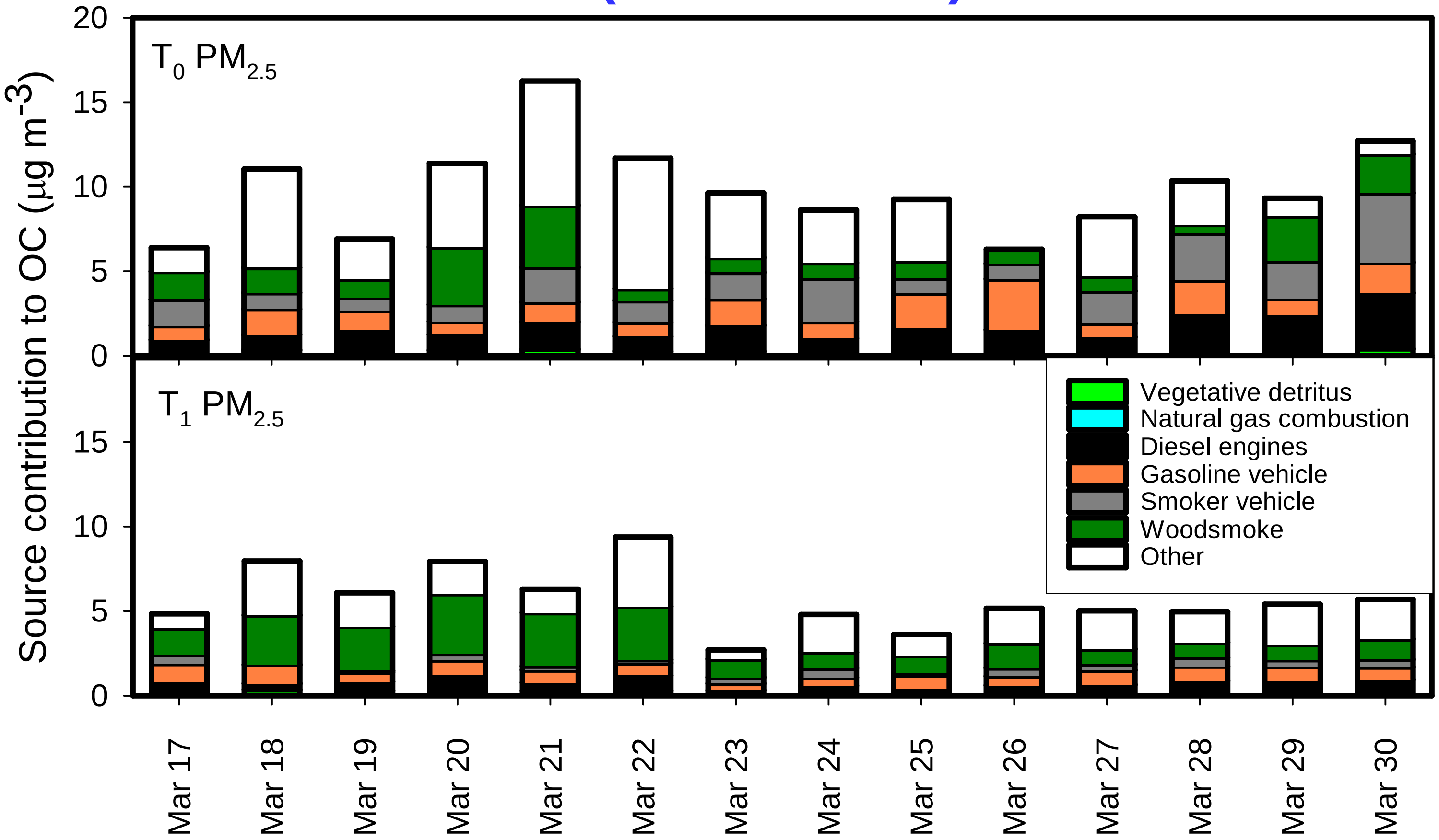


LAA site (north of CDMX)
Nov, 2014 – April, 2015

(Guerrero at al., 2017)

Source apportionment of fine organic aerosol

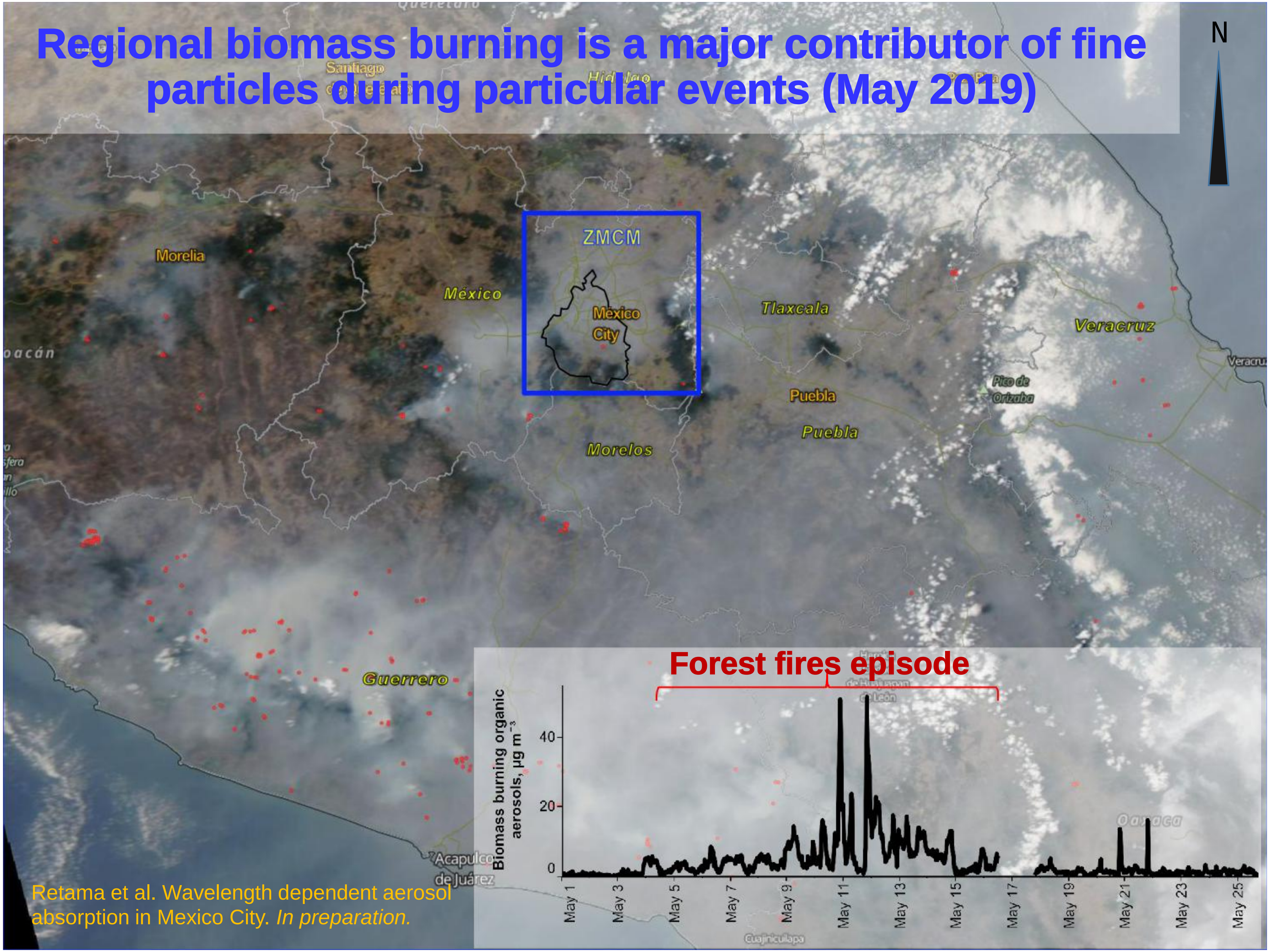
(MILAGRO-2006)



