Reconfigured Atmospheric Science Program and 2006 Mexico City Campaign

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Department of Energy

Biological and Environmental Research Advisory Committee Washington, D.C.   July 10, 2006

ASP Management

Atmospheric Science Program (ASP)

- Program Managers
- Ashley Williamson (DOE-CCRD)
- Rickey Petty (DOE-CCRD)
- Chief Scientist

Stephen Schwartz – BNL

ASP Major Milestones

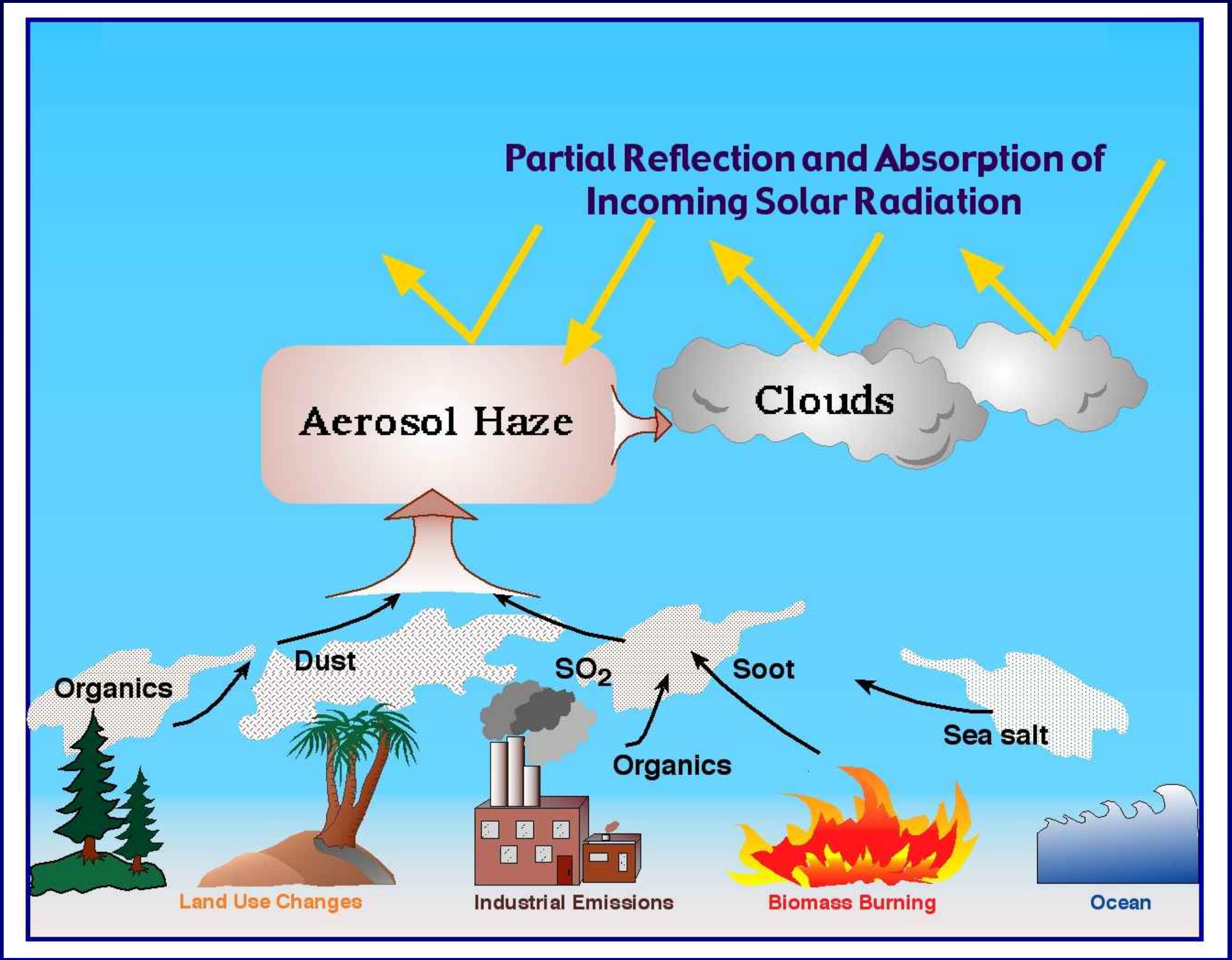
2004: March 2 - Chief Scientist selected
April 29 - BERAC approval of ASP reconfiguration
May 4 - Federal Register announcement
June 21 - Proposals due; ~154 proposals received
September 21 - Proposal reviews completed

