Second MILAGRO Science Meeting
SRE, Mexico, D.F. May 15, 2007

MILAGRO CAMPAIGN

Megacity **I**nitiative: **L**ocal **A**nd **G**lobal **R**esearch **O**bservations

Mexico City Case Study

Luisa T. Molina and the MILAGRO Science Team

Distribution of Global Population by Size of Settlement (1950-2030)

	Population (in billions)				
Major area	**1950**	**1975**	**2000**	**2003**	**2030**
Total population					
World	2.52	4.07	6.07	6.30	8.13
More developed regions	0.81	1.05	1.19	1.20	1.24
Less developed regions	1.71	3.02	4.88	5.10	6.89
Urban population					
World	0.73	1.52	2.86	3.04	4.94
More developed regions	0.43	0.70	0.88	0.90	1.01
Less developed regions	0.31	0.81	1.97	2.15	3.93
Rural population					
World	1.79	2.55	3.21	3.26	3.19
More developed regions	0.39	0.34	0.31	0.31	0.23
Less developed regions	1.40	2.21	2.90	2.95	2.96

Source: United Nations Population Division, World Urbanization Prospects, The 2003 Revision.

Megacities: Urban Areas with over 10M Inhabitants

National Geographic Society, 2002

MEGACITIES

> 10 Million

1950 – 2 (NYC, Tokyo)

1995 – 14

2015 – 22

Mini – MEGACITIES

5 Million – 10 Million

1995 – 7

2015 – 40

1 million inhabitants

2000: > 300 cities

Asia and Africa

- fastest growing urban centers

Population of 20 Megacities of the World

City	1950	City	1975	City	2005	City	2015
1 New York	12.3	1 Tokyo	26.6	1 Tokyo	35.2	1 Tokyo	35.5
2 Tokyo	11.3	2 New York	15.9	2 Mexico City	19.4	2 Mumbai	21.9
		3 Mexico	10.7	3 New York	18.7	3 Mexico City	21.6
				4 São Paulo	18.3	4 São Paulo	20.5
				5 Mumbai	18.2	5 New York	19.9
				6 Delhi	15.0	6 Delhi	18.6
				7 Shanghai	14.5	7 Shanghai	17.2
				8 Kolkata	14.3	8 Kolkata	17.0
				9 Jakarta	13.2	9 Dhaka	16.8
				10 Buenos Aires	12.6	10 Jakarta	16.8
				11 Dhaka	12.4	11 Lagos	16.1
				12 Los Angeles	12.3	12 Karachi	15.2
				13 Karachi	11.6	13 Buenos Aires	13.4
				14 Rio de Janeiro	11.5	14 Cairo	13.1
				15 Osaka-Kobe	11.3	15 Los Angeles	13.1
				16 Cairo	11.1	16 Manila	12.9
				17 Lagos	10.9	17 Beijing	12.9
				18 Beijing	10.7	18 Rio de	12.8
				19 Manila	10.7	19 Osaka-Kobe	11.3
				20 Moscow	10.7	20 Istanbul	11.2
						21 Moscow	11.0
						22 Guangzhou	10.4

Source: UN World Population Prospect: The 2005 Revision (2006).

Impacts of Megacities and Large Urban Centers

Traffic in Beijing, China

Coke plant in Cairo, Egypt

Metro Manila, Feb, 2007

Biomass burning in Mexico

Baby taxi in Bangkok, Thailand

Jeepney in Manila, Phili**ppines**

Local, Regional, and Global Consequences of Urbanization

Increased energy usage in urban areas including motor vehicles and industrial activities leads to high levels of gases and aerosols.

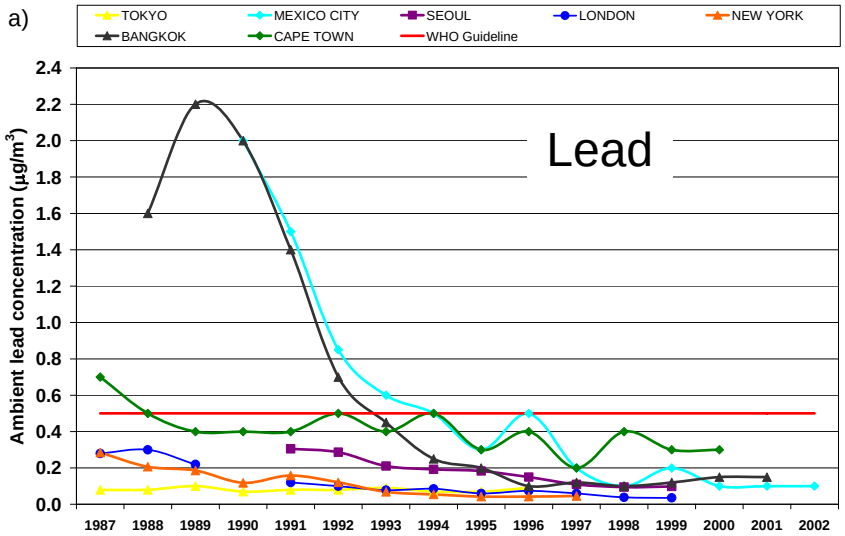
- ***Urban air quality degradation;***
- ***both chronic and acute health effects;***
- ***visibility reduction.***