- **Motor vehicles consistently accounted for ½ of PM2.5, OC at T0 and 1/3 at T1.**
- **The daily contribution of biomass burning to OC was highly variable (10-50%) over the two sites.**

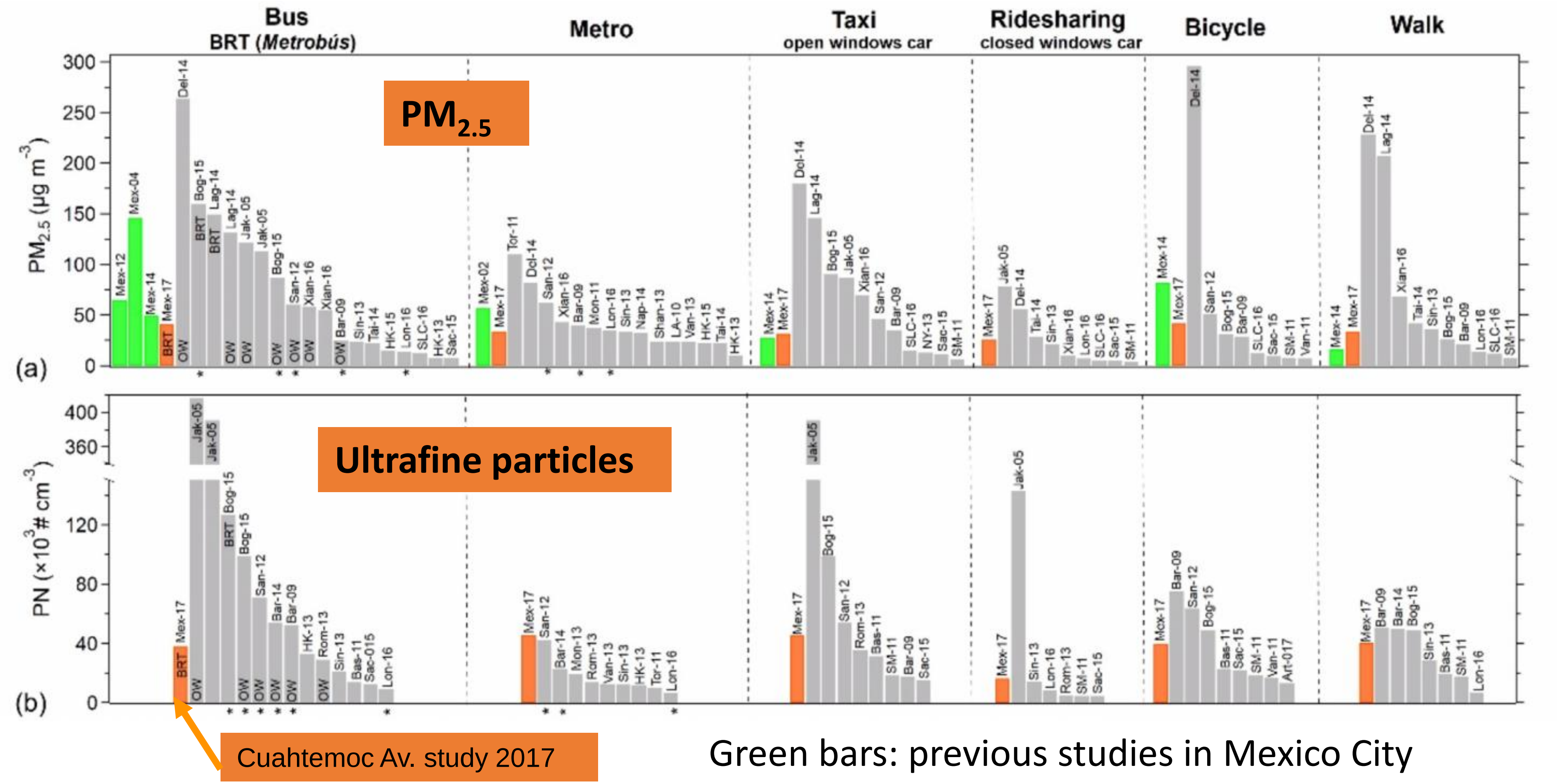
(E. A. Stone et al., ACP, 2008)

Regional biomass burning is a major contributor of fine particles during particular events (May 2019)



Retama et al. Wavelength dependent aerosol absorption in Mexico City. *In preparation.*

Exposure to $PM_{2.5}$ and ultrafine particles in traffic microenvironments in Mexico City vs other cities



Green bars: previous studies in Mexico City

The exposure in Mexico City is moderate compared to cities in Latin America (e.g., Bogota, Santiago), Africa (e.g., Lagos), and Asia (e.g., Delhi, Jakarta), but slightly higher than in US and European cities.

(Velasco E, Retama A, Segovia E, Ramos R. (2019). *Atm. Env.,* In Press)

Polycyclic Aromatic Hydrocarbons (PAHs) in Mexico City

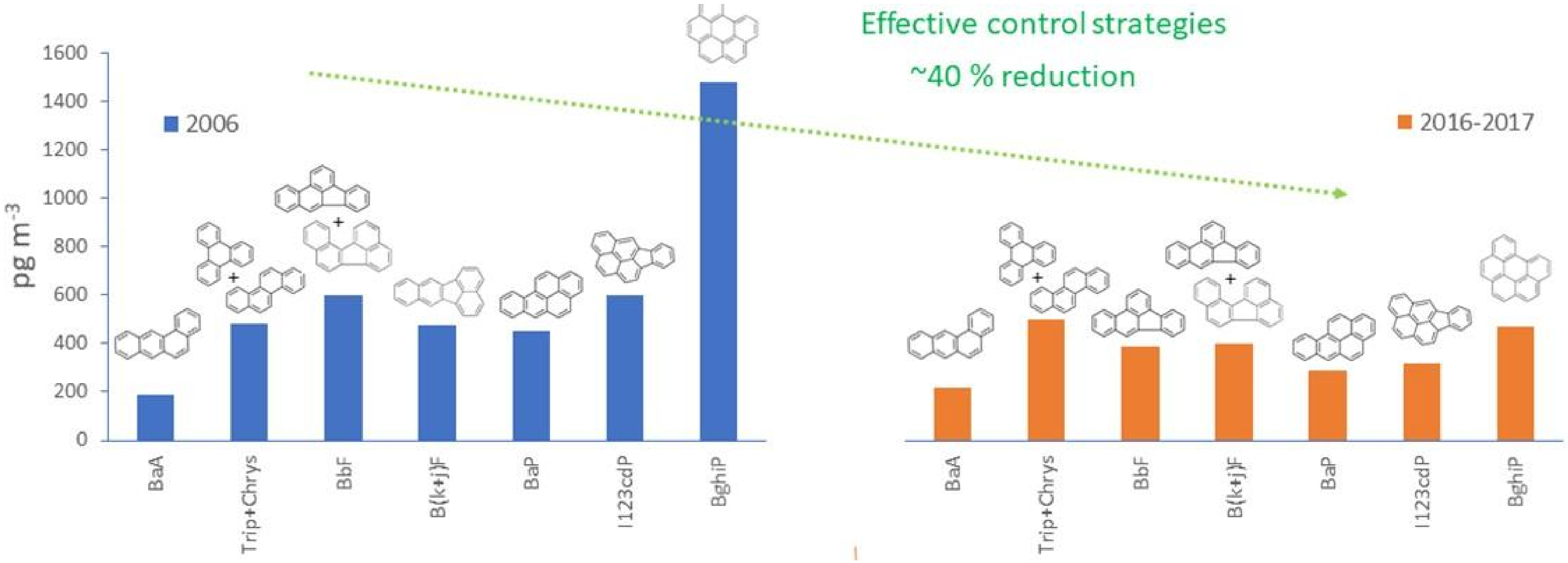
- **Polycyclic aromatic hydrocarbons (PAHs):** a class of chemicals that occur naturally in coal, crude oil, and gasoline. They also are produced when coal, oil, gas, wood, garbage, and tobacco are burned. PAHs generated from these sources can bind to or form small particles in the air. They comprise the largest mass fraction of UFPs, the primary urban source of which is also gasoline aromatics.