2005: January 25 - Science Team meeting (FY 2005)
May - Black carbon measurement intercomparison
July - MASE - MArine Stratus Experiment
October 31 - Science Team meeting (FY 2006)

2006: March - MAX-MEX Megacity Aerosol eXperiment - MEXico City
August - MAX-TEX Megacity Aerosol eXperiment - TEXas
October - MILAGRO Data workshop
October - Science Team meeting (FY 2007)

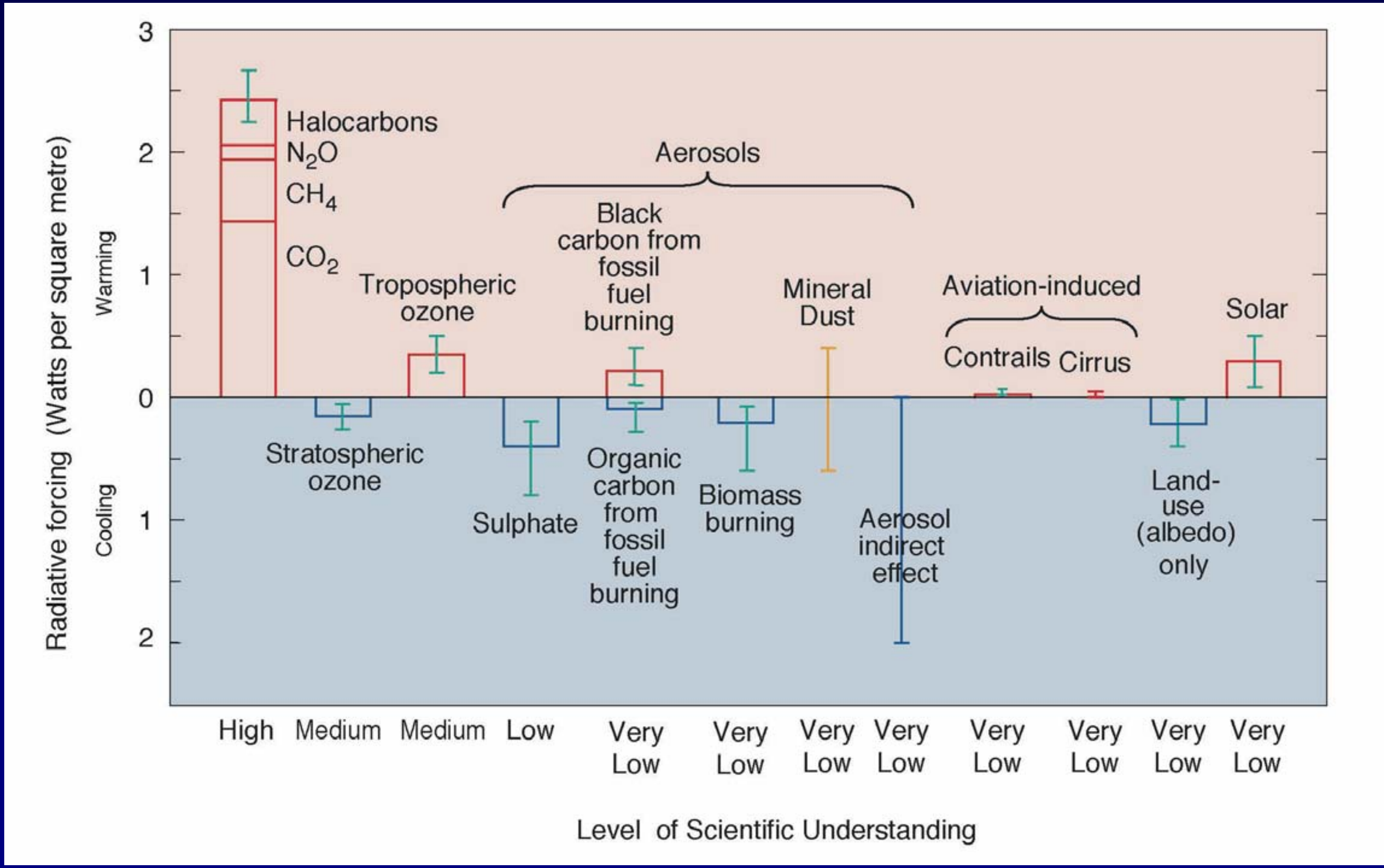
2007: Solicitation for FY-08 ASP science team starts
June - CHAPS Cumulus Humilis Aerosol Processing Study