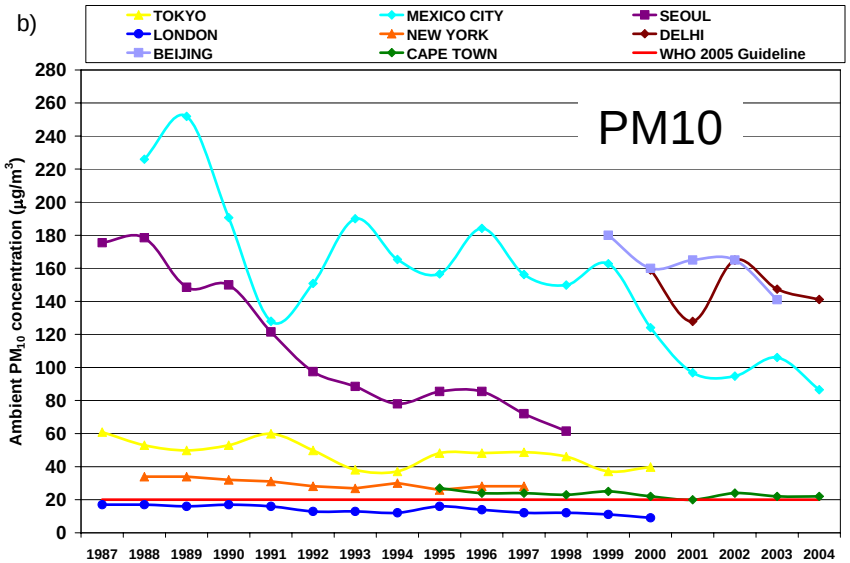
Pollutants emitted from urban areas can react in sunlight to form other products downwind of the cities.

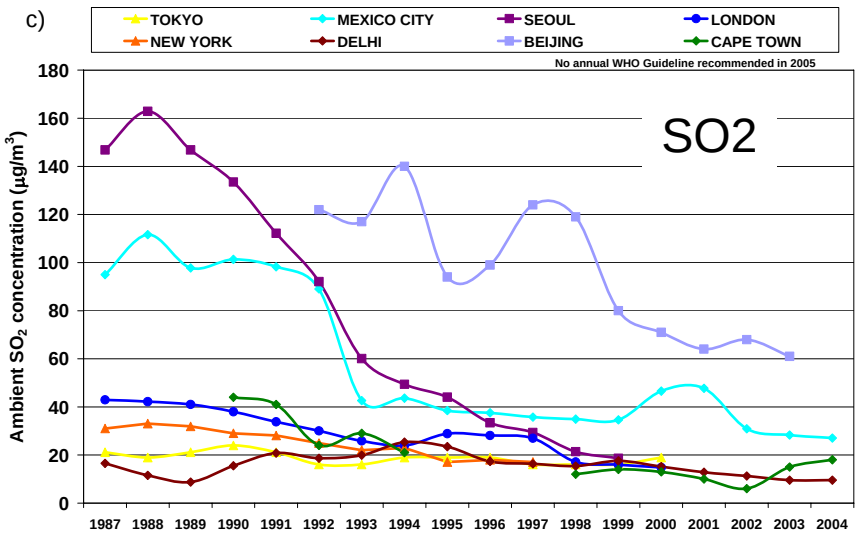
- ***acid deposition;***
- ***ecosystem degradation;***
- ***changes in regional climate.***

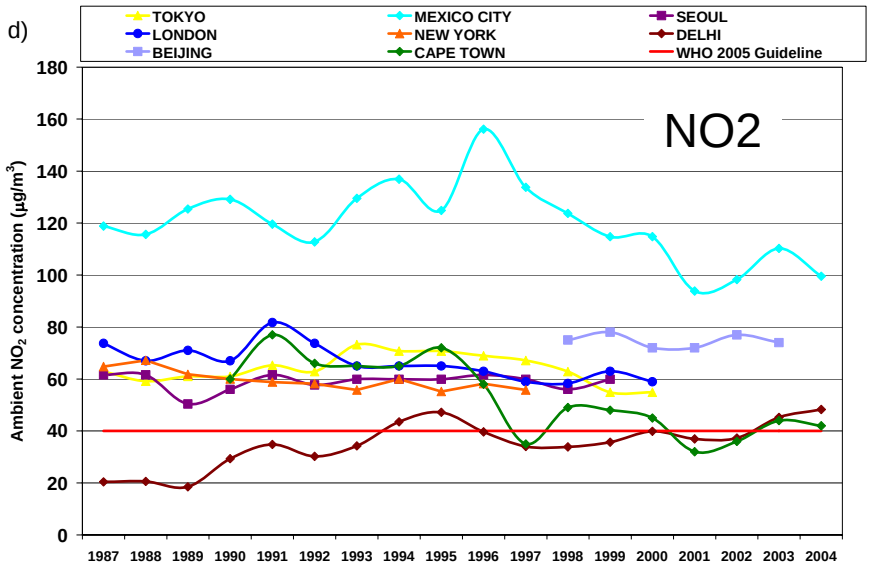
Global Impacts from trace gases and aerosols can lead to weather modification and global climate change.

Trends in average annual urban concentrations of pollutants (µg/m3) at selected cities worldwide (1987–2004)





