Overview: Megacity Aerosol Experiment-Mexico City (MAX-Mex)

Jeffrey S. Gaffney

University of Arkansas at Little Rock

Second MILAGRO Science Team Meeting

Mexico City, Mexico, DF

Tuesday May 15, 2007

UNIVERSITY OF ARKANSAS AT LITTLE ROCK

MILAGRO - March 2006

Megacity Initiative - Local and Global Research Observations

MCMA-2006 – *Mexico City Metropolitan Area – 2006*

Lead Scientist – Luisa Molina (Molina Center for Energy and Environment, MIT)

Adrian Fernandez – Instituto Nacional de Ecologia

MAX-Mex – ***Megacity Aerosol Experiment – Mexico City***

DOE: Lead Scientist, Jeff Gaffney (ANL, UALR)

Program Manager, Rickey Petty

MIRAGE-Mex – *Megacity Impacts on Regional and Global Environments – Mexico City*

NSF: Lead Scientist, Sasha Madronich (NCAR)

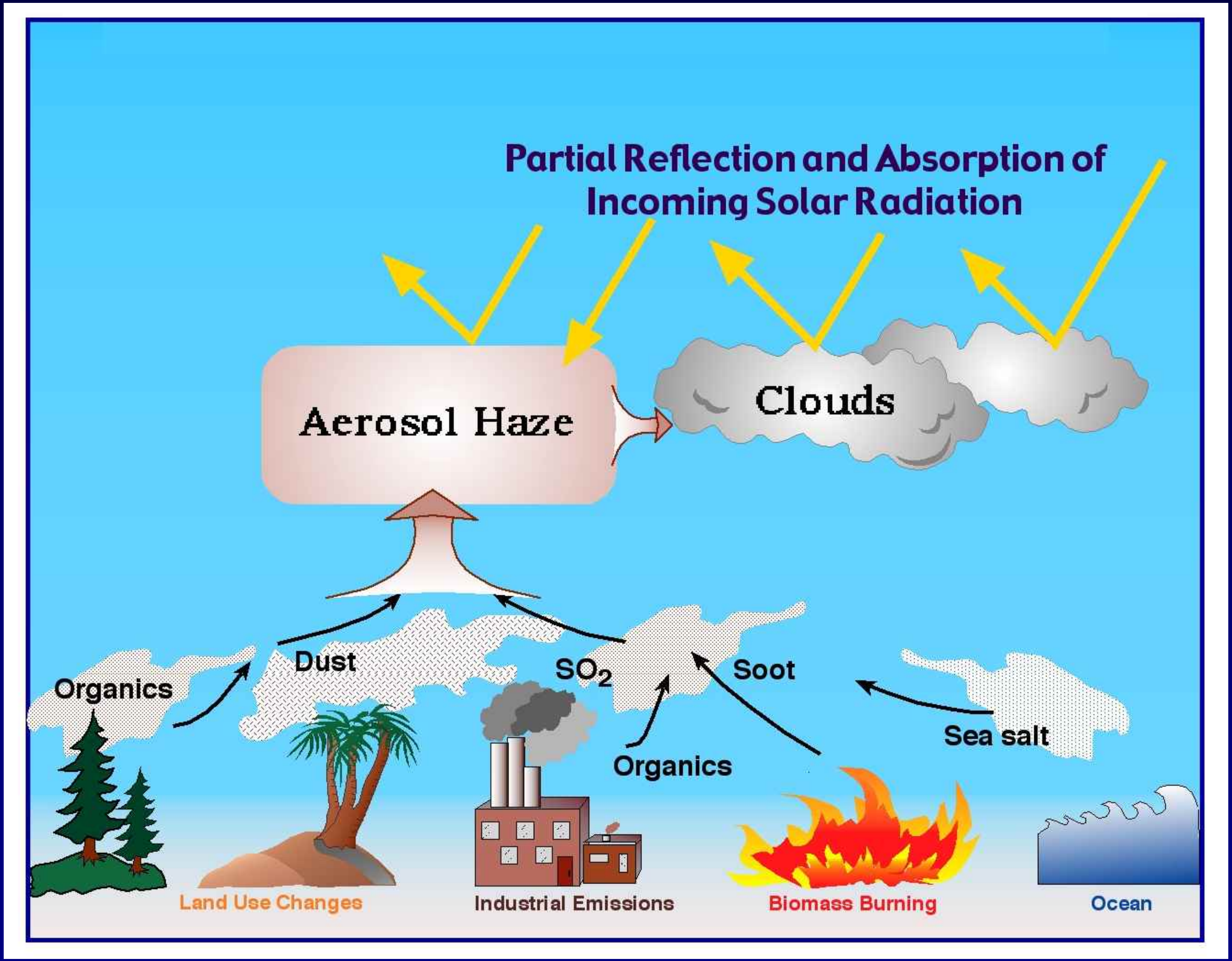
Program Manager, Anne-Marie Schmoltner

INTEX-B – *Intercontinental Chemical Transport Experiment (NASA, NSF)*

NASA: Lead Scientist, Hanwant Singh

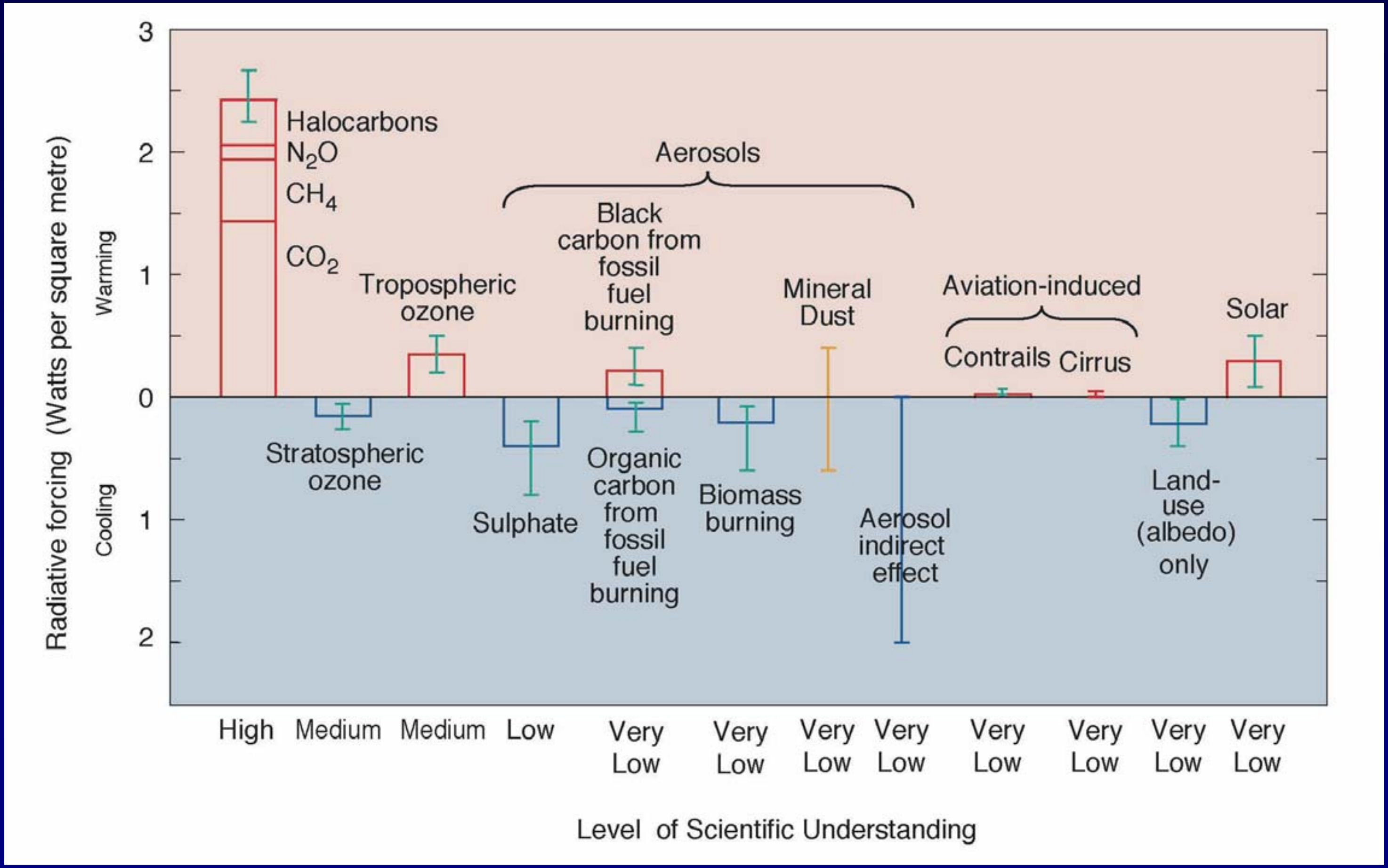
Program Manager, Bruce Doddridge

Radiative Forcing by Tropospheric Aerosols



Uncertainties in Global Climate Predictions

Global Mean Radiative Forcing of the Climate System for the Year 2000, Relative to 1750



Largest uncertainties associated with aerosols and clouds (IPCC 2001)

Objectives of ASP

http://www.asp.bnl.gov

Aerosol radiative forcing of climate:

- Enhance scientific knowledge needed to represent radiative forcing and other climatic influences of aerosols in climate models

Characterize, understand, and develop model representation of:

- Sources of particles and gaseous precursors
- Aerosol transformations
- Local and regional transport of particles and gaseous precursors
- Concentrations of gas-phase aerosol precursors
- Chemical, optical, microphysical, and cloud nucleating properties of aerosols
- Aerosol influences on atmospheric radiation

Aerosol Influences on Radiation and Climate

Direct Shortwave Radiative Effects (Clear air)

Light scattering – Cooling influence

Light absorption – Warming influence, depending on surface

Indirect Shortwave Radiative Effects – Aerosols influence cloud properties

More droplets – Brighter clouds

More droplets – Enhanced cloud lifetime

More droplets – Broadening of drop distribution – warming

Semi-Direct Shortwave Radiative Effect

Absorbing aerosol heats air and evaporates clouds

Longwave Radiative Effect (Clear sky)

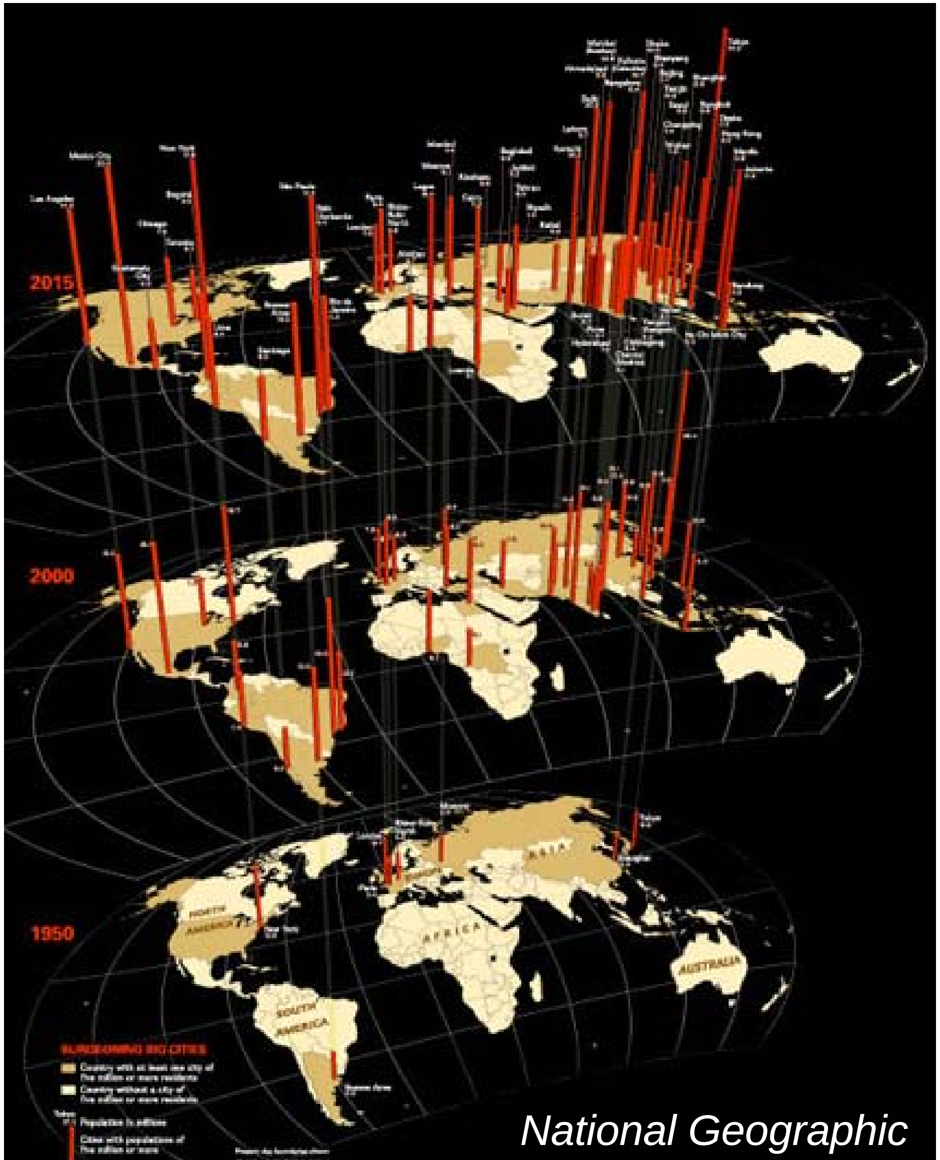
Greenhouse effect of aerosol particles

Hydrological Effects

Suppressed surface evaporation - spinning down the water cycle

Displaced precipitation - clouds last longer or evaporate

Megacities



National Geographic

Megacities

Population >10 Million

1950 – 1 (NYC)

