

# **Megacity Impacts on Regional and Global Environments: Mexico City case study (MIRAGE-Mex)**

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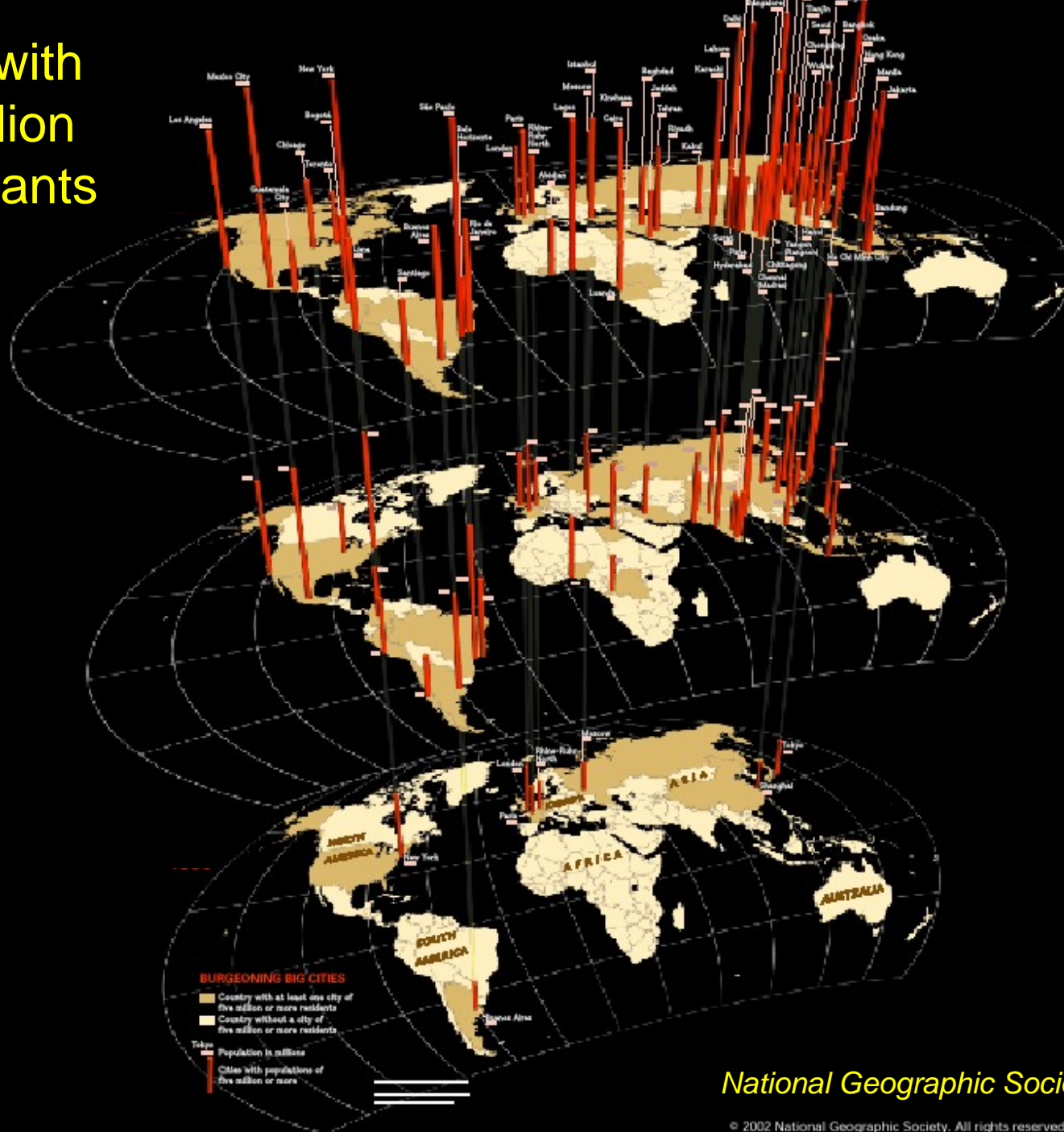
**NCAR**