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

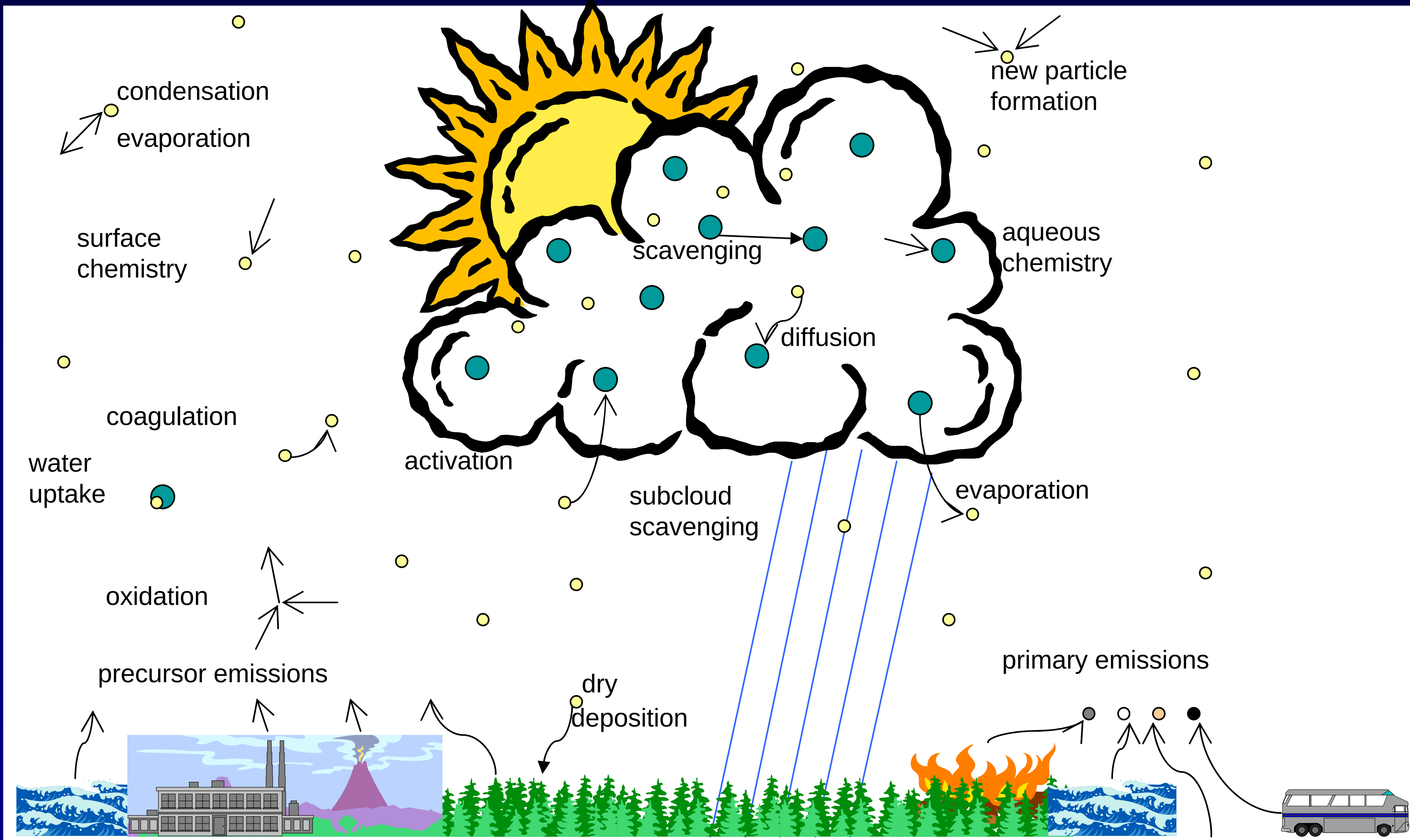
Hydrological Effects

Suppressed surface evaporation - spinning down the water cycle

Displaced precipitation - clouds last longer or evaporate

Aerosol Processes

Processes that Need to be Understood and Represented in Models



Ghan and Schwartz 2006 submitted to BAMS

Types of Aerosols

Primary Aerosols

Combustion

Diesel Soots

Biomass Burning

Secondary Inorganic Aerosols

NH_4NO_3, $(NH_4)_2SO_4$, etc.