1995 – 14

2015 – 21

Mini – Megacities

5 Million – 10 Million

1995 – 7

2015 – 37

Asia – Africa

2/3 rural to 1/2 urban by 2025

Sources of Aerosols and Precursor Gases

Megacities and mini-megacities are major sources

Need to better characterize aerosol properties and evolution for models.

Size, composition, size dependent composition, optical properties, cloud-nucleating properties.

High concentrations of aerosols and precursors

Carbonaceous aerosols: organic and black carbon; primary and secondary; fossil, biofuel, and biogenic; fossil and biogenic precursors

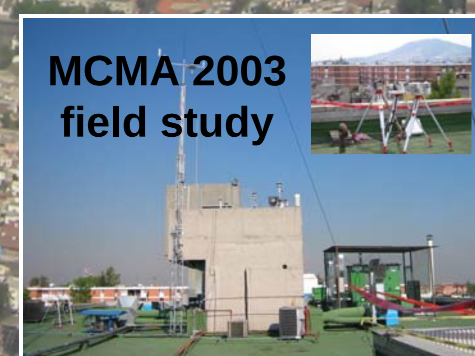
Inorganics: sulfate, nitrate and precursors SO_2, NO_x.

These sources will be changing over time as cities develop and technologies evolve.

Mexico City

Ideal Field Study Opportunity

- World's 2nd largest megacity
- Largest megacity in North America
- Basin meteorology - complex terrain
- Infrastructure connections!
- Size reasonable for aircraft and ground study
- Preliminary ground field studies - 1997 & 2003



MAX-Mex Science Tasks, Issues, Questions

Characterize aerosol size-dependent composition

Internal mixture vs external mixture
Water uptake dependence on relative humidity

Characterize aerosol optical properties and dependence on controlling variables

Composition, size dependence, size-dependent composition, humidity
Effects of chemical processing/aging
Contribution of BC and species other than BC to absorption

Characterize aerosol cloud nucleating properties and dependence on controlling variables

Composition, size dependence, size-dependent composition, humidity
Effects of chemical processing/aging

MAX-Mex Science Tasks, Issues, Questions, Cont.

Characterize and quantify secondary aerosol formation and aerosol evolution

New particle formation vs condensational growth

Role of coagulation in modifying size and composition distribution

Mechanism(s) of new particle formation and responsible species

Dependence on gas-phase precursors

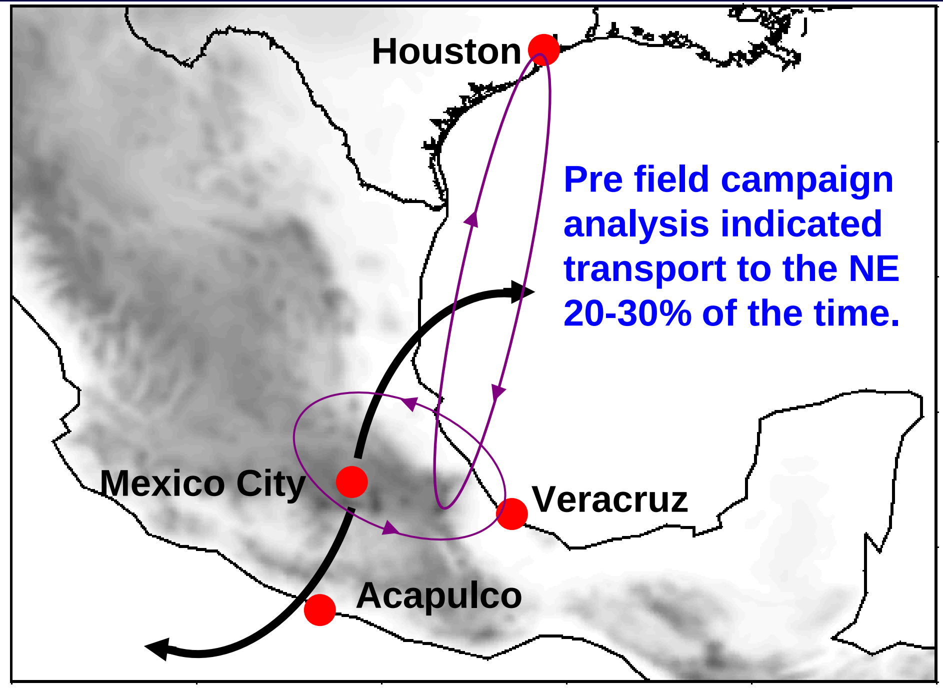
Urban vs regional vs global impacts – Effects of transport and scale for aerosol forcing

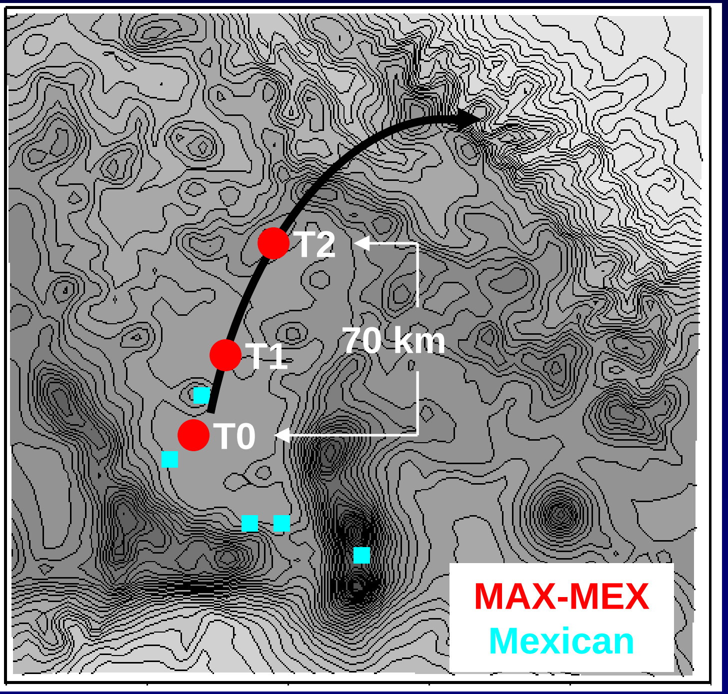
Spatial Impacts – Horizontal and Vertical – Temporal

Pre Field Campaign Activities

Modeling Used to Target Meteorology, Chemistry, and Aerosol

Instrumentation Sites for 2006 Field Campaigns



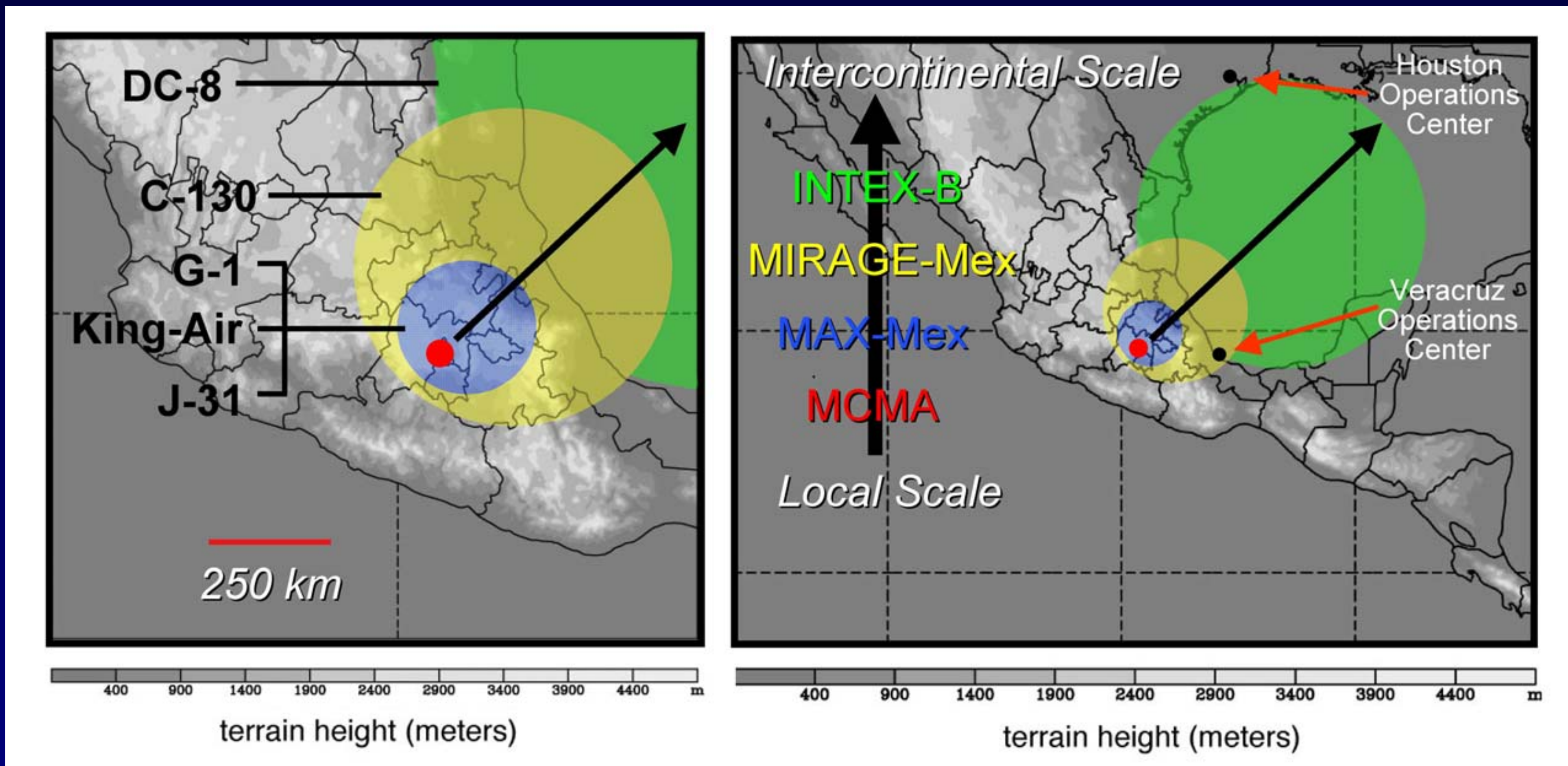


- Operational rawinsondes (NSF): supplemented to 4 per day at Veracruz and Mexico City and 2 per day at Acapulco
- Aircraft operations: Veracruz – NASA at Houston

- Radar wind profilers: T0, T1, T2, Veracruz
- Microwave radiometer: T0
- GPS radiosondes: T1, T2
- Tethersonde: T1
- Micropulse Lidar: T1

J. Fast, PNNL

Geographic Relation of Projects




G-1 (DOE)


C-130 (NCAR)


King-Air (NASA)