# Cities with >5 million inhabitants

2015

2000

1950



National Geographic Society, 2002

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# GLOBAL CONCERNS

## ➤ **Regional and global air quality**

- Human health
- Impacts on agriculture and natural ecosystems
- Deteriorating visibility

## ➤ **Climate change**

- Increases in tropospheric O<sub>3</sub>
- Direct radiative effects of aerosols
- Indirect aerosol effects on clouds and precipitation

## ➤ **Tropospheric self-cleaning (oxidizing) capacity**

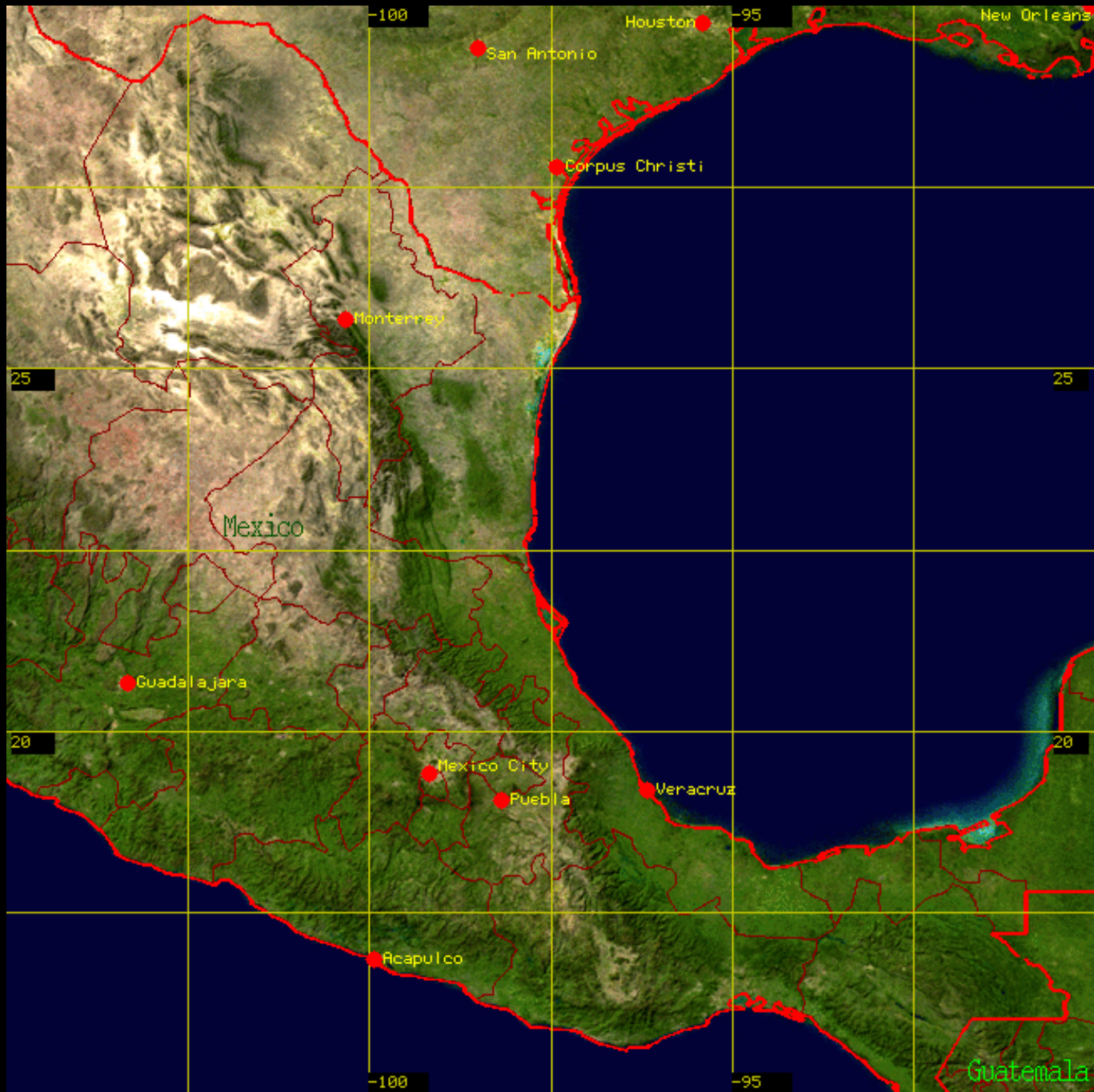
- Changes in atmospheric residence times of other climatically important gases (CH<sub>4</sub>, HCFC's...)
- Changes in spatial distributions (SO<sub>2</sub>, NO<sub>x</sub>, ...)