Secondary Organic Aerosol

Humic Like Substances (HULIS)

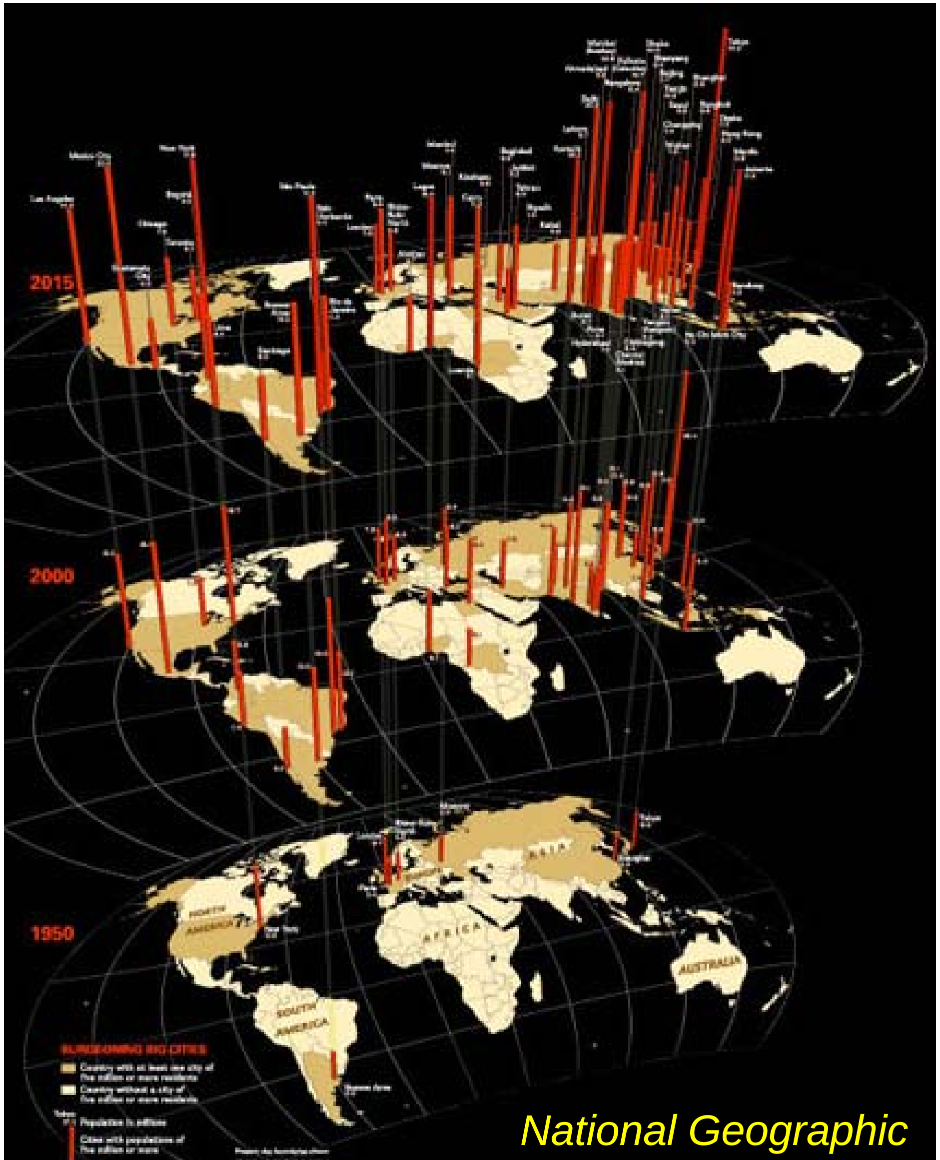
Oxidized Organic Compounds

Ideal Field Study Situation

Attributes

- High aerosol concentrations in representative area - large signal
- High concentrations of primary black carbon (BC)
- High photochemical activity to maximize chemistry changes
- Abundant gas-phase organics to look at secondary organic aerosol (SOA)
- Good meteorology support and infrastructure
- Infrastructure conducive to safe operations
- Ground and aircraft operations - downwind sites