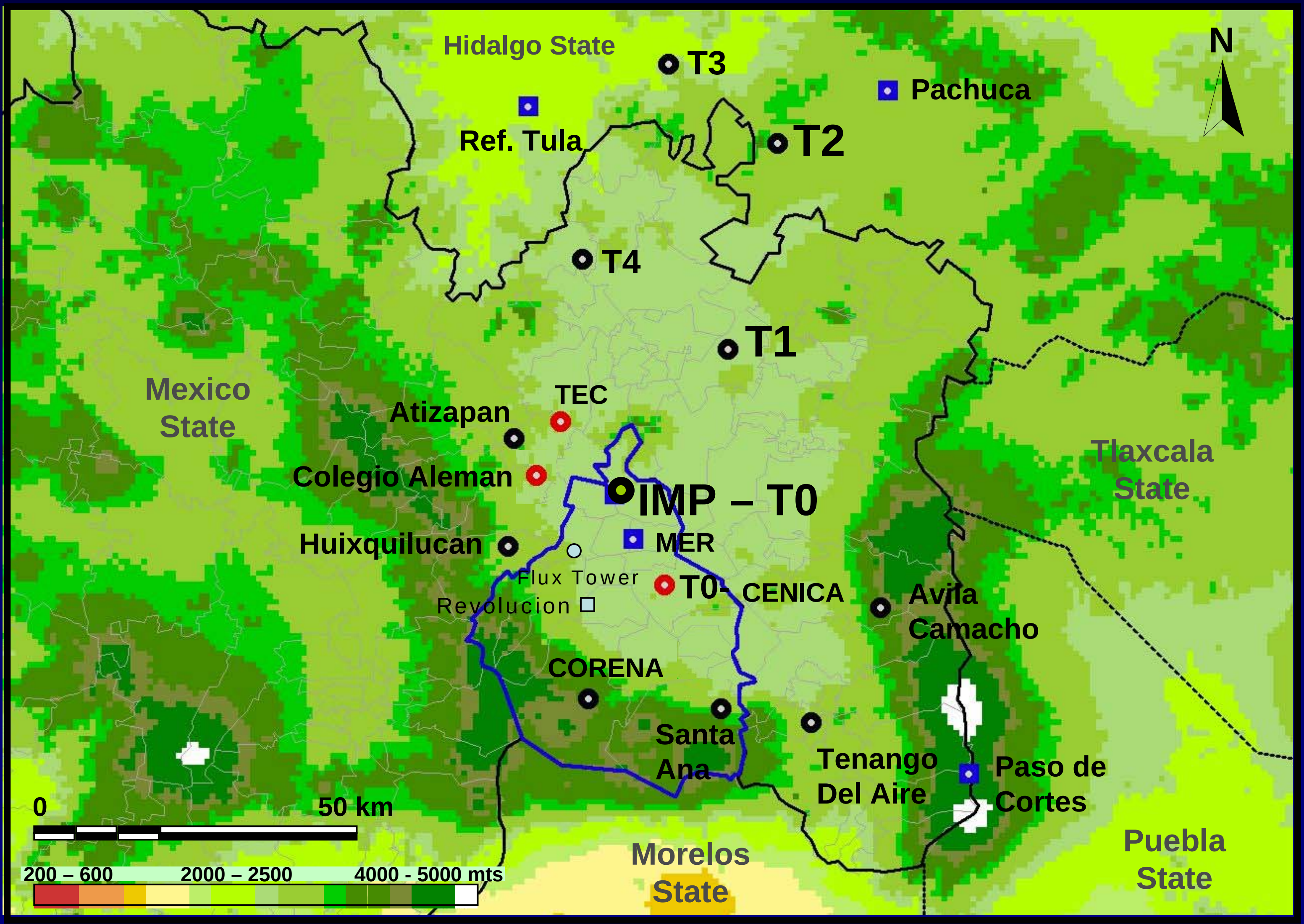

Twin Otter (U Montana)


J-31 (NASA)


DC-8 (NASA)

J. Fast, PNNL

MILAGRO Measurement Sites



Mobile site
Fixed site
Other measurements

MAX-Mex Participants and Instrumentation

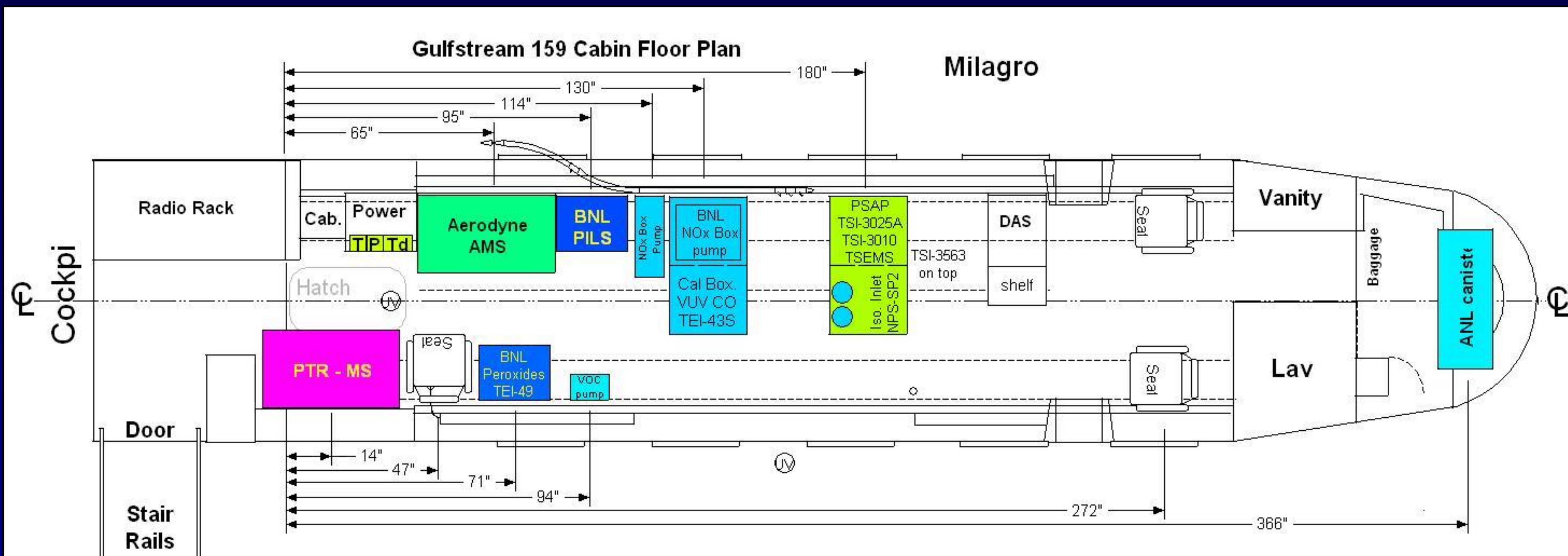
T0 Supersite

Mexico City
IMP

MET
RADIATION
AEROSOLS

UALR/ANL	Aethalometer (7 channel)	BC Aersosol absorption
UALR/ANL	Multi-angle Absorption	BC Aersosol absorption
UALR/ANL	Nephelometer 3 wavelength	particle scattering
UALR/ANL	Nephelometer 1 wavelength dry	dry particle scattering
UALR/ANL	Nephelometer 1 wavelength wet	wet particle scattering
UALR/ANL	Filter Sampler	OC/EC, humic like substances
UALR/ANL	Open path NIR TDLAS	NH3
UALR/ANL	Filter Sampler	14C, 40K, 210Pb, 7Be, 210Po, 210Bi,
UALR/ANL	RB Meter	UVB
UALR/ANL	Weather Station	wind speed/dir., rain, temp, press, RH
BNL	CCN Counter	cloud condensation nuclei
BNL	Scanning Mobility Particle Sizer	aerosol size distributions
DRI, U of Nev, Reno	Photoacoustic Spect.	aerosol absorption
PNNL	MFRSR	radiation, aerosol optical depth
PNNL	Solar Tracker	broad band radiometer
PNNL/EMSL	DRUM Aerosol Sampler	sampling for PIXE/PESA/STEM
PNNL/EMSL	TRAC Aerosol Sampler	sampling for TEM, SEM/EDX analysis
Aerodyne Res. Inc.	ARI H.R. TOF-AMS/soft ions	non-refractory fine PM size & comp.
University of Colorado	High Res. TOF-AMS	aerosol size and composition
University of Colorado	Thermal Denuder	aerosol volatility before AMS
University of Colorado	Aerosol Concentrator	aerosol concentration before AMS
University of Colorado	Optical Particle Counter	aerosol size, number (Grimm 1.109
University of Colorado	TSI SMPS	particle size distribution
University of Colorado	TSI nano-SMPS	nanoparticle size distribution
University of Colorado	TSI DustTrak	aerosol concentration

ASP G-1 Research Aircraft Facility Layout

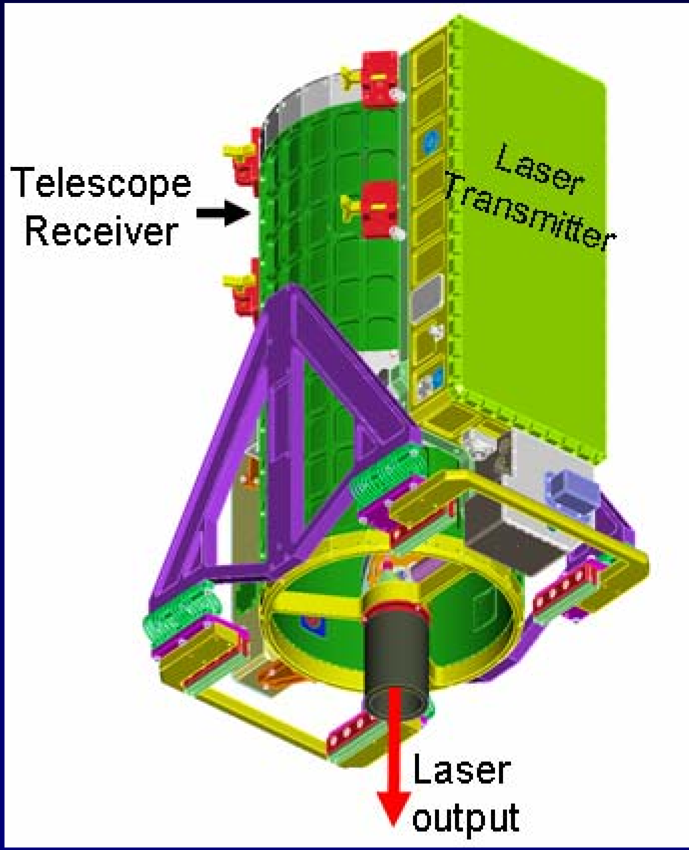


PCASP, CAPS – PNNL, BNL: Senum, Hubbe
State – PNNL: Hubbe
PTRMS - EMSL: Alexander, Ortega
AMS - Aerodyne, EMSL: Alexander, Jayne
Peroxides - SUNY, BNL: Lloyd, Bowerman
VOCs – York: Hubbe, Rudolf
PILS – BNL: Lee

CO, NO, NO_2, NO_y O_3, SO_2 – BNL: Springston, Senum
PSAP, Neph, CNCs – PNNL: Group
TSEMs – BNL: Wang
MFRs – PNNL: Barnard
SPSP – DMT, CIRPAS: Kok, Jonsson, Senum
Balloons – PNNL: Zaveri, Hubbe
Data – PNNL, BNL: Hubbe, Springston, Senum