# GENERAL HYPOTHESES

- The polluted outflow from a single megacity is sufficiently reactive to affect the regional atmosphere and environment.
- The polluted outflow from all urban areas, taken together, affects the global atmosphere and environment, and will do so increasingly in the future.

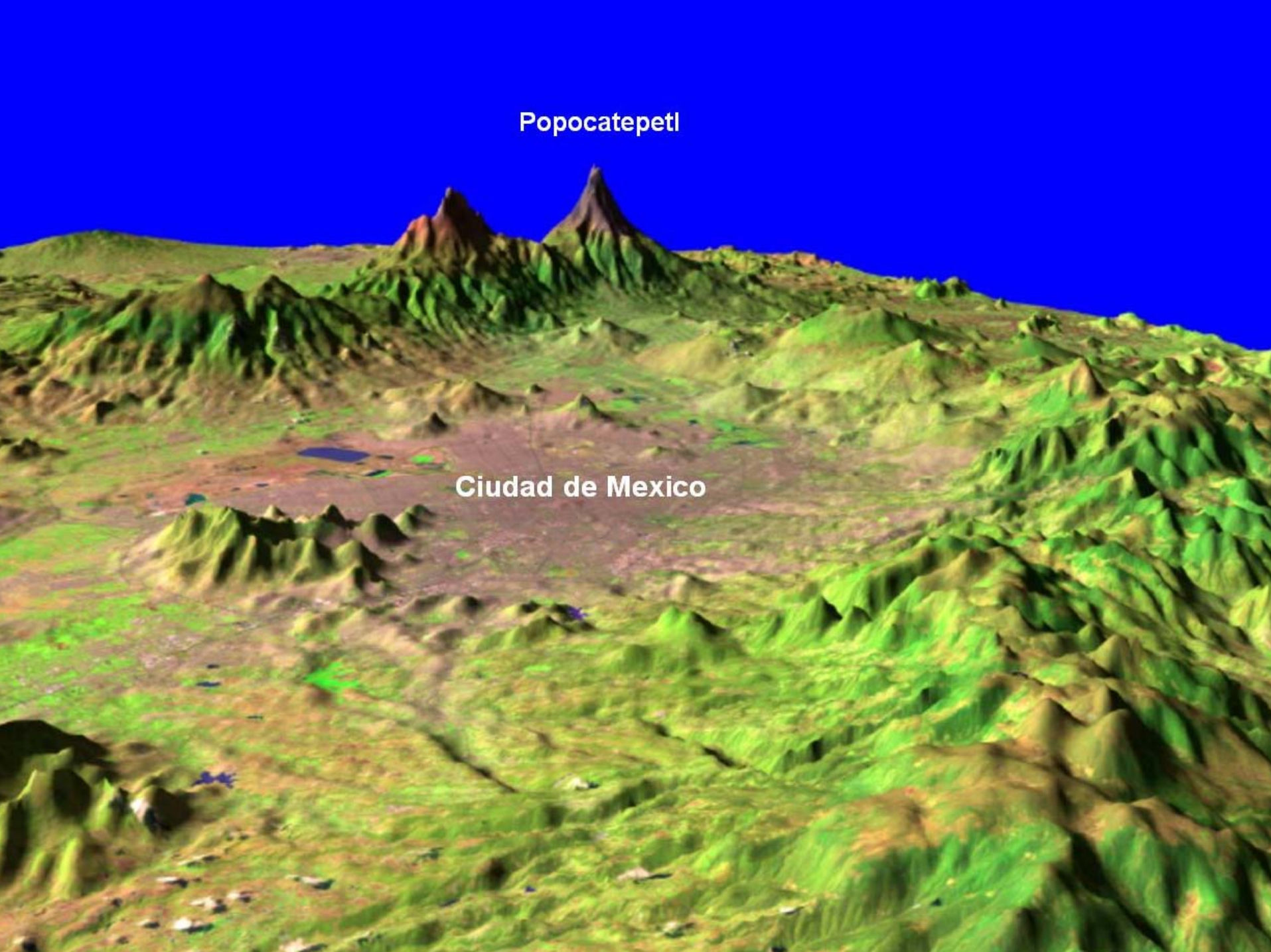
# MEXICO CITY

- **Size:** current population ~ 20 million.
- **Representative:** mature megacity with economy intermediate between emerging and fully developed.
- **Location:** tropics, high solar irradiation, strongest source in region (strong signal/background in outflow plume)
