GIFT Workshop
EGU General Assembly 2007
April 17, 2007 Vienna, Austria

MILAGRO CAMPAIGN

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

Mexico City Case Study

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Outline of Presentation

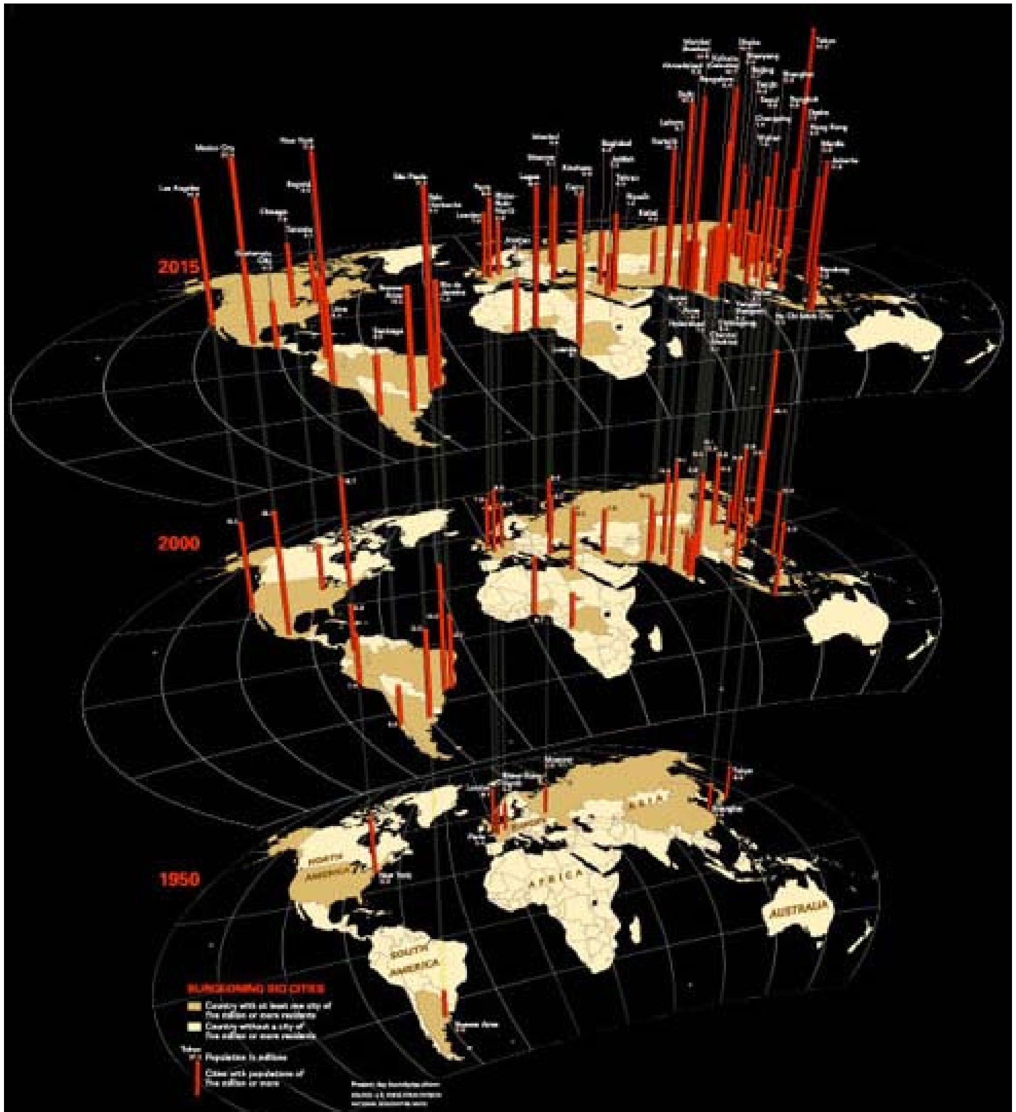
- The Impacts of Degraded Air Quality in Megacities
- Air Quality in the Mexico City Metropolitan Area
- MILAGRO Field Measurement Campaign
- Challenges for Megacities
- MILAGRO Documentary Trailer

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

Jeepney in Manila, Philippines

Diesel bus in Mexico City

Biomass burning in Mexico

Baby taxi in Bangkok, Thailand

Air Pollution in Megacities

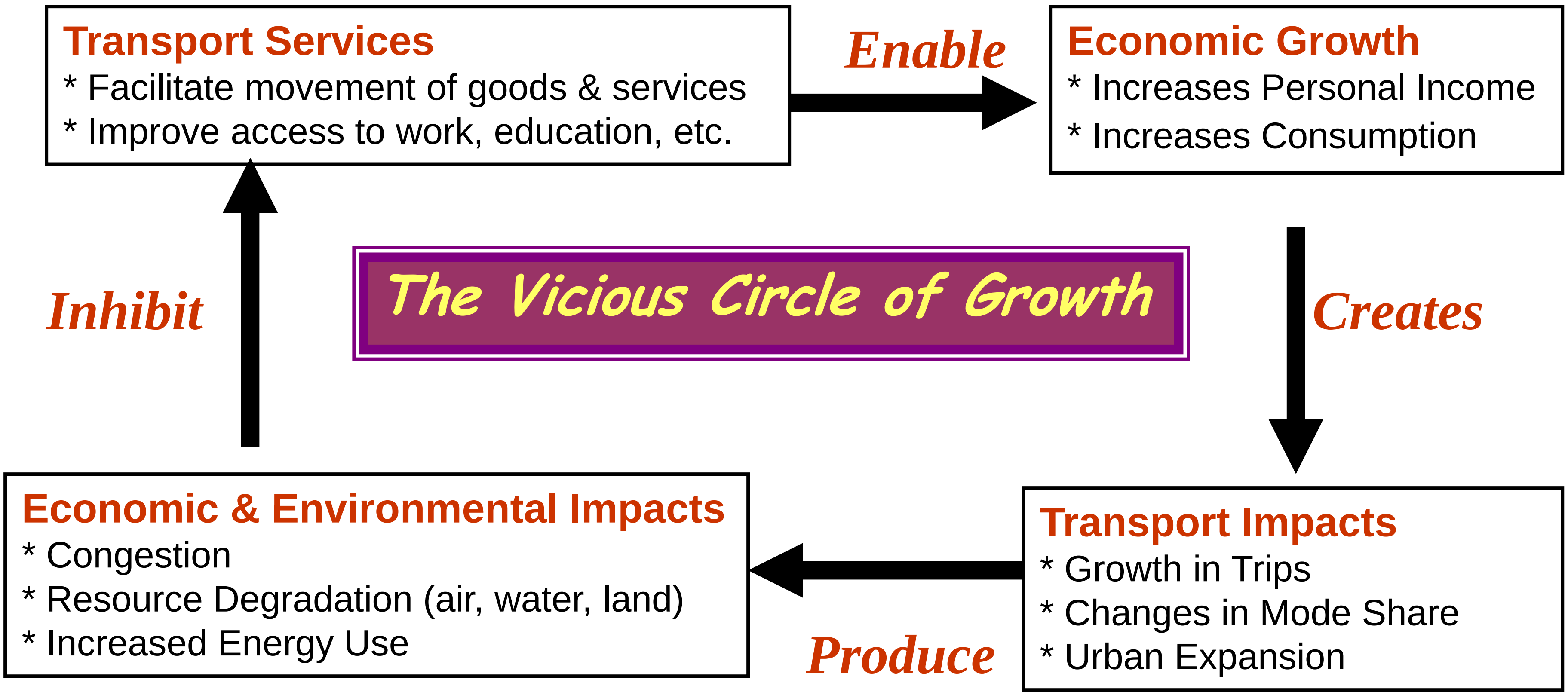
Metro Manila

(Photo L.T. Molina, Feb 2007)

Mexico City Metropolitan Area

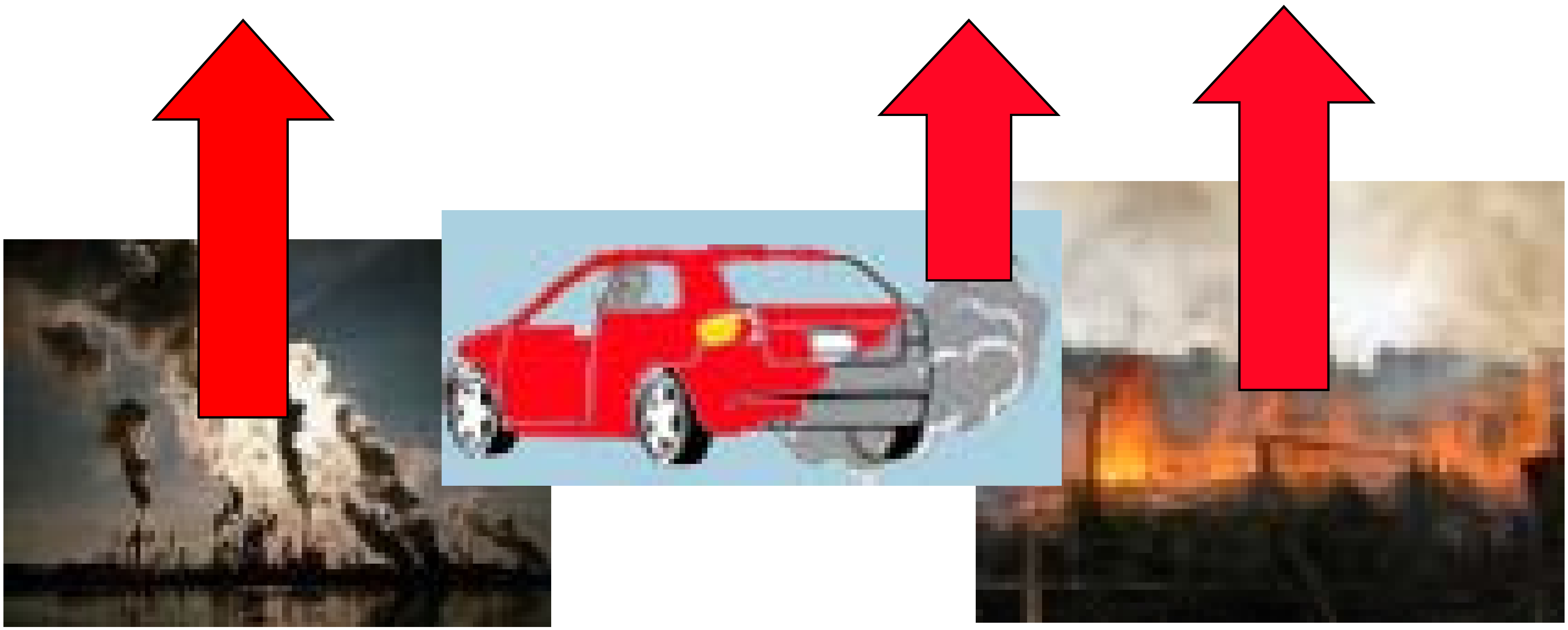
(Photo L.T. Molina, March 2006)

Growth without Regulation creates Congestion and Pollution



Main Pollutants emitted into the atmosphere

- small particles (also called aerosol particles)
- volatile organic compounds (VOCs)
- nitric oxide (NO) + nitrogen dioxide (NO_2) = NO_x
- carbon monoxide (CO)

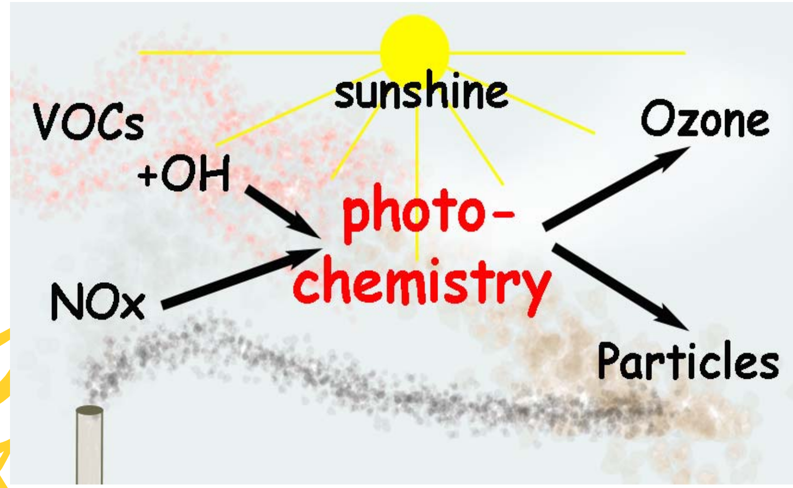


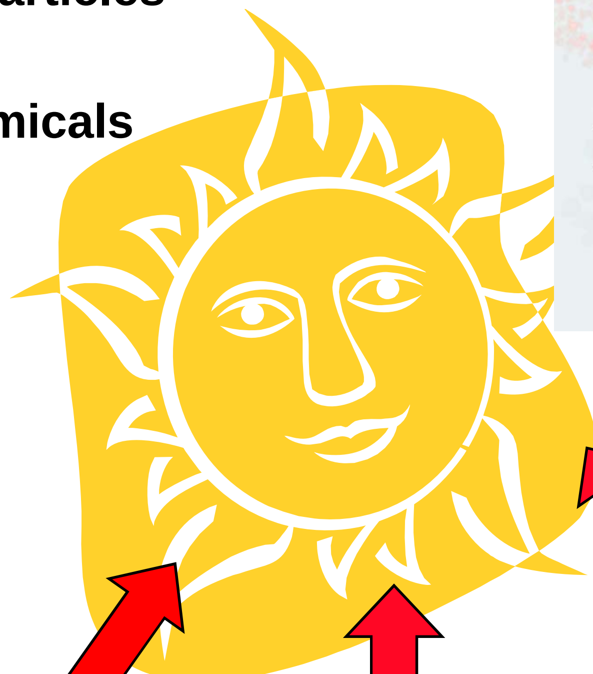
Not much happens until …

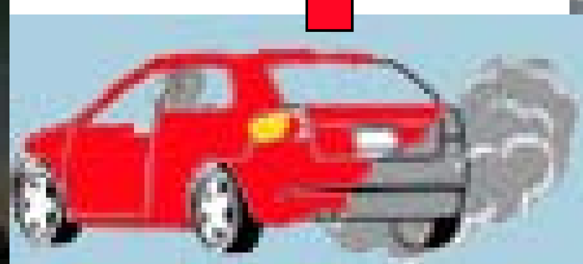
Photochemical Processes in the Atmosphere

the Sun comes up. Then,

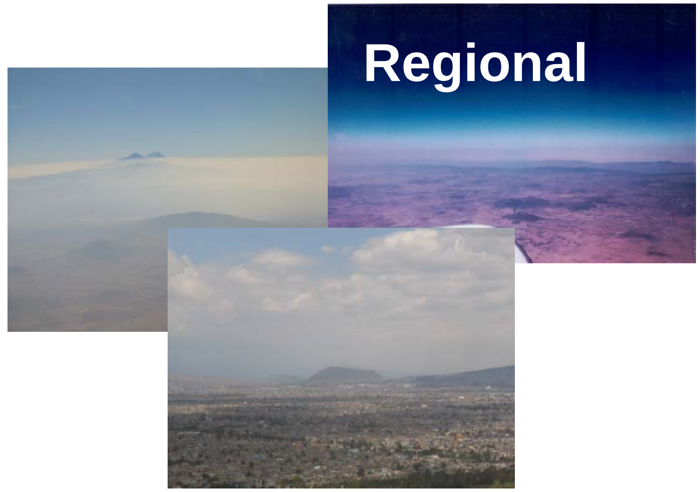
- even more small particles
- ozone (O_3)
- other harmful chemicals







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.