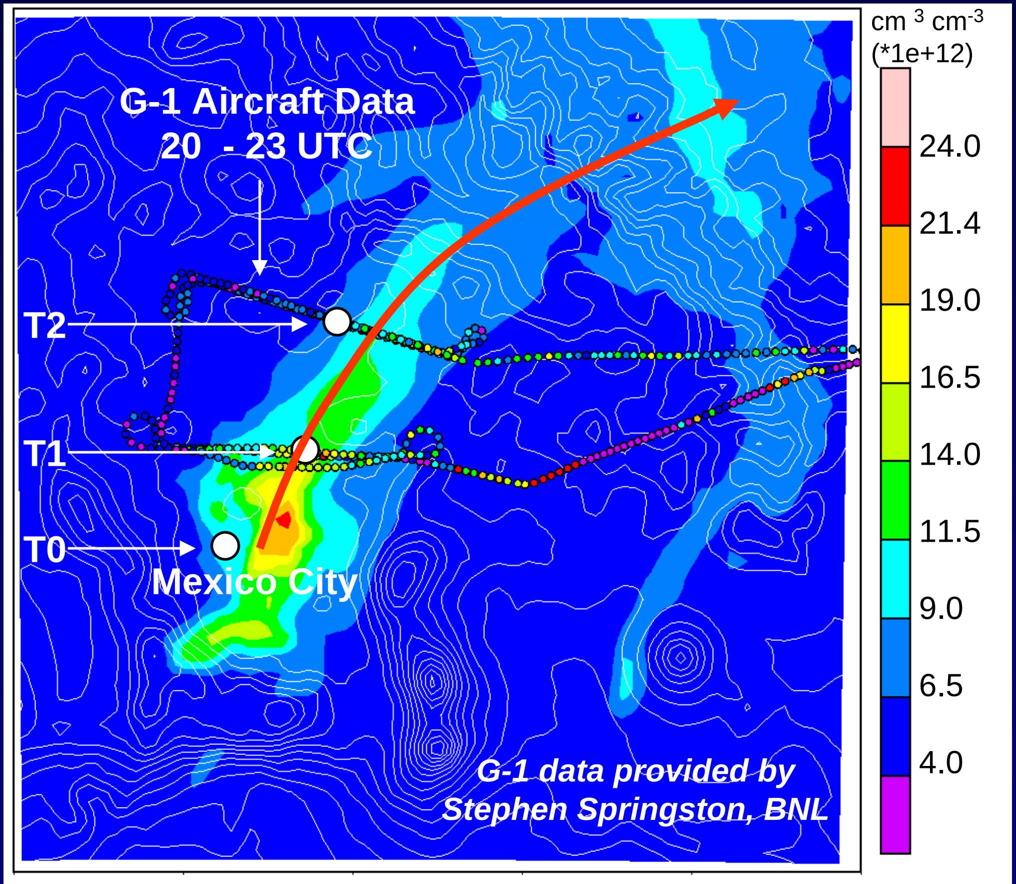
NASA King Air

Base: Veracruz
Airborne High Spectral
Resolution Lidar (HSRL)

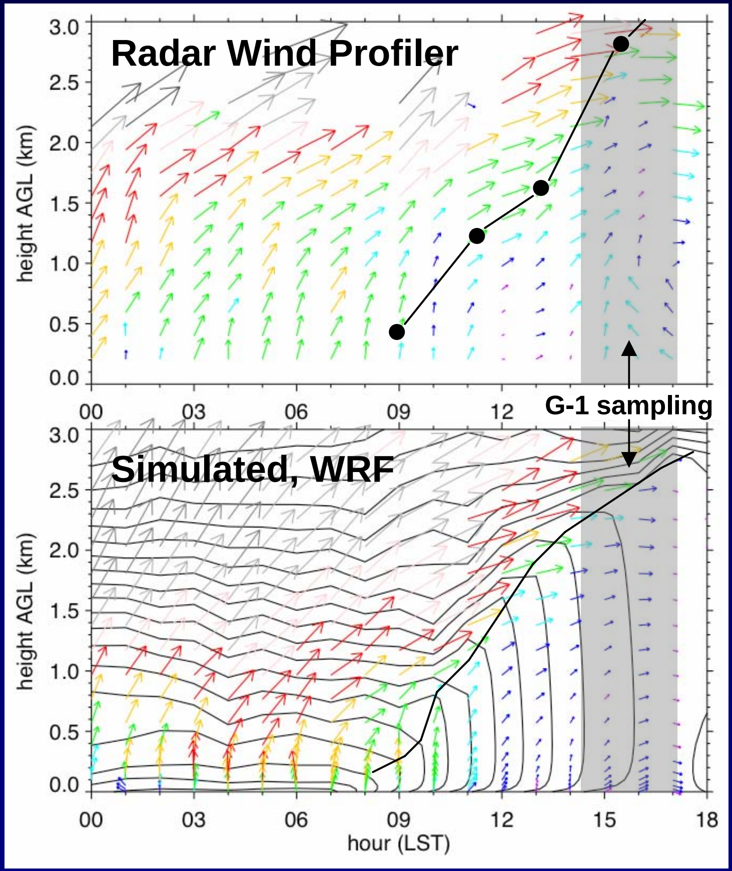


Sampling Strategy a Success

WRF-chem Particulate Volume Prediction
21 UTC 20 March, ~990 m AGL



Wind Profiles and PBL
at T1, 20 March



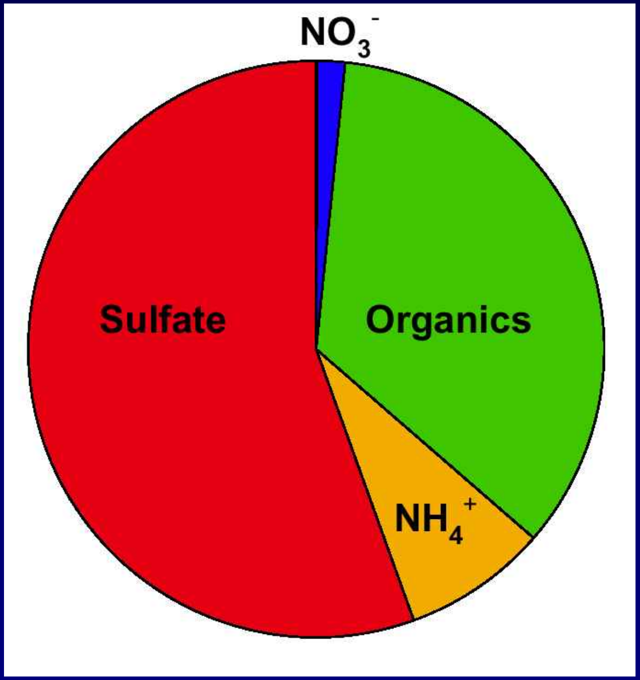
- T1/T2 transport scenario occurred on 4-5 days during March 2006.
- Simulated downwind plume in good agreement with observations.
- Strong ambient SW flow aloft decreases during day.

J. Fast, PNNL

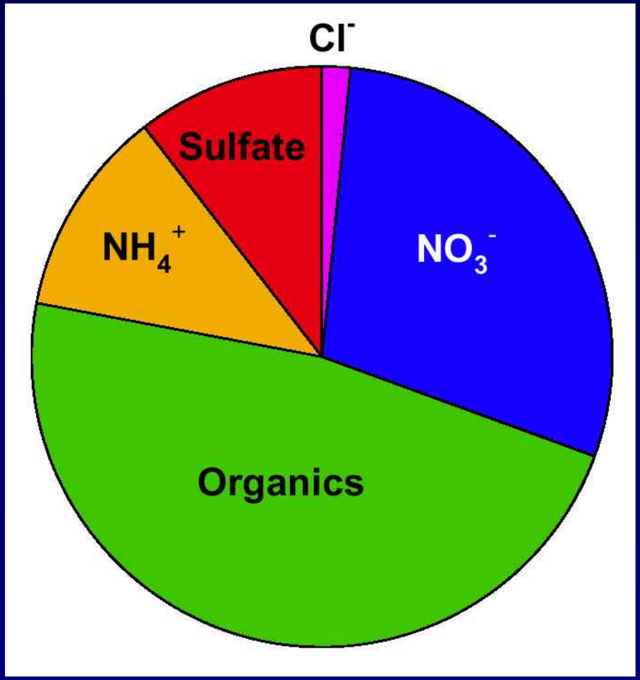
Aerosol Composition Comparison

Aerosol Mass Spectrometer Measurements from G-1

Eastern U.S. Regional Pollution



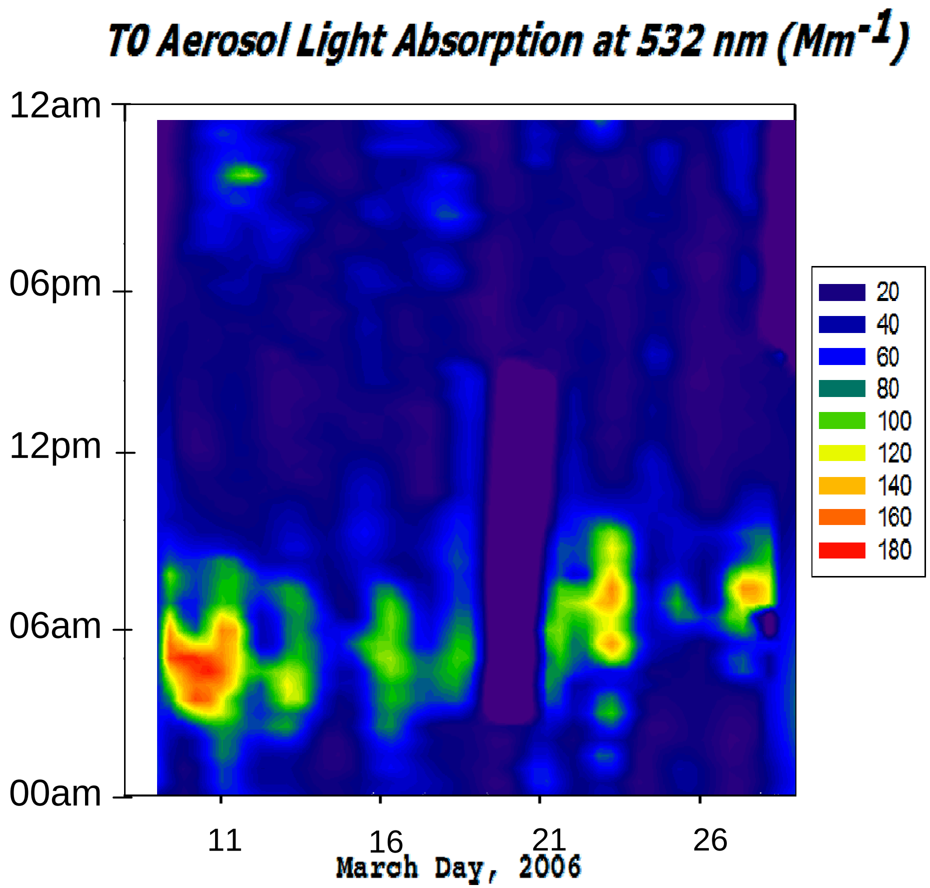
Mexico City Urban

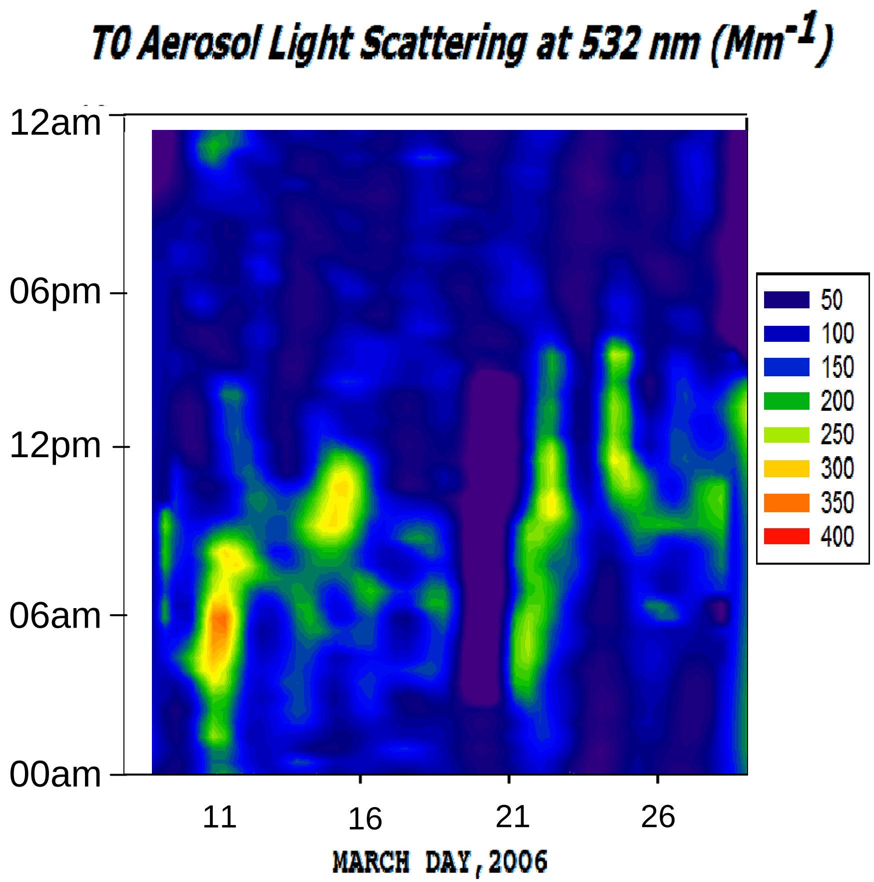


- Eastern U.S. episodes - sulfate dominated
- Mexico urban aerosol - organic dominated, with nitrate