- **Knowledge baseline:** emissions inventories, routine long-term monitoring, intensive field campaigns.



Popocatepetl

Ciudad de Mexico



# URBAN AIR QUALITY

Impacts on human health





## **REGIONAL AIR QUALITY**

Impacts on agriculture and natural ecosystems

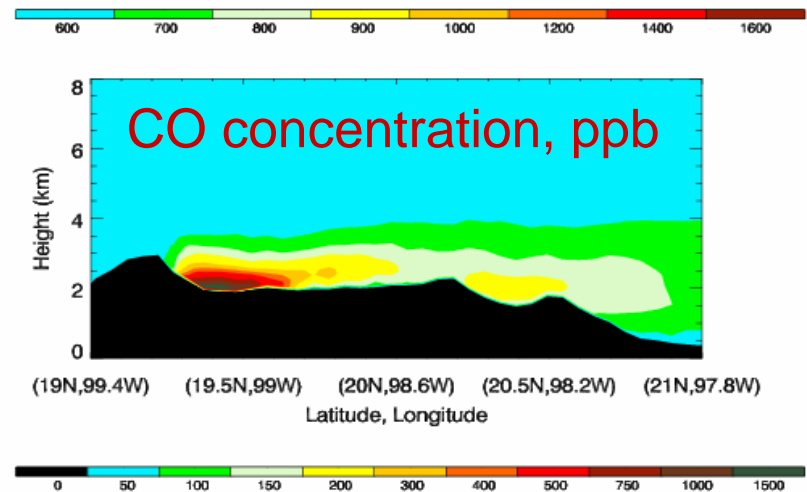
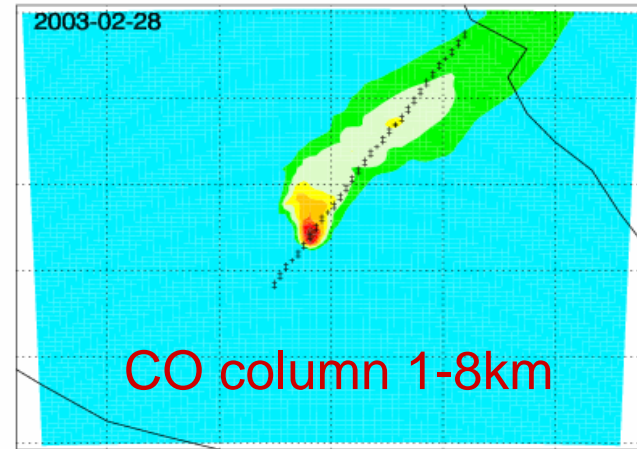
Deteriorating visibility

Changes in regional meteorology



# MIRAGE-Mex FIELD CAMPAIGN

- Organized by NCAR on behalf of the atmospheric sciences community
- 1-29 Mar 2006
- Observations near and down-wind of Mexico City, using the NSF/NCAR C-130 aircraft
- Ground based observations in and outside city
- Satellite observations
- Modeling