Megacities



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

April 2003 Field Campaign

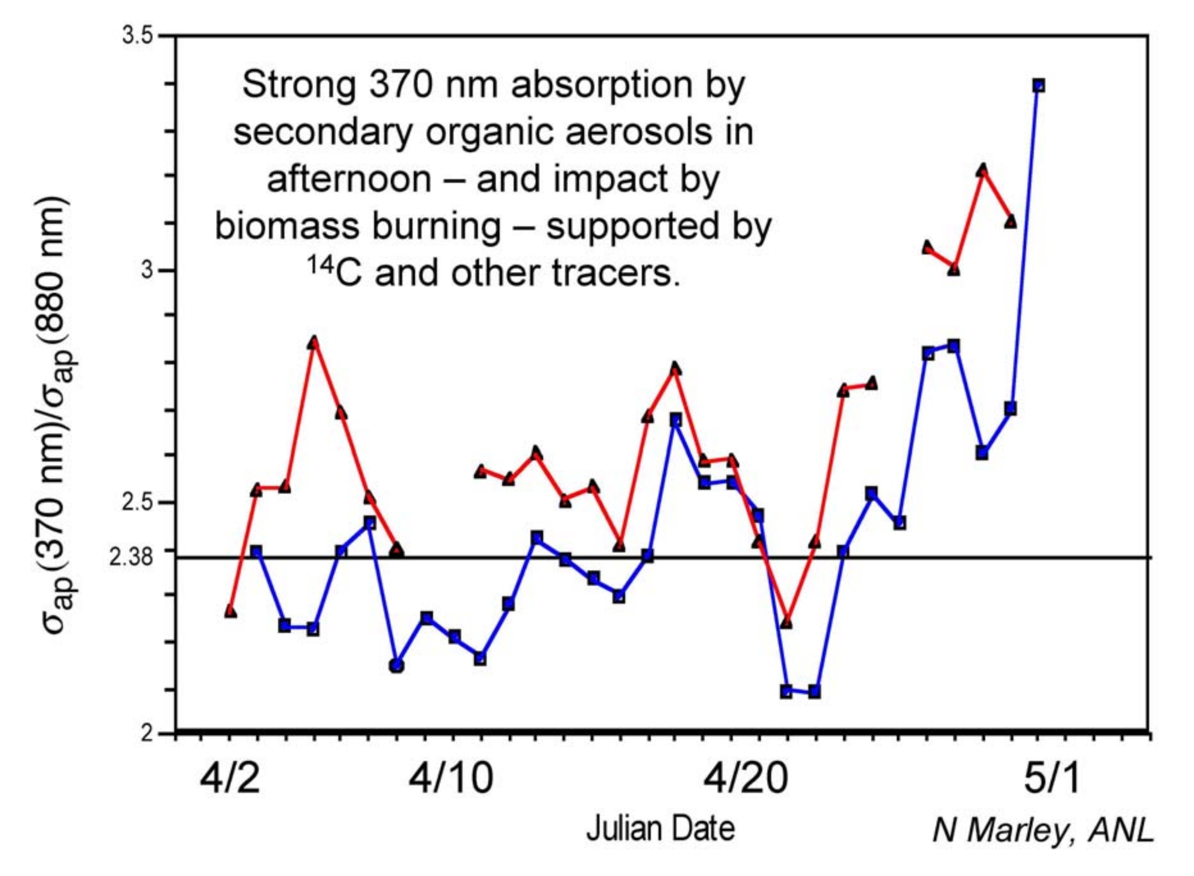
Mexico City Metropolitan Area (MCMA) 2003
DOE Mexico City Megacity 2003

Aerosol Related Findings:

- High BC – High 0.1 - 1.0 µm aerosol concentrations
- Evidence for significant secondary organic aerosol
- Evidence for SOA: 300 - 440 nm absorption
- Evidence for biomass burning – aerosol transport
- High precursor gas concentrations (ammonia and organics)
- Evidence for fresh black carbon resistance to washout
- High OH and HO_2 concentrations – High UV
- 1997 and 2003 – strong diurnal variation – indicating ***basin clearing on daily basis***

Aerosol Absorption

2003 – Mexico City Dependence of aerosol absorption on time of day



1/λ dependence for broadband absorbers

AM (2400 – 1200) and PM (1200 – 2400) average ratios of aerosol absorption 370 nm / 880 nm in Mexico City

MAX-Mex

Megacity Aerosol Experiment - Mexico City (MAX-Mex)