L. Kleinman, BNL

TO Site Mexico City, Aerosol Optics for 532 nm



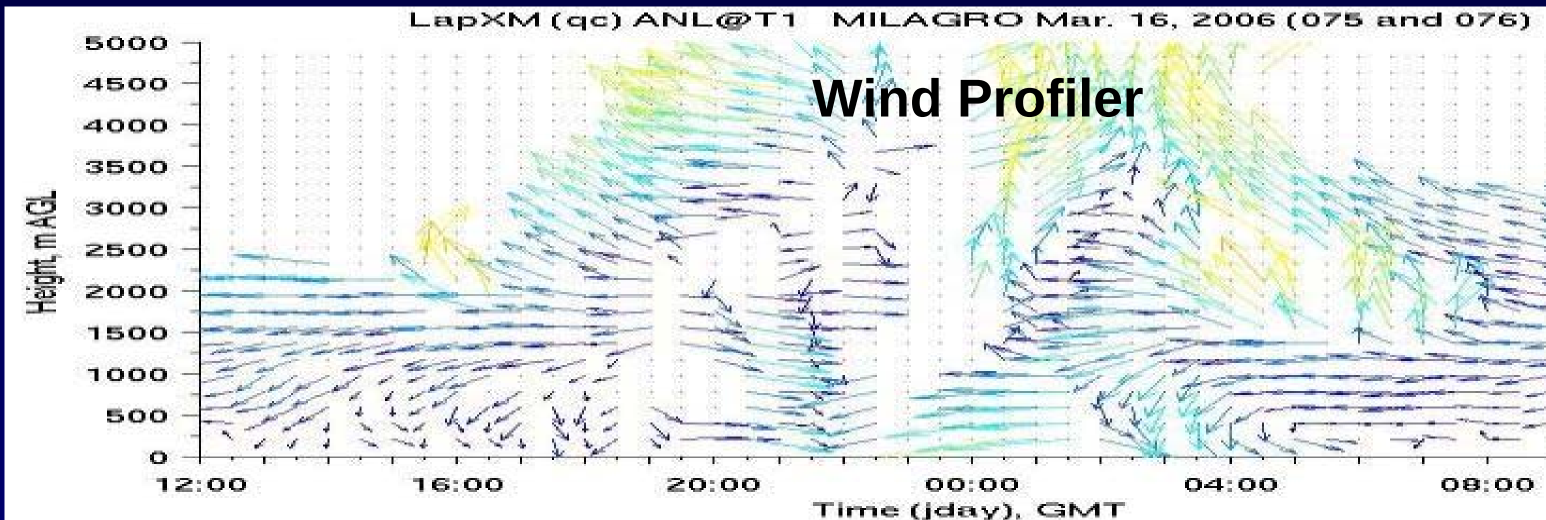


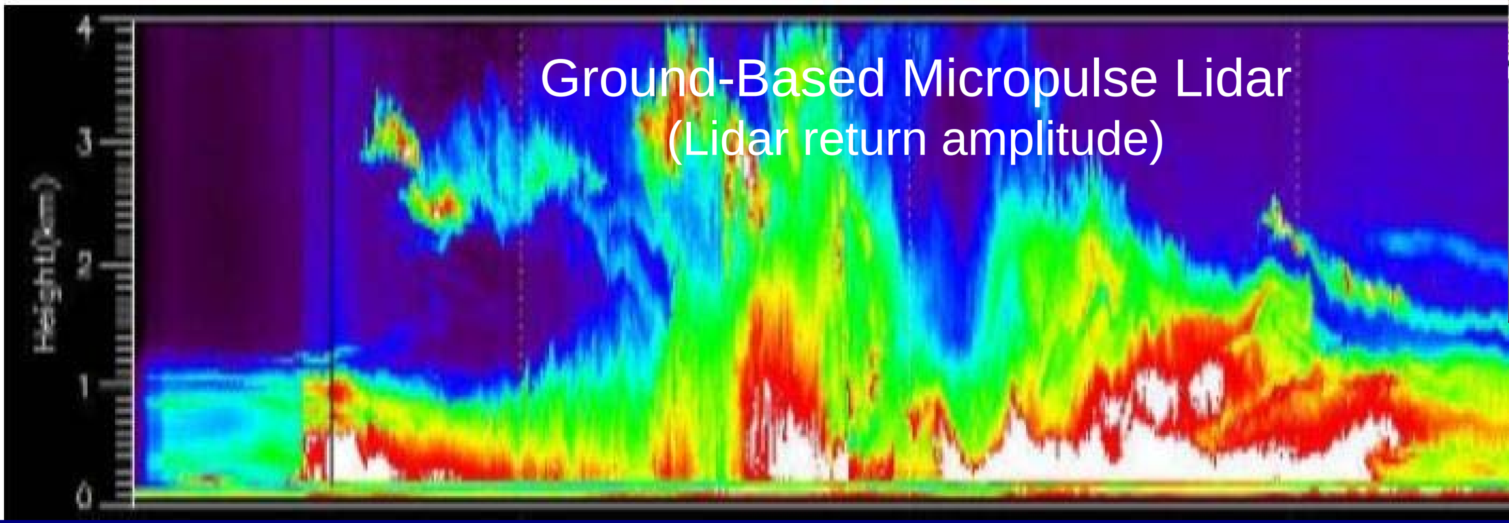
Aerosol Absorption: *Note the day to day variability in the peak absorption, probably due to meteorology.*

Aerosol Scattering: *peaks later in the day than absorption, due to dust, OC, secondary organic aerosol, and inorganics. (W. Patrick Arnott, U. Nev. Reno)*

Layering of Aerosols aboveT1

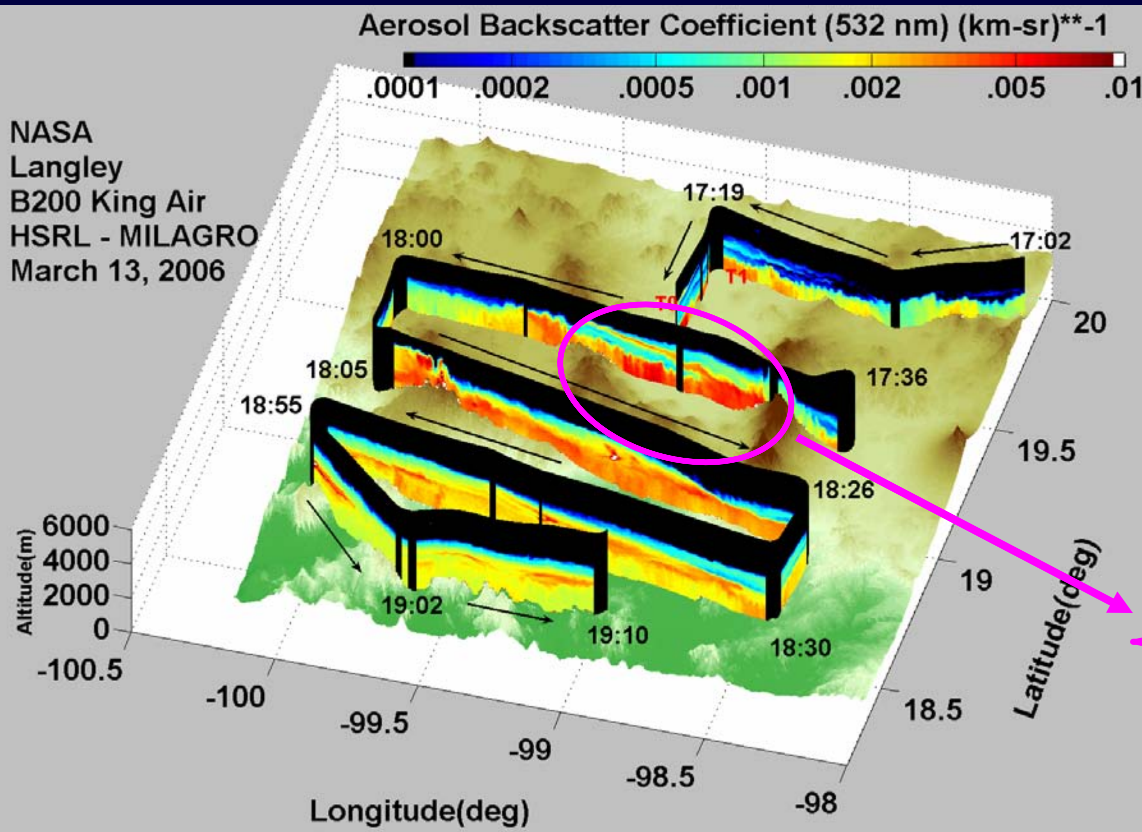
Aerosols lofted from Boundary Layer into Lower Troposphere

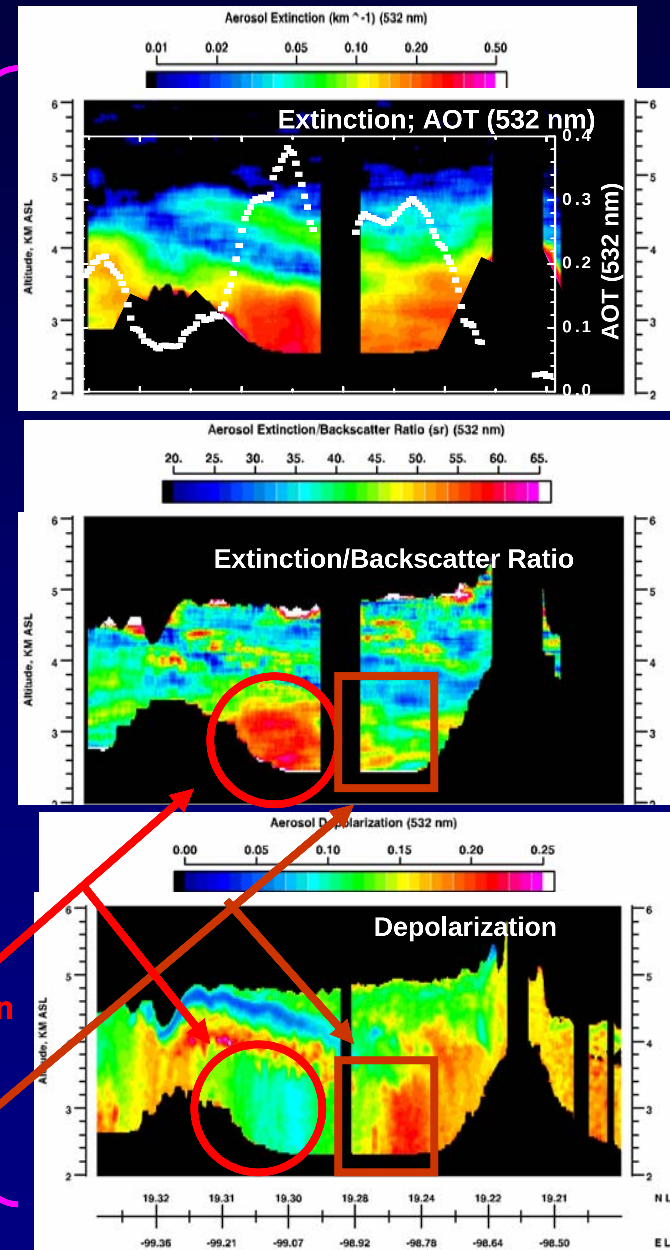




R. Coulter, ANL

Determination of Aerosol Type



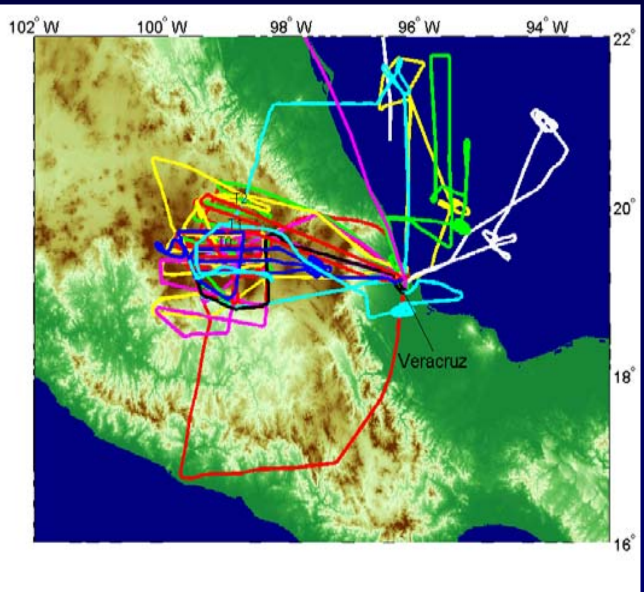


Aerosol types inferred from HSRL measurements Over Mexico City (MC) during INTEX-B/MILAGRO