'Global Air Quality' study

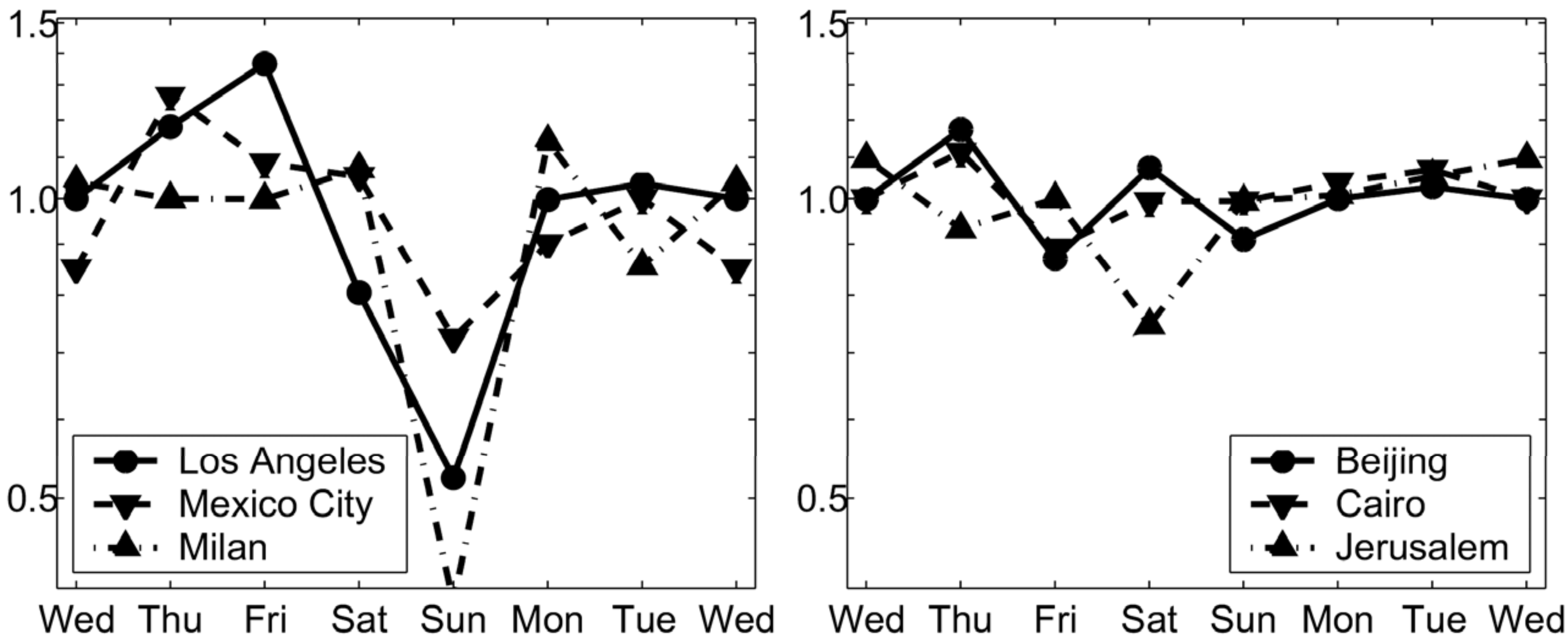
NRC NAS NAE IOM

motivating factors:

It is projected that over the next few decades, rapid industrialization and growth of 'megacities' in many parts of the world may lead to dramatic increases in total global air pollution emissions. As a result, intercontinental pollution transport is likely to become a growing problem. For instance, studies indicate that in the coming years, pollution transported from Asia could have significant impacts upon U.S. air quality.

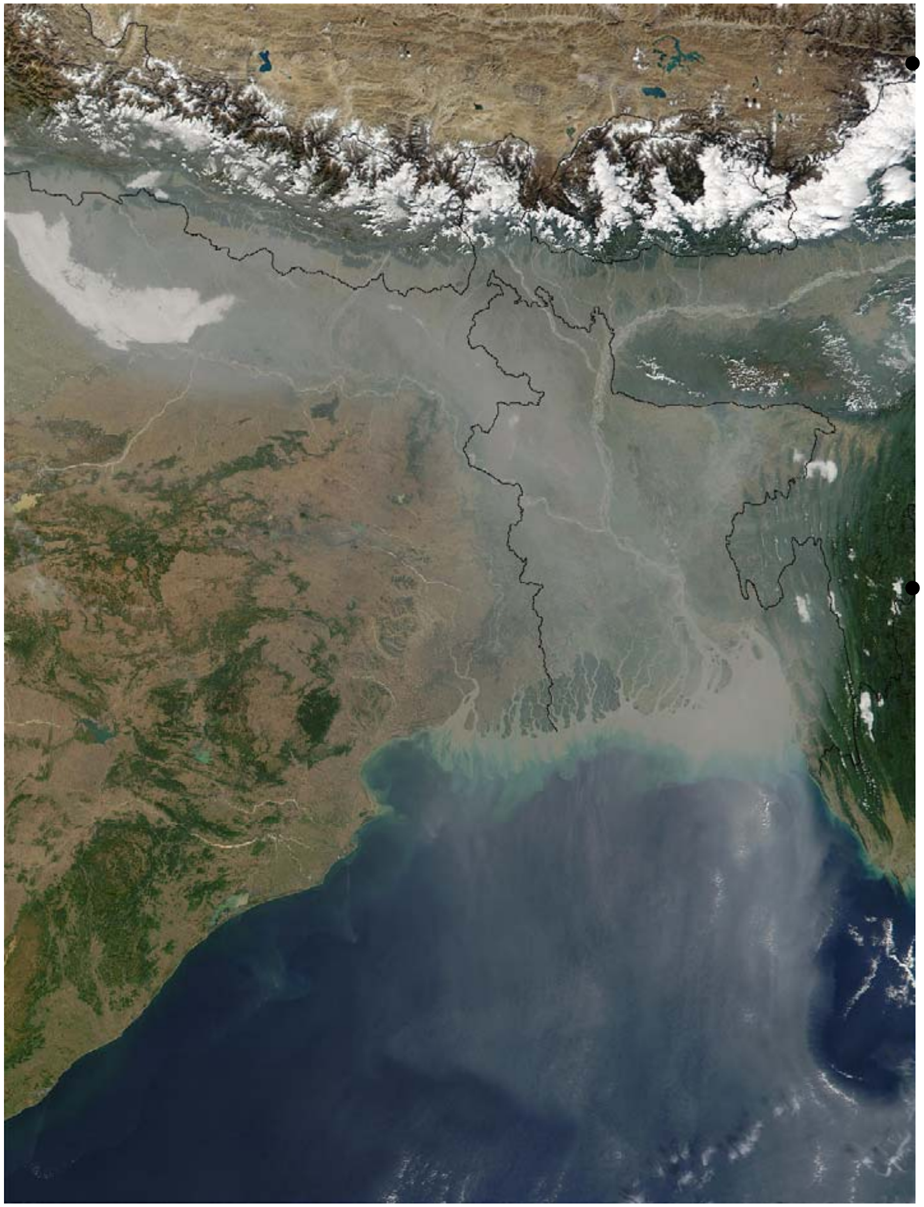
Air pollution affects climate through radiative forcing (O_3 and aerosols) and through chemical feedbacks which alter the lifetime of reactive greenhouse gases. In turn, climate change can influence the emissions, formation, transport, and deposition of numerous air pollution species. These climate/chemistry feedbacks need to be better understood, both to make accurate predictions of future climate changes and to design effective long-term air quality management strategies.

Weekly cycle of mean tropospheric NO_2 vertical column densities for 6 urban centers



Source: Beirle, S.; Platt, U.; Wenig, M.; Wagner, T. Weekly cycle of NO_2 by GOME measurements: a signature of anthropogenic sources; *Atmospheric Chemistry and Physics* **2003**, *3*, 2225-2232

Outflow of Aerosol, North India

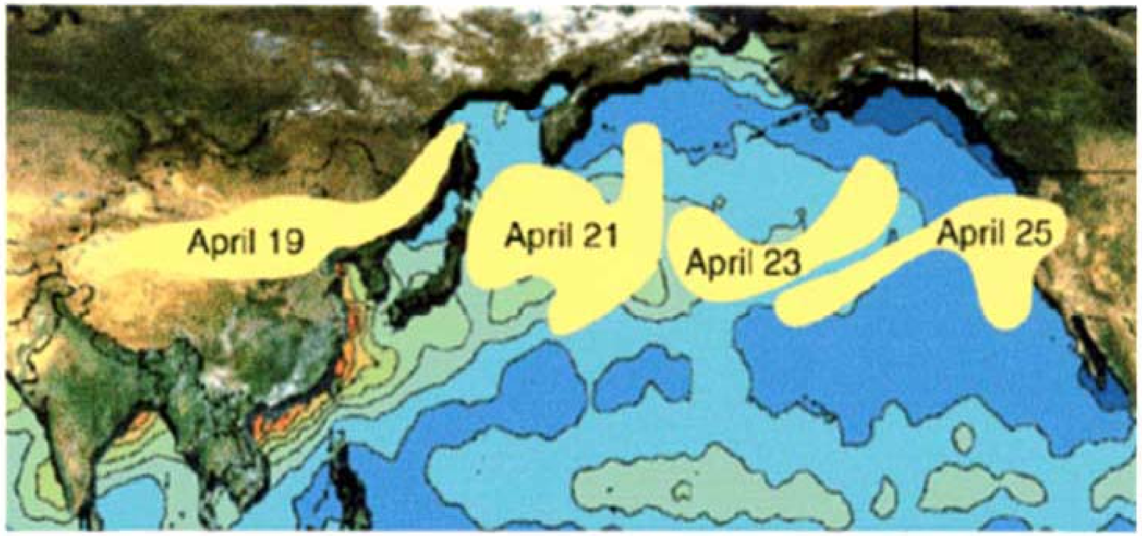


- The skies over Northern India are filled with a thick soup of aerosol particles all along the southern edge of the Himalayan Mountains, and streaming southward over Bangladesh and the Bay of Bengal.
- These particles pose a health hazard to the population living in the region and also can have a significant impact on the regional climate.

(Source: NASA satellite photo)

Trans-Pacific Air Pollution

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

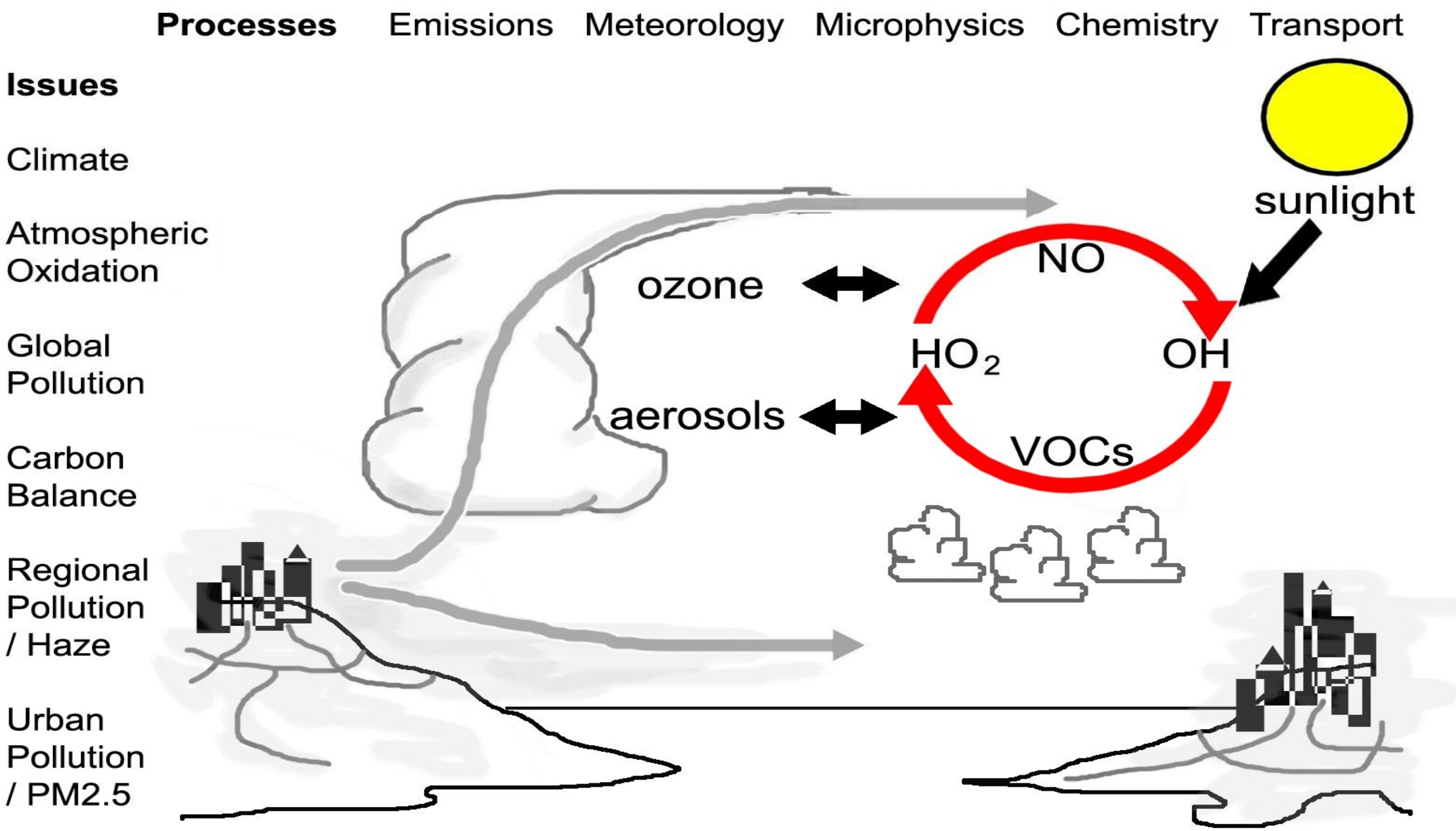


Pollution from afar. Satellite remote sensing images of trans-Pacific transport of aerosols in April 1998 originating from a massive dust storm in China.

SCIENCE, vol 290, October 2000

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

Important Processes for Air Pollution

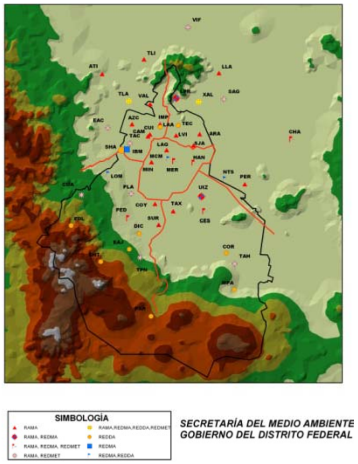


(figure from W. Brune)

Reducing pollution requires understanding of all these processes. Our current understanding is good, but not good enough. We need an observing / modeling system!