Planning Began January 2005

- Jeff Gaffney (ANL) –
  Lead Scientist

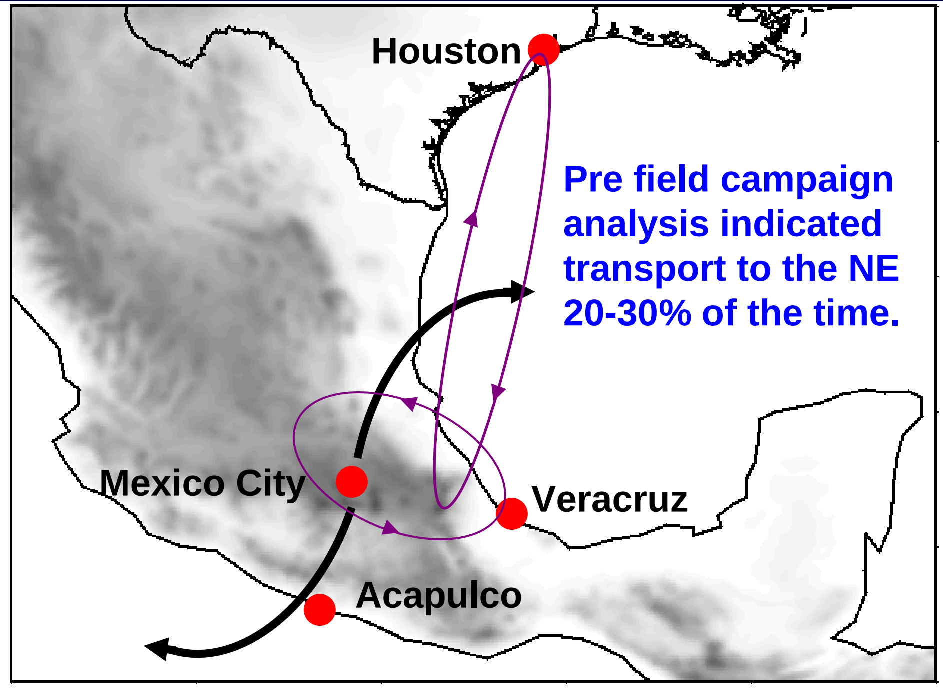
- Larry Kleinman (BNL), John Hubbe (PNNL) –
  Research Aircraft Operations and Flight Plans

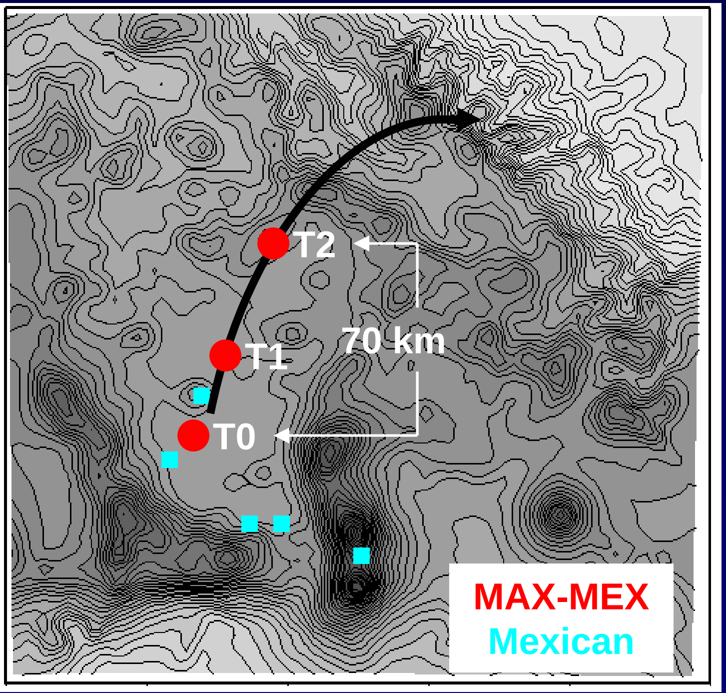
- Jerome Fast (PNNL) –
  Modeling, Forecasts, Planning for Ground and G-1

- Christopher Doran (PNNL), Will Shaw (PNNL), Rich Coulter (ANL) –
  Ground Site Identification, Meteorological Infrastructure Deployment

Pre Field Campaign Activities

Modeling Used to Target Meteorology, Chemistry, and Aerosol Instrumentation Sites for 2006 Field Campaigns