- Particle-bound PAHs are considered to be very hazardous to human health. Exposure to PAHs, by breathing air contaminated with motor vehicle exhaust, cigarette smoke, wood smoke, etc., has been linked to cancer, cardiovascular disease, and poor fetal development.

- Emissions from vehicles (cars, trucks, etc.) can be a substantial outdoor source of PAHs in urban and suburban locations. Gasoline PAHs are high molecular weight (4 – 6 rings), as opposed to diesel PAHs, which are low molecular weight. HMW PAHs are more toxic, and more persistent than LMW PAHs.

- Major roadways are sources of PAHs, which may distribute in the atmosphere or deposit nearby. Catalytic converters are estimated to reduce PAH emissions from gasoline-fired vehicles by 25-fold.

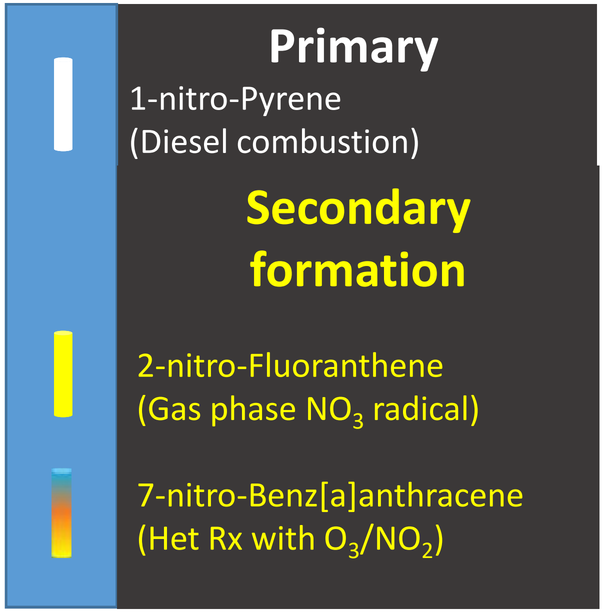
PAHs in $PM_{2.5}$ at a Receptor Site in Mexico City

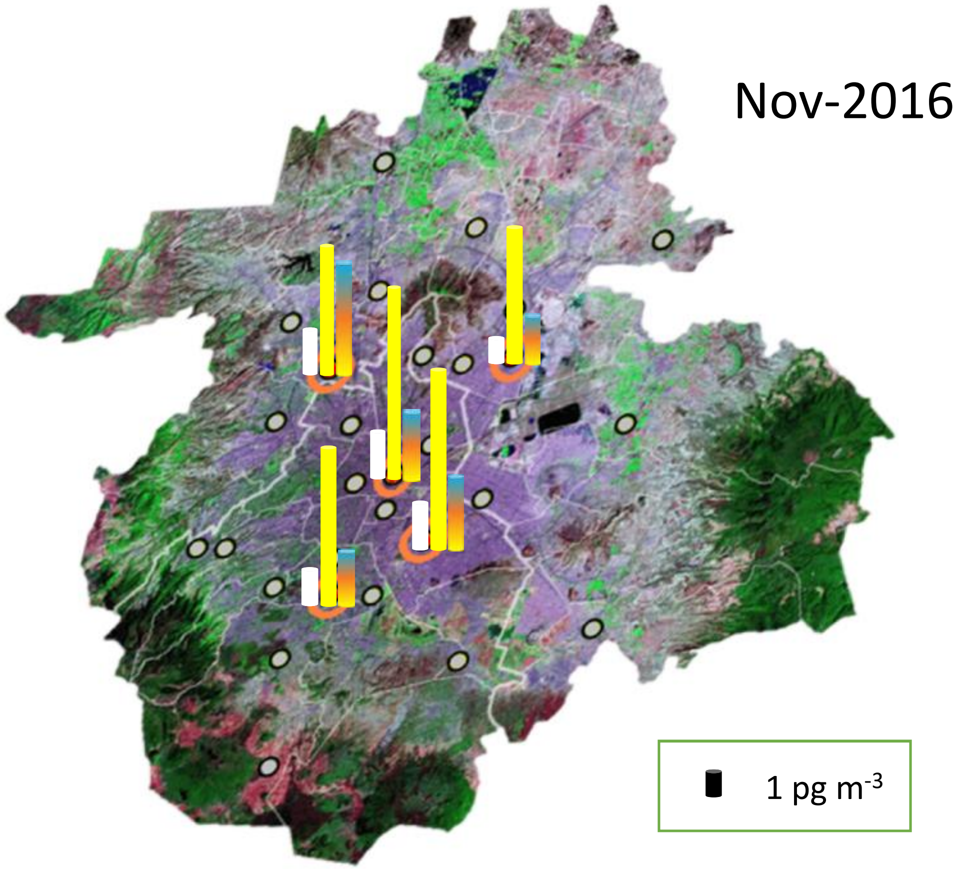


- PM2.5 sampling conducted in the southwest part of Mexico City during Nov 2016-Mar 2017 (using GC-MS and EchoChem PAS-2000).
- Observed ~ 40% reduction in carcinogenic PAH between 2006 and 2016–2017, inspite of nearly two-fold increase in vehicle fleet during the same period.
- The PAH decrease trend agrees with the decrease trend of CO, NO and NO2
- Carcinogenic PAH (mostly found in particle phase) are mainly emitted from vehicles, the reduction can be attributed to adequate strategies implemented by the local and federal governments

Amador-Muñoz *et al.* (2019) Sci. Tot. Environ. *In press.*

Nitro-PAH in $PM_{2.5}$ in the MCMA





Monthly median concentrations of nitro-PAH in $PM_{2.5}$

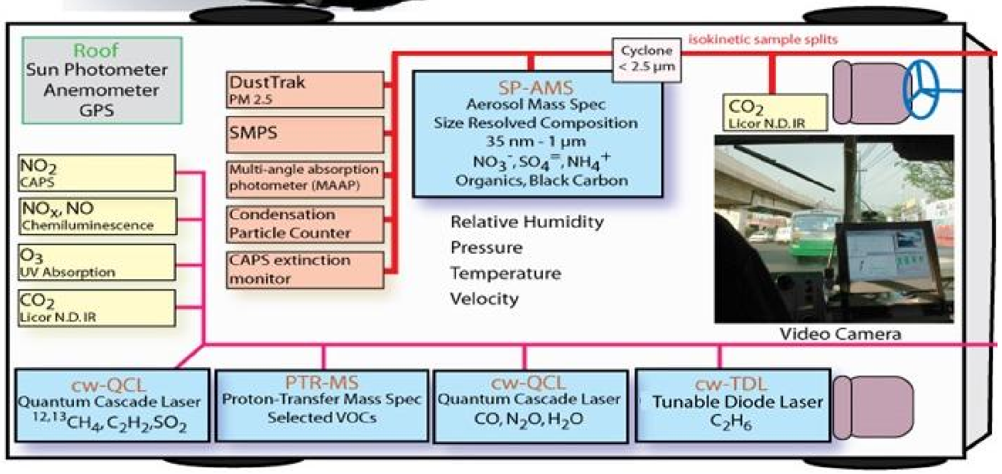
- Nitro-PAH are emitted from diesel combustion (primary) and also formed by OH or NO3 reaction (secondary).
- Samplings were done on high-volume samplers around MCMA during Nov. 2016.
- Nitro-PAH were extracted from organic solvent and analyzed by GC-MS.

(Trejo-Pacheco (2018). Thesis, UNAM; Amador-Muñoz et al. In prep.)