## SCIENCE OBJECTIVES: Quantify ...

1. Geographical extent and temporal persistence of the urban plume
2. Regional production of oxidants and radicals
3. Fate of hydrocarbon oxidation products
4. Long-range transport of reactive nitrogen
5. Coupled gas-aerosol processes
6. Evolution of aerosol radiative and microphysical properties
7. Regional surface-atmosphere interactions

# **MILAGRO: Megacity Initiative: Local and Global Research Observations**

## **THREE COORDINATED FIELD CAMPAIGNS 1-29 March 2006**

### **MIRAGE-Mex**

Megacity Impacts on Regional and Global Environments – Mexico

Lead scientist: Sasha Madronich (NCAR/National Science Foundation)

### **MCMA-2006**

Mexico City Metropolitan Area – 2006

Lead scientists: Luisa and Mario Molina (U. California San Diego)

### **MAX-Mex**

Megacity Aerosol Experiment - Mexico

Lead scientist: Jeff Gaffney (U.S. Department of Energy)

### **Other supporting studies:**

NASA DC-8 overflights

Satellite measurements

Laboratory analyses

Numerical models

# MILAGRO GEOGRAPHIC COVERAGE



**IMPEX**  
(NASA/NSF)

**MIRAGE-Mex**  
(NSF)

**MAX-Mex**  
(DOE)

**MCMA-2006**  
(Molina et al.)

# MÉXICAN INSTITUTIONS

**Centro Mario Molina para Estudios Estratégicos sobre Energía y Medio Ambiente**  
**Instituto Nacional de Ecología (INE)**  
**Universidad Nacional Autónoma de México (UNAM)**  
**Universidad Autónoma Metropolitana (UAM)**  
**Instituto Mexicano del Petróleo (IMP)**  
**Centro Nacional de Investigación y Capacitación Ambiental (CENICA-INE)**  
**Universidad Autónoma del Estado de Morelos (UAEM)**  
**Universidad Autónoma de San Luis Potosí (UASLP)**  
**Instituto Tecnológico de Estudios Superiores (Campus Monterrey y Estado de México)**  
**Instituto Nacional de Investigaciones Nucleares (ININ)**  
**Instituto de Investigaciones Eléctricas (IIE)**  
**Universidad Tecnológica de Tecámac (Estado de México)**  
**Universidad de Veracruzana (Estado de Veracruz)**  
**Instituto Nacional de Salud Pública (INSP)**  
**Secretaría de Medio Ambiente del Gobierno del Distrito Federal (SMA-GDF)**  
**Gobierno del Estado de México, Secretaría de Ecología (SEGEM)**  
**Consejo Estatal de Protección al Ambiente (Estado de Veracruz)**  
**Consejo Estatal de Ecología (Estado de Hidalgo)**  
**Consejo Nacional de Ciencia y Tecnología (CONACyT)**  
**Fundación México-Estados Unidos para la Ciencia (FUMEC)**

# U.S. INSTITUTIONS

Aerodyne Research, Inc.	U. California Berkeley
Argonne National Laboratory	U. California San Diego
Brookhaven National Laboratory	U. California Riverside
California Inst. of Tech.	U. California Irvine
Colorado State U.	U. Colorado
Georgia Inst. of Tech.	U. Iowa
Harvard U.	U. Hawaii
Lawrence Berkeley National Laboratory	U. Houston
Los Alamos National Laboratory	U. Massachusetts
Massachusetts Inst. of Tech	U. Miami
Montana State U.	U. Minnesota
National Center for Atmospheric Research	U. Montana
Pacific Northwest National Laboratory	U. Nevada
Pennsylvania State U.	U. Washington
Texas A&M U.	U. Wisconsin
U. Arizona	Washington State U.