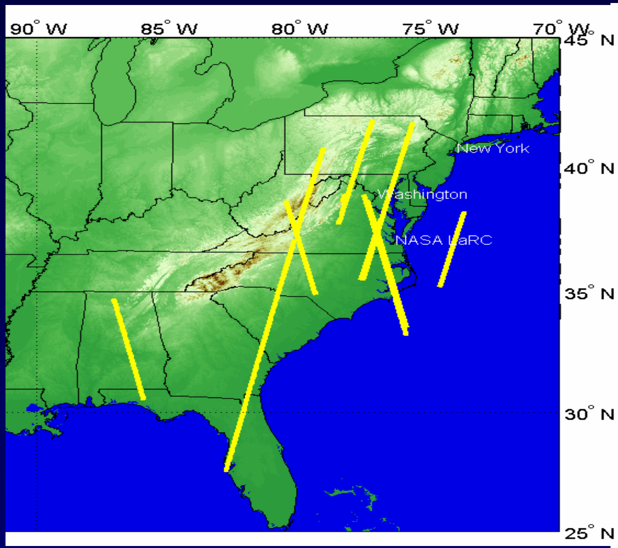
- **West side of MC basin**
  - **High extinction/backscatter ratio, low depolarization: urban pollution**
- **East side of MC basin**
  - **Low extinction/backscatter ratio, high depolarization: dust**

Hostetler,Ferrare NASA

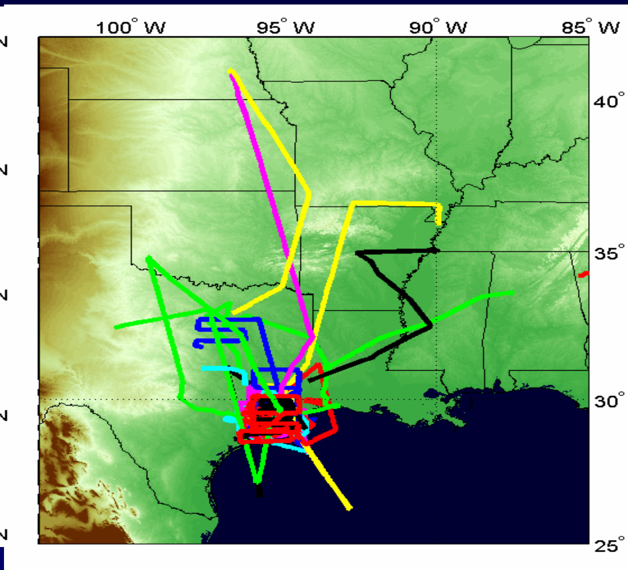
B200/HSRL Field Missions in 2006



MAXMex/MILAGRO/INTEX-B
DOE-NSF-NASA-Mexico
March 1-30



CALIPSO Validation
June 14 – Aug 10



TexAQS II/GoMACCS
NOAA-DOE-NASA
Aug 27 – Sep 29

15 science flights, 55 flight hr

- 5 flights with J-31
- 6 flights with G-1
- 4 flights with C-130
- 5 MISR coincidences
- 10 MODIS coincidences

10 CALIPSO validation flights

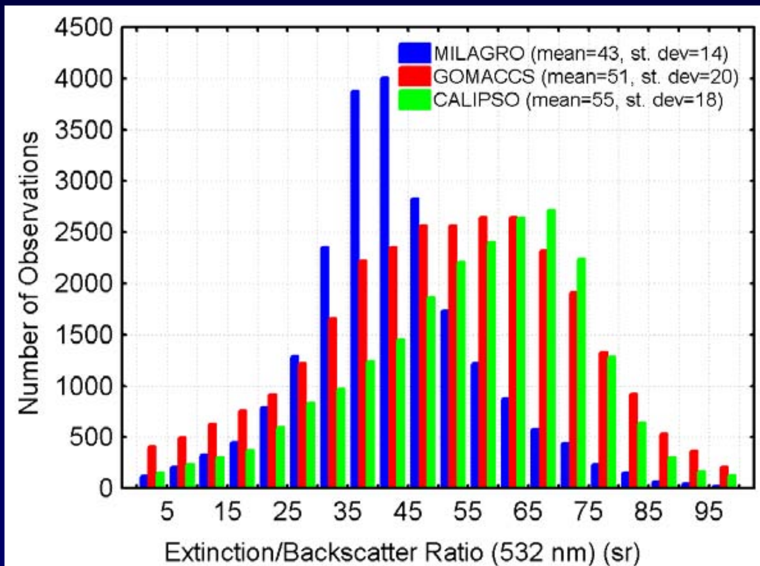
- 6 flights in “Early Phase” starting immediately after CALIPSO configured for science ops (14-30 June)
- 4 flights as part of CCVEX (July-Aug)

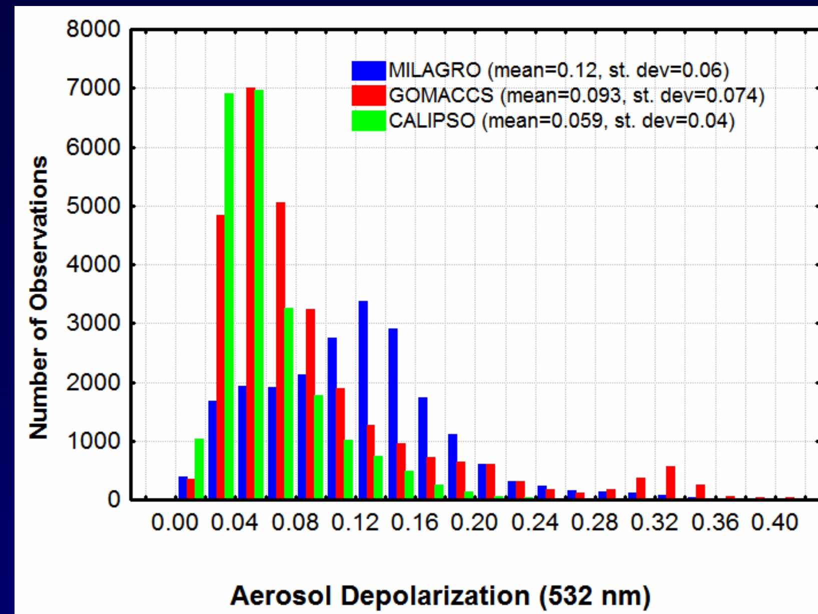
22 science flights, 90 flight hr

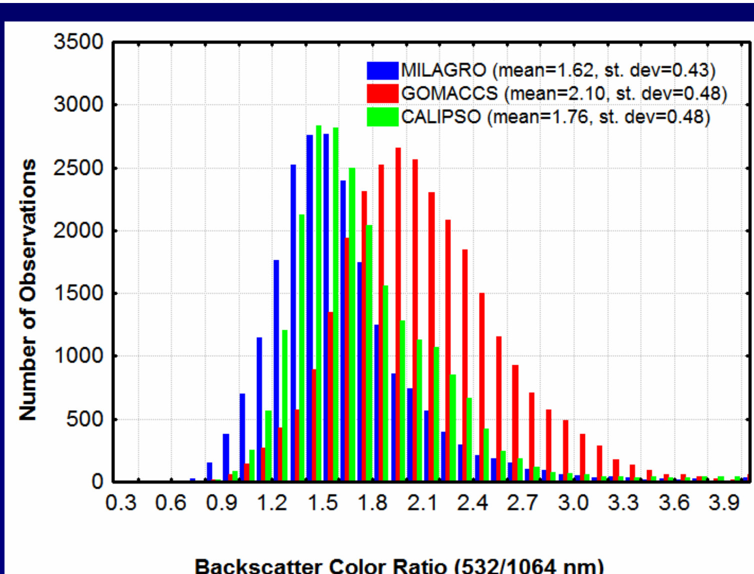
- 7 flights with NOAA WP-3
- 6 flights with NOAA Twin Otter
- 7 flights with CIRPAS Twin Otter
- 2 flights over the RHB
- 4 MISR LM coincidences
- 14 MODIS coincidences