Characterization of emissions from diesel vehicles

SLCF Mexico-2013

Aerodyne Mobile Lab

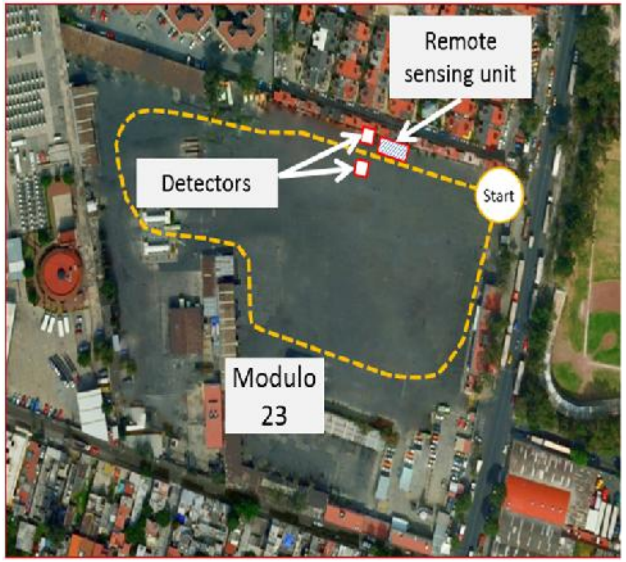


- 17 buses, 16 commercial trucks, 102 Metrobuses (March 2013).
- EPA98, EPA03, EPA04, EURO3-5, HYBRID.
- Collaborators: MCE2, Aerodyne, SMA-DF, RTP, METROBUS, COCA COLA-FEMSA, TURIBUS.
- Sponsors: GEF, MCE2, INECC

- AML measurement: targeting on-road vehicles in “chase” and/or road-side “exhaust plume-sampling” techniques. by positioning the mobile laboratory downwind of the target vehicles.
- A high-level remote sensing unit was also used for the measurement of emissions factors from the same vehicles sampled by the mobile laboratory inside the module 23 RTP facilities.
- AXION Portable Emissions Measurements System (PEMS) platform to obtain the relevant data for estimating emissions factors from one Dina bus tested vehicle.

SLCFs-Mexico: Transport Sector

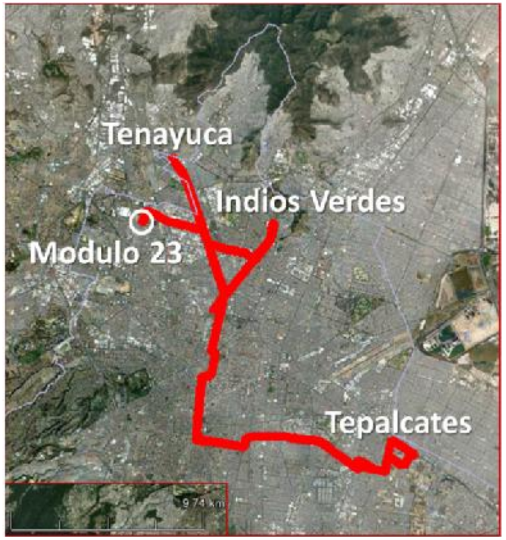
Chasing on-site (RTP facility)



AML measurements: Emissions ratios were obtained by correlating the sampled exhaust plume (gaseous or particle) signals with above background CO_2, which acts as a combustion tracer.

Remote Sensing

Chasing Metrobuses

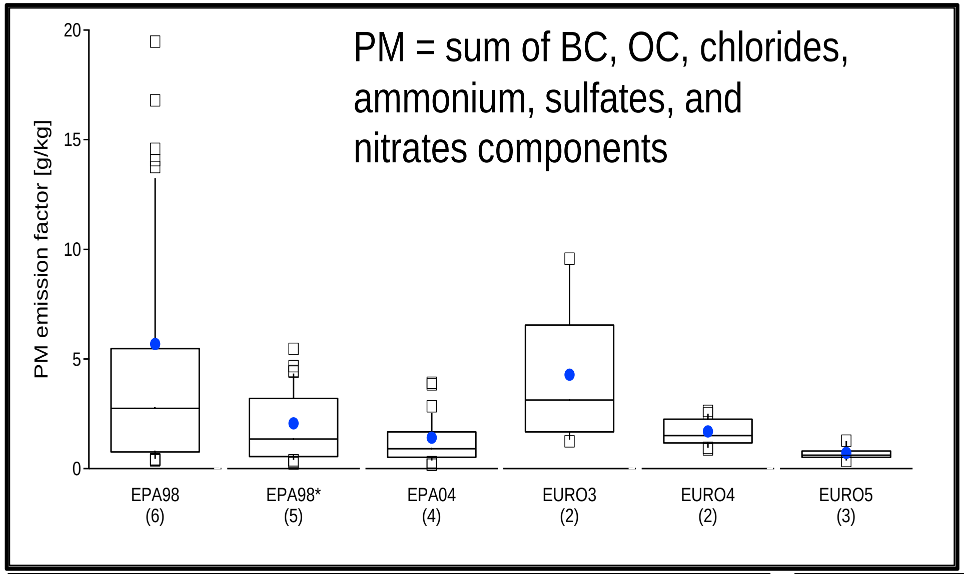


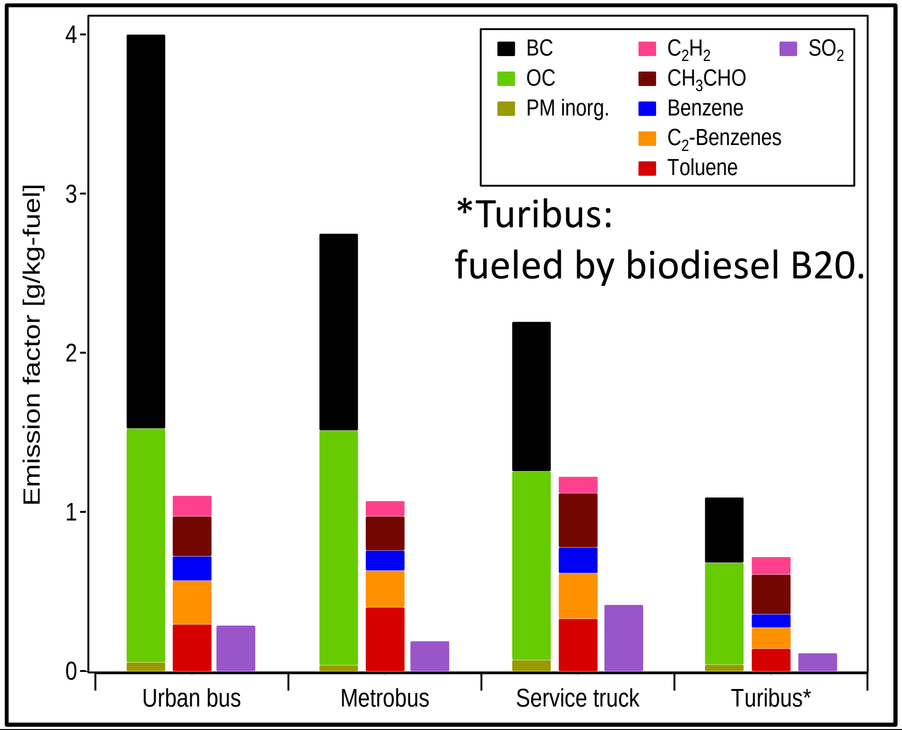
Stationary Sampling

On-board measurements

Comparison of fuel-based emission factors (g/kg fuel) by vehicle type and control technology