Strategy for Pollution Studies

Monitoring Network



strengths

- continuous measures critical pollutants
- special studies add other pollutants

weaknesses

- generally few sites
- measures few pollutants all the time

Aircraft

strengths

- regional range
- can chase pollution plumes
- complete chemical payload are possible

weaknesses

- only for special studies
- only one place at a time
- moderately expensive (a few million dollars)

Satellites

strengths

- global observations every day or so
- constant surveillance measures critical pollutants

weaknesses

- limited number of measured pollutants
- some satellites can't see to the ground
- expensive (hundreds of millions of dollars)

We need to use all three platforms and many models

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

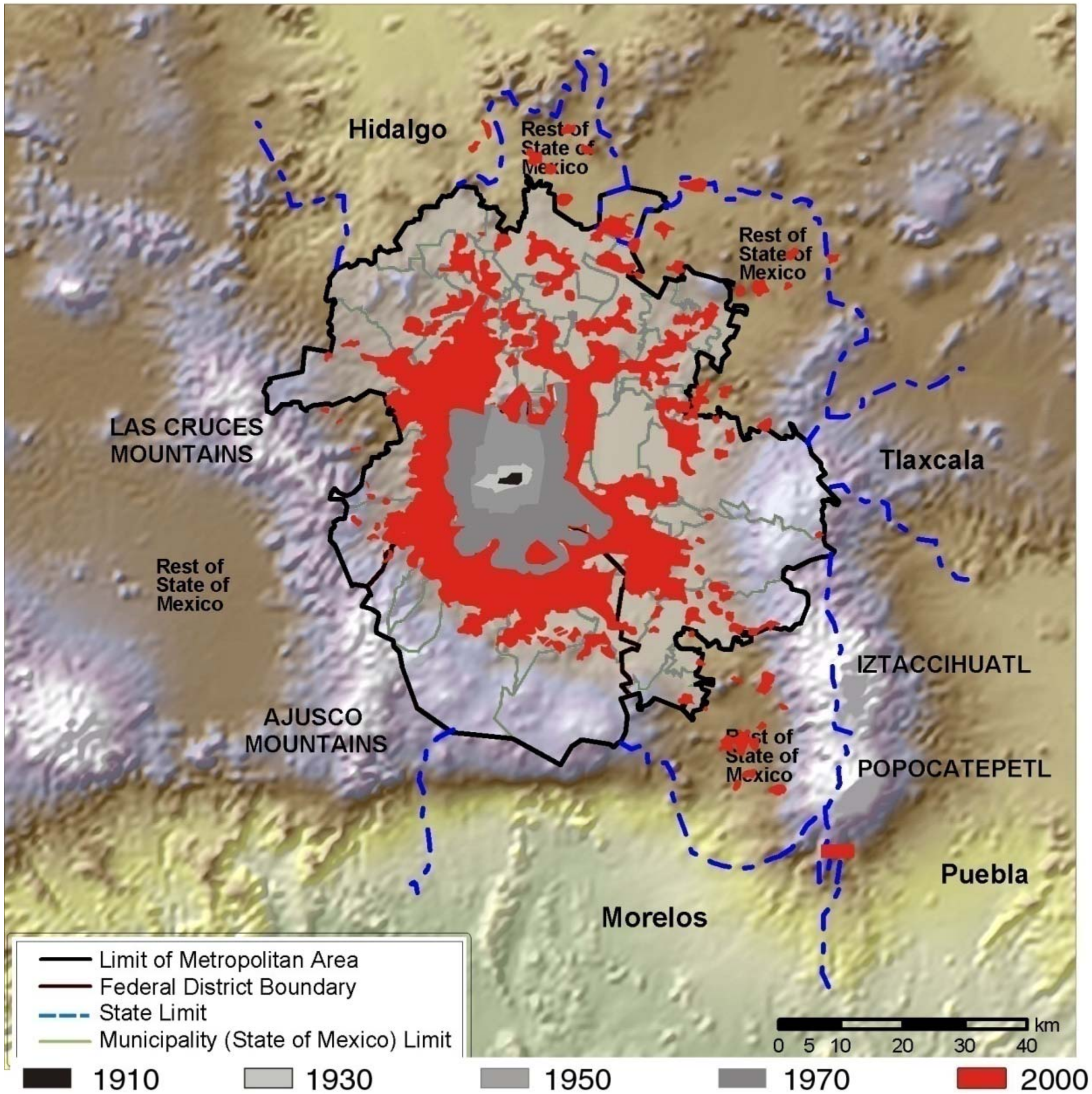
Excellent scientific collaborations

Previous Campaign: MCMA-2003

- **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

Topographical Map of Mexico City Metropolitan Area showing the Urban Expansion



- Population Growth
  - >18 million (2000): 20-fold increase since 1900
- Urban Sprawl
  - >1500 km2 (2000): 10-fold increase since 1960
  - >Expansion to peripheral areas
- Geographic and Topographical Conditions
  - >High altitude (2240m): less efficient combustion processes
  - >Mountains are a physical barrier for winds
  - >2nd largest megacity in the world
  - >Temperature inversions in the dry season
- Increases in Emissions Sources

Source: L.T. Molina and M.J. Molina, ed., Air Quality in the Mexico Megacity: An Integrated Assessment, Kluwer Publishers, 2002.

Mexico City Population at Risk

- 20 million inhabitants, including:
  - 2.2 million children
  - 250,000 street vendors
  - 250,000 taxi, microbus and bus drivers
- More than 30 million trips-person are made every day
- Residents spend on average 3 hr commuting per day; 20% of commuters spend 4 or more hours
- CO, PM, VOCs and NOx exposure levels are 3-4 times higher in commuting microenvironments than at fixed site monitoring stations

Mexico City Metropolitan Area Air Quality Situation

- **In the early 1990s:**
  - **Air Quality Standards for ALL CRITERIA POLLUTANTS frequently exceeded**
  - **Ozone standard exceeded 90% of the days**

    Peaks above 300 ppb 40-50 days a year

- **In the late 1990s:**
  - **Pb, SO_2 levels always within standard**
  - **CO and NO_2 standards rarely exceeded**
  - **Ozone peaks above 300 ppb only 3-4 days a year**
  - **Ozone still above standard 85% of days**
  - **PM10 exceeds standard on 20-30 % of days**

Main Reasons for Air Quality Improvement in the MCMA (1990-1999)

Lead

- Unleaded gasoline introduced in 1990
- Leaded gasoline completely phased out in 1997

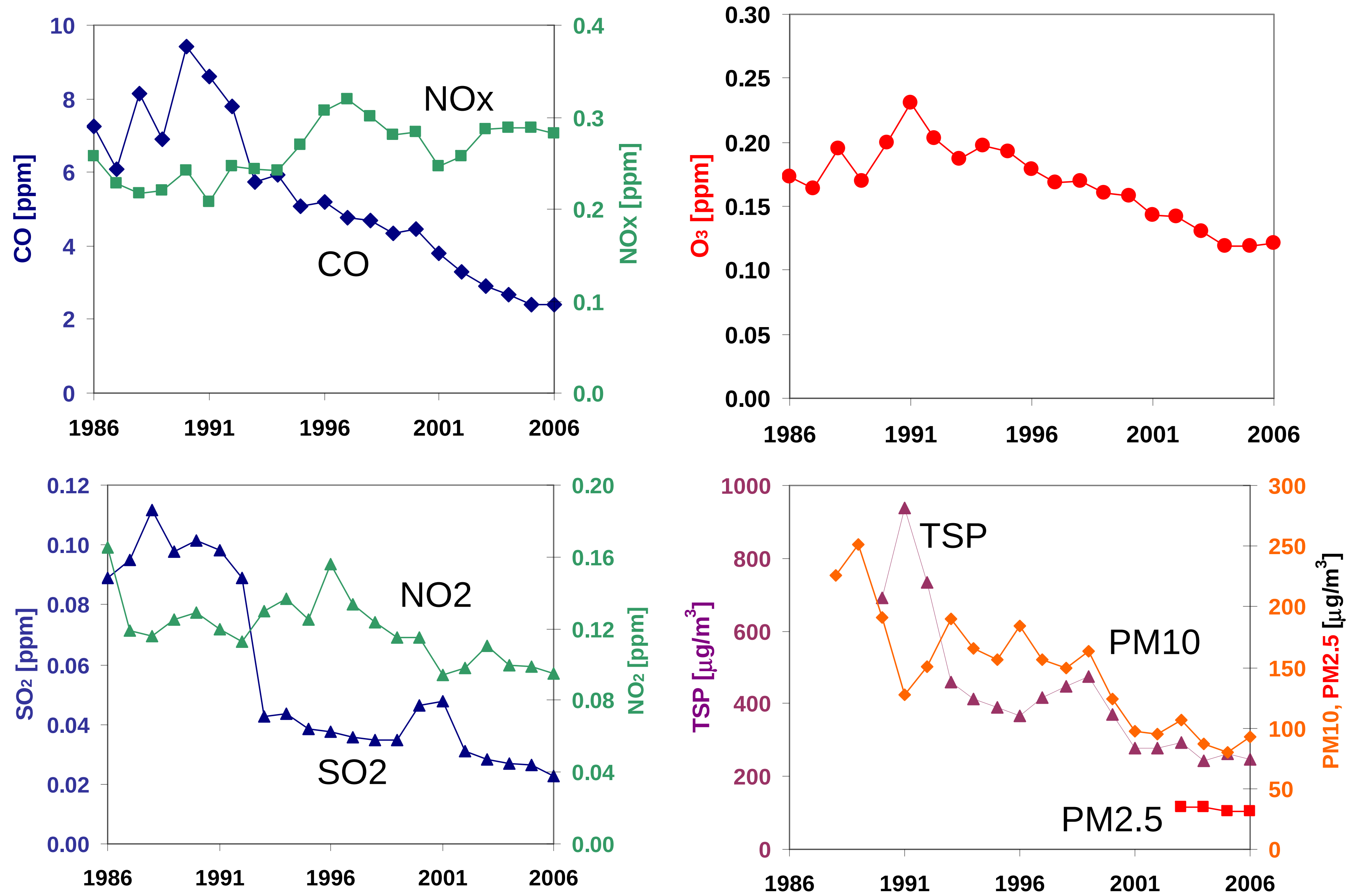
Sulfur Dioxide

- Industrial heavy fuel oil was phased out in mid 1990s
- Sulfur content of diesel was reduced to 0.05% in 1995
- Power plants and other industry shifted to natural gas in the early 1990s

Ozone peaks and CO levels

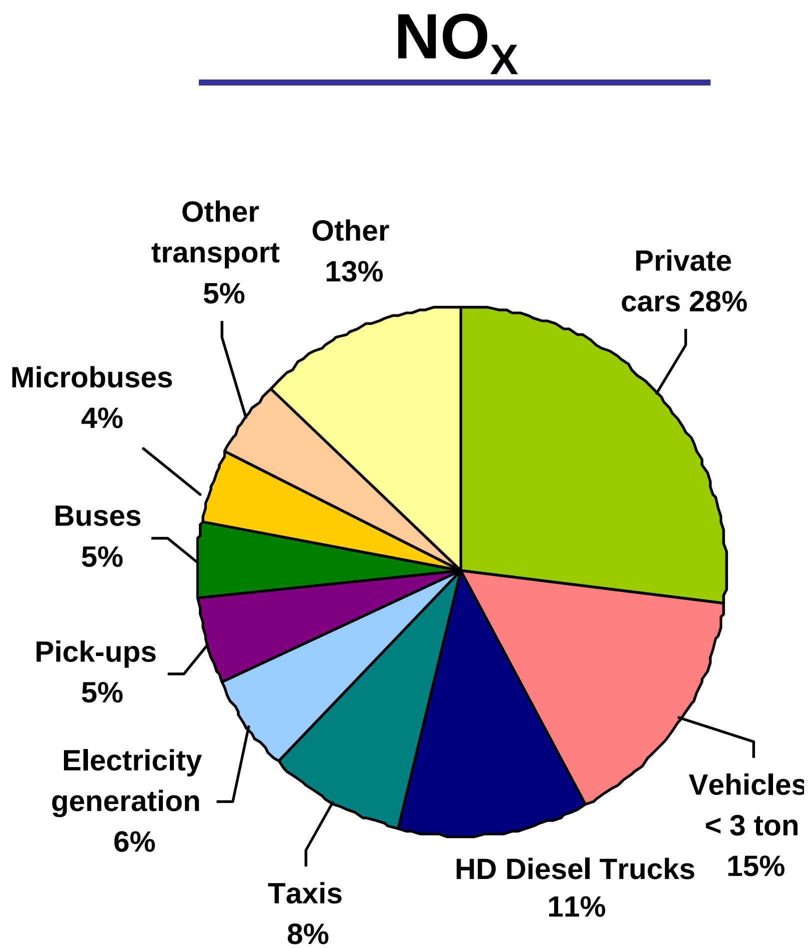
- Oxygenated gasoline introduced in early 1990s
- Vehicle Inspection Program upgraded in 1993
- 3-way catalysts introduced in 1993
- Vapor recovery systems installed in gasoline storage tanks and service stations

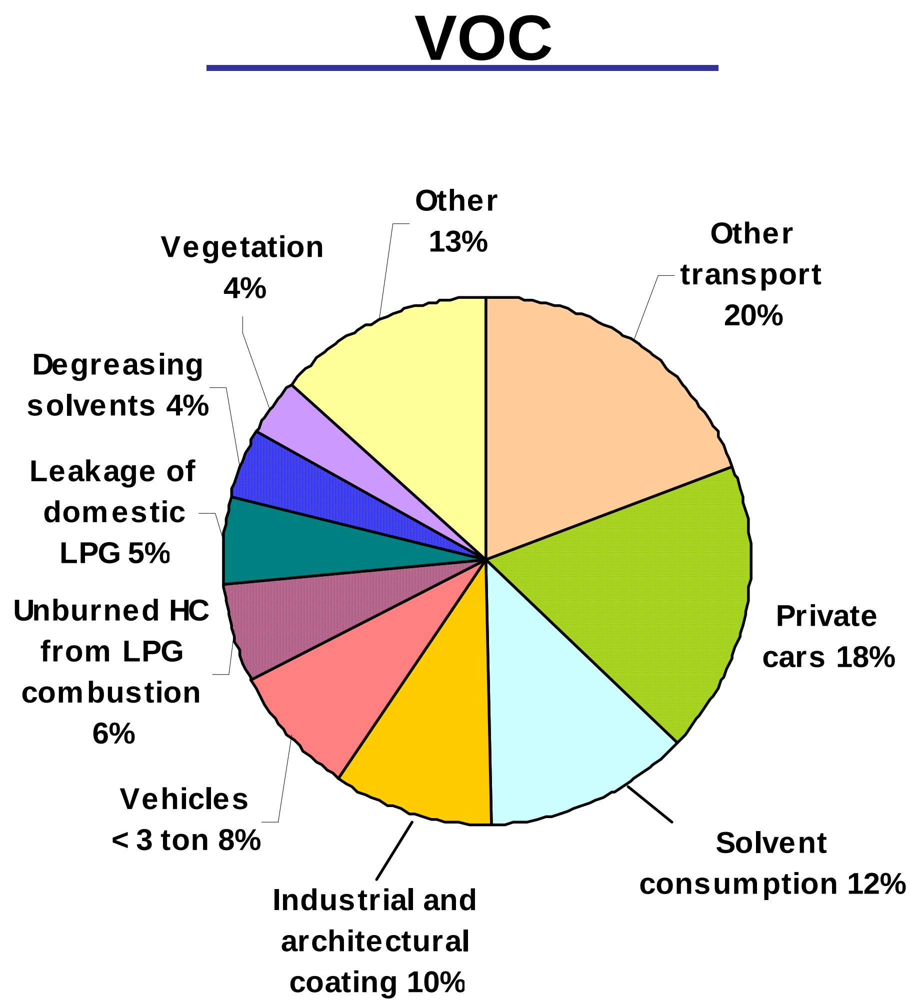
Air Quality Trends in Mexico City



Source: Mexico City, Federal District Government 2006.