Hostetler,Ferrare NASA

Aerosol Intensive Parameters derived from HSRL data



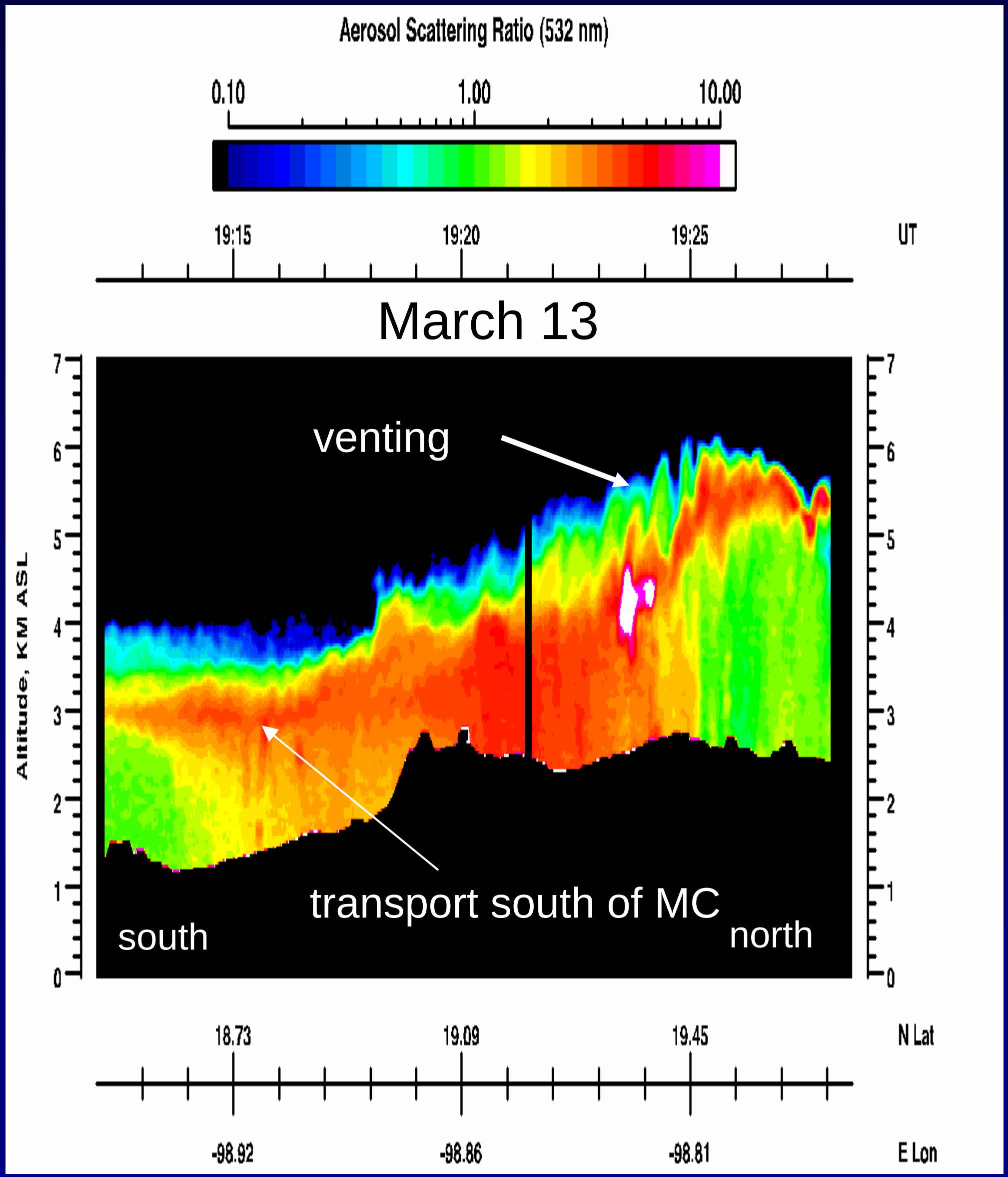


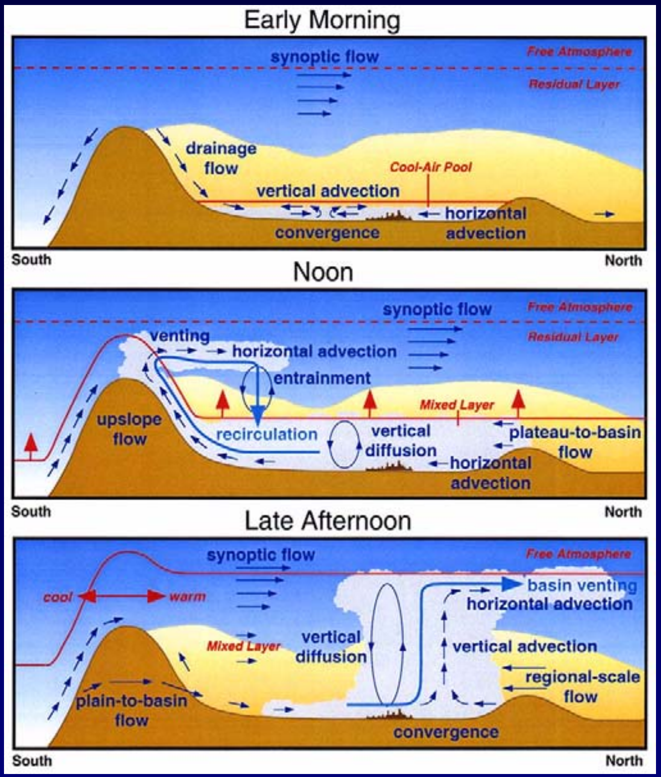


- **MILAGRO (Mexico)**
  - **higher depolarization, smaller color ratio, smaller S_a**
  - **larger, more non-spherical**
  - **dominated by "dust"**
- **GOMACCS (Houston)/CALIPSO (Eastern U.S.)**
  - **smaller depolarization, higher color ratio, larger S_a**
  - **smaller, more spherical**
  - **dominated by "urban/biomass"**

Hostetler,Ferrare NASA

Aerosol Venting into Free Troposphere



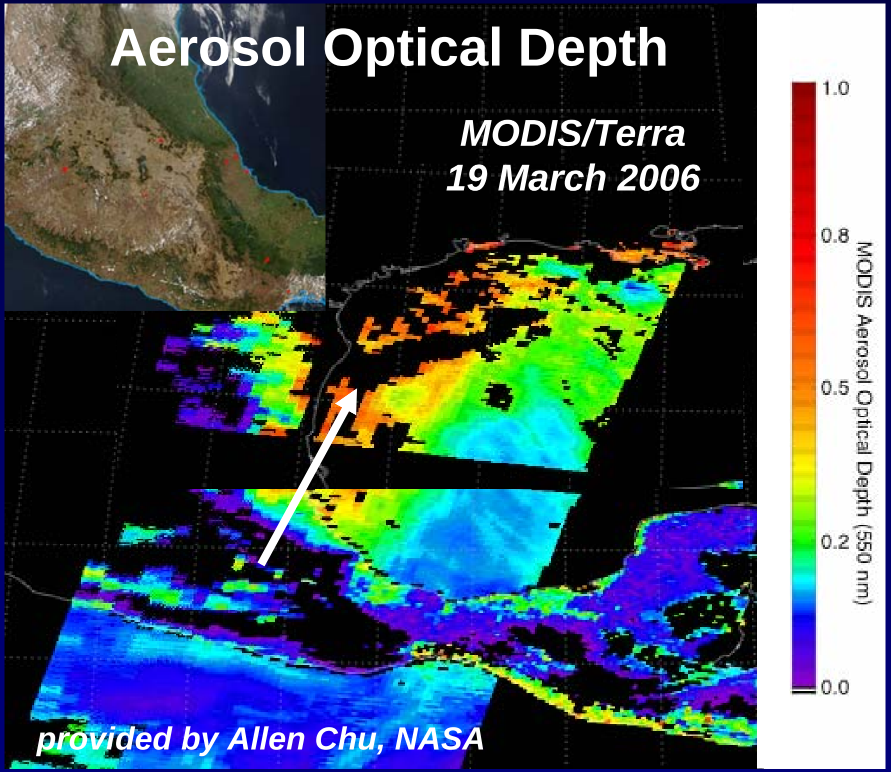


- Lidar measurements confirm earlier DOE / ASP modeling studies
- Models are being used to determine the effect of venting on aerosol evolution and radiative forcing

Hostetler,Ferrare NASA; J. Fast , PNNL

Use of Satellite Measurements

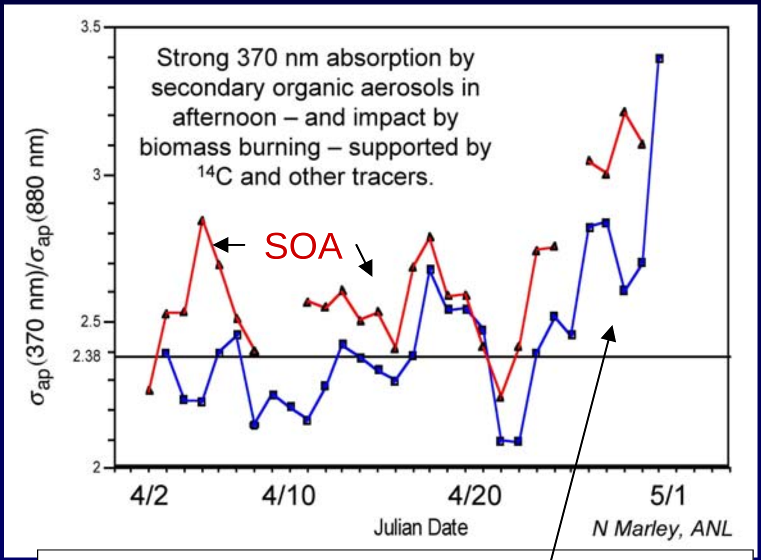
Satellite and Aircraft Intercomparisons for Biomass Burning and Dust Events

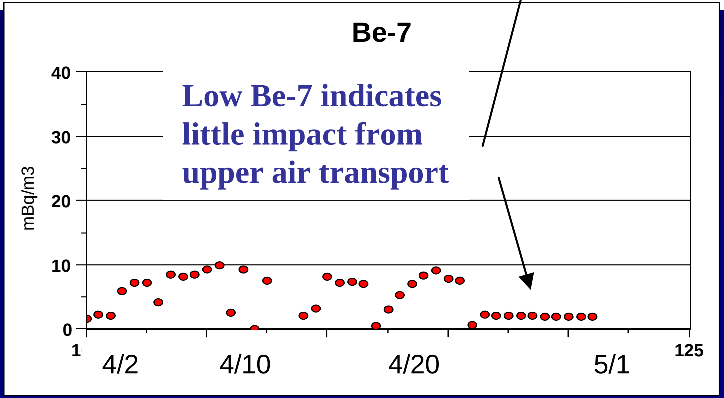


- Very dry conditions contributed to higher-than-normal biomass burning events.
- Mixing of anthropogenic and biomass burning particles.

- Aircraft measurements permit determination of the height of particles downwind of Mexico City and the relative contribution of anthropogenic and biomass burning sources to aerosol optical depth.

Aerosol Absorption – Changes due to Secondary Organic Aerosols and Biomass Burning





2003 – Mexico City

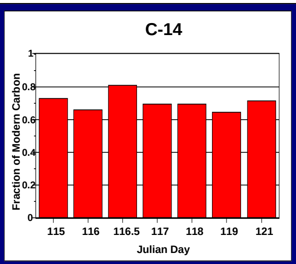
Departure from $1/\lambda$ behavior of 370 nm / 880 nm ratios for broadband absorbers. Note changes in aerosol absorption ratio vs time of day:

AM (2400 – 1200) and PM (1200 – 2400)

MODIS satellite image showing wildfires April 18, 2003

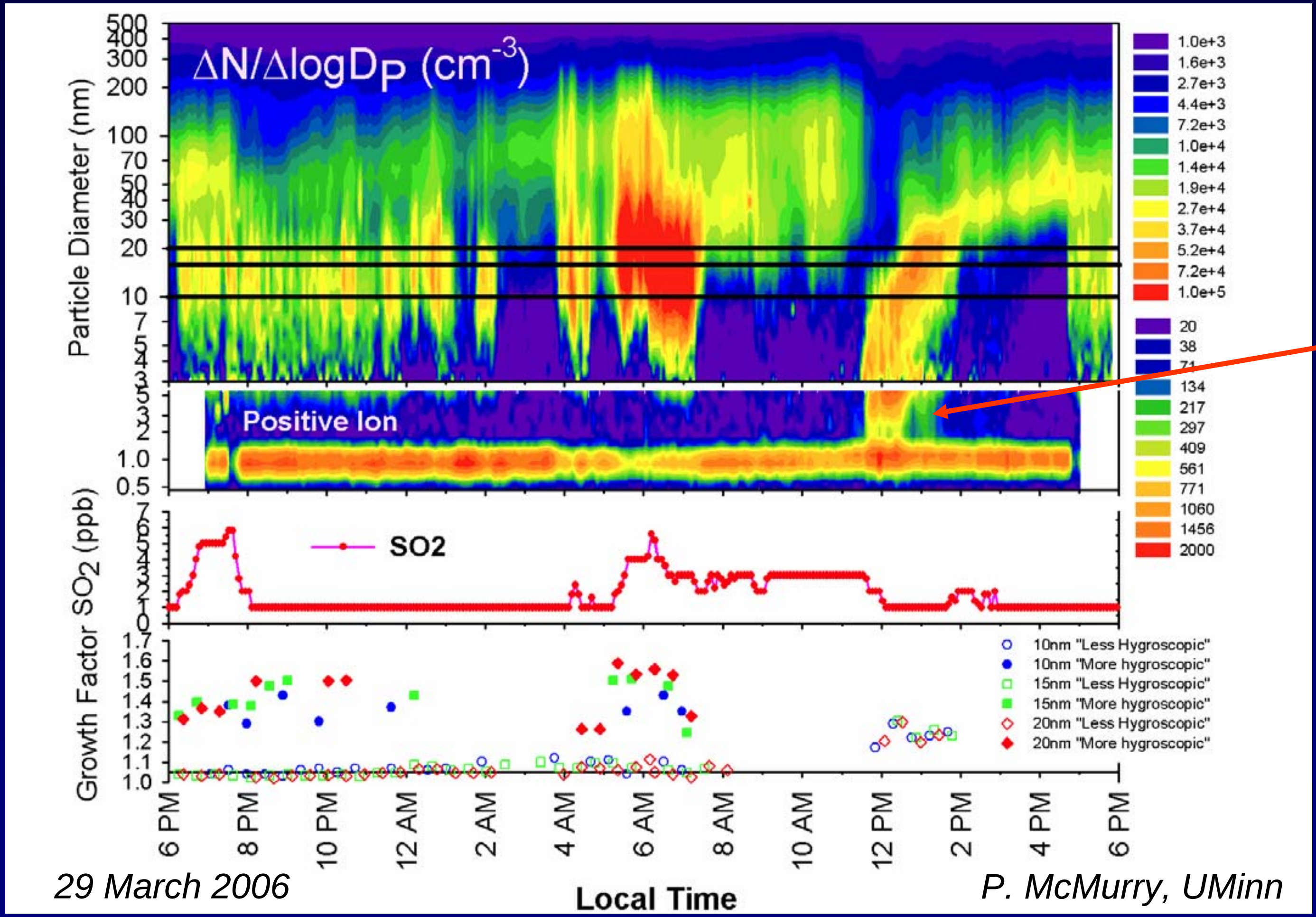
- Satellite data MODIS indicated that plumes from Yucatan fires impacted the Valley of Mexico during this time in April 2003.
- ^{14}C is consistent with transport from Yucatan to Mexico City during same time period.
- ^{7}Be is produced in upper troposphere. Low levels are consistent with little upper air transport and mixing during this period
- ^{14}C contributions could also be from SOA from natural hydrocarbons and from "biomass trash burning"

^{14}C results show 70% biogenic carbon in aerosols in Mexico City samples during end of April 2003. 4/21-4/27



Marley/Gaffney UALR

New Particle Formation



J. Smith, NCAR

New particle formation was frequently observed.
New particles exhibited variable hygroscopicity indicating external mixture.