Box plots of PM emission factors measured by control technology

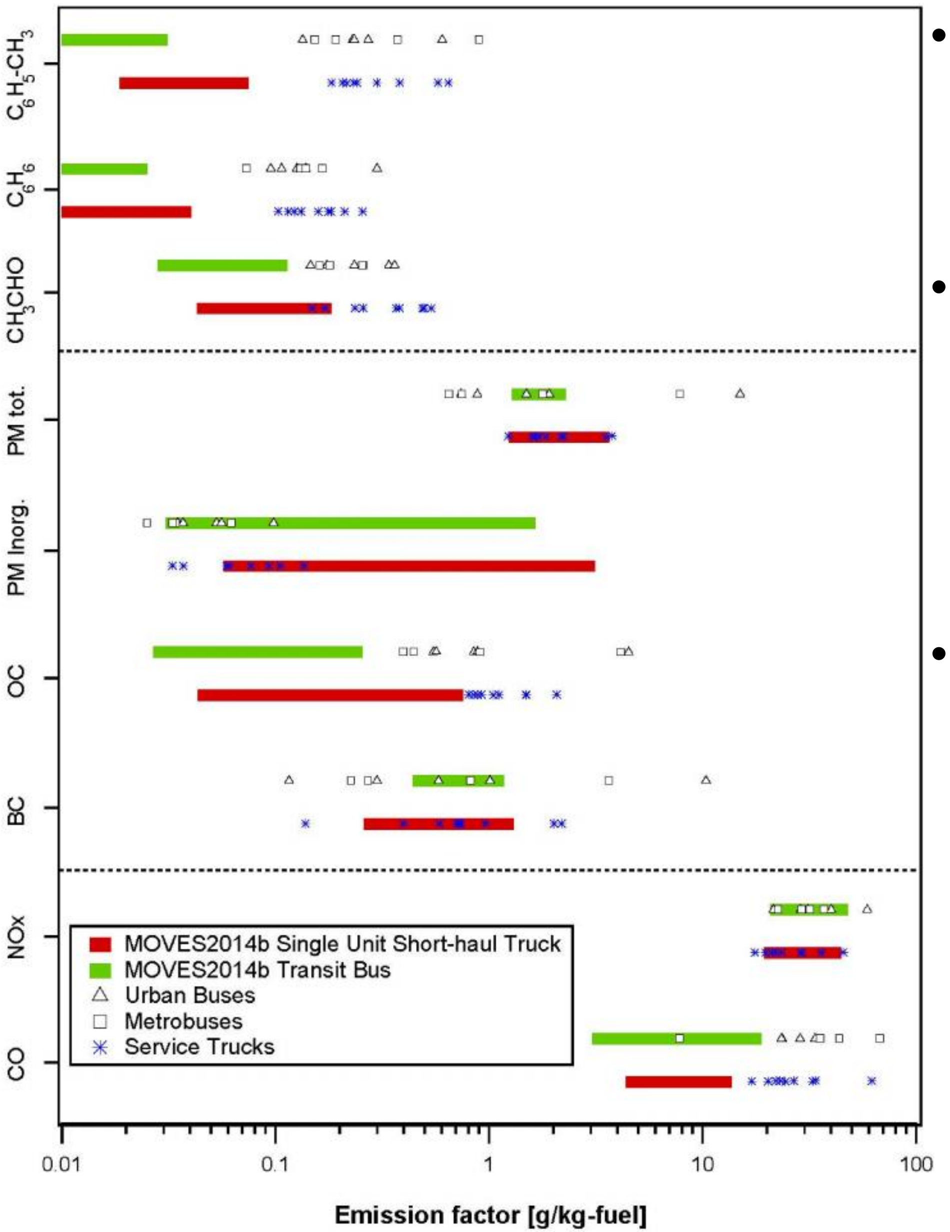




The numbers in parenthesis represent the number of sampled vehicles. The first box plot of the EPA98 technology category includes one high emitter vehicle, whereas the adjacent box plot does not include this vehicle.

- BC and OC emission factors for public transport buses are higher than for metrobuses and service diesel trucks.
- Substantial differences were present depending on vehicle technology and driving mode.
- The variability of the EFs estimated demonstrates the importance of **local-based** measurements

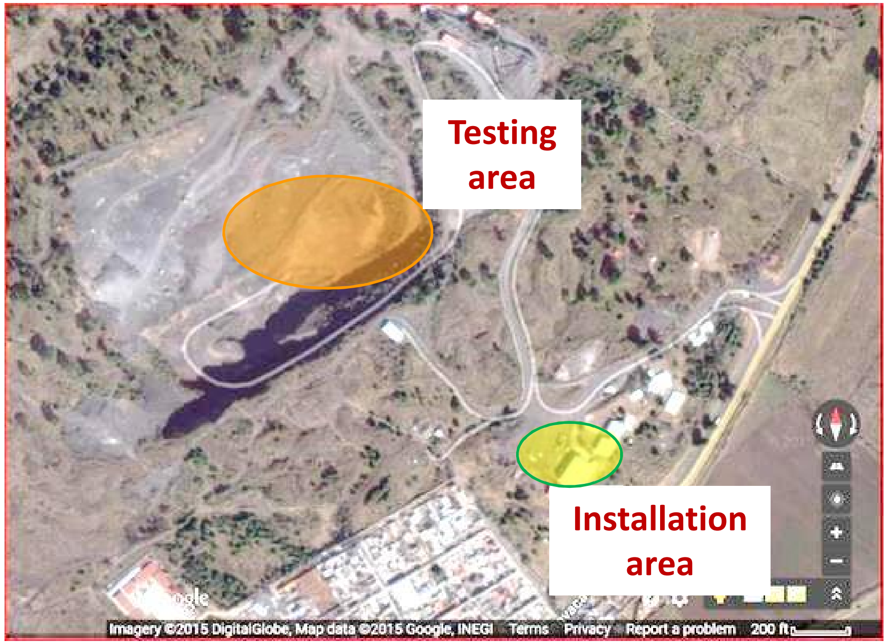
Comparison: Measured vs MOVES2014b Emission Factors

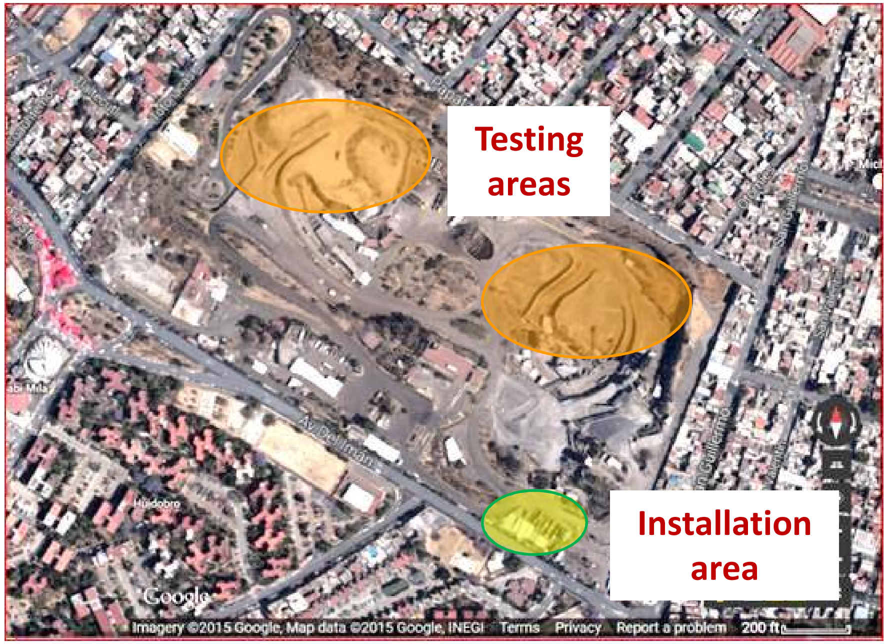


- The model underestimated the CO, OC, and selected VOCs but had better agreement for NOx and BC emission factors.
- Due to the small sampling size in this pilot study, caution should be exercised when attempting to extrapolate the results from this comparison to other vehicle categories and model years.
- Nevertheless, the results demonstrate the need for locally adjusting the emission factors database for the diesel vehicle fleet in the MOVES2014 Mexico model using real-world driving conditions to improve the emission estimates during inventory development.