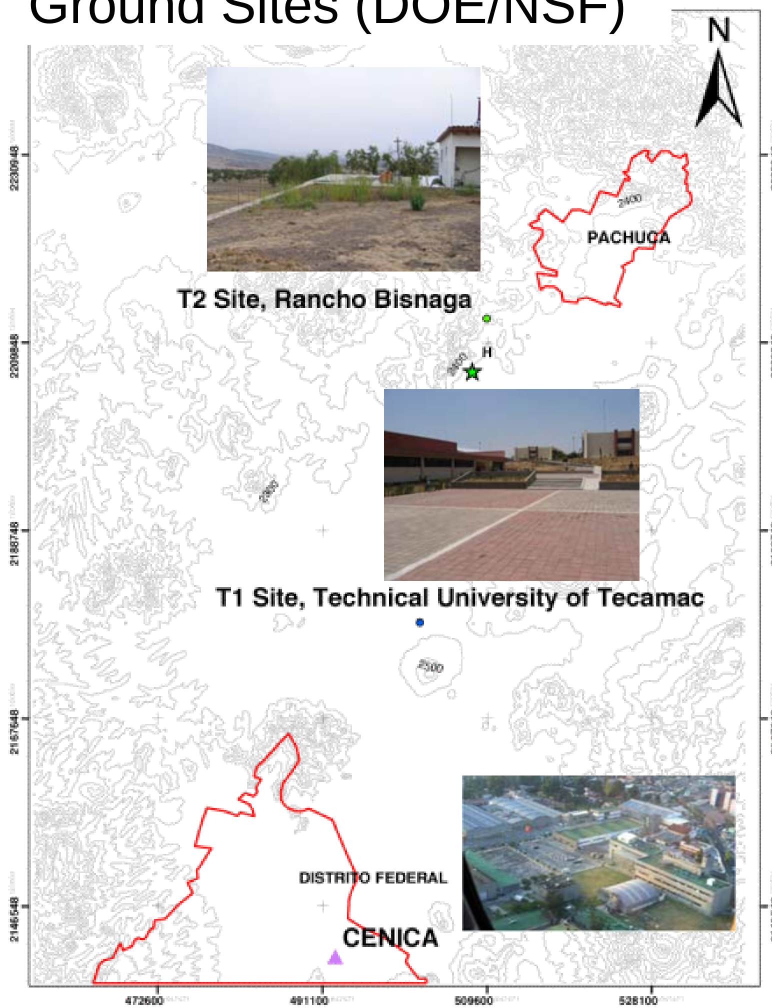
- Operational rawinsondes (NSF): supplemented to 4 per day at Veracruz and Mexico City and 2 per day at Acapulco
- Aircraft operations: Veracruz – NASA at Houston

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

J. Fast, PNNL

Pre Field Campaign Activities

Ground Sites (DOE/NSF)



Ground Sites Identified in April 2005 –Veracruz Selected for G-1 Operation

Aircraft Operations - Veracruz

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)