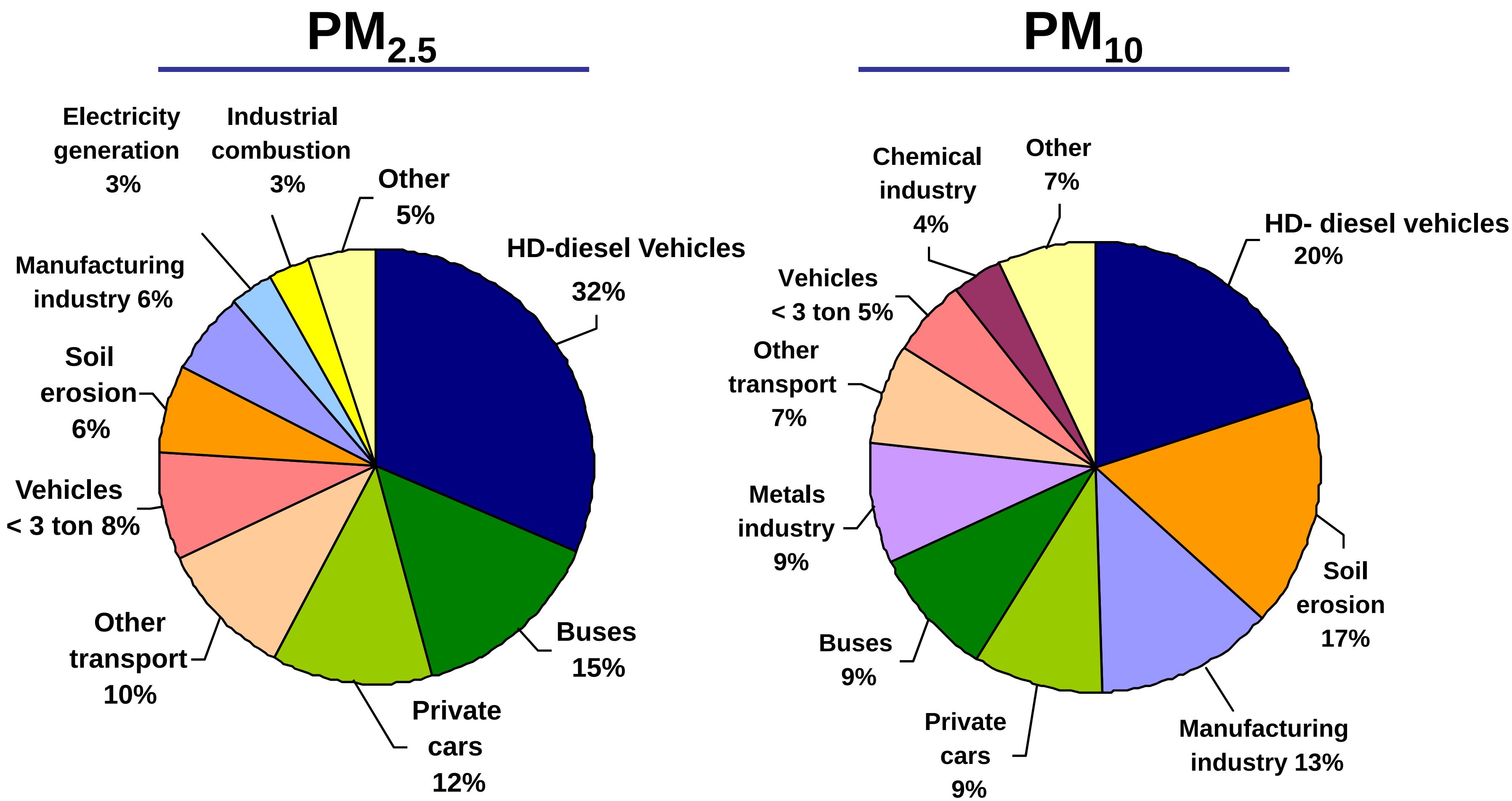
Percentage of emissions from the MCMA in 2000 by source category





2004 EI: Mobile sources contribute 82% NOx and 35% VOCs

Percentage of emissions from the MCMA in 2000 by source category



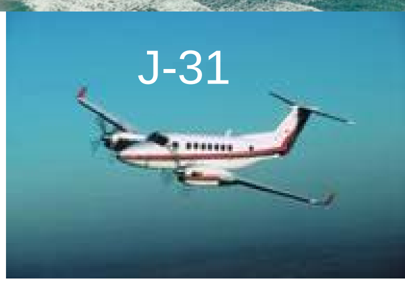
2004 EI: Mobile sources contribute 57% of PM2.5 and 23% of PM10

MILAGRO Campaign: Geographic Coverage

INTEX-B	MIRAGE-Mex	MAX-Mex	MCMA-2006
NASA DC-8	NSF C-130,	DOE G-1,	Supersites,
J-31, Satellites	King Air, Supersite	KingAir, Supersite	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)

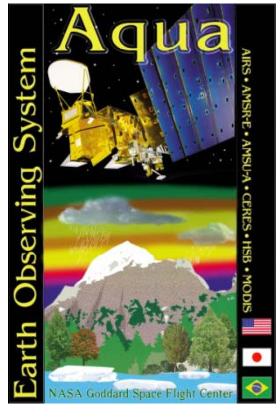
Satellites Observations

Terra (NASA)

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

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

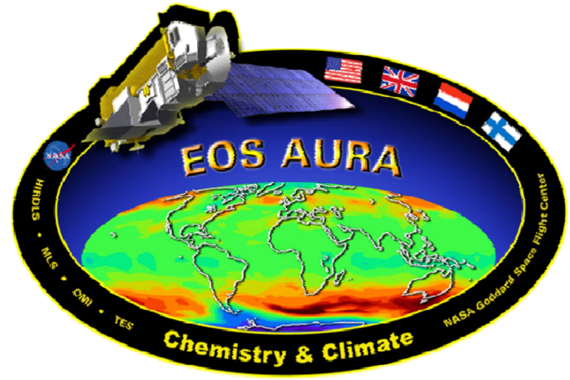
MISR (Multi-angle Imaging Spectro-Radiometer)
- Measurements of aerosol amount, type, & vertical distribution



Aqua (NASA)

AIRS (Atmospheric InfraRed Sounder)
- Measurements of CO

MODIS
- Measurements of aerosol optical depth



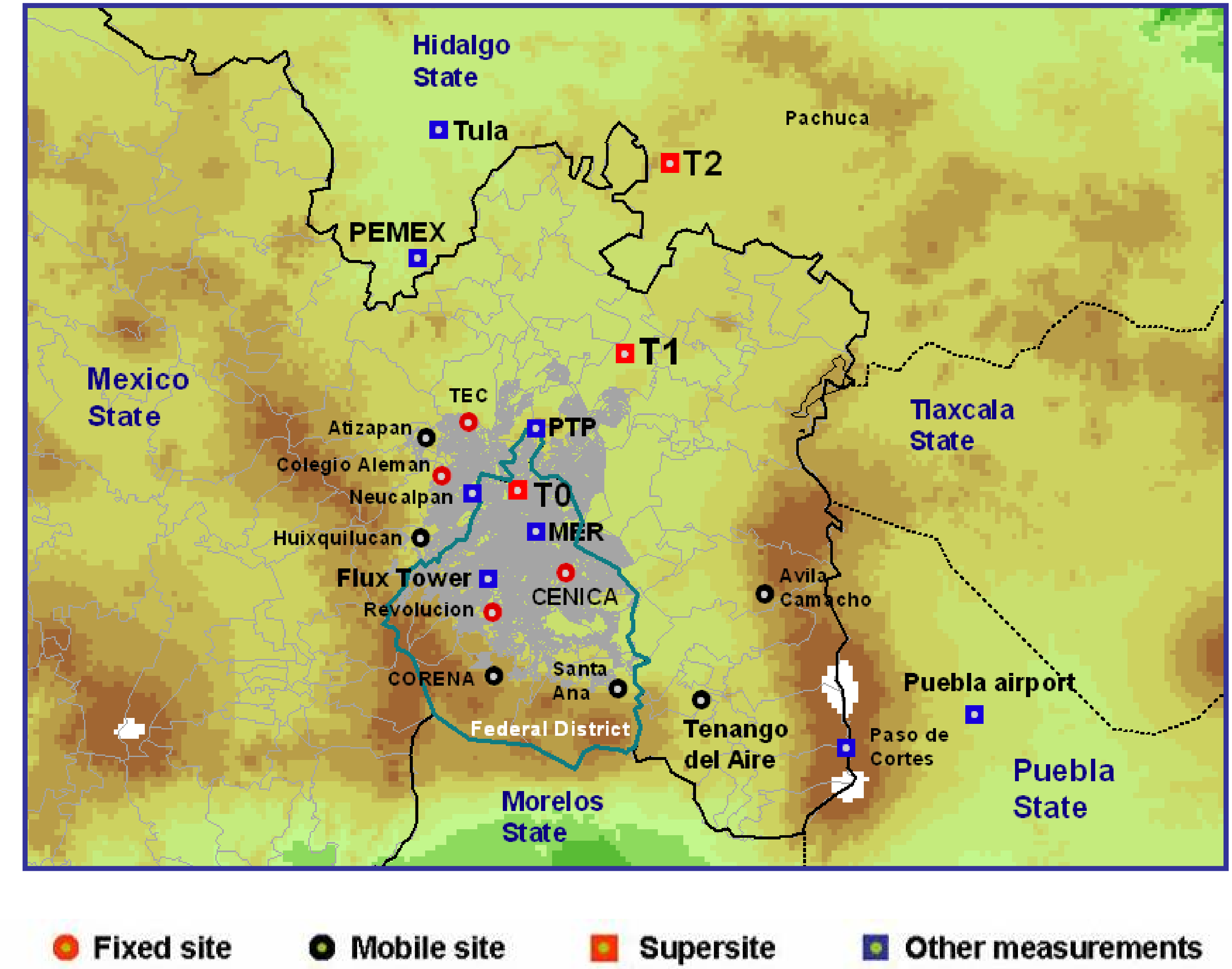
Aura (NASA)

TES (Tropospheric Emission Spectrometer)
- Measurements of O_3, CO, and HNO_3

OMI (Ozone Monitoring Instrument)
- Measurements of O_3, NO_2, HCHO, SO_2, and aerosol properties

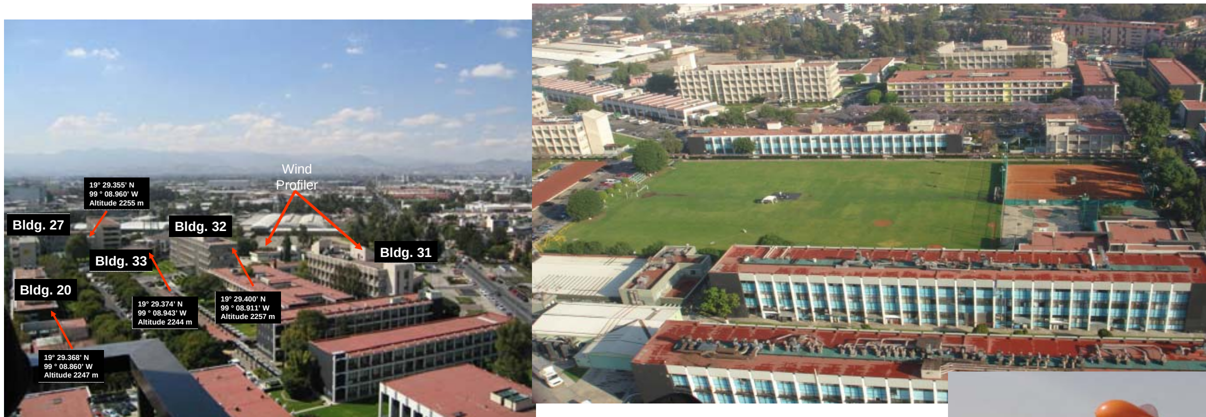
SCHIAMACHY (University of Bremen):
Tropospheric NO_2, glyoxal, H_2O, HCHO

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: Instituto Mexicano del Petróleo, DF

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

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

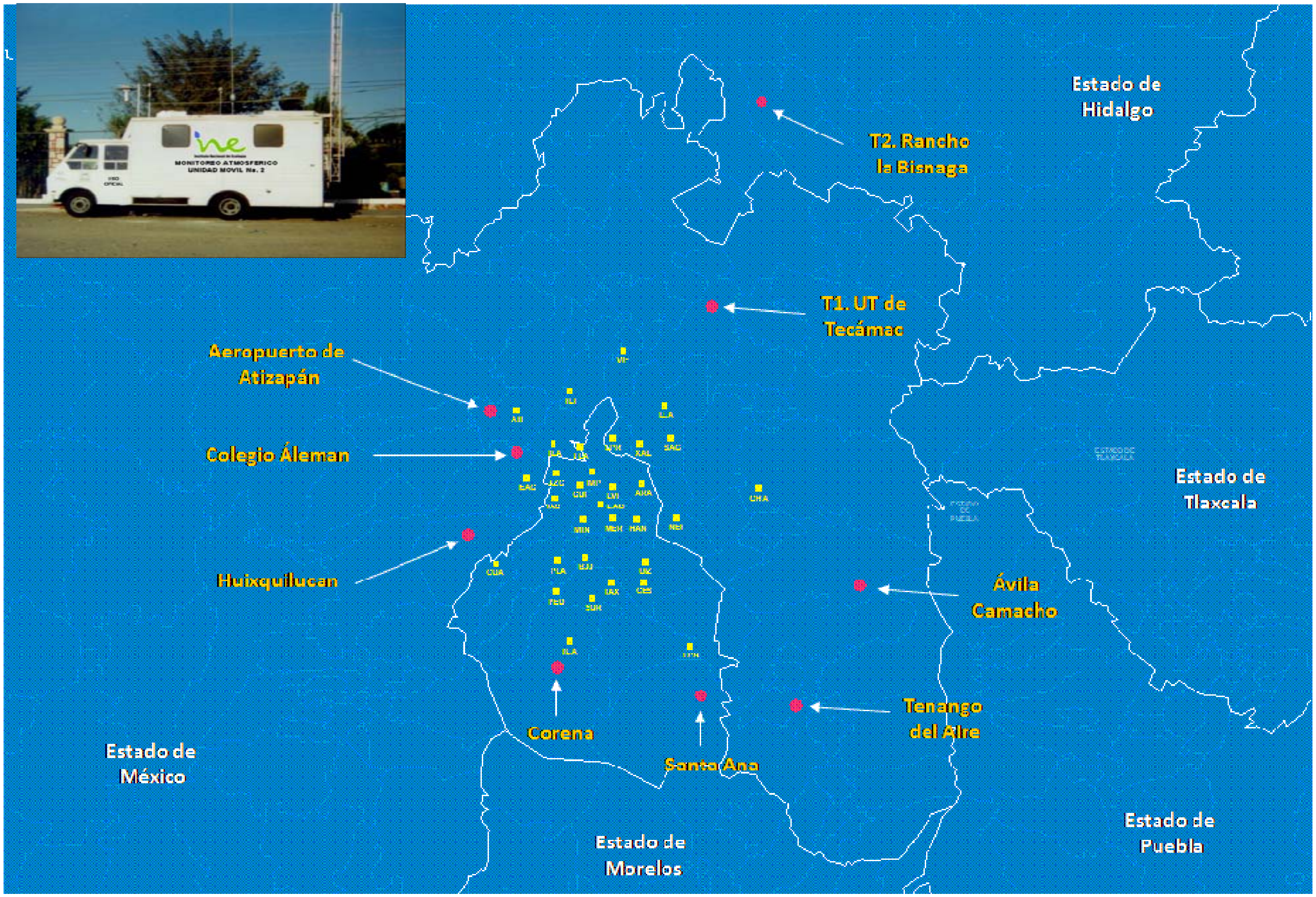
MILAGRO Campaign: Boundary Sites

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

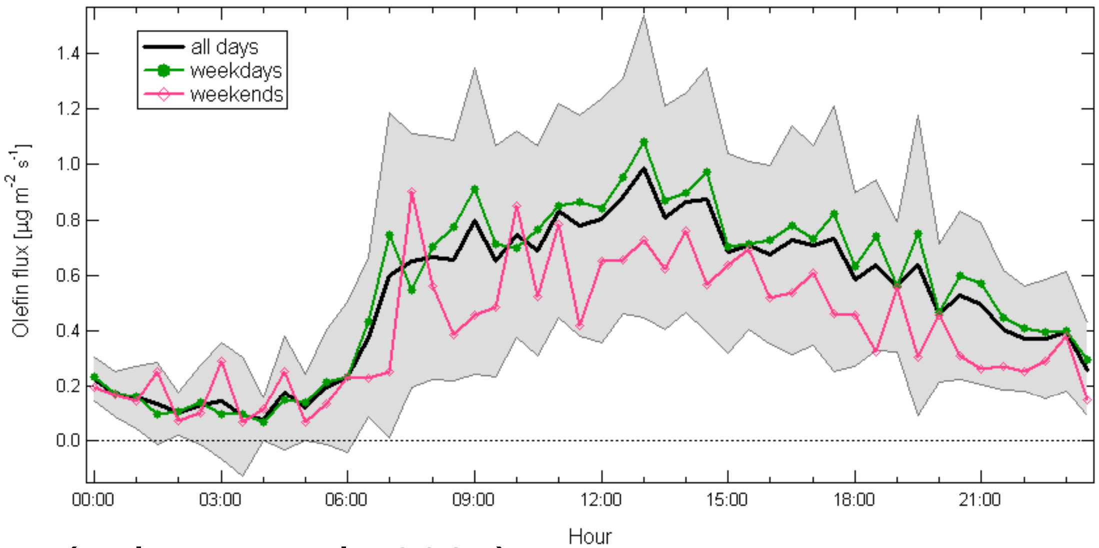


MCMA-2006: Urban Flux Measurements

Flux Tower located at SIMAT Site
- 42 km asl
- 3 km radius: fixed and mobile emitting sources
- evaluate and validate local emissions inventory