Measurement of BC emissions from off-road vehicles
using Portable Emissions Measurement Systems (PEMS)

Site A **Planta de Asfalto del DF** **Site B**





ECOSTAR
From ITESM

CO, CO_2, NO, NO_2

AVL Micro-Soot Sensor
From CARB

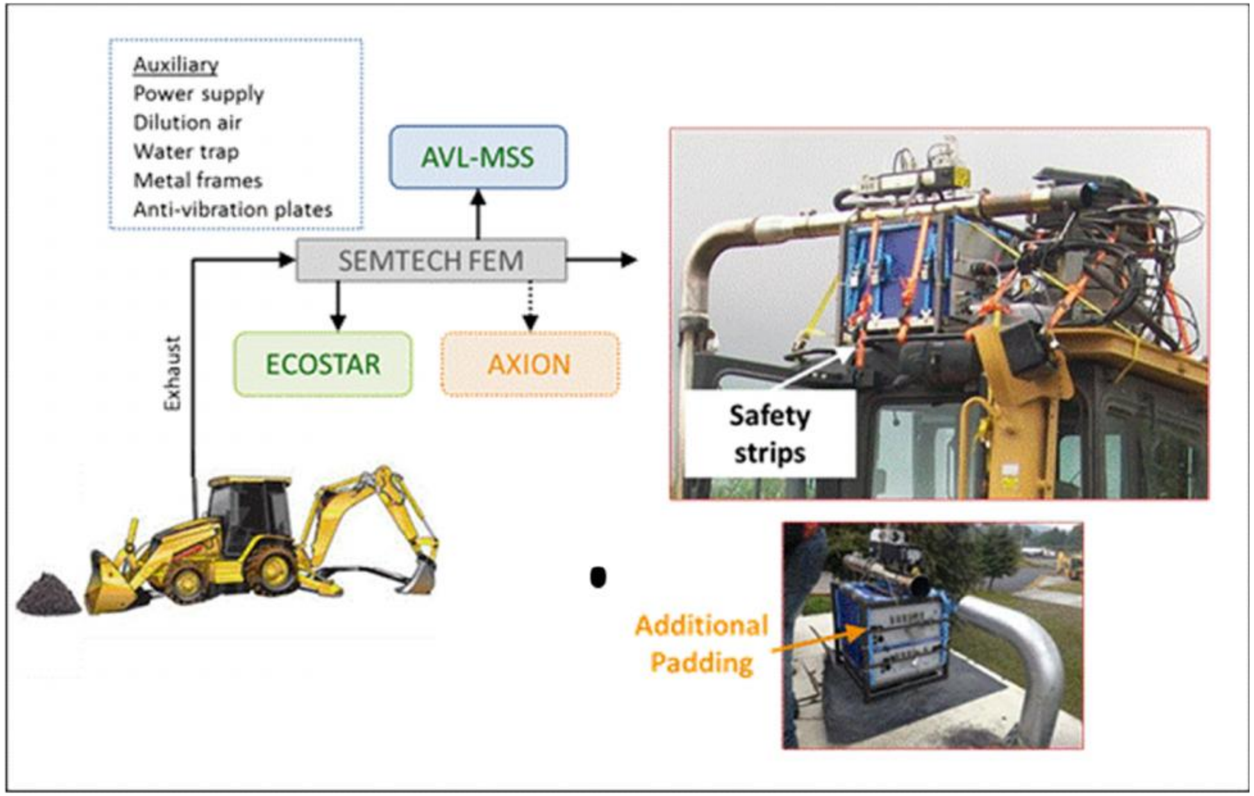
BC in PM

AXION R/S
From UNAM

CO, CO_2, NO_X, PM10

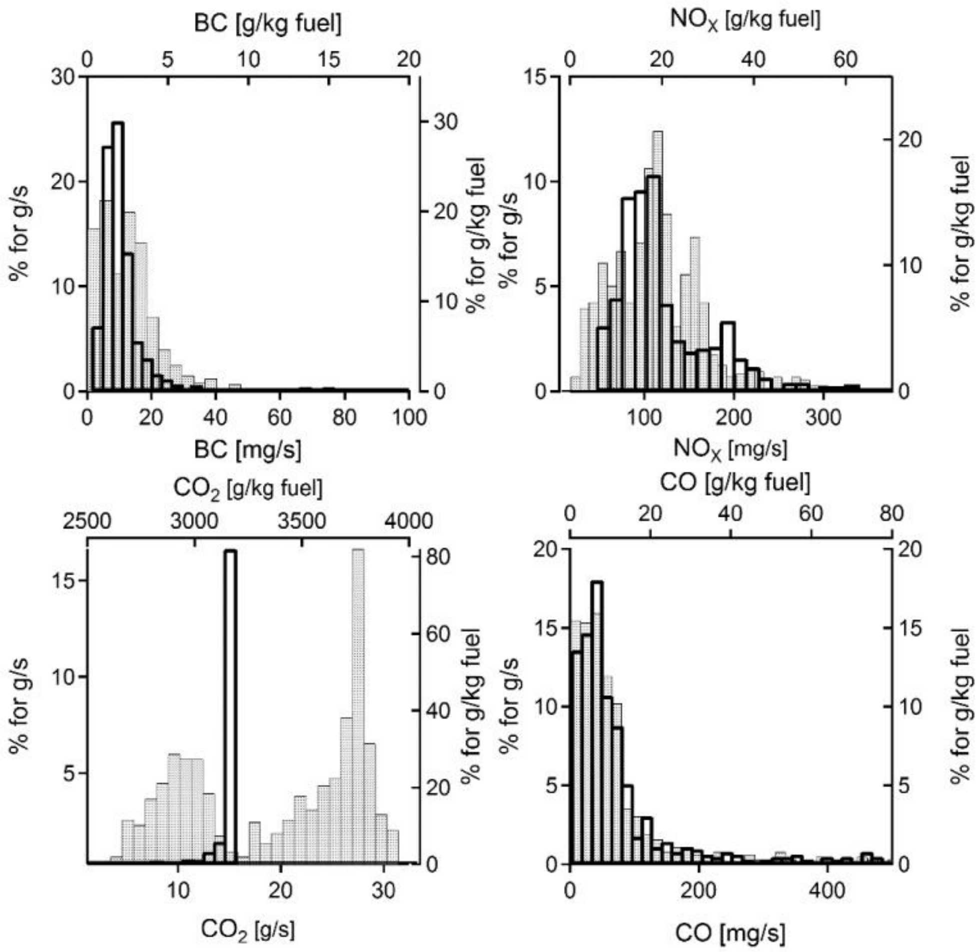
Collaborators: Planta de Asfalto del DF, Sistema Maíz, GeoConstruccion, CARB, UNAM, ITESM, MCE2, INECC, SEDEMA, Ambientales

General schematics of the sampling setup during the testing of the selected off-road vehicles



- The AVL-MSS and the ECOSTAR PEMS were deployed in all sampled vehicles; the AXION PEMS was deployed in a small subset of vehicles.
- The selected vehicles included backhoes, tractor, crane, hammer, front loaders, bulldozers, compressor, and power generators, representing an important variety of heavy- and medium-duty diesel off-road vehicles.