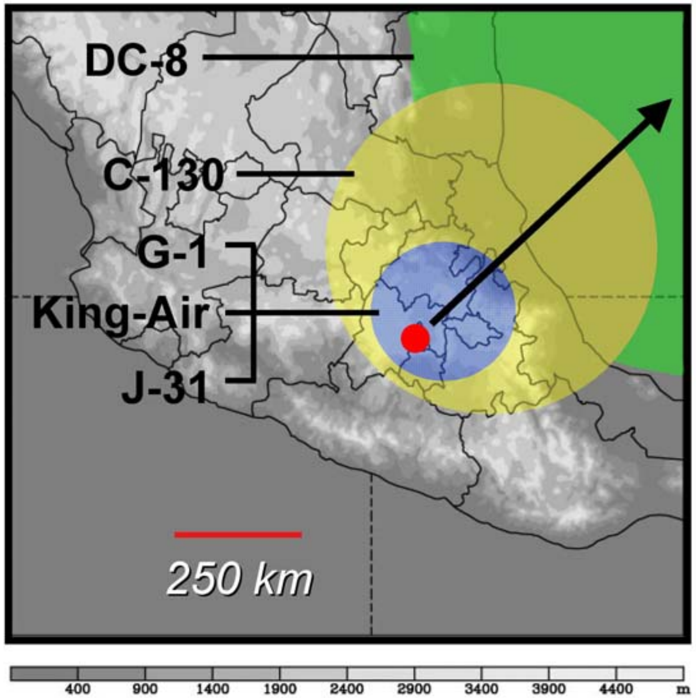
Program Manager, Anne-Marie Schmoltner

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

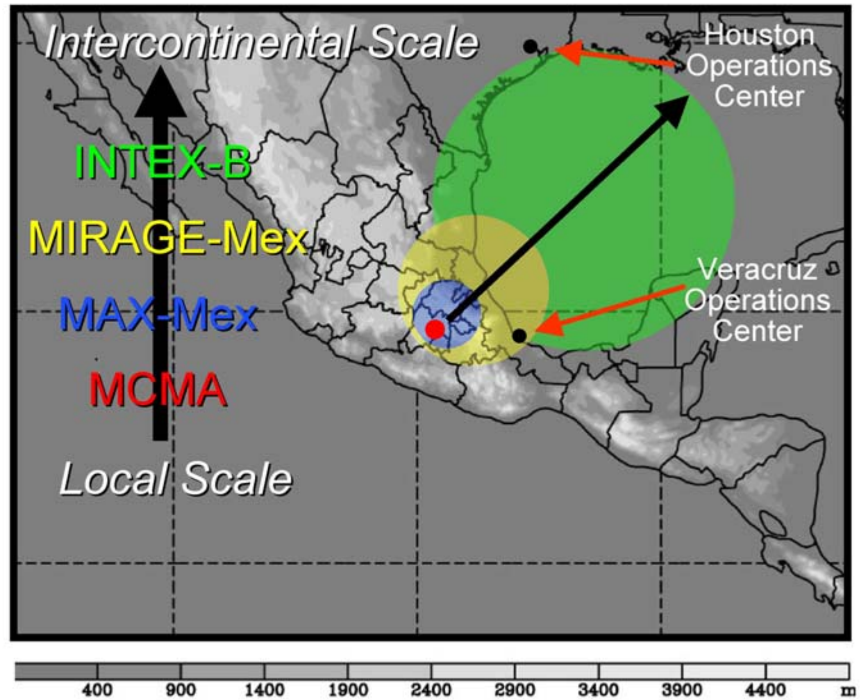
NASA: Lead Scientist, Hanwant Singh

Program Manager, Bruce Doddridge

Geographic Relation of Projects

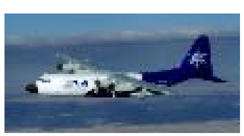


terrain height (meters)



terrain height (meters)

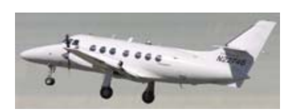
G-1 (DOE)



C-130 (NCAR)

King-Air (NASA)

Twin Otter (U Montana)



J-31 (NASA)

DC-8 (NASA)

J. Fast, PNNL

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

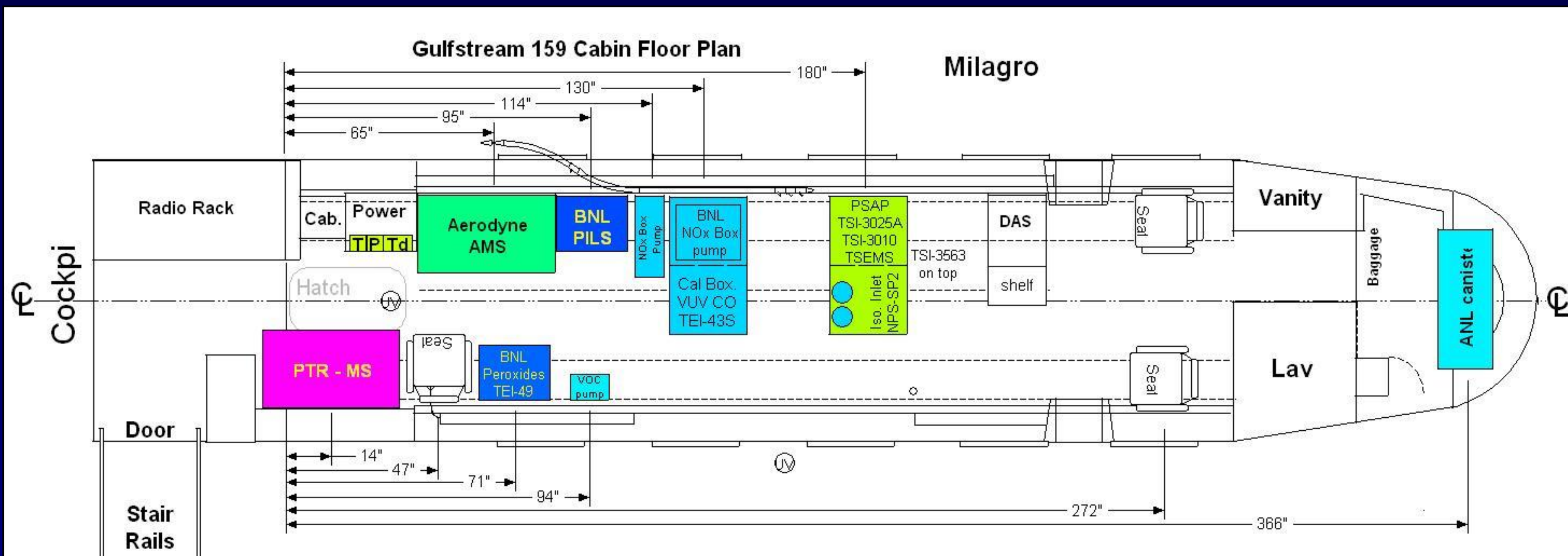
DOE MAX-Mex Participants

- 63 Scientists
- 3 Field sites
- 2 Aircraft
- 1 Mobile van

- MILAGRO total: 300