An Overview of MILAGRO 2006 Campaign: Mexico City Emissions and their Transport and Transformation

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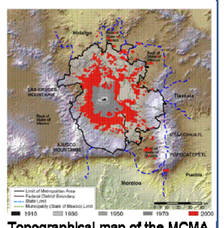
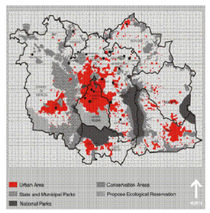
Introduction

MILAGRO (**Megacity Initiative: Local And Global Research Observations)** is an international collaborative project to examine the behavior and the export of atmospheric emissions from a megacity. The Mexico City Metropolitan Area (MCMA) – one of the world's largest megacities and North America's most populous city – was selected as the case study to characterize the sources, concentrations, transport, and transformation processes of the emissions to the MCMA atmosphere and to evaluate their impacts on air quality and climate.

The measurement phase took place during March 2006, using a wide range of instruments at ground sites, on aircraft and satellites, and enlisting over 450 scientists from 150 institutions in 30 countries. The overall campaign was complemented by meteorological forecasting and numerical simulations, satellite observations and surface networks. Together, these research observations have provided the most comprehensive characterization of the MCMA's urban and regional air pollution.

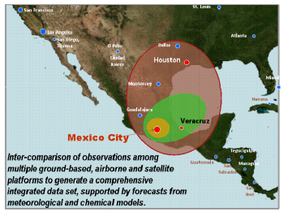


Topographical map of the MCMA

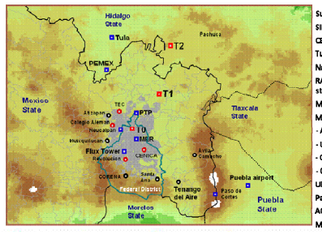


Megalopolis in the year 2000

MILAGRO Campaign: Four Coordinated Components Provide Different Geographic Coverage



MCMA-2006: Ground-Based Measurement Sites



- Supersites (T0, T1, T2)
- SIMAT (Flux Tower)
- CENICA
- Tula (refinery, power plant)
- Naucalpan (industrial zone)
- RAMA (36 monitoring stations)
- Mobile units (9 stations)
- Mobile Labs
  - ARI Mobile Lab
  - U. Iowa (Lidar)
  - Chalmers (DOAS)
  - CMET
- Ultralight airplane
- Paso de Cortes (Altzomoni)
- AOD Network
- Max-DOASNetwork

INTEX-B	MIRAGE-Mex	MAX-Mex	MCMA-2006
NASA DC-8 J-31, Satellites (NASA)	NSF G-130, Twin Otter, Supersite (NCAR)	DOE G-1, King Air (2), Supersite (DOE ASP)	Supersites, Mobile Laboratories (MCE2)

Fixed site · Mobile site · Supersite · Other measurements

Key Findings from MILAGRO and MCMA-2003

Meteorology and dynamics

•Similar overall synoptic conditions and boundary layer circulations to previous MCMA studies and consistent with prior climatology.

•Predominant transport of Mexico City pollutant plume towards the northeast.

•Multiple layering due to complex mixing processes over central Mexico.

Volatile Organics Compounds

•Evaporative fuel and industrial emissions are important sources for aromatics.

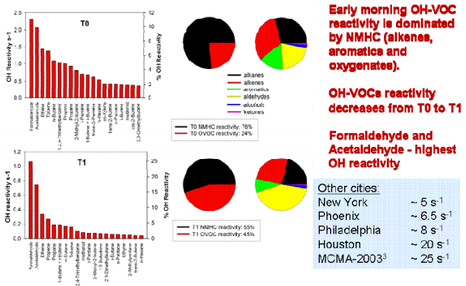
•LPG use continues to be an important source of alkanes.

•Formaldehyde and acetaldehyde contribute most to OH reactivity.

•Formation of secondary VOCs is very important in MCMA.

Volatile Organic Compounds and OH Reactivity

The top 20 compounds measured at T0 and T1 in terms of OH reactivity between 9:00 and 18:00 LT (averaged over the month of March, 2006)



Early morning OH-VOC reactivity is dominated by NMHC (alkenes, aromatics and oxygenates).

OH-VOCs reactivity decreases from T0 to T1

Formaldehyde and Acetaldehyde - highest OH reactivity

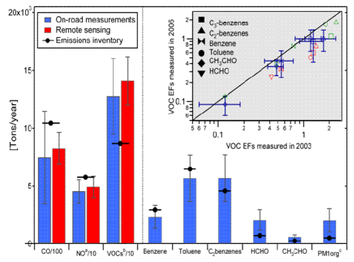
Other cities	
New York	~ 5 s^{-1}
Phoenix	~ 6.5 s^{-1}
Philadelphia	~ 8 s^{-1}
Houston	~ 20 s^{-1}
MCMA-2003[3]	~ 25 s^{-1}

- Rapid photochemistry transforms the VOC OH reactivity from NMHCs domination in the morning hours in the MCMA basin to OVOCs domination aloft and downwind.
- Large non-biogenic sources of methanol in the MCMA basin.

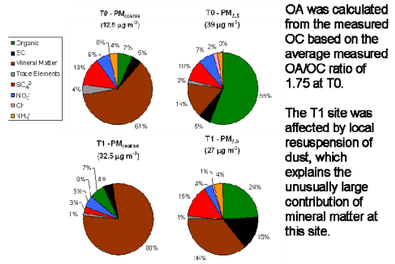
MCMA emissions of gases & fine PM

- MILAGRO demonstrated the synergy of using multiple bottom-up and top-down analysis techniques with data obtained from multiple platforms and instruments to evaluate emissions inventories, which helps to reduce uncertainties in the emissions estimates and helps in further development of emissions inventories.
- Mobile emission sources remain the main contributors of gaseous pollutants and PM in the MCMA. Relative contribution of diesel vehicles to overall NO_x levels has increased over time.
- Emissions inventory gives accurate emission estimates of CO_2, olefins and selected aromatic and oxygenated VOCs from combustion sources, but overestimates evaporative emissions from area sources, and large discrepancy in PM estimate.
- Additional sources from informal commerce and street side food preparation and some species (e.g., NH_3, dust, metals) warrant further study in the MCMA.

Comparison among LDGV on-road mobile emissions estimated during MILAGRO



Average composition of PM_{coarse} (PM_{10}-$PM_{2.5}$) and $PM_{2.5}$ at the T0 and T1



OA was calculated from the measured OC based on the average measured OA/OC ratio of 1.75 at T0.

The T1 site was affected by local resuspension of dust, which explains the unusually large contribution of mineral matter at this site.

Ambient Particulate Matter

•PM10 & PM2.5 concentrations in the urban area were ~ twice those in the rural areas.

•PM2.5 made up about half of the PM10 concentrations, with small amounts of mass in the PM2.5-PM1.0 range.

•Mineral matter made up about 25% of PM10 and 15% and 28% of the PM2.5 in the urban and rural areas, respectively. About 25% of PM2.5 was secondary inorganic ions with the remaining comprised of largely carbonaceous aerosol.

•Elemental carbon mass absorption efficiency was relatively constant for aircraft and surface measurements.

•Dominant sources of carbonaceous aerosol were secondary organic aerosol, biomass burning, and vehicle exhaust emissions.

•Impact of biomass burning on the aerosol outflow from the region was much larger than on the surface concentrations inside the city.

•SOA formation from primary semivolatile and intermediate volatility precursors has the potential to close the gap in predicted vs. measured SOA. However these predictions are poorly constrained by the data and more specific measurements are needed in future campaigns.

•Biogenic SOA advected from the coastal ranges contributes about 1 μg m-3 to concentrations in the MCMA.

•Primary Organic Aerosol (POA) from anthropogenic and biomass burning sources was semivolatile, while SOA was less volatile than POA and aged SOA was essentially non-volatile, in contrast with current models.

•Growth rates of new particle formation in Mexico City were very large and found to be impacted by nitrogen containing organic compounds, organic acids, and hydroxyl organic acids, with only a smaller fraction of sulfate aerosol.

Acknowledgement.
The MILAGRO/INTEX-B Campaign is the collaborative efforts of a large number of participants with the support of multi-national agencies. We thank the governments of the Federal District, the States of Mexico, Hidalgo and Veracruz, the Mexican Ministries of the Environment, Foreign Relations, Defense and Finance and the US Embassy in Mexico for their logistical support; IMP, U-Tecámac, and Rancho La Bisnega for hosting the supersites as well as many other Mexican institutions for their support. The MILAGRO/INTEX-B participants are grateful for funding from the Mexican Metropolitan Environmental Commission, Mexican Ministry of the Environment, CONACyT, PEMEX, NSF Atmospheric Chemistry Program, DOE Atmospheric Science Program and NASA Tropospheric Chemistry and Radiation Science Programs.

Urban and regional photochemistry:

•Measured levels of OH and HO_2 were higher than predicted in the morning when NO_x is high, suggesting significant missing radical source in current photochemical models in polluted environments.

•Photolysis of HONO and HCHO and ozonolysis of alkenes are important sources of radicals in MCMA.

•Ozone production is VOC-limited in the urban region.

•Regional O_3 production is sensitive to either NO_x or VOCs and CO, with regional OH radical reactivity dominated by oxygenated organics and CO.

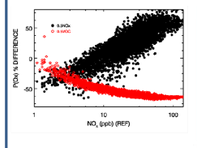
•On the regional scale significant enhancements of O3 were observed in the MCMA-origin plumes.

•Long-range export of reactive nitrogen from Mexico City took place primarily via the formation of PANs.

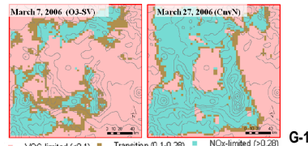
•Biomass burning has significant influence on regional chemistry, contributing more than half of the organic aerosol and about one third of the benzene, reactive nitrogen, and carbon monoxide to the regional outflow.

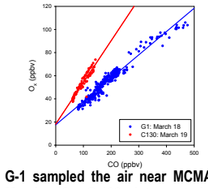
Ozone sensitivity during MCMA-2006/MILAGRO **O_3 Production in Mexico City Plume**

Simulated % change of $P(O_3)$ as a function of base case NO_x in the urban area at 12-17 LT



Spatial distribution of the production ratio of H2O2 to HNO3 at 14:00 LT





G-1 sampled the air near MCMA on March 18; C-130 intercepted the plume ~ 1000 km downwind on March 19. Ox/CO increases -> continuing Ox production during plume export

Optical Properties of Aerosols

•Single scattering albedos at the surface sites were in the 0.7-0.8 range with some early morning values having even lower values, consistent with high absorbing aerosol loading from both fossil and biomass burning sources.

•Aerosol contributions from biomass burning sources contained both black carbon and oxidized organics, indicating that biomass burning activities can have important impacts on the absorption or heating by carbonaceous aerosols in megacity (urban) as well as regional scales.

•Oxidized organics from primary fires and from secondary aerosol formation have strong absorption in the 300-400 nm region, leading to enhanced optical absorption by these aerosols over that anticipated from black carbon alone.

•Measurements of surface albedo and reflectance in the MCMA showed that many urban surfaces are more reflective than assumed in common satellite retrieval algorithms, and that use of larger visible surface reflectance in algorithms can produce more accurate retrieved aerosol optical depth.

Conclusions

•The MILAGRO campaign has shown the synergy of using multiple measuring platforms, instrumentation, and data analysis techniques for obtaining an improved understanding of the physical and chemical characteristics of emissions in a megacity.

•The deployment of a significant number of advanced instruments and a large number of established air quality monitoring instruments on aircraft, mobile laboratories and at surface sites have provided opportunities to intercompare and evaluate a number of instruments in a highly polluted environment.

•All data sets and publications are available to the scientific community.

•New results from MILAGRO/INTEX-B will continue to contribute to our understanding of megacity emissions and its potential impacts on human health, ecosystem viability, and climate change on urban, regional, and even hemispheric scales. This information will improve significantly the scientific understanding that decision makers in Mexico will need to craft effective policies and provide insights to other megacities around the world.

References

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