Time based emission rates and fuel-based emission factors frequency distributions for CO_2, CO, NO_X, and BC

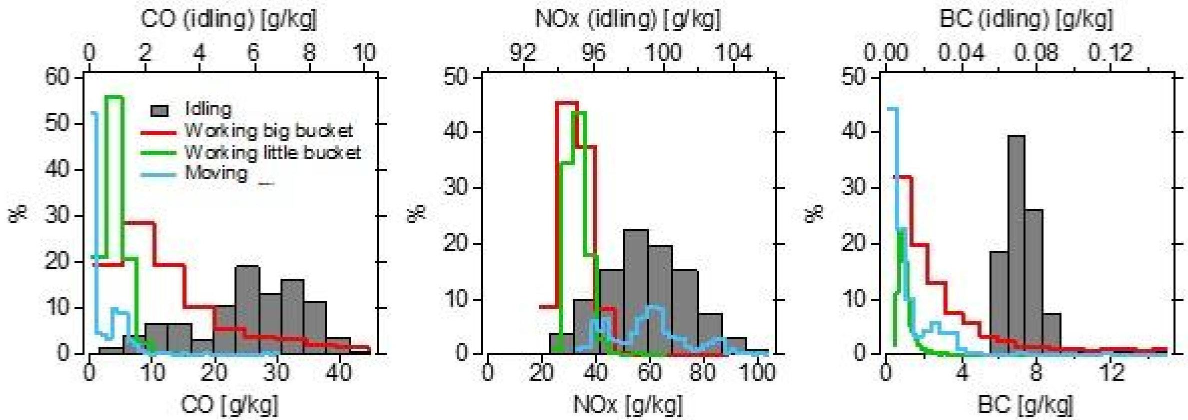


Grey filled bars (bottom axes) – emission rates

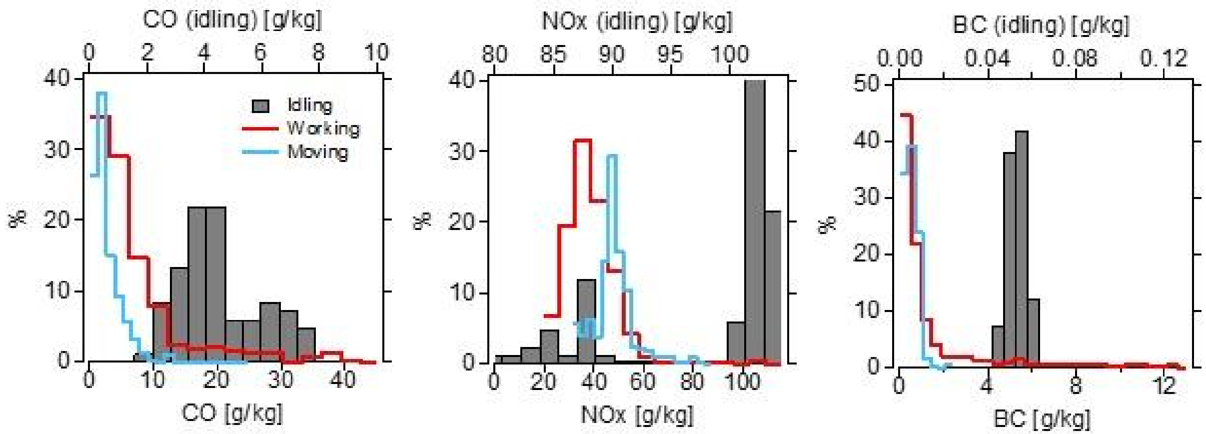
Dark transparent bars, (top axes) – emission factors frequency distribution of a bulldozer (BH-2) during an earth pushing working task.

Frequency distributions of pollutant fuel-based EFs measured in various operating conditions for a backhoe

Baseline



With p-DPF



Operating conditions are indicated by color:
top horizontal axes - Idling conditions
bottom axes – all other operating conditions

- Emission factors from off-road vehicles are highly variable due to the transient operations of the engine.
- The extent of the variability depends on the pollutant and vehicle type.
- The variability is better described using **frequency distributions for the emission factors** rather than the traditional single-statistic (e.g. average) emission factor.

(Zavala et al., JAWMA, 2017)

Summary of off-road vehicles emissions study

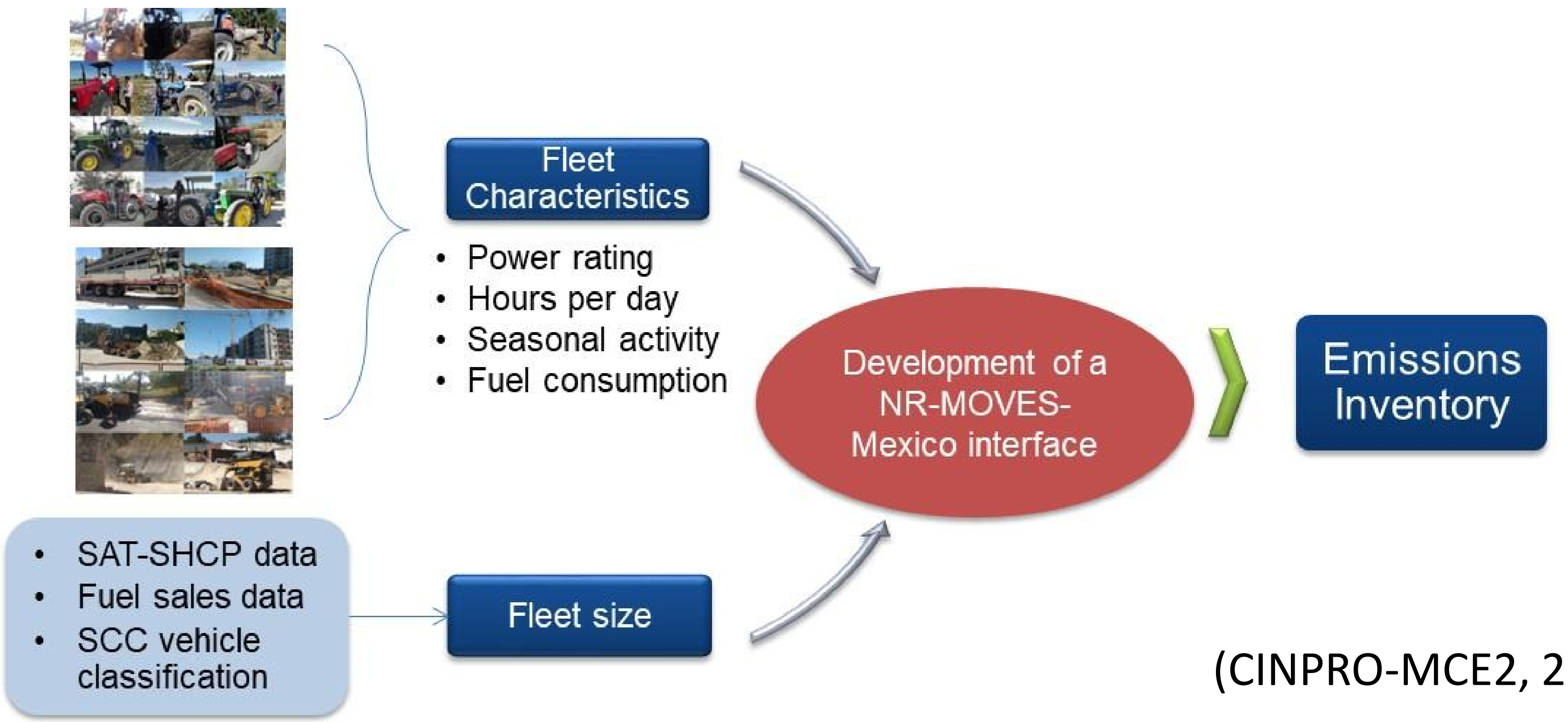
- Measurements of off-road vehicles used in construction and agricultural activities in Mexico using on-board portable emissions measurements systems (PEMS) showed that these vehicles can be major sources of black carbon and NOx.
- For a selected number of these vehicles, the emissions were further characterized with wall-flow diesel particle filters (DPFs) and partial-flow DPFs (p-DPFs) installed.
- Mass-based reductions for black carbon EFs were substantially large (above 99%) when DPFs were installed and the vehicles were idling, and the reductions were moderate (in the 20–60% range) for p-DPFs in working operating conditions.
- The results indicated that diesel particle filters (DPFs) are an effective technology for control of diesel particulate emissions and can provide potentially large emissions reduction in Mexico if widely implemented.
- Emission factors varied significantly under real-world operating conditions, suggesting the need for detailed vehicle operation data for accurately estimating emissions inventories.
- A larger database is needed in building up accurate inventories.