## OTHER INTERNATIONAL PARTICIPANTS

Freie University of Berlin, Germany

University of Heidelberg, Germany

University of Leipzig, Germany

Ecole Polytechnique Federal of Lausanne, Switzerland

ETH-Zurich, Switzerland

Chalmers Technical University, Sweden

Göteborg University, Sweden

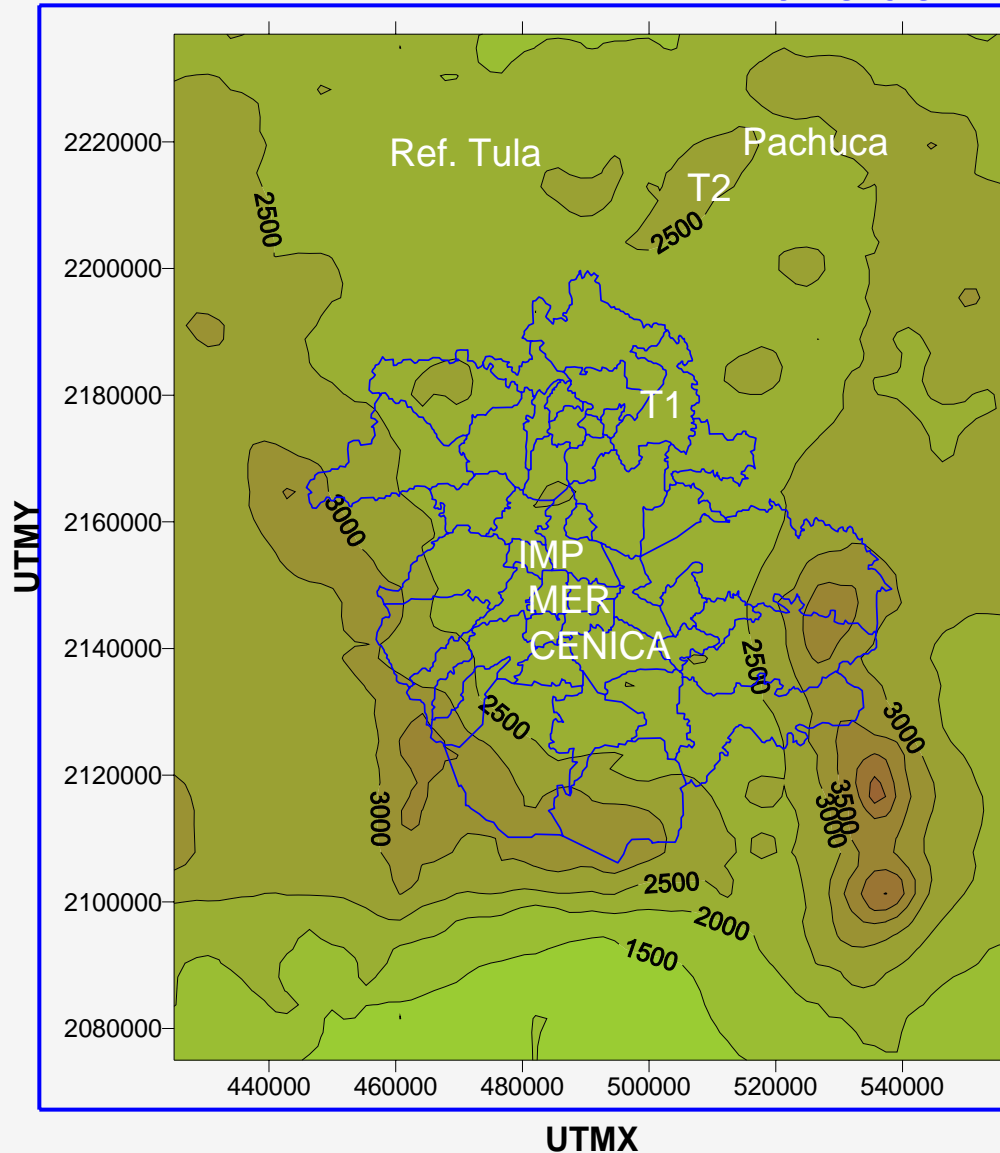
Centro de Estudios de la Tierra, Barcelona, Spain