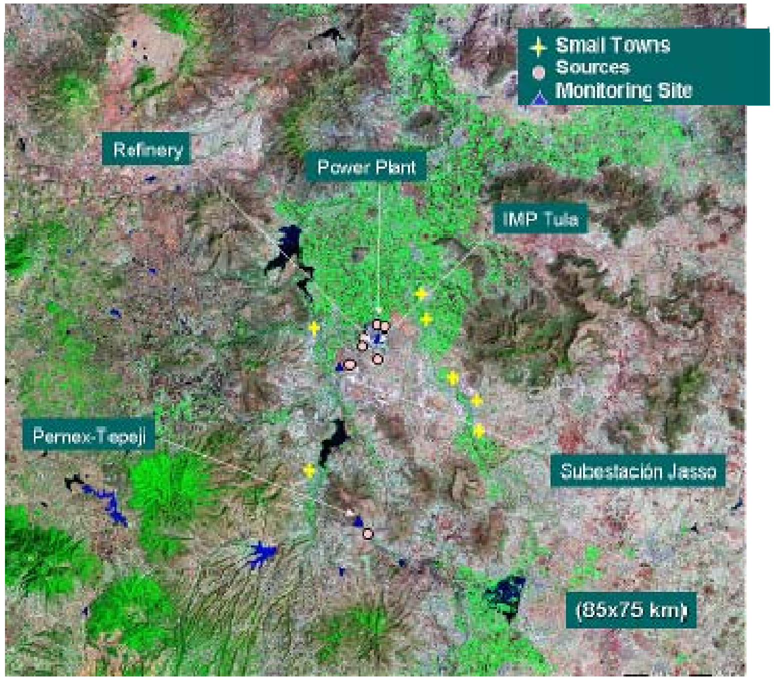
- VOCs
- CO_2
- CO
- Aerosols
- Energy (*Q**, *Qh*, *Qe*)
- Momentum (*u**)

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

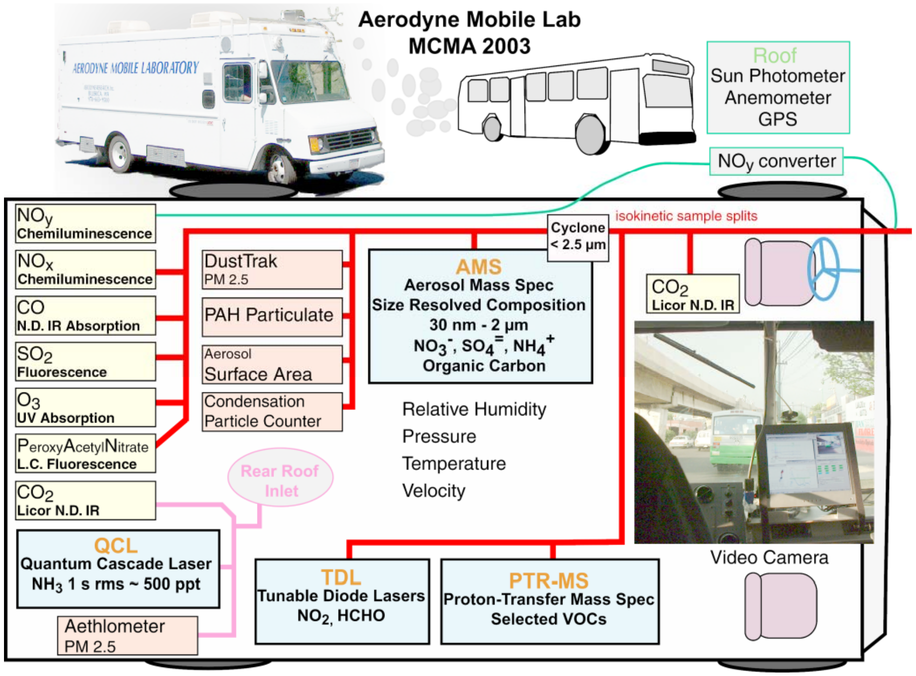
- 355,000 T/Y of SO2 are released by two major industries: PEMEX Power Plant and Refinery.

- 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 Laboratory

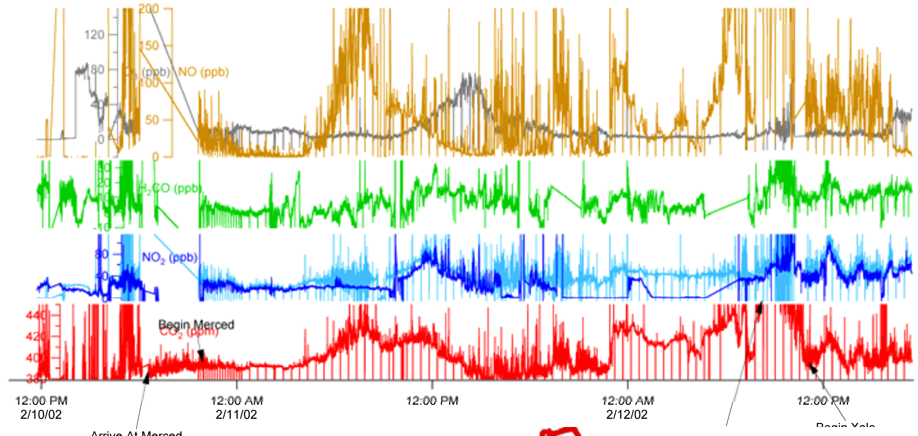


The Aerodyne Research, Inc. mobile laboratory was deployed at various sites throughout the MCMA to investigate the effects of photochemical aging of aerosols, and the local boundary layer ventilation.

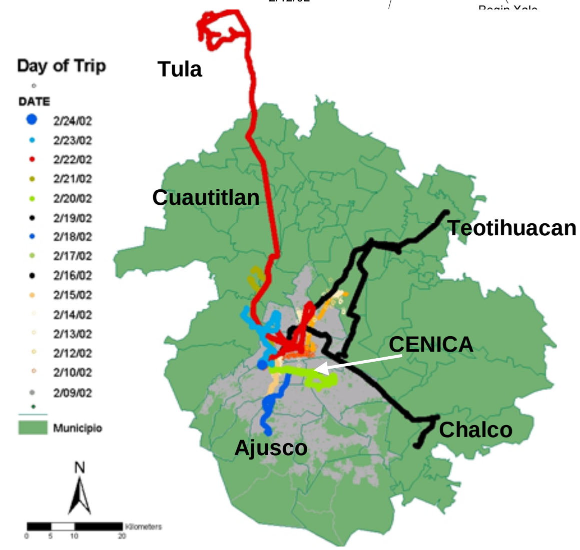
One of the sites is Pico de Tres Padres - a mountain raising ~900 m above the valley floor - to sample city plumes vented to the northeast.

Mobile Laboratory Modes of Operation
February 2002 & April 2003

Stationary Sampling
High time resolution point sampling
Quality Assurance for conventional air monitoring sites



Mobile Sampling/Mapping
Motor vehicle pollution emission ratios
Large source plume identification
Ambient background pollution distributions

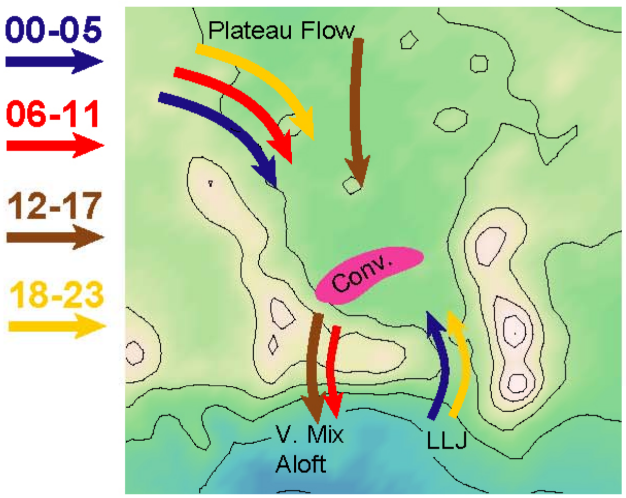


Chase
Detailed mobile source emissions characterization
Plume tracer flux measurements

MCMA Conceptual Wind Circulation Model

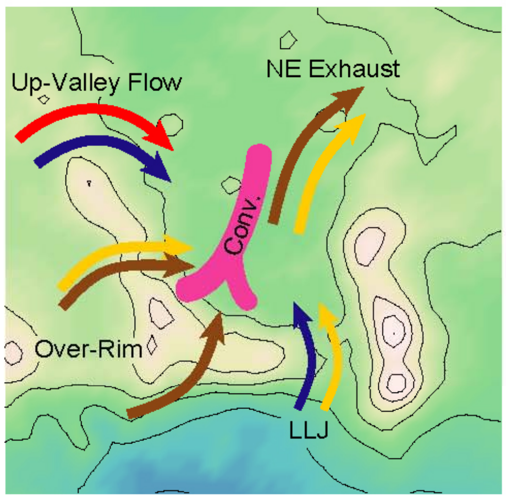
Because of surrounding mountains, MCMA has complex winds.
A convergence zone forms in the afternoon with winds coming from both sides.
This leads to pollutant accumulation and high concentration levels.
The days are classified into 3 episodes:

O3-South



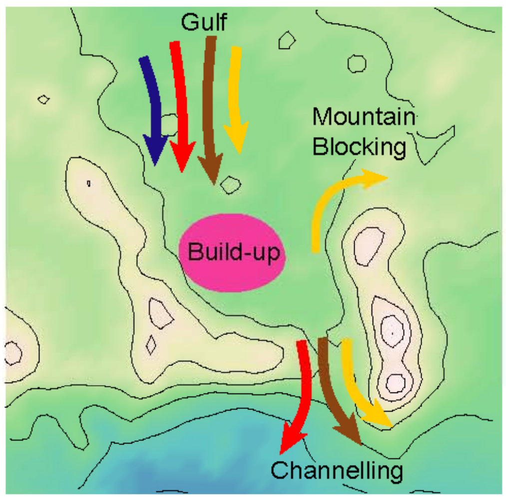
Weaker gap flow

O3-North



Stronger eastward flow

Cold Surge



It is cold so there is little vertical mixing and high concentrations at the surface.

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

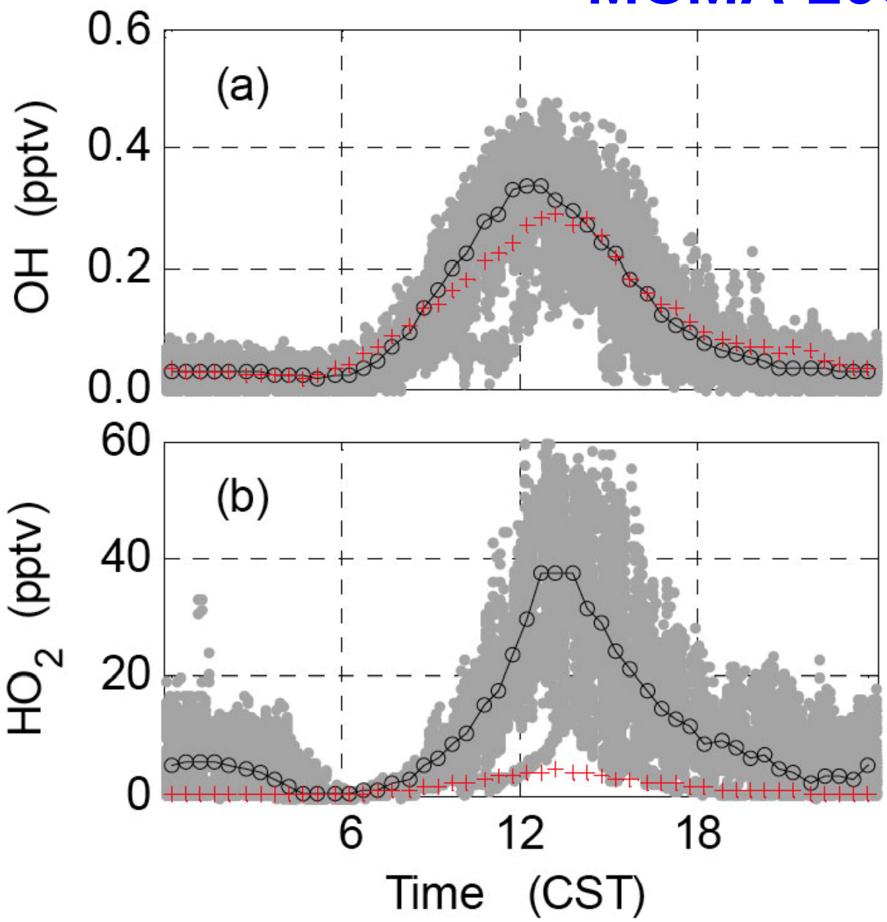
Mid-End March: Storms over the US -> O3-North, Lagrangian transport

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

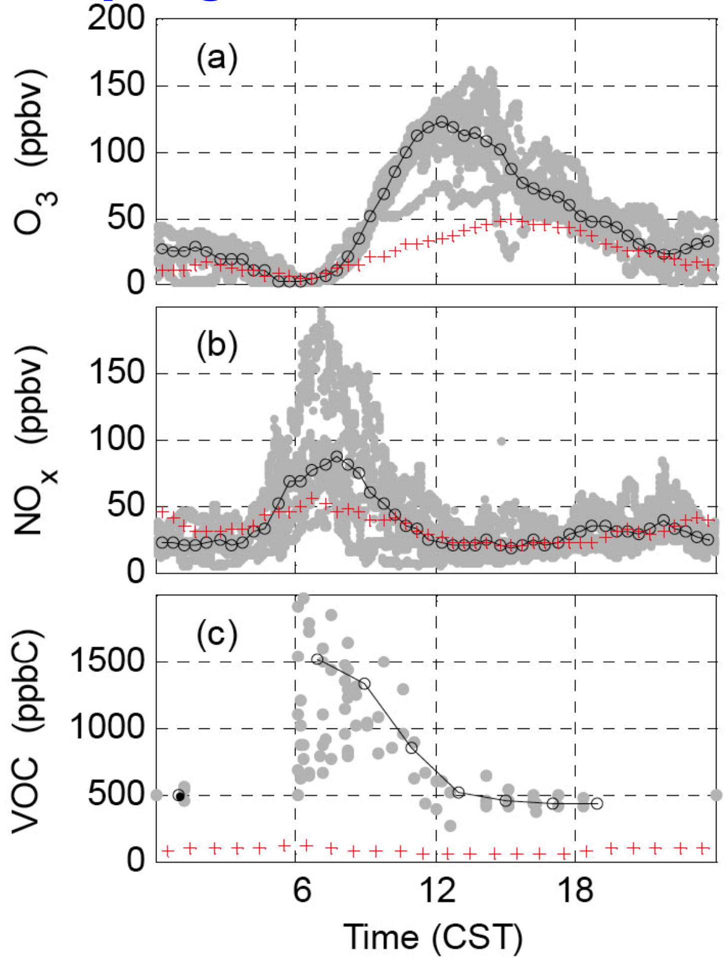
Overall, forecasts helped in locating the plume

Ongoing: Model evaluation and intercomparison

Diurnal Variation of some photochemical variables in MCMA-2003 Campaign



(a): Measured OH in MCMA (solid line) and in NYC (plusses); **(b)**: measured HO2 in MCMA (solid line) and NYC (plusses). Gray dots are individual MCMA measurements.