Characterization of activity data and emissions from Agriculture and Construction Sectors in Mexico

Methodology

- ❑ 386 and 214 surveys targeting agriculture and construction activities, respectively, in selected regions of the country were used to obtain representative characteristics of the vehicle fleet.
- ❑ Data from Servicio de Administración Tributaria (SAT-SHCP) and fuel sales data were used to constrain fleet population estimates.
- ❑ A new NR-MOVES-Mexico interface was developed for estimating emissions using the Mexican fleet characteristics using the MOVES-2014 model.

Surveys



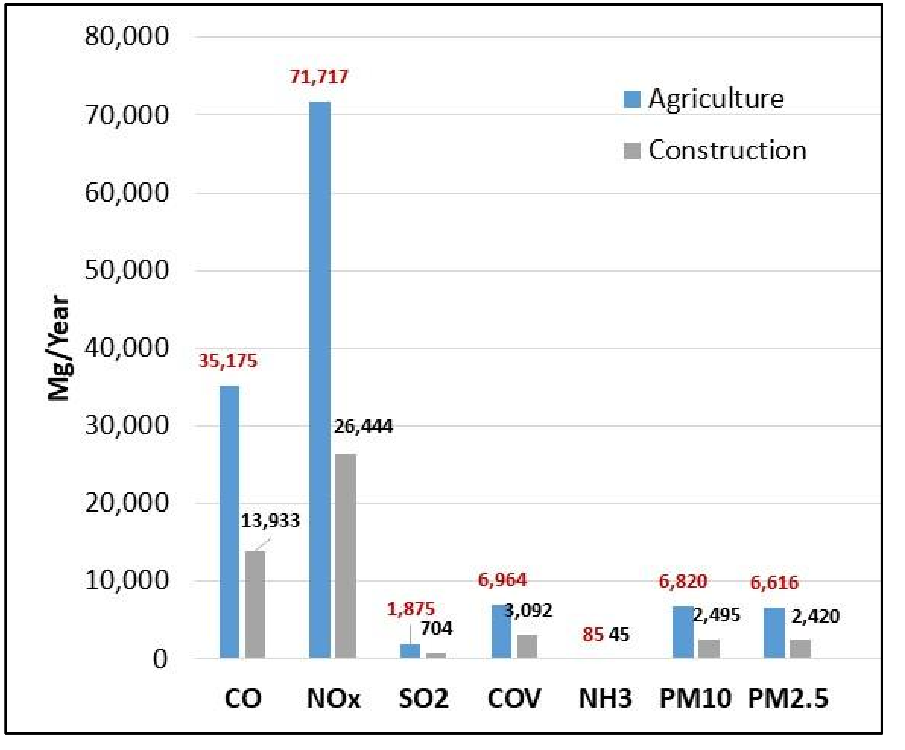
(CINPRO-MCE2, 2018)

Estimated Annual Emissions 2016

Sector	[Mg/year]							
	CO_2	CO	NO_x	SO_2	COV	NH_3	PM_{10}	$PM_{2.5}$
Agriculture	10,417,961	35,175	71,717	1,875	6,964	85	6,820	6,616
(%)	(65.0)	(71.6)	(73.1)	(72.7)	(69.3)	(65.1)	(73.2)	(73.2)
Construction	5,598,534	13,933	26,444	704	3,092	45	2,495	2,420
(%)	(35.0)	(28.4)	(26.9)	(27.3)	(30.7)	(34.9)	(26.8)	(26.8)
Total	**16,016,495**	**49,108**	**98,161**	**2,579**	**10,056**	**130**	**9,315**	**9,036**

Fleet composition

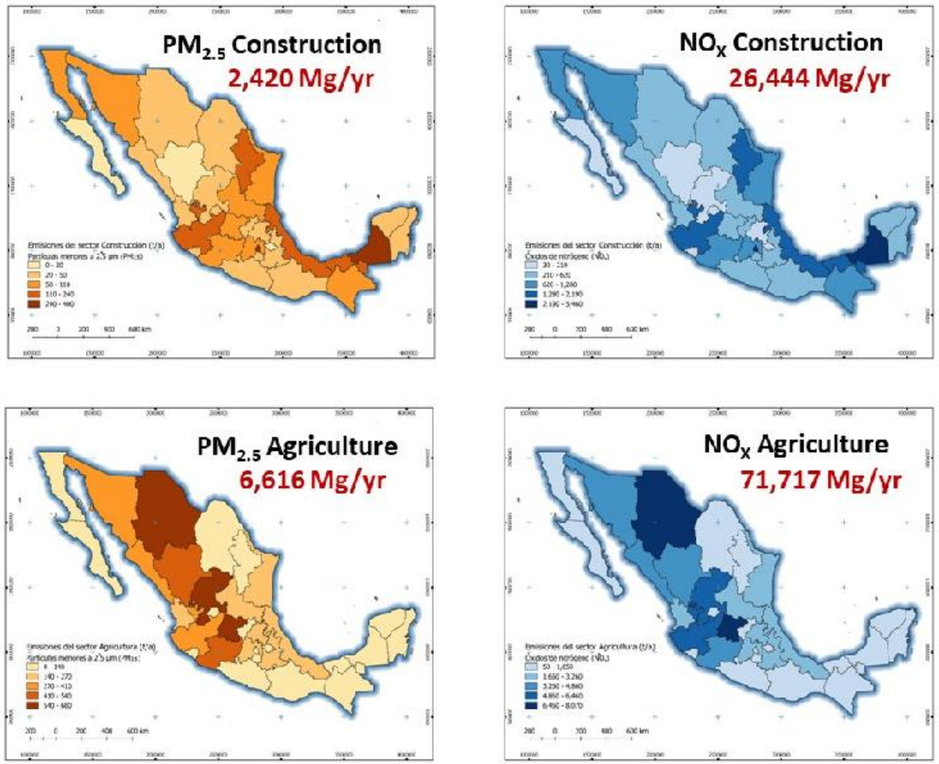
Sector	Description	Vehicles
Construction	Tractors/Loaders/Backhoes	71,843
	Skid Steer Loaders	65,462
	Rubber Tire Loaders	39,808
	Trenchers	31,025
	Crawler Tractor/Dozers	20,356
	Off-highway Trucks	19,340
	Excavators	15,767
	Tampers/Rammers	13,539
	Plate Compactors	13,378
	Rollers	10,046
	Others	43,440
	Total construction	344,004
Agriculture	Agricultural Tractors	111,136
	Other Agricultural Equipment	71,458
	Agricultural Mowers	53,099
	Combines	47,933
	Swathers	47,823
	Others	41,275
	Total agriculture	372,724
	Total	**716,730**



Summary of off-road emissions

- New activity databases were constructed using surveys, official and institutional data for the construction and agricultural sectors in Mexico.
- Agriculture sector is a higher emitter than the construction sector (65-73%), even though their fleet size is comparable.
- Spatial distributions of emissions were obtained for the whole country at the state and municipal levels.
  - Chihuahua, Guanajuato, Zacatecas, Michoacán, Durango, Jalisco y Sinaloa, contribute between 55-58% of agriculture emissions.
- These results could contribute to reducing the uncertainty of emissions estimates for off-road vehicles, this in turn helps in improving air quality modeling applications.

Spatial Distribution of Emissions



Acknowledgements

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Global Environmental Facility, UNEP, INECC, USAID, MCE2, CONACYT

Many collaborators for the On-road and off-road studies, including:

MCE2, Aerodyne, SEDEMA, RTP, METROBUS, COCA COLA-FEMSA, TURIBUS, Planta de Asfalto del DF, Sistema Maíz, GeoConstruccion, CARB, UNAM, ITESM, MCE2, INECC, Ambientales, UNAM-CCA, Secretaría de Obras y Servicios del DF, Planta de Asfalto del DF, GeoConstruccion, Sistema Maíz, CINPRO

Thank you for your attention!