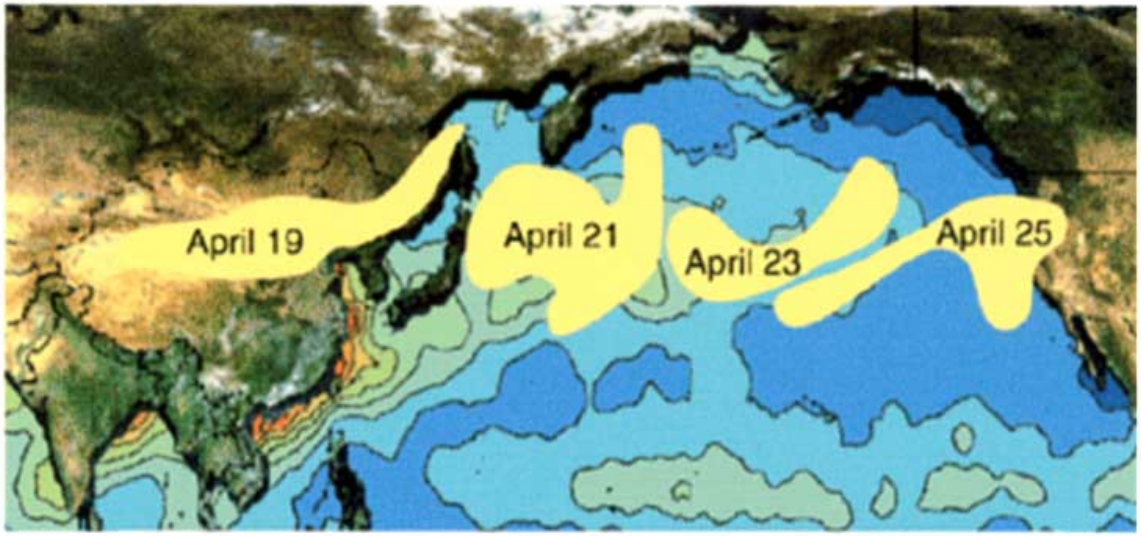




Sources: GEO data portal 2006, OECD 2002, APMA 2002, WHO 2006a, Beijing Bureau of Statistics 2005, TERI 2001, CPCB 2001–2006, City of Cape Town 2006, Mexico City, Federal District Government 2006.

Trans-Pacific Air Pollution

Kenneth E. Wilkening, Leonard A. Barrie, Marilyn Engle



Pollution from afar. Satellite remote sensing images of trans-Pacific transport of aerosols in April 1998 originating from a massive dust storm in China.

SCIENCE, vol 290, October 2000

Intercontinental transport of air pollutants on a time scale of a week.

MILAGRO Campaign

Megacity Initiative: Local And Global Research Observations

Scientific Goals:

- What is the temporal and spatial extent of pollution plumes from megacities?
- How and where are urban pollutants removed from the atmosphere?
- What are the regional and gloal impacts of urban plumes?

MILAGRO Campaign: four coordinated components

MCMA-2006 (Mexico City Metropolitan Area – 2006)

- examine emissions and boundary layer concentrations within México City;
- study the exposure patterns and effects on human health;
- evaluate policies to reduce pollutant levels.

MAX-Mex (Megacity Aerosol Experiment – Mexico)

- examine the properties and evolution of aerosols and gas-aerosol interactions in the immediate urban outflow.

MIRAGE-Mex (Megacity Impacts on Regional & Global Environments – Mexico)

- examine the evolution of the México City plume on larger regional scales.

INTEX-B (Intercontinental Chemical Transport Experiment –Phase B)

- study the transport, transformation and impacts of aerosols and gases on air quality and climate from local to global scales.

Inter-comparison of observations among multiple ground-based, airborne and satellite platforms in order to generate a comprehensive integrated data set.

Data to be shared among all MILAGRO participants (open to the public in 2008).

The overall Campaign is supported by forecasts from meteorological and chemical models and surface network.

MILAGRO Case Study: Why Mexico City?

Representative tropical megacity

Extensive air quality monitoring network

Good meteorology support, emissions inventories and infrastructure

Excellent scientific collaborations

Previous Campaign: MCMA-2002/2003 (supported by CAM and NSF)

- **Surface gas and aerosol measurements at supersite and using mobile labs**

- **Plenty of aerosol from representative area - large signal**

- **High photochemical activity to maximize chemical changes**

- **Significant organics to look at secondary organics aerosols**

Ground and aircraft operations – downwind sites

Dominant city in this region – unique location to follow urban plumes

MILAGRO Campaign: Geographic Coverage

INTEX-B
NASA DC-8
J-31, Satellites

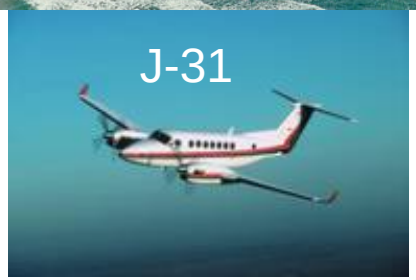
MIRAGE-Mex
NSF C-130,
King Air, Supersite

MAX-Mex
DOE G-1,
KingAir, Supersite

MCMA-2006
Supersites,
Moblle Laboratories

MILAGRO: Aircraft Measurements

(Intercomparison, coordinated flights, sharing of data)



5 aircraft based in Veracruz
To study:

- pollution in the region over Mexico City, the rise of pollution from the surface, and its spread into the region;
- effects of aerosol particles on visibility, sunlight, and climate;
- fires

DC-8: Based in Houston, Texas - Study pollution throughout the Gulf of Mexico region at altitudes from near the surface to 10 km; help improve satellite observations.

Ultralight plane (IMK-IFU)

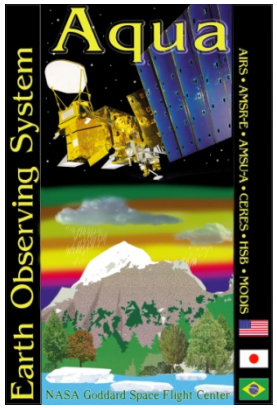
Satellites Observations

Terra (NASA)

MOPITT (Measurements of Pollution In The Troposphere)
- Measurements of CO

MODIS (MODerate resolution Imaging Spectroradiometer)
- Measurements of aerosol optical depth

MISR (Multi-angle Imaging Spectro-Radiometer)
- Measurements of aerosol amount, type, & vertical distribution



Aqua (NASA)