Publications – Atmospheric Chemistry and Physics (ACPD and ACP) Special Issues

The T1-T2 study: evolution of aerosol properties downwind of Mexico City
J. C. Doran, W. P. Arnott, J. C. Barnard, R. Cary, R. Coulter, J. D. Fast, E. I. Kassianov, L. Kleinman, N. S. Laulainen, T. Martin, G. Paredes-Miranda, M. S. Pekour, W. J. Shaw, D. F. Smith, S. R. Springston, X.-Y. Yu **Atmos. Chem. Phys. Discuss., 6, 12967-12999, 2006**

A meteorological overview of the MILAGRO field campaigns
J. D. Fast, B. de Foy, F. Acevedo Rosas, E. Caetano, G. Carmichael, L. Emmons, D. McKenna, M. Mena, W. Skamarock, X. Tie, R. L. Coulter, J. C. Barnard, C. Wiedinmyer, S. Madronich, **Atmos. Chem. Phys. Discuss., 7, 2037-2089, 2007**

Anticipated Further Analyses and Results

- Examination of size-dependent aerosol composition as function of "age" subsequent to emission and chemical processing.
- Attribution of changes in size-dependent composition to specific processes.
- Quantification of secondary organic aerosol production.
- Comparison of properties of biomass burn and urban soot aerosols.
- Examination of dust events and dust interactions with urban aerosol.
- Examination of hygroscopic growth, CCN properties, and precipitation scavenging in relation to aerosol properties.
- Quantitative description of aerosol transport.
- Examination of evolution of composition and optical properties of black carbon and secondary organic aerosol.
- Evaluation of performance of current models.
- Development of new and/or improved treatments of aerosol processes.

VERY RICH DATA SET!

MAX-Mex and MILAGRO Continue

Data: Final Data Sets – March 2007

MILAGRO Science Meeting – October 2006

Publications – Atmospheric Chemistry and Physics (ACPD and ACP) Special Issues

EGU Symposium – Vienna, Austria (April 16-20, 2007)

MILAGRO Science Team Meeting (Mexico City – May 15-20, 2007

AGU Symposium – Acapulco, Mexico (May 22-25, 2007)

Acknowledgments

ASP MAX-MEX Science Team

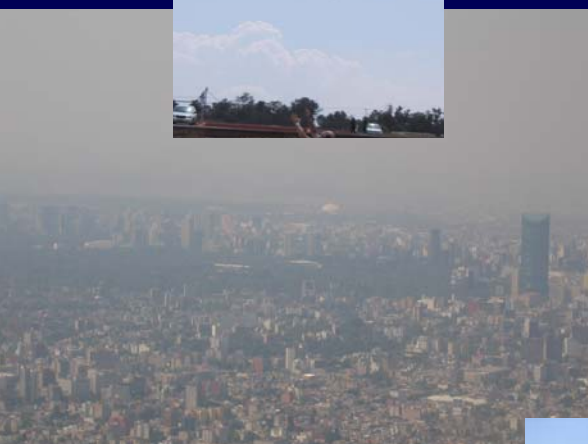
Pilots and ASP Science Support personnel

MILAGRO Participants

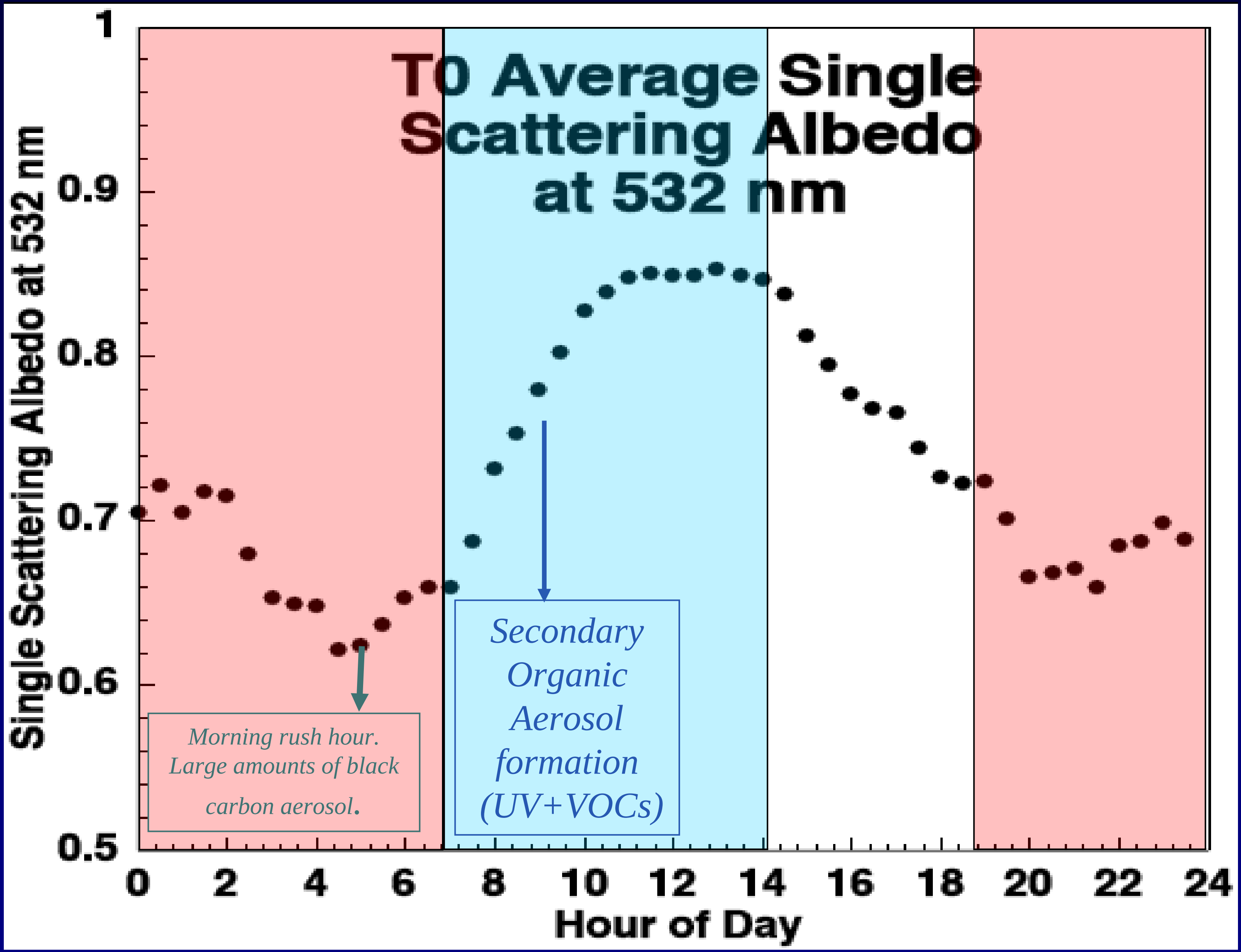
Our Mexican Hosts – INE, CENICA, SENEAM, IMP, UT Tecamac

THE PROJECT WAS CARRIED OUT SAFELY WITH NO INCIDENTS.

MAX-MEX/MILAGRO

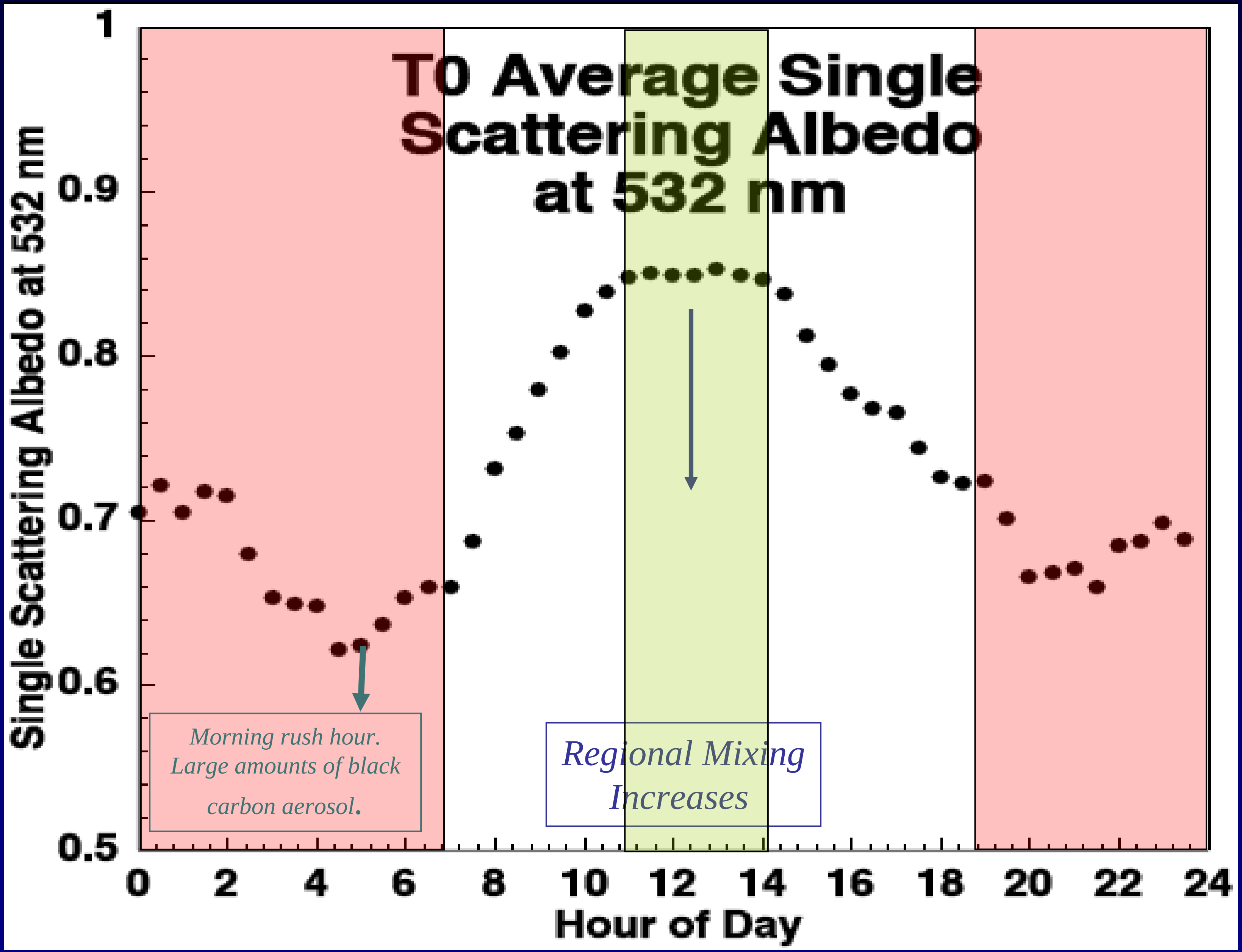


Albedo:



T0 Average Single Scattering Albedo at 532 nm
Single Scattering Albedo at 532 nm
1
0.9
0.8
0.7
0.6
0.5
0
2
4
6
8
10
12
14
16
18
20
22
24
Hour of Day
Morning rush hour. Large amounts of black carbon aerosol.
Secondary Organic Aerosol formation (UV+VOCs)

Albedo:


T0 Average Single
Scattering Albedo
at 532 nm
Single Scattering Albedo at 532 nm
Hour of Day
0.5
0.6
0.7
0.8
0.9
1
0
2
4
6
8
10
12
14
16
18
20
22
24
Morning rush hour.
Large amounts of black
carbon aerosol.
Regional Mixing
Increases