(a): Median ozone in MCMA 2003 (solid line) and NYC 2001 (plusses). **(b)**: Median NOx in MCMA 2003 (solid line) and NYC 2001 (plusses). Gray dots are individual MCMA measurements. **(c)**: Median VOCs from 4 sites in MCMA 2003 (solid line) and NYC 2001 (plusses).

Source: Shirley, T. R., Brune, W. H., Ren, X., Mao, J., Lesher, R., Cardenas, B., Volkamer, R., Molina, L. T., Molina, M. J., Lamb, B. , Velasco, E. , Jobson, T., Alexander, M.: Atmospheric oxidation in the Mexico City Metropolitan Area (MCMA) during April 2003, *Atmos*. *Chem*. *Phys*.*,* 6, 2753-2765, 2006.

Some conclusions about MCMA photochemistry from MCMA-2003

- **MCMA's high levels of NO_x + very high levels of reactive VOCs + lots of sunlight =**

  high levels of HO_2 =

  high levels of ozone +

  rapid particle formation.

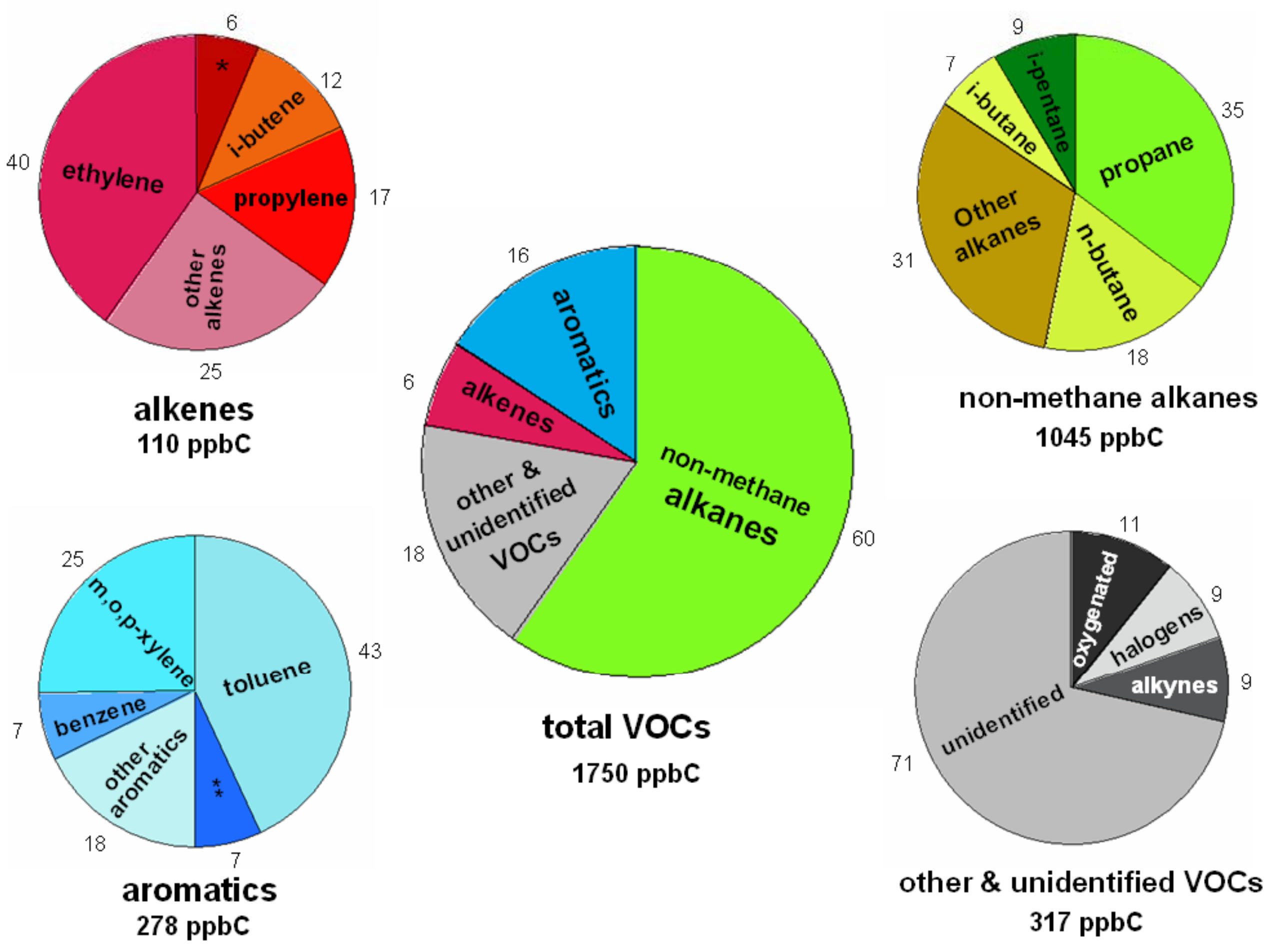
- **More than 80% of ozone production was VOC-limited.**

Which VOCs need to be controlled?

Ongoing analysis: using MILAGRO data.

(Source: L.T. Molina et al., Air Quality in North America's most populous city – overview of MCMA-2003 Campaign. Atm. Chem. Phys. Discuss., 2007.)

Average VOC Distribution (6-9 hr) from MCMA-2003



Low molecular weight alkanes: 65% from LPG used for cooking, water heating.

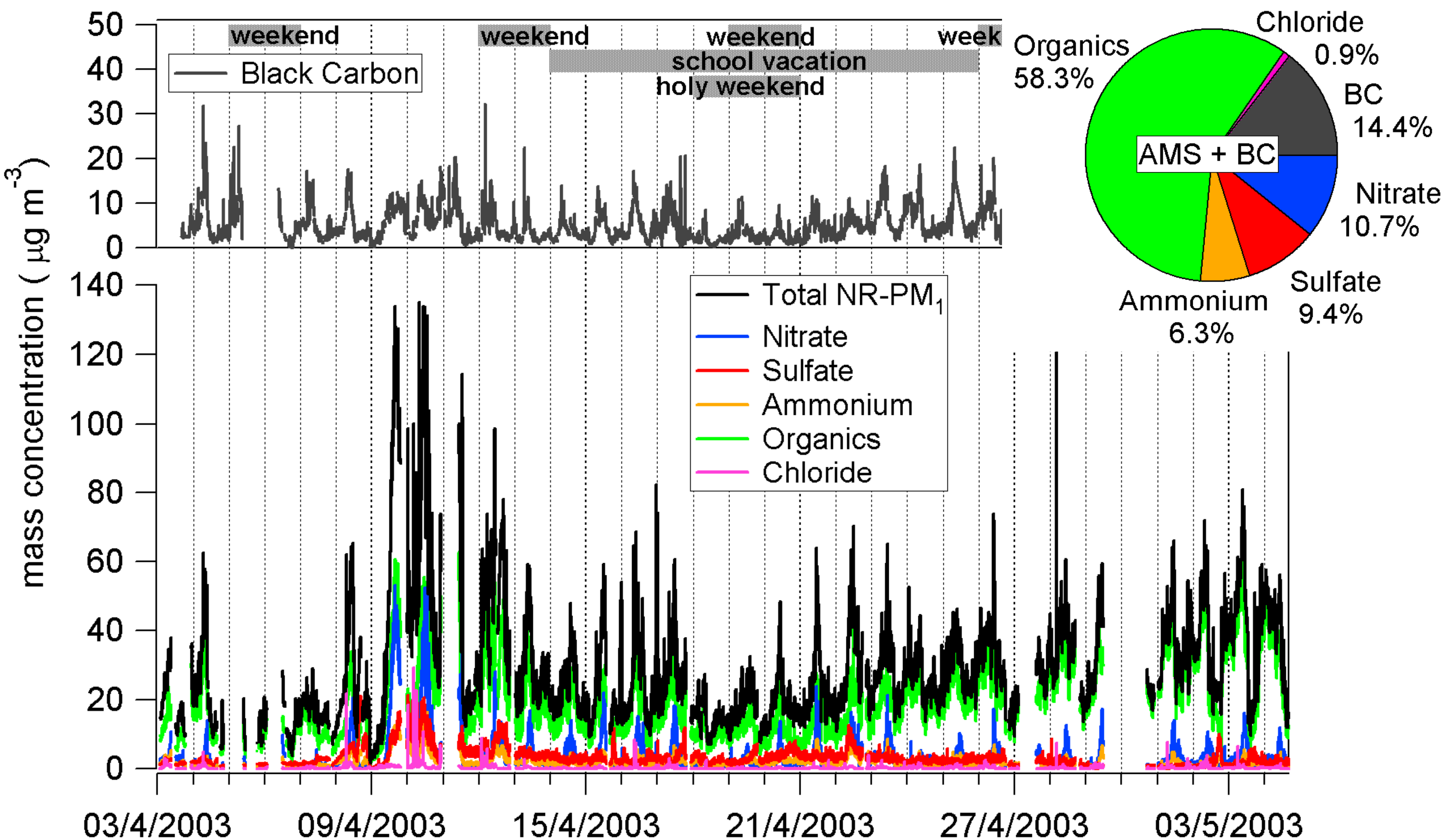
Olefins and aromatics: mainly from vehicular emissions.

Total VOCs concentration is lower than obtained from previous campaign

*2-methyl-1-butene, ** 1,2,4-trimethylbenzene.

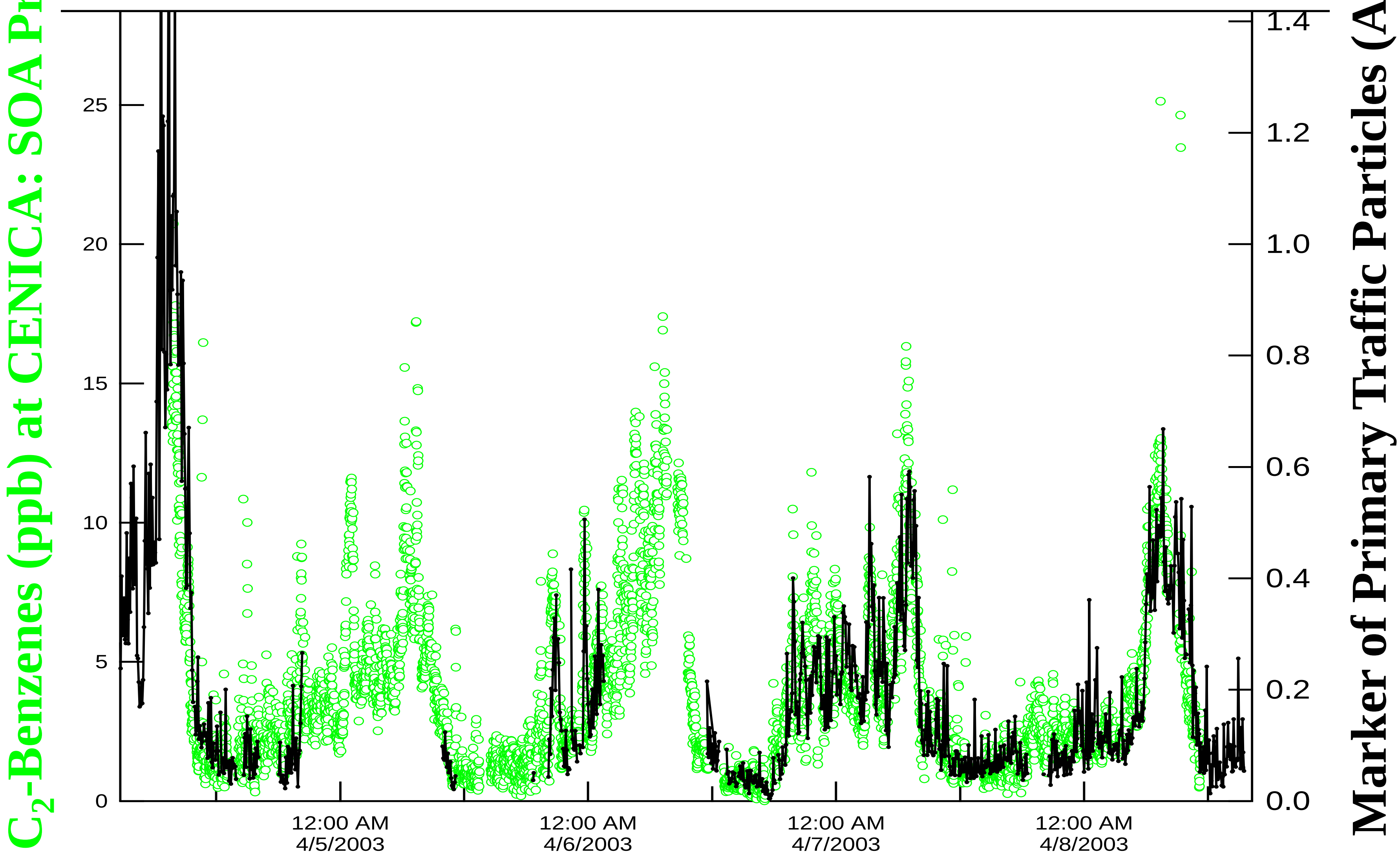
Source: Velasco et al., Distribution, magnitudes, reactivities, ratios and diurnal patterns of volatile organic compounds in the Valley of Mexico during the MCMA 2002 and 2003 Field Campaigns, *Atmos. Chem. Phys.,* 7, 329-353, 2007.

$PM_{2.5}$ Mass Concentration: weekend-weekday-holidays



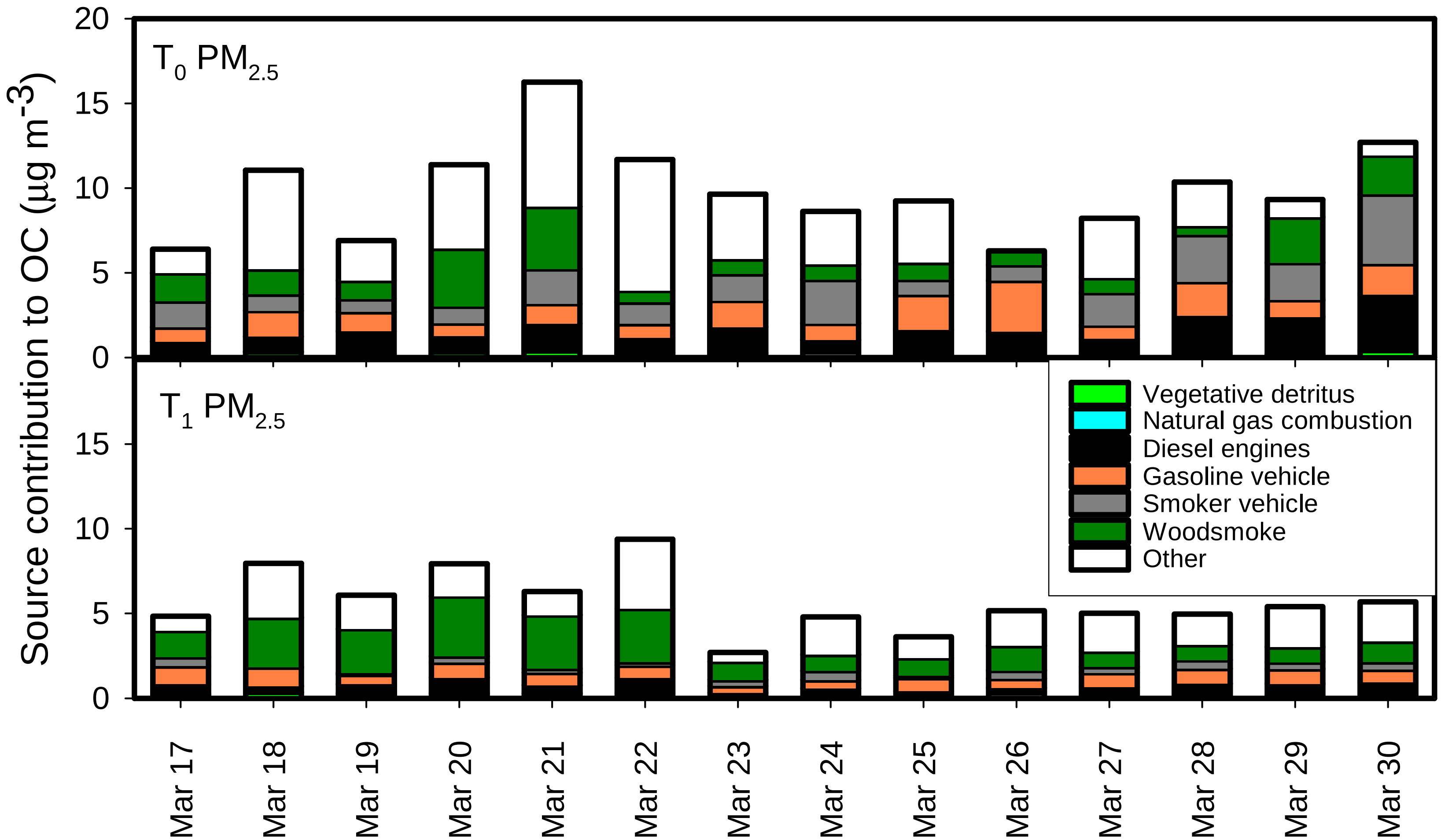
Salcedo et al. *Atmos Chem Phys.*, 2006

SOA Precursor Gases and Traffic



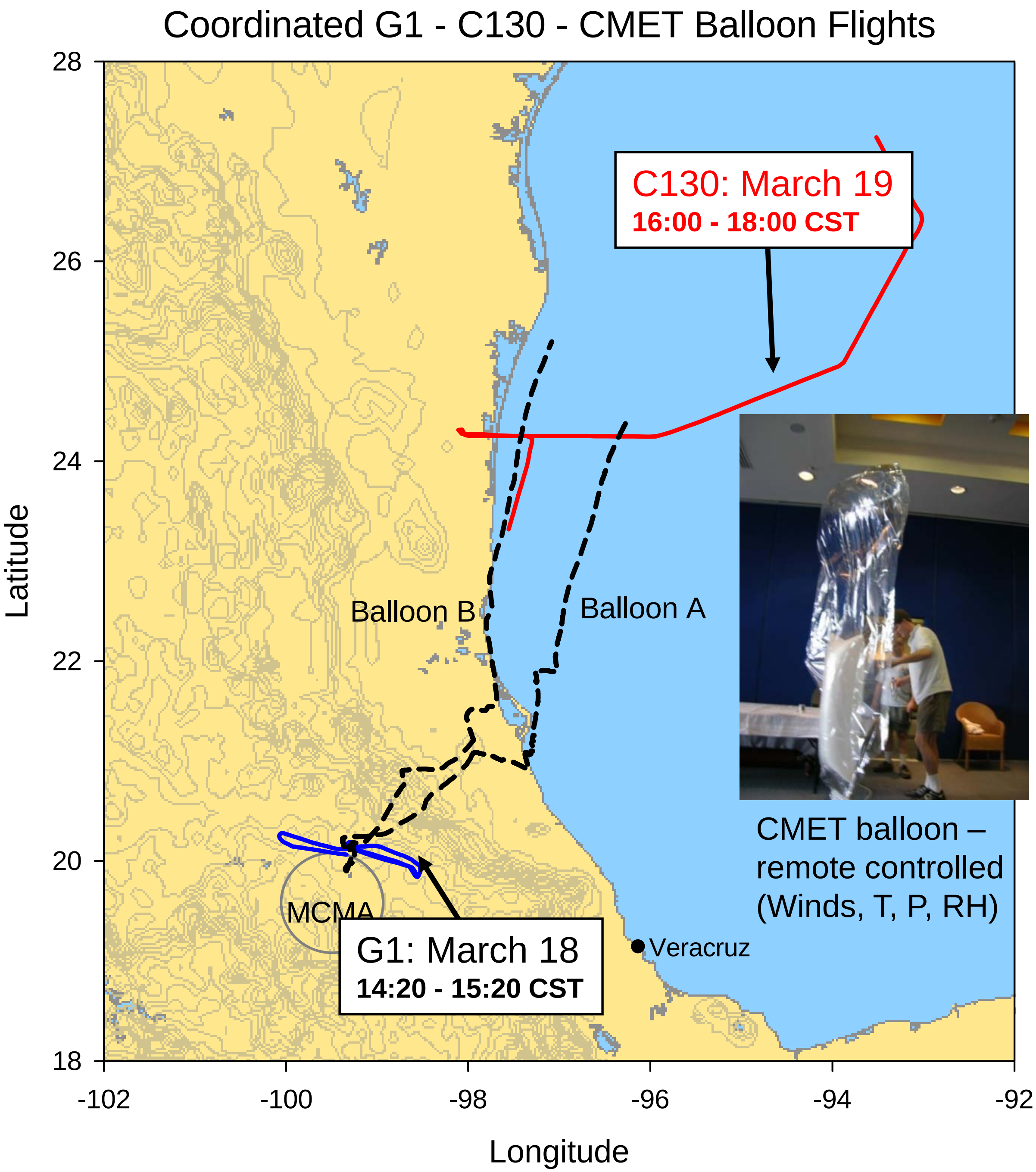
PTR-MS data from T. Jobson & M.L. Alexander, PNNL

Source apportionment of fine organic aerosol



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, D. C. Snyder, R. J. Sheesley, and J. J. Schauer
University of Wisconsin-Madison



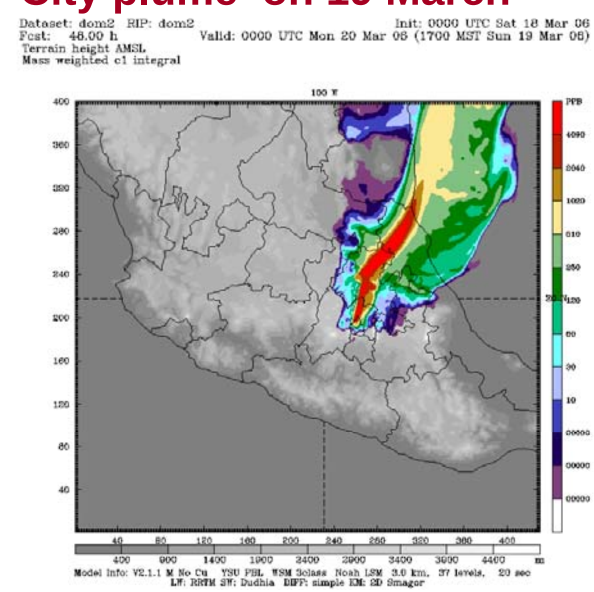
CMET balloon – remote controlled (Winds, T, P, RH)

On 18 March, the G-1 sampled air near Mexico City and two CMET balloons were launched from near T1.

On 19 March, the C-130 intercepted the plume and the balloon trajectories in the Gulf of Mexico.

The WRF model predicted correctly this situation.

WRF simulation of Mexico City plume on 19 March



O_3 Production in Mexico City Plume during MILAGRO Campaign

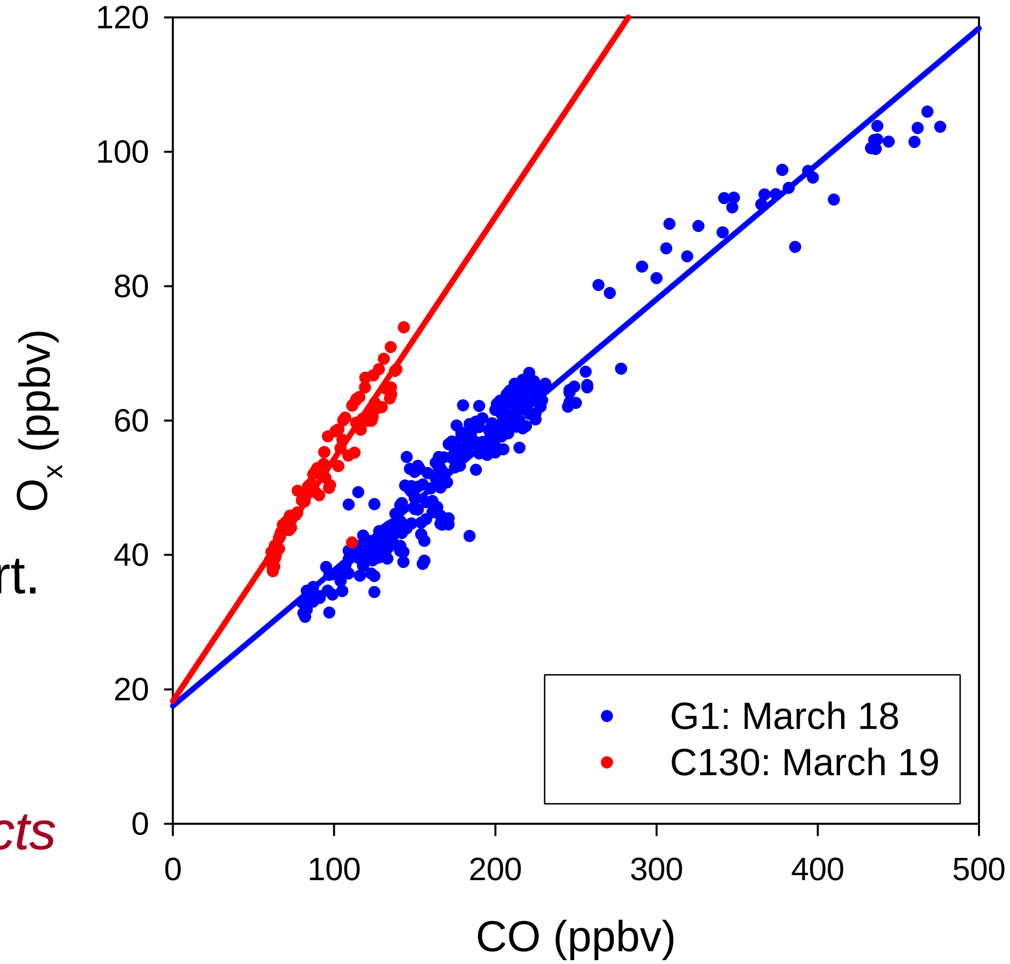
In 1-day-old plume

CO and Ox (O_3 + NO_2) decrease because of mixing with cleaner air;

but Ox/CO increases, indicating continuing Ox production during the plume export.

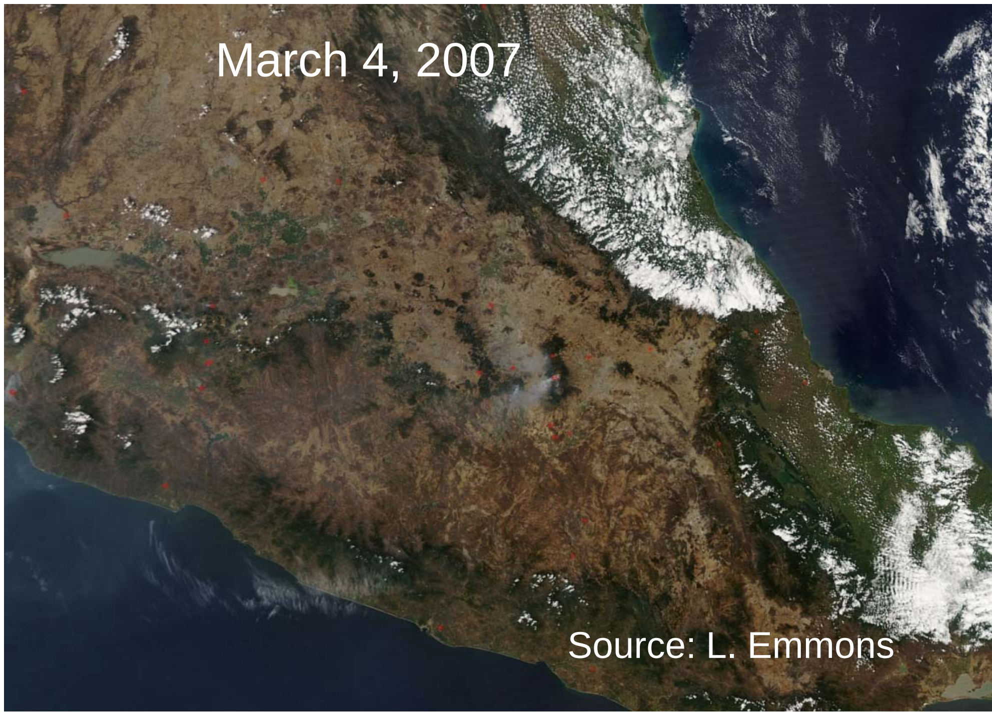
O3 - Greenhouse Gas

Regional and global climate impacts



P. Voss, R. Zaveri, T. Hartley, P. DeAmicis, I. Deonandan, O. Martinez, G.Contreras, D. Greenberg, M. Estrada, F. Flocke, S. Madronich, L. Kleinman, S. Springston, J. Hubbe, B. de Foy

Biomass Fires in Mexico City



Satellite image

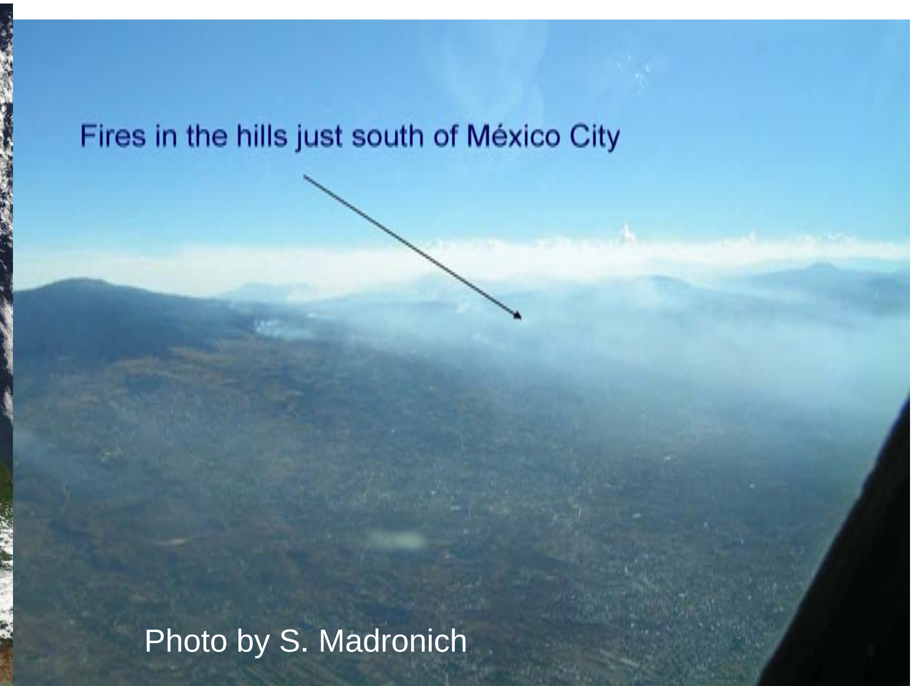


Photo taken from C-130

Numerous biomass fires were detected by satellite and their plumes were seem from the aircraft. Modeling is underway to determine the influence of biomass fires on urban and regional air quality.

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

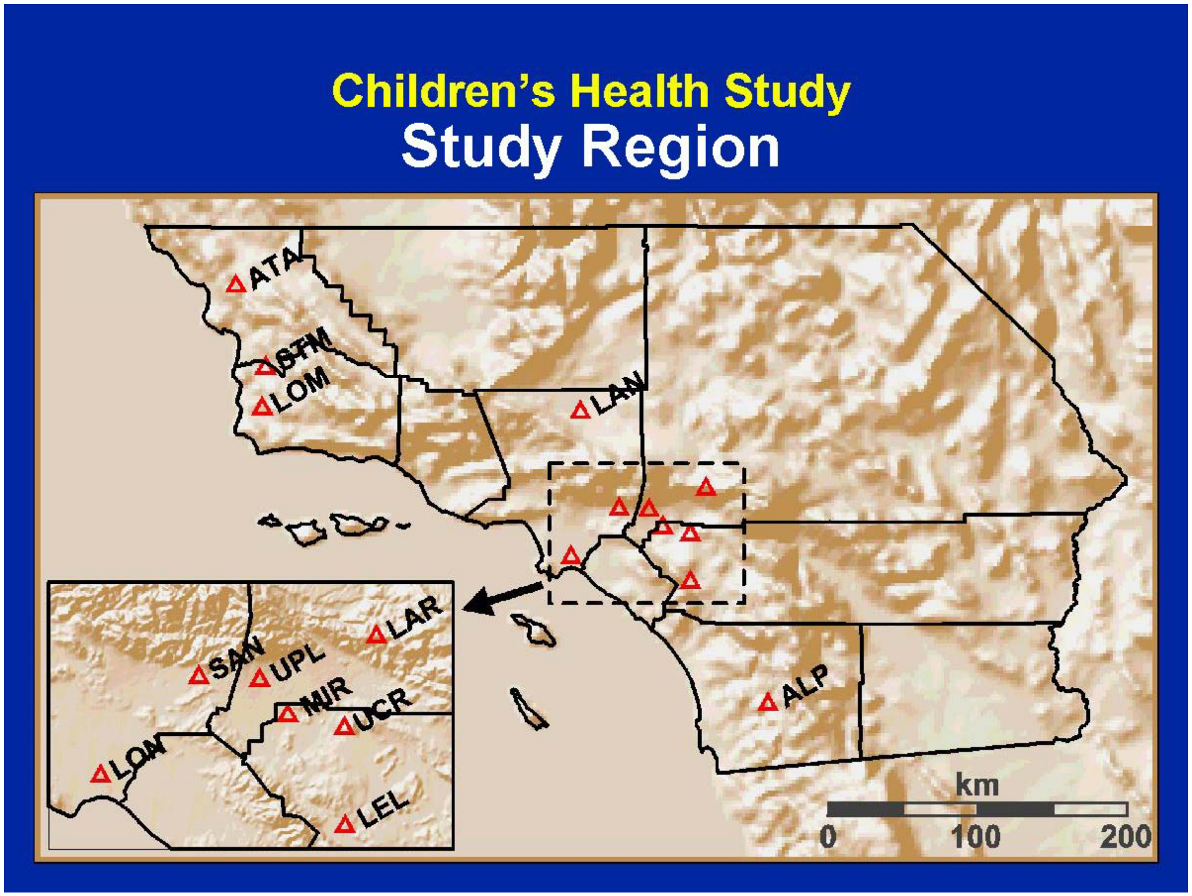
- **To analyze air pollution-related oxidative stress and health problems**

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

PI: H. Tovalin (UNAM)

California Air Resources Board

Air pollution harms children's lungs for life

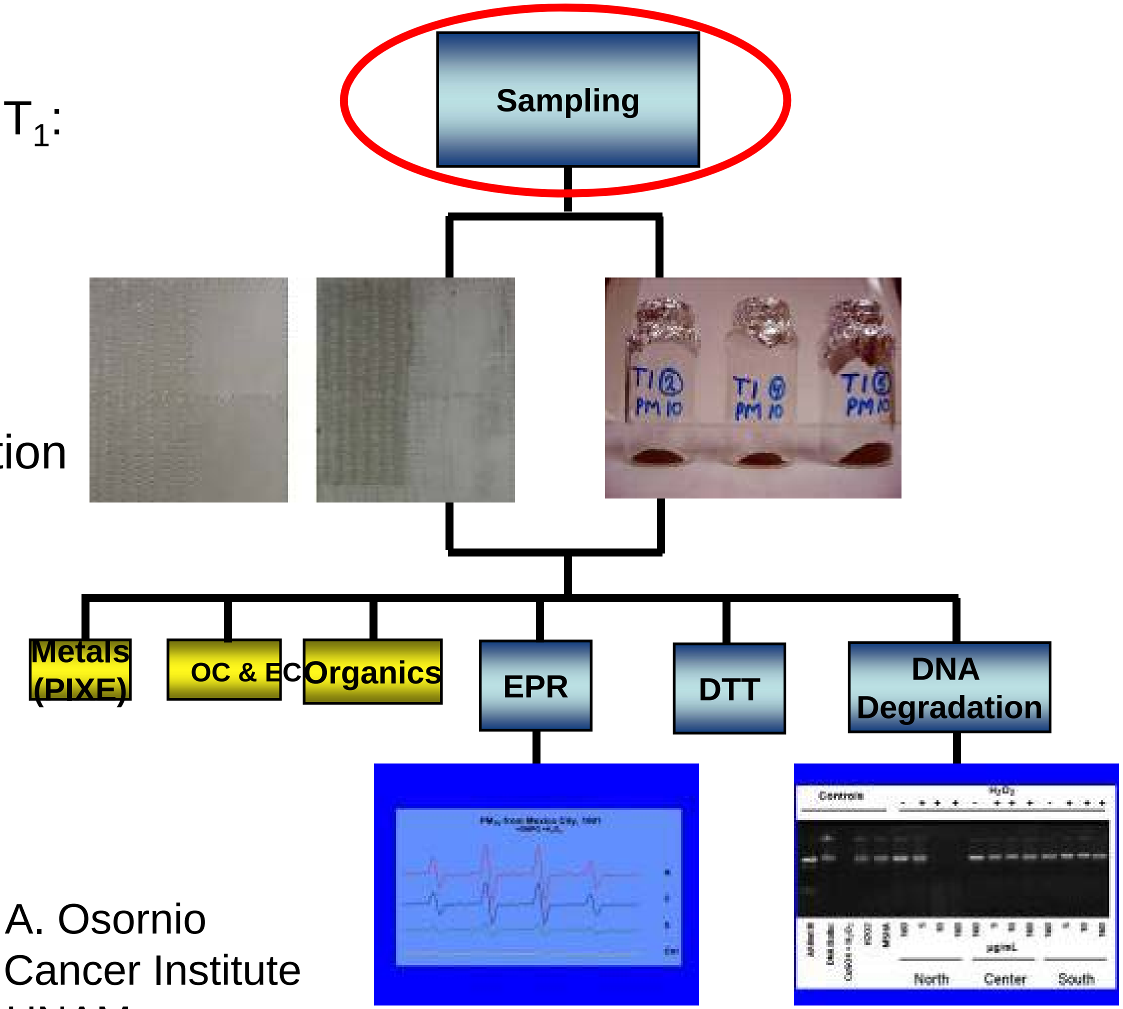


Children exposed to higher levels of particulate matter and other air pollutants had significantly lower lung function

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

Objetives

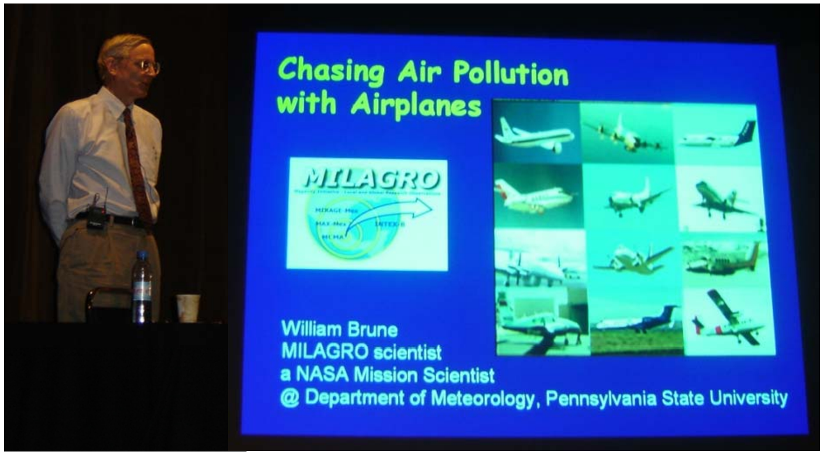
- Determine oxitavive potential of PM_{10} & $PM_{2.5}$ obtained at T_0 and T_1:
  - EPR
  - DNA Degradation
  - DTT Assay
- Compare oxidative potential (T_0 vs. T_1) and relate to composition and ventilation patterns.



PI: A. Osornio
National Cancer Institute
UNAM

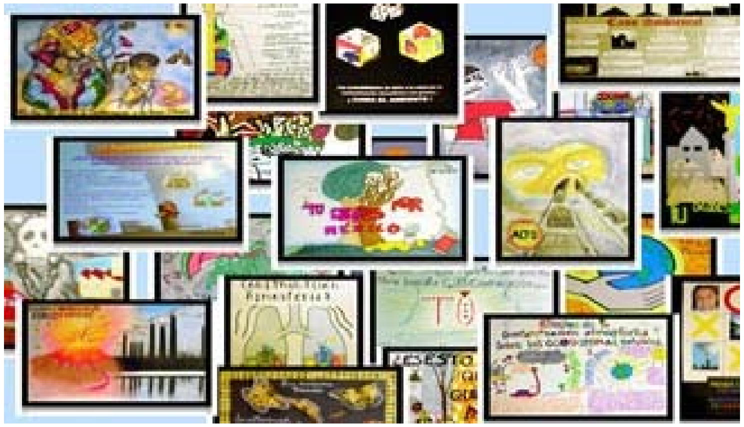
Education and Outreach Activities during MILAGRO

- **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.
- Guided tours to the supersites for officials and students

- Meteorological workshop for elementary students

- Internship for college students
- Documentary
- Communication via webpages
  - MCE2
  - "Windows to the Universe" (UCAR)

Source: http://www.mce2.org

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:
  - May 2007, Mexico City
  - December 2007 AGU Fall Meeting, San Francisco

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.

Challenges of Developing Countries

- Information gap - sources, emissions, ambient quality, health impact, costs/benefits ...
- Exponential growth in all sectors
- Lack of institutional capacity and organization
- Cross sectoral issues; governance
- Perception vs. Reality - lack of analysis
- Cost-effectiveness of options
- Financial constraints
- Lack of enforcement and public acceptance

→ ***Difficult task for decision makers***

Challenges for reducing transportation's contribution to air pollution

- Exploding demand for private automobile ownership
- Excessive age of vehicle fleet
- Quality of fuels
- Limited availability of technical and analytical skills
- Institutional capacity

Emission Control Strategies

- **Technology-based regulations**
- **Economic instruments**

  e.g., Emission trading

  Emission taxes

  Road pricing
- **Policy adaptation**

  e.g., Land use planning

  Infrastructure development

  Traffic management

There is no “magic bullet”: a mix of policy measures is needed to improve air quality. Need to integrate relevant policies for transportation, land use and air quality.

Strategies to reduce Transport-related Emissions in Mexico City

- Launch a program to retrofit or retire the dirtiest fleets of truck, buses, and automobiles.
- Tighten the “tailpipe standards” on all new cars, trucks, and buses sold in Mexico, so they conform to world class standards.
- Introduce ultra-low sulfur fuels, both gasoline and diesel, which is required for clean car and truck technologies.
- Build strategic corridors to reduce congestion and improve air quality
- Substitute low-capacity buses with Bus Rapid Transit (Metrobus)

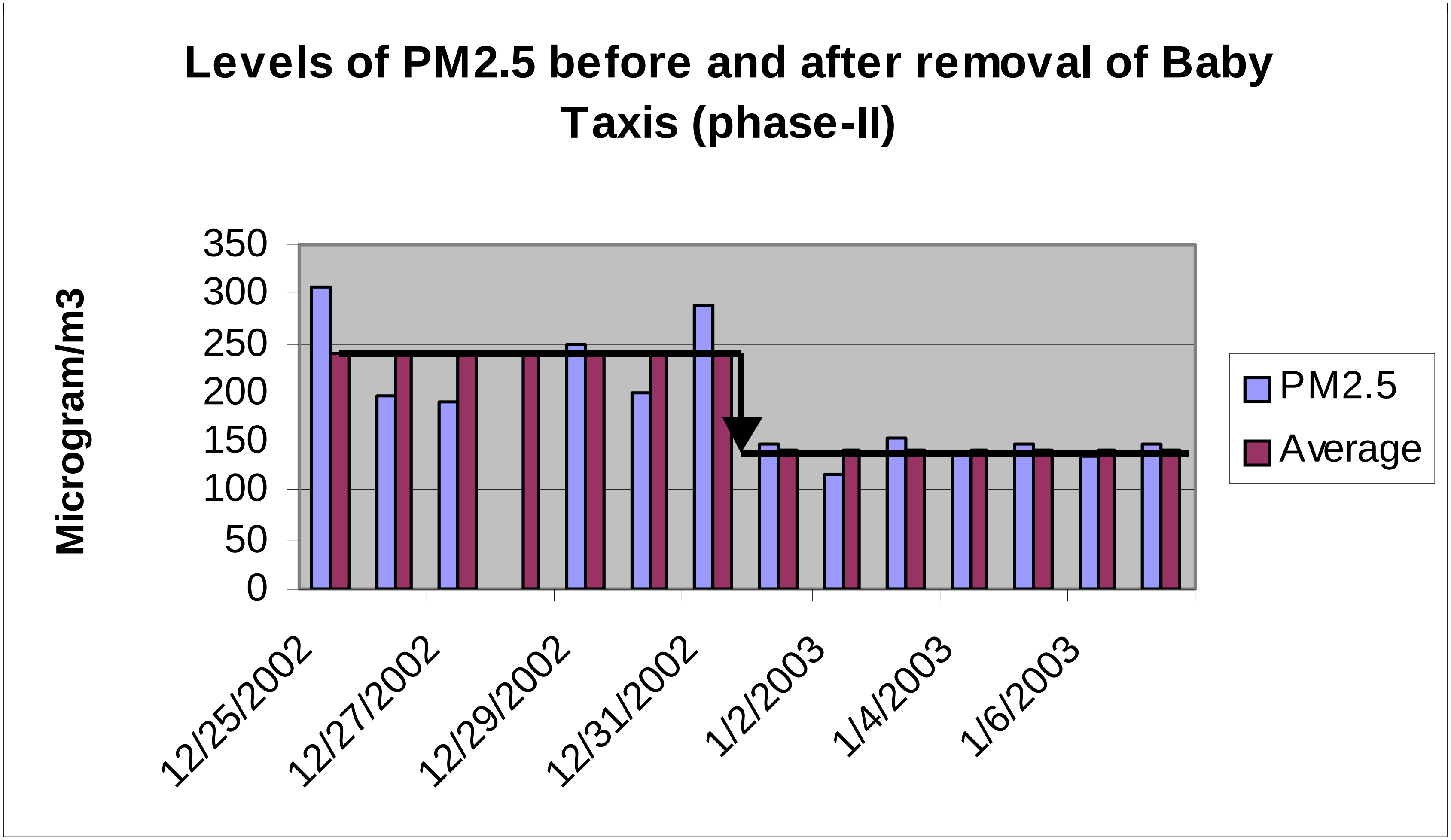
The TransMilenio BRT System of Bogotá, Colombia

- Bus Rapid Transit (BRT): includes exclusive median bus lanes on arterial roads, large buses, level boarding, prepayment, Intelligent Transportation Systems (ITS)
- Based upon successful experiences of Brazilian cities (especially Curitiba) and Quito,

Photo: TRANSMILENIO S.A.

Photo: TRANSMILENIO S.A.

Dhaka, Bangladesh: Two Stroke Phase-out PM2.5 concentrations decline 41%



Air Quality in Dhaka improved noticeably when the two wheelers were phased out on January 1, 2003.. However, the replacement diesel public transport vehicles called "human haulers" which were allowed in Dhaka have since negated some of this gain!

Conclusions

- Megacities present a major challenge for the global environment.
- Well-planned, densely populated settlements can reduce the need for land conversion and provide proximity to infrastructure and services.
- Sustainable development must include:

  1) appropriate air quality management plans;

  2) adequate access to clean technologies;

  3) improvement of data collection and assessment.
- Learning from the experiences and best (and worst) practices in other regions is important
- A successful result will be to arrive at integrated control strategies that are effectively implemented and embraced by the public.

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
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Universidad Nacional Autónoma de México (UNAM)
Universidad Tecnológica de Tecámac (Estado de México)
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Participating U.S. Institutions

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- Others