National Institute for Environmental Studies, Tsukuba, Japan



# MILAGRO – SURFACE MEASUREMENTS

## Valle de México



**Surface measurement of gases, aerosol, and radiation at 3 supersites in and near Mexico City.**

**T<sub>0</sub>: CENICA (Inside Mexico City)**

**T<sub>1</sub>: Universidad Tecnológica de Tecámac (Estado de México)**

**T<sub>2</sub>: Ranch La Bisnaga (near Pachuca, Hidalgo)**

# Veracruz International Airport



03.31.2005

# MIRAGE-Mex

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Aircraft based in Veracruz (gases, particles, radiation)  
Surface measurements north of Mexico City

**NSF/NCAR C-130**



# MEASUREMENTS FROM C-130

**Gases:** H<sub>2</sub>O, O<sub>3</sub>, H<sub>2</sub>O<sub>2</sub>, NO, NO<sub>2</sub>, NO<sub>y</sub>, HNO<sub>3</sub>, HNO<sub>4</sub>, RONO<sub>2</sub>, total PANs, OH, HO<sub>2</sub>+RO<sub>2</sub>, NH<sub>3</sub>, SO<sub>2</sub>, H<sub>2</sub>SO<sub>4</sub>, DMS, OCS, MSA, H<sub>2</sub>, CO, CO<sub>2</sub>, speciated HCs, MtBE, halogenated organics, CH<sub>2</sub>O, OVOCs, CH<sub>3</sub>OOH, organic acids, HCN

**Aerosols:** size distributions, CN, CCN, bulk soluble organics, size-resolved non-refractory composition, absorption and scattering, size-resolved hygroscopicity, volatility, and mixing state, single particle soot mass, organic filters, morphology

**Physical:** Lat, lon, z, P, T, RH, IR, VIS, UV-A, spectral actinic flux,

# Far Transport Flight Plan 1



Pt.	Latitude	Longitude	Altitude	Time
0	<b>19.1640</b>	<b>-96.1710</b>	100	4:00
1	21.2214	-97.1079	20000	4:23
	Spiral descent			
	21.2214	-97.1079	1000	4:42
2	23	-97.5	10000	5:14
3	21.5	-95.8	10000	5:53
2	23	-97.5	16000	6:33
3	21.5	-95.8	16000	7:12
4	24.3	-97.5	10000	8:10
5	22	-95	10000	9:08
4	24.3	-97.5	16000	10:07
5	22	-95	16000	11:05
0	<b>19.1640</b>	<b>-96.1710</b>	100	11:54

# S Flight Plan 1



Pt.	Latitude	Longitude	Altitude	Time
0	<b>19.1640</b>	<b>-96.1710</b>	100	11:00
1	21.3428	-98.2512	18000	11:18
2	18	-100	18000	12:25
3	18	-98.1	(18000)	12:57
2	18	-100	12000	13:30
3	18	-98.1	(12000)	14:02
2	18	-100	1000AGL	14:35
3	18	-98.1	(1000AGL)	15:07
4	16.33	-100.5	20000	15:59
5	16.33	-97.75	(20000)	16:46
4	16.33	-100.5	13000	17:34
5	16.33	-97.75	(13000)	18:21
4	16.33	-100.5	7000	19:09
5	16.33	-97.75	(7000)	19:56
0	<b>19.1640</b>	<b>-96.1710</b>	100	21:44

# MAX- Mex

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Aircraft based in Veracruz (gases, particles, radiation)  
Surface measurements north of Mexico City

**DOE Gulfstream-1**



# DOE/NASA King Air

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Bases: Veracruz (nadir LIDAR)





# NASA J-31

Base: Veracruz (14- $\lambda$  radiation, aerosol optical depths)



# NSF – King Air

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Base: Pachuca (FTIR, observations of fires)

U. Montana/U.S. Forest Service



# IMPEX Intercontinental and Megacity Pollution Experiment

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Aircraft based in Houston, Texas (gases, particles, radiation)

**NASA DC-8**



# EXPECTED BENEFITS

- **Specific to Mexico City region:**  
First assessment of the regional air quality problem.
- **Geo-societal:**  
Gain early understanding of how future urbanization will influence air composition on large geographic scales.
- **Scientific:**  
Opportunity to study poorly-understood but important processes (coupled gas, aerosols, radiation, meteorology) in ageing urban air.