AIRS (Atmospheric InfraRed Sounder)
- Measurements of CO

MODIS
- Measurements of aerosol optical depth

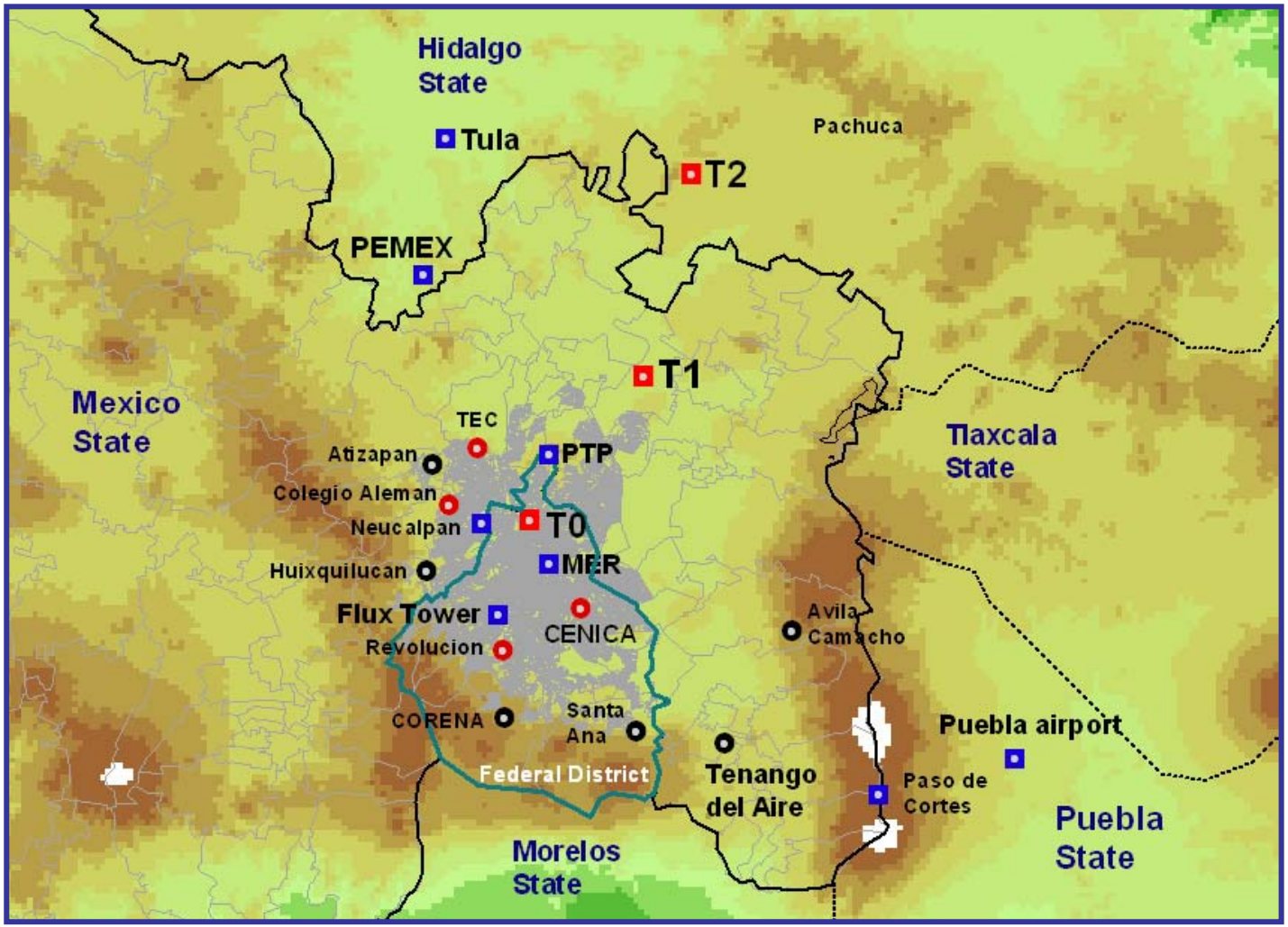
European satellites:
- SCHIAMACHY
- GOMES

Aura (NASA)

TES (Tropospheric Emission Spectrometer)
- Measurements of O3, CO, and HNO3

OMI (Ozone Monitoring Instrument)
- Measurements of O3, NO2, HCHO, SO2, and aerosol properties

MCMA-2006: Ground-Based Measurement Sites



Supersites (T0, T1, T2)
SIMAT (Flux Tower)
CENICA
Tula (refinery, power plant)
Naucaplan (industrial zone)
RAMA (36 monitoring stations)
Mobile units (9 stations)
Mobil Labs
- ARI Mobile Lab
- U. Iowa (Lidar)
- Chalmers (DOAS)

Ultralight airplane
Paso de Cortes
AOT Network

MILAGRO Campaign: Supersites

T0: supersite of MCMA-2006, equipped with instruments to measure gases, aerosols, radiation and meteorological parameters to characterize the emissions of pollutants from the urban area

T0: Instituto Mexicano del Petróleo, DF

T1: Universidad Tecnológica de Tecámac, EM
Supersite of MIRAGE-Mex:
examine outflow of urban plume

T2: Rancho La Bisnaga (near Tizayuca, Hidalgo)
Supersite of MAX-Mex: study the evolution of aerosols

MILAGRO Campaign: Boundary Sites

Measure criteria pollutants and meteorological parameters at selected boundary sites and cover different scenarios of ventilation

Mobile Unit Participants

- GDF/SIMAT
- GUANAJUATO
- HIDALGO
- INE/DGCENICA
- MONTERREY
- QUERETARO
- TOLUCA
- UNAM

SOURCE:
CENICA/INE: Ana Patricia Martínez, Alejandra Sánchez, José Zaragoza, Oscar Fentanes.
SMA-GDF: Rafael Ramos, Armando Retama, Roberto Muñoz.
UNAM: Bertha Mar, Luis Gerardo Ruiz, Ricardo Torres, Alejandro Torres. Jorge Martínez

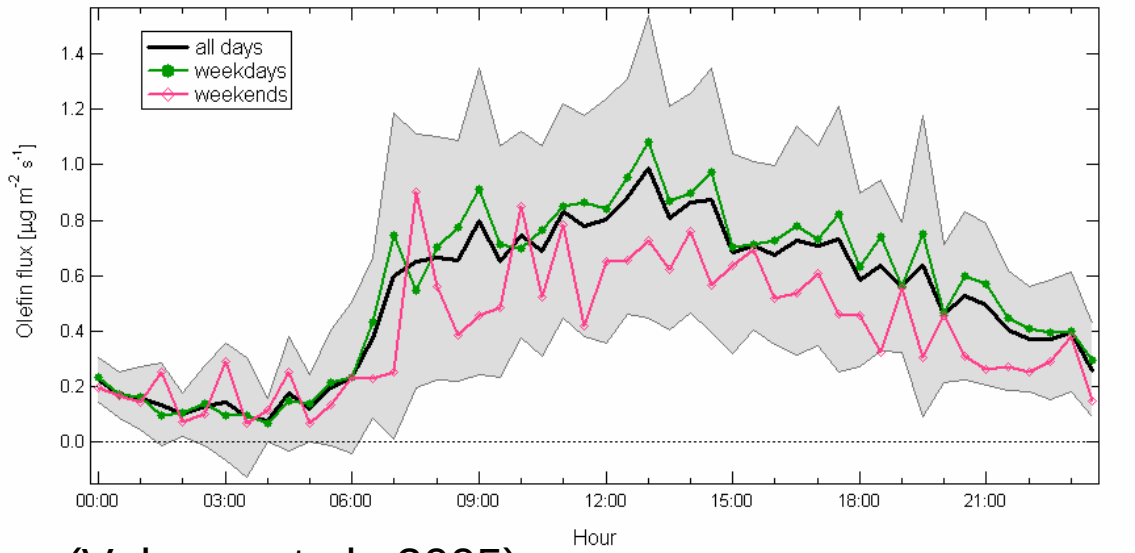
MCMA-2006: Urban Flux Measurements

Flux Tower located at SIMAT Site

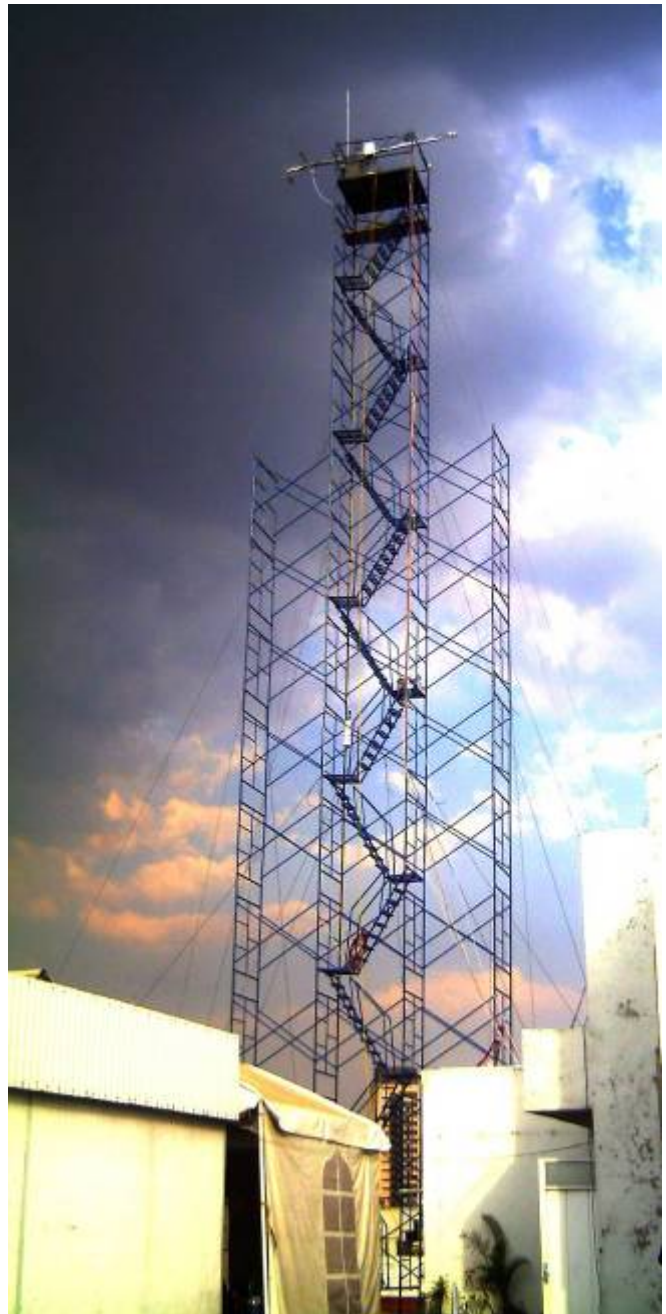
- 42 km asl
- 3 km radius: fixed and mobile emitting sources
- evaluate and validate local emissions inventory

- VOCs
- CO_2
- CO
- Aerosols
- Energy (*Q**, *Qh*, *Qe*)
- Momentum (*u**)

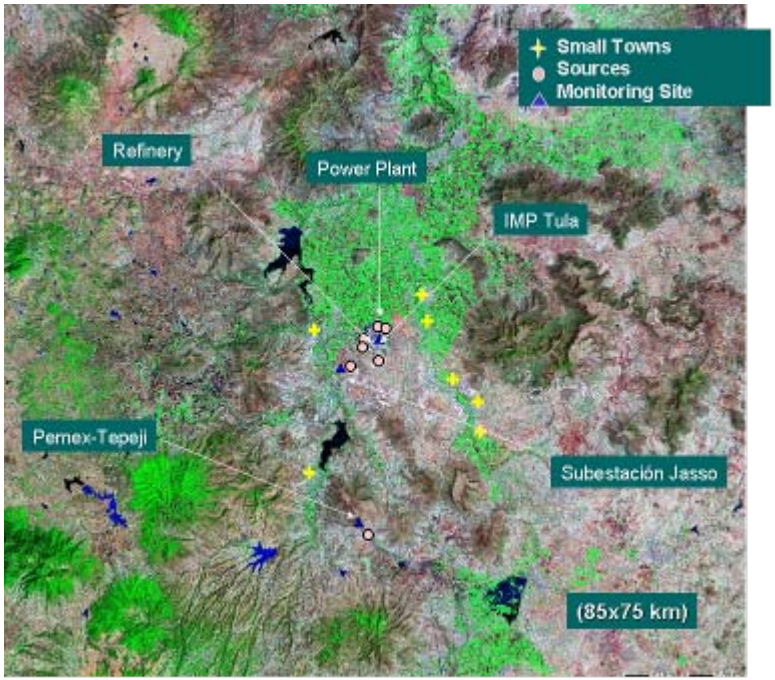
Result from 2003 campaign at CENICA --First flux measurement of trace gases in a developing world city:



(Velasco et al., 2005)



Tula: Pemex Refinery Region



- 60 km Northeast from the downtown Mexico City Metropolitan Area

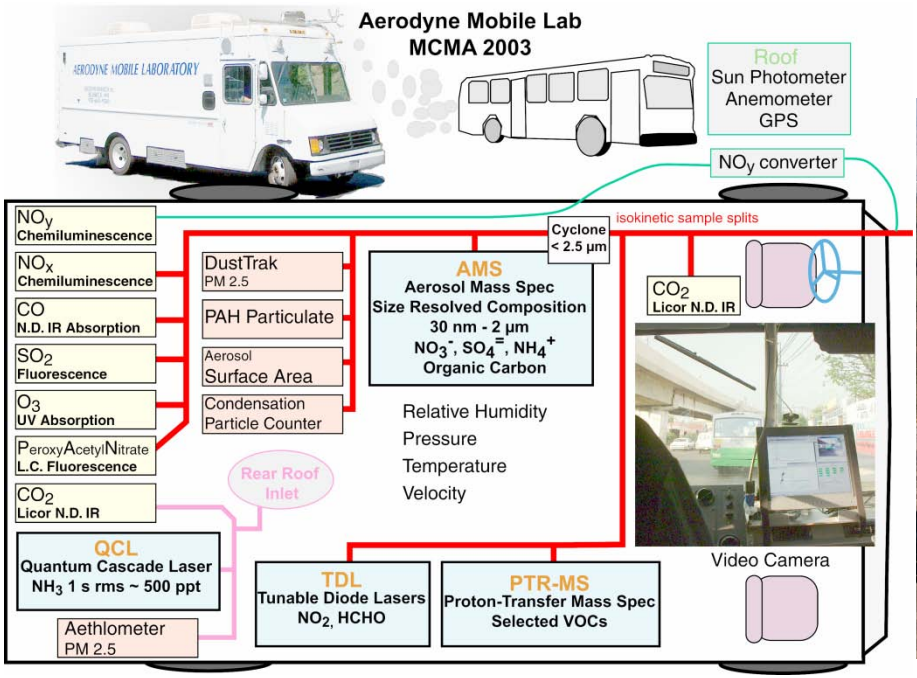
- 355,000 T/Y of SO2 are released by two major industries: PEMEX Power Plant and Refinery.

- Other important industry are cement plants and open-sky mines, responsible for important particle matter emissions and soil degradation.

IMP Measurement campaign: March 18 to April 22, 2006

Objective: to determine the influence of this heavily industrial area to the total MCMA emissions, and to better understand the processes of transport and transformation of these pollutants into the atmosphere.

Mobile Laboratories



The Aerodyne Research, Inc. mobile laboratory was deployed at various sites throughout the MCMA to investigate the effects of photochemical aging of aerosols, and the local boundary layer ventilation.

One of the sites is Pico de Tres Padres - a mountain raising ~900 m above the valley floor - to sample city plumes vented to the northeast.

MILAGRO Forecasting

Veracruz Operations Center Forecasting Team

- **Daily briefings at 11:00**
  - 7 Campaign-Specific Model Simulations
  - Experience of local meteorologist
  - Global model forecasts
  - Satellite and Radar observations
  - Surface and upper air measurement networks
- **Customized forecast products**
- **Individual interpretation and guidance** for planes, balloons, mobile vans, fixed sites and all interested parties.

Quick Overview:

Early March: Hot and dry -> O3-South events

Mid-End March: Storms over the US -> O3-North, Lagrangian transport

End March: “El Norte” (Cold Surge) -> Cold and wet

Overall, forecasts helped in locating the plume

Ongoing: Model evaluation and intercomparison

Health Studies: Urban and Semi-rural Populations Personal and Micro-environmental Exposures

- **To analyze the contribution of the regional transport of air pollutants from Mexico City in the personal exposure of children and their parents at three different sites to the following pollutants: VOCs , O3, CO, PM2.5, nanoparticles**

Participants:
- 121 children (age: 9-12 years)
- 67 parents

- **To analyze air pollution-related oxidative stress and health problems**

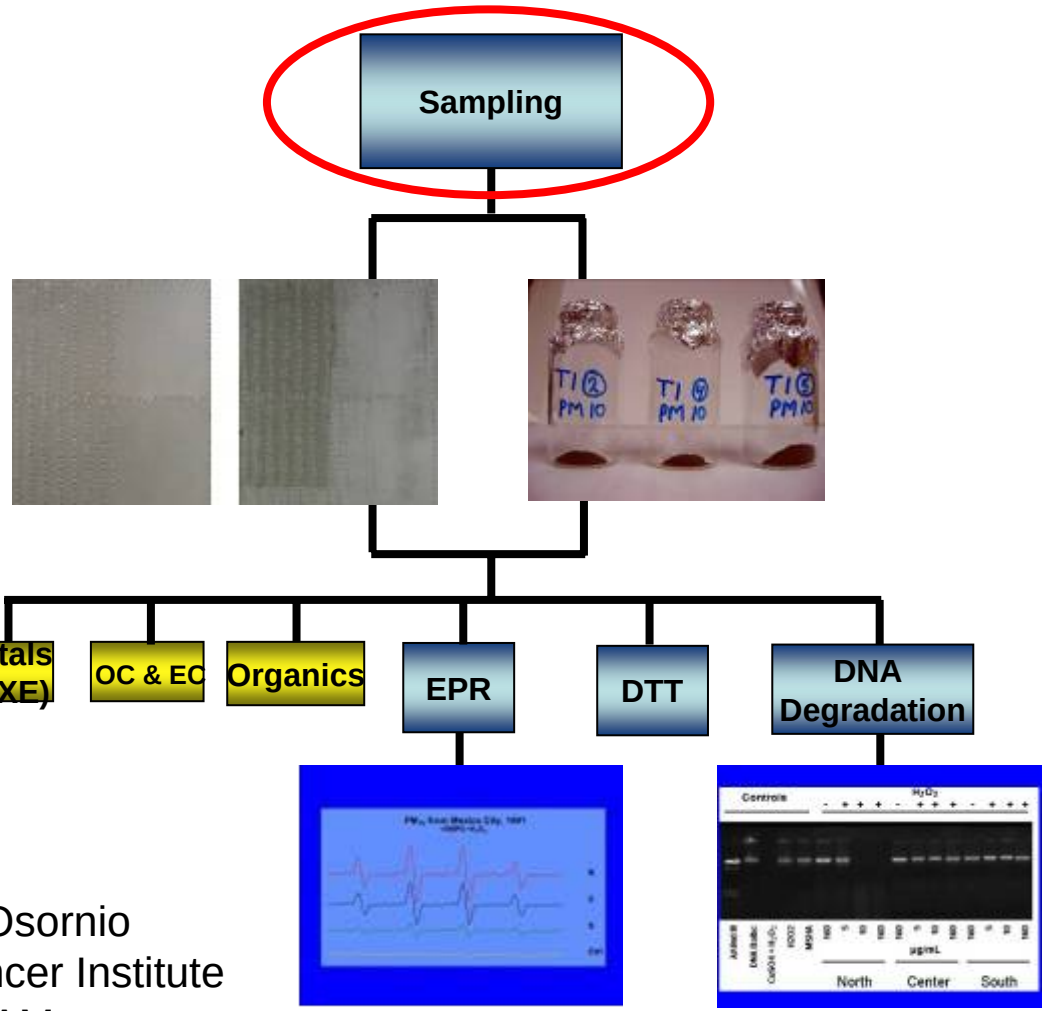
Participants:
- 155 children (age: 10-12 years)
- 90 parents

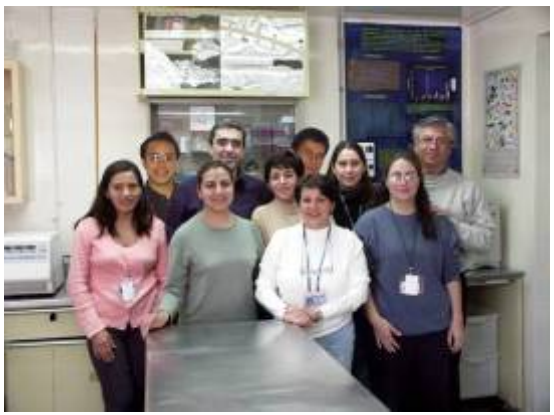
PI: H. Tovalin (UNAM)

Oxidative Potential of PM obtained at T0 & T1:
An evaluation by EPR and DNA degradation

Objetives

- Determine oxitavive potential of PM_{10} & $PM_{2.5}$ obtained at T_0 and T_1:
  - EPR
  - DNA Degradation
  - DTT Assay
- Compare oxidative potential (T_0 vs. T_1) and relate to composition and ventilation patterns.

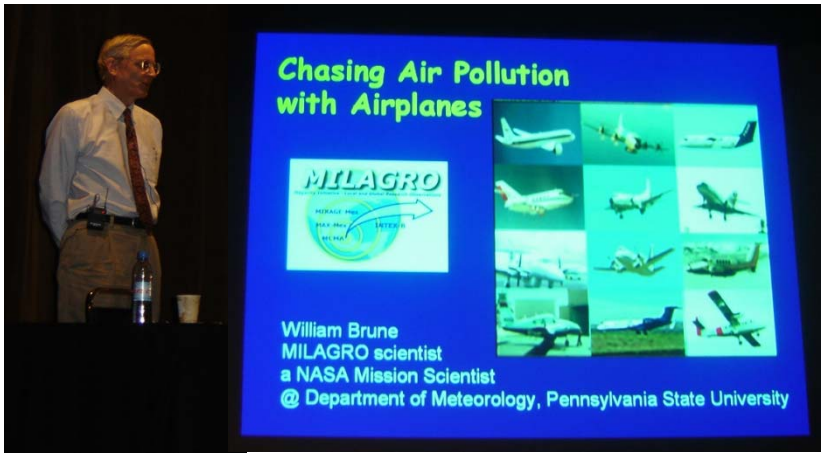




PI: A. Osornio
National Cancer Institute
UNAM

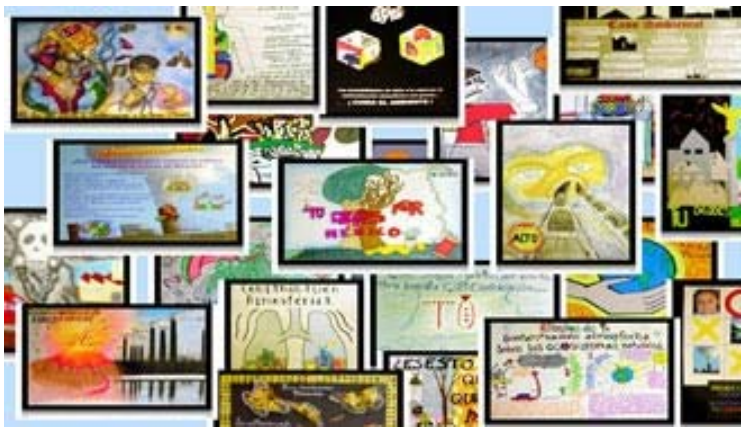
Education and Outreach Activities during MILAGRO

- **Public lecture series at various locations**



- **Essay and poster contest for high school student**

  “Hagamos un Milagro por el aire” (Let’s make miracle out of the air)



Education and Outreach Activities during MILAGRO

- Special poster exhibit for MILAGRO Campaign at different sites.

- uided tours to the supersites for officials and students

- eteorological workshop for elementary students

- nternship for college students

- ocumentary
- ommunication via webpages

Expected Benefits from MILAGRO

Scientific knowledge:

- First assessment of the regional air quality problem in a megacity
- Opportunity to study poorly understood but important processes (coupled gas, aerosols, radiation, meteorology) in aging urban air.
- Improved understanding the importance of difference emissions sources (urban, biomass burning, natural)

Global society:

- Gain early understanding of how future urbanization will influence atmospheric composition on large geographic scales.

Education and capacity building

- Opportunity for local and international students to work with multi-national experts in different disciplines.
- Opportunity for collaboration between local technical personnel and government officials and international scientists.

MILAGRO Campaign: Summary

- Initial phase: measurements
  A very rich data set for improving urban, regional and global models
- Second phase: data validation, analysis and modeling;
  comparisons of satellites, aircraft, and ground measurements
- Strong daily ventilation of Mexico City
- Urban and regional biomass burning is often important contribution to pollution
- Urban O_3 is VOC-limited
- Production of O_3 and absorbing aerosol continues strongly outside of the city
- Very high levels of particles, secondary organics dominant
- Assess policy implications
- Science team meetings:
  - October 2006, Boulder, CO
  - May 2007, Mexico City
  - December 2007 AGU Fall Meeting, San Francisco

Second MILAGRO Science Meeting

Objectives:

- Updates from Working Groups
  - Progress on preparation of publications from designated lead authors
    (Report on findings and identify remaining issues)
- Overview and status reports from major components
- Researchers present and discuss individual results
- Identify cross-cutting issues, model-measurement comparisons; ground-based and aircraft- or satellite- based measurements, etc.
- Identify gaps and needs and identify new work
- Discuss and prepare report to Mexican government agencies.

Agenda divided into three sessions:

- Plenary Sessions
- Breakout Sessions (6 Working Groups)
- Poster Sessions

Other events

Tuesday (May 15)

19:30-21:30 Reception (Hotel Sheraton Centro Historico)

Thursday (May 17)

MILAGRO Documentary Premiere and Reception at Palacio de la Autonomia

Participating Mexican Institutions

- Petróleos Mexicanos (PEMEX)
- Secretaría de Comunicaciones y Transporte (SCT)
- Secretaría de Educación Pública (SEP)
- Secretaría de Gobernación (SEGOB)
- Secretaría de Hacienda y Crédito Público (SHCP) – Administración General de Aduanas (AGA)
- Secretaría de la Defensa Nacional (SEDENA)
- Secretaria de Desarrollo Sustentable-Gobierno del Estado de Querétaro
- Secretaría de Marina (SEMAR)
- Secretaria de Medio Ambiente del Gobierno del Distrito Federal (SMA-GDF)
- Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT)
- Secretaría de Relaciones Exteriores (SRE)

Servicio Meteorológico Nacional (SMN)
Servicios a la Navegación en el Espacio Aéreo Mexicano (SENEAM)
Sindicato Nacional de Telefonistas de la República Mexicana
Universidad Autónoma de San Luis Potosí (UASLP)
Universidad Autónoma del Estado de Morelos (UAEM)
Universidad Autónoma Metropolitana (UAM)
Universidad Nacional Autónoma de México (UNAM)
Universidad Tecnológica de Tecámac (Estado de México)
Universidad Veracruzana (Estado de Veracruz)

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Participating U.S. Institutions

Aerodyne Research, Inc.
Argonne National Laboratory
Brookhaven National Laboratory
California Inst. of Tech.
Colorado State U.
Georgia Inst. of Tech.
Lawrence Berkeley National Laboratory
Los Alamos National Laboratory
Massachusetts Inst. of Tech
Molina Center for Energy and Environment (MCE2)
Montana State U.
National Center for Atmospheric Research (NCAR)
NARSTO
Pacific Northwest National Laboratory
Pennsylvania State U.
Texas A&M U.

U. Arizona
U. Arkansas, Little Rock
U. California Berkeley
U. California San Diego
U. California at Riverside
U. California Irvine
U. Colorado
U. Iowa
U. Hawaii
U. Houston
U. Massachusetts
U. Miami
U. Minnesota
U. Montana
U. Nevada
U. Washington
U. Wisconsin
Washington State U.

European Institutions and others

Universidad Freie de Berlín, Germany

Universidad Heidelberg, Germany

Universidad de Leipzig, Germany

IMK-IFU (Germany)

Ecole Polytechnique Federal of Lausanne, Switzerland

ETH-Zurich, Switzerland

Chalmers Technical University, Sweden

Göteborg University, Sweden

Centro de Estudios de la Tierra, Barcelona, Spain

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INE/SEMARNAT, GDF/SMA, IMP, UTTEC, FUMEC, SENEAM, SRE,
DGAC –SCT, SEDENA, SHCP, Consejo Estatal de Ecología (Estado de Hidalgo),
Consejo Estatal de Protección al Ambiente (Estado de Veracruz)
and many other Mexican institutions and agencies.