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Supplement of

Emission factors of black carbon and co-pollutants from diesel vehicles in Mexico City

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Supplemental Material

This Supplemental Material document contains additional information on the instrumentation deployed, a description of the driving conditions during the measurement of emissions from the selected on-road vehicles, as well as additional figures and tables discussed in the manuscript.

1. Instruments on-board the Aerodyne Mobile laboratory

Tables S1 and S2 show the characteristics of the instruments deployed by the ARI mobile laboratory and the remote sensing unit, respectively, during the on-road measurements.

Table S1. Characteristics of instruments deployed by the ARI mobile laboratory.

Instrument	Pollutants measured	Detection limit by pollutant
Quantum Cascade Tunable Infrared Laser Differential Absorption Spectrometers (QC-TILDAS)	Carbon monoxide (CO) and nitrous oxide (N_2O); ethane (C_2H_6); methane isotopes ($^{13}CH_4$ and $^{12}CH_4$), sulfur dioxide (SO_2), and acetylene (C_2H_2).	Typical detection limits are 0.1 ppbv in 1-s, each of the pollutants quantified in this work is detected in plume encounters well above the detection limit.
Proton Transfer Reaction Mass Spectrometer (PTRMS)	Oxygenates, aromatics.	Typical detection limits are 0.3 – 0.8 ppbv depending on compound in 1-s of integration time.
Soot Particle Aerosol Mass Spectrometer (SP-AMS)	70 nm – 1.5 µm aerodynamic diameter aerosol, composition resolved into black carbon; sulfate; nitrate; ammonium; chloride and organic PM.	300 ng/m^3 in 1-s integration time.
Thermo Electron 42i chemiluminescent detector	NO, NO_y	0.4 ppbv in 1-s integration time for each species.
LiCor 6262 Non-Dispersive Infrared (NDIR)	CO_2	300 ppb in 1-s integration time. Plume enhancements in excess 5 ppm were quantified.

Table S2. Characteristics of instruments deployed by the Remote Sensing (RS) unit.

Pollutants measured	**Detection limit by pollutant**
[1]CO_2 plume> 20%-cm	
CO [%]	±0.1 or ±10% of reading, whichever is greater
HC (as propane) [ppm]	±100 or ±10% of reading, whichever is greater
NO [ppm]	±150 or ±10% of reading, whichever is greater
Smoke number[2]	±0.05 or ±10% of reading, whichever is greater
[1]CO_2 plume< 20%-cm	
CO [%]	±0.15 or ±15% of reading, whichever is greater
HC (as propane) ppm	±150 or ±15% of reading, whichever is greater
NO [ppm]	±225 or ±15% of reading, whichever is greater
Smoke number[2]	±0.1 or ±15% of reading, whichever is greater

[1] Static background conditions and mean value. Source: RSD4600 NextGen Operator's Manual. Edition 1.0. Environmental Systems Products. 4-000-MAN1160.

[2] Units are ~ grams diesel particulate per 100 gram fuel.

2. Sampling driving conditions

To the best of our knowledge, there are no studies on the characteristics of driving cycles for diesel vehicles in Mexico and thus it is not possible to assess the representativeness of the tested driving conditions. In this pilot study we focused instead on sampling the selected vehicles in slow to medium speeds with frequent acceleration and deceleration periods as we anticipate these are common driving conditions in Mexico City routes.

The selected vehicles were sampled using similar driving conditions by following the same route and driving under similar ranges of speeds and accelerations multiple times. The vehicles engines were previously warmed up before each measurement, and thus the measurements do not represent cold-start emissions conditions. In addition, all RTP buses, Metrobuses and Turibuses vehicles were sampled in full load capacity with the kind collaboration of volunteer students (an exception was the single DINA bus sampled, which was ballasted using filled water cans), whereas service trucks were ballasted with actual goods provided by the participating institutions. The sampled vehicles were driven by actual drivers from the corresponding participant institutions.

As described in the main manuscript, a global positioning system (GPS) was used on-board the mobile laboratory to obtain the spatial coordinates during the study. Since the measurements are obtained in vehicle “chase” mode, at a first approximation these data can be used to describe the speed and acceleration driving conditions. The average time for a given driving cycle was of 3.3 minutes with an average speed of 5.5 m/s. To assess the fraction of the time that the measurements are obtained in acceleration, deceleration, or cruising modes it is necessary to define a speed change criteria over the GPS data acquisition time (1 second). Following the procedure of Tong et al (2000) we have defined the acceleration, deceleration, and cruising modes as follow:

1) Acceleration mode: positive incremental speed changes of more than 0.1 m/sec/sec during the 1-second interval.
2) Deceleration mode: negative incremental speed changes of more than to 0.1 m/sec/sec during the 1-second interval.
3) Cruising mode: absolute incremental speed changes of less than or equal to 0.1 m/sec/sec during the 1-sec interval.

The resulting driving cycle distribution is shown in Table S3.

Table S3. Summary characteristics of sampling driving cycles.

Mode	**% of time**
Acceleration	22.3
Deceleration	34.8
Cruising	29.1
Idling	13.8

Reference:

H.Y. Tong, W.T. Hung and C.S. Cheung (2000) On-Road Motor Vehicle Emissions and Fuel Consumption in Urban Driving Conditions, Journal of the Air and Waste Management Association, 50:4, 543-554, DOI: 10.1080/10473289.2000.10464041.

3. Additional figures

The following figures are discussed in the text of the manuscript. As a note, the emissions of CO, NO_x, HC and PM for a Dina vehicle were further co-sampled using an AXION PEMS instrument (see Figure S1). Therefore, for this vehicle the chasing, cross-road remote sensing, and PEMS techniques were applied simultaneously. However, the results of the inter-comparison of the three techniques are not included in this manuscript but are discussed in separate publication.

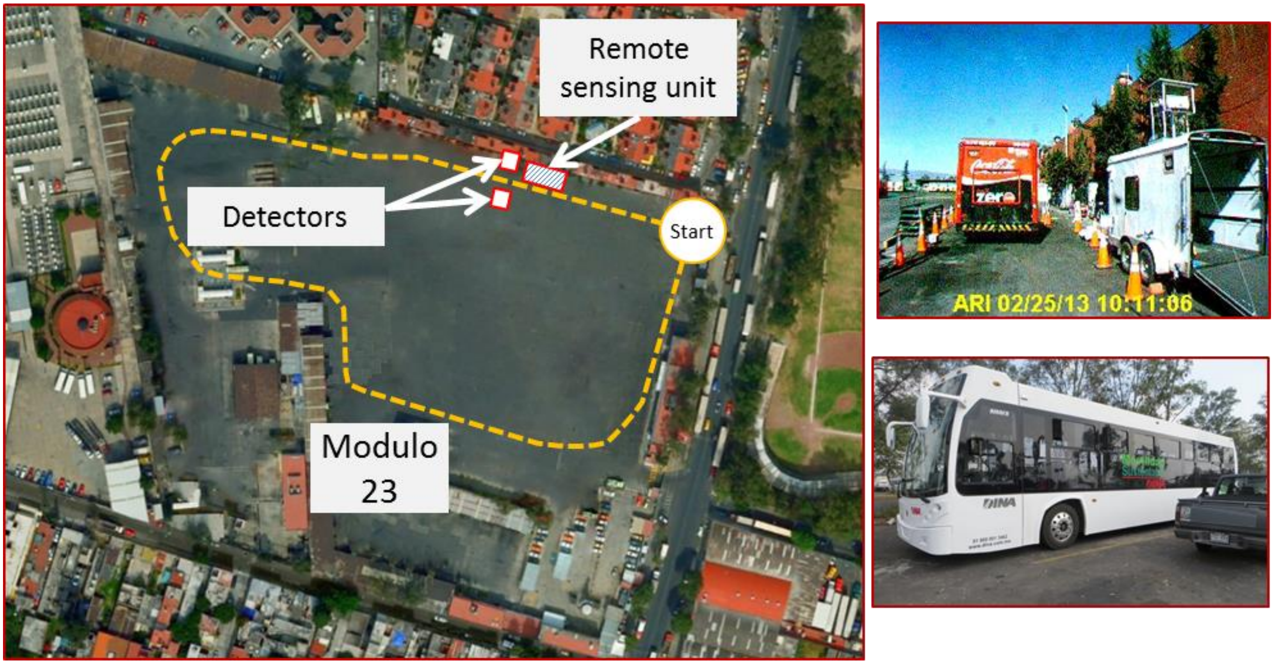
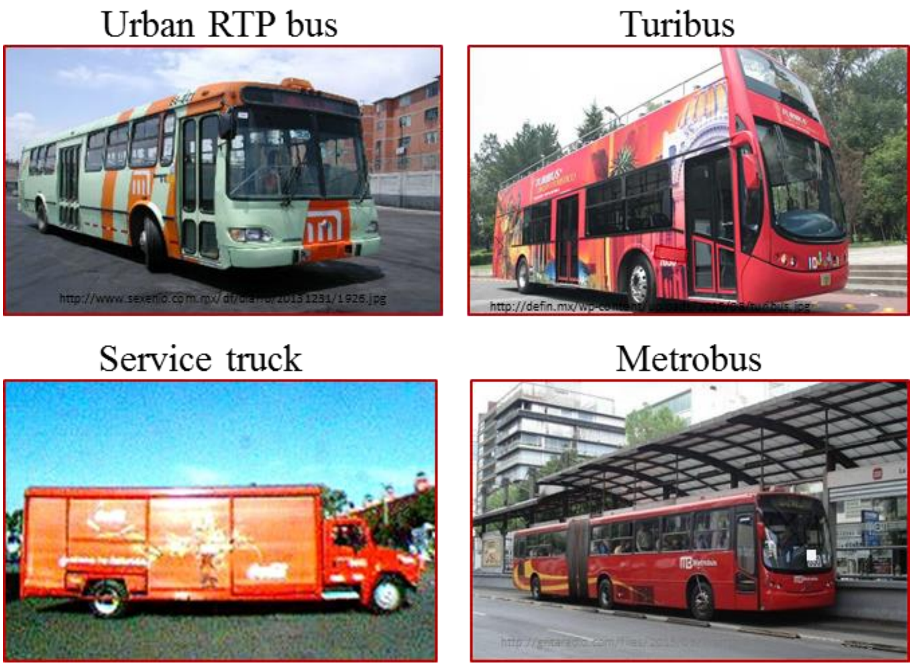


Figure S1 Top figure shows an aerial photo of the Modulo 23 of the RTP facilities with an indication of the location of the remote sensing unit and the area for the chasing experiments. Photos on the right show a service truck passing through the remote sensing detectors unit (top-right photo) and the Dina bus sampled with the mobile laboratory, remote sensing and PEMS techniques.



Urban RTP bus

http://www.sexenio.com.mx/df/[illegible]/20131231/1926.jpg

Turibus

http://defin.mx/wp-co[illegible]

Service truck

Metrobus

Figure S2. Examples of the four vehicle types (Metrobus, Turibus, urban RTP bus, and service truck) sampled in this pilot study.

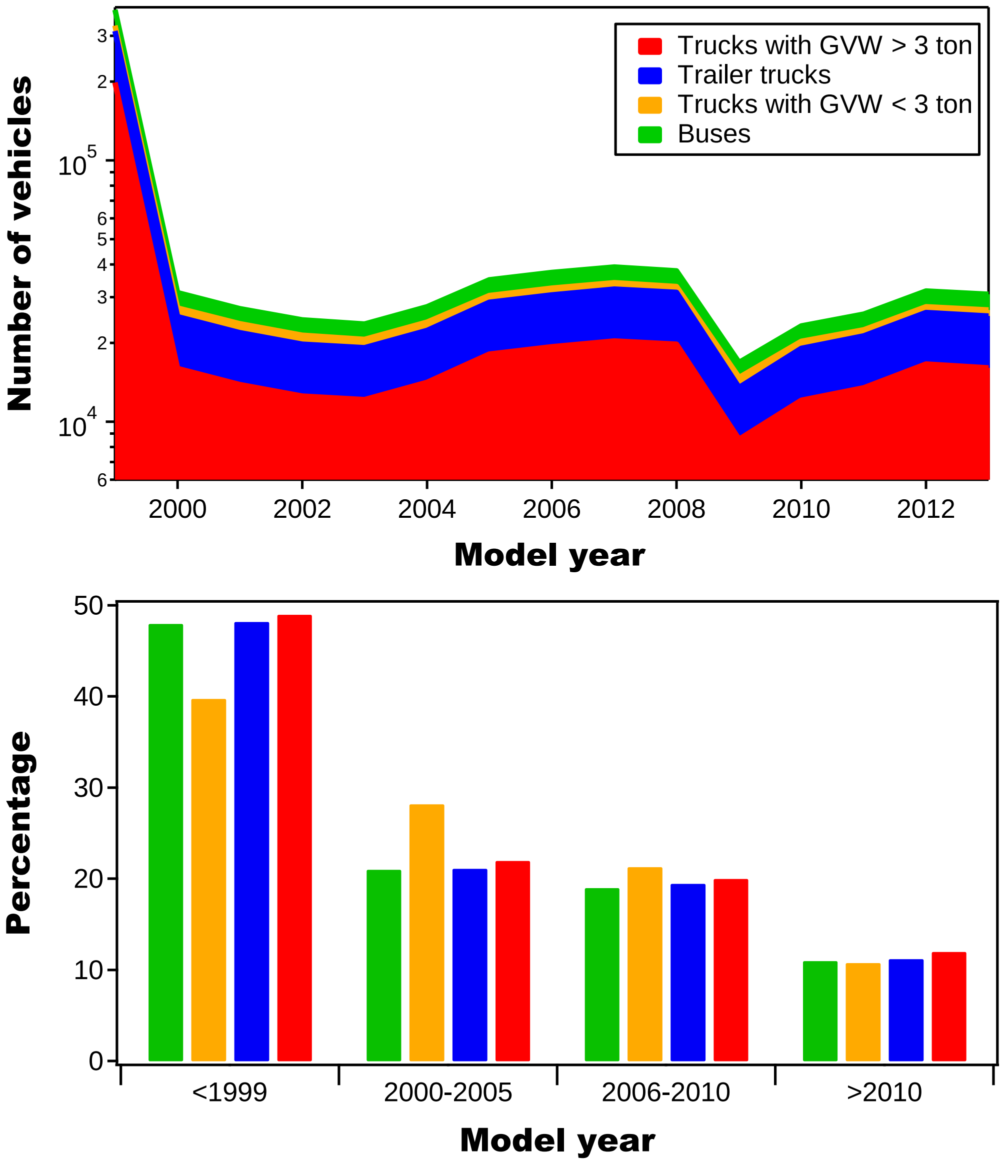


Figure S3. Top panel shows the number of diesel-powered vehicles by model year for the Mexican fleet for the year 2013. Trucks are classified by gross vehicle weight (GVW). Bottom panel shows the corresponding percentage of the number of diesel powered vehicles by model year. Source: prepared from data from the 2013 Mexican Nacional Emissions Inventory (SEMARNAT, 2015).

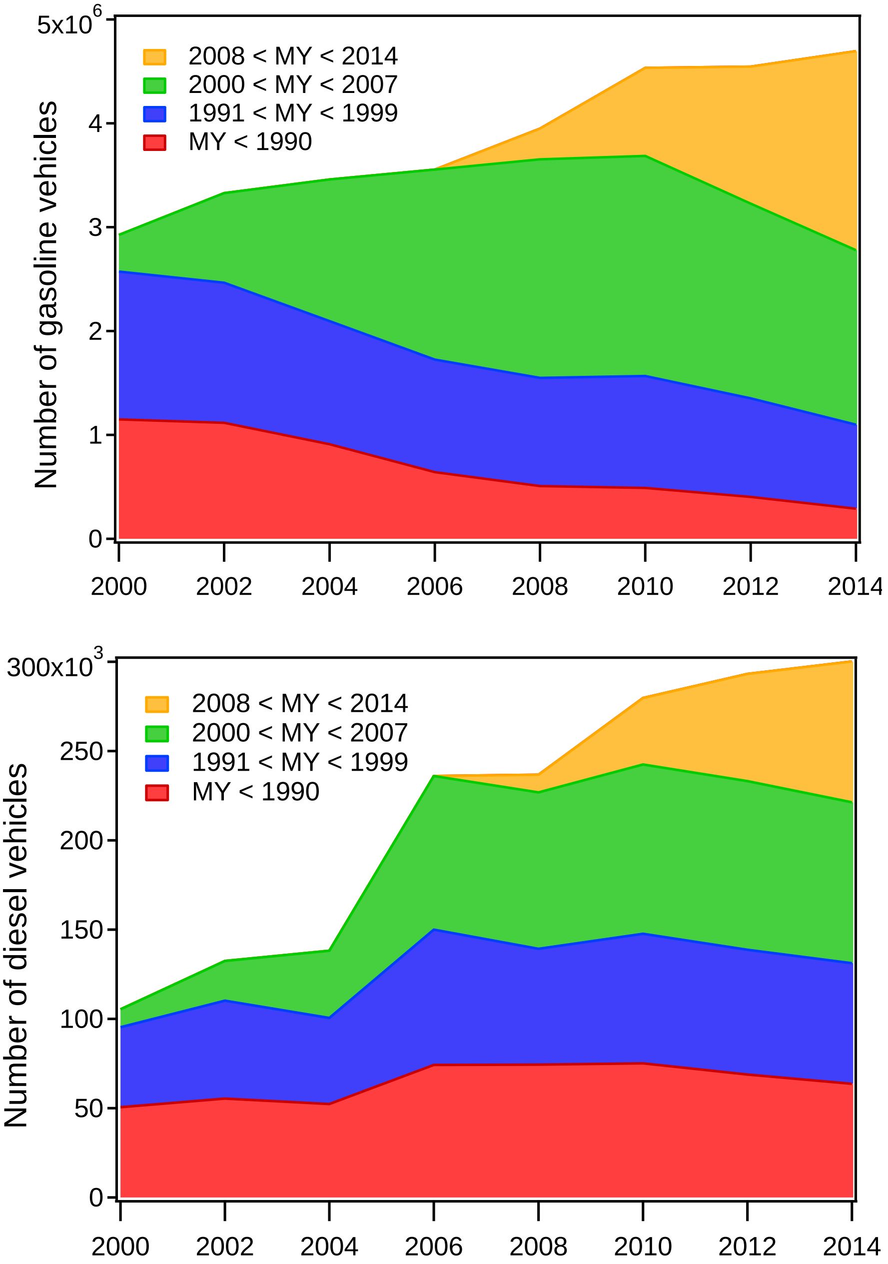


Figure S4. Top and bottom panels show the time evolution of number of gasoline-powered vehicles and diesel-powered vehicles, respectively, by model year (MY) in Mexico City. The figure shows a more rapid decline in the number of older gasoline vehicles than of diesel vehicles. Thus, older diesel vehicles remain in-use in the fleet for much longer periods than the gasoline vehicles. Source: prepared from data from the 2014 Mexico City Metropolitan Area Emissions Inventory (SEDEMA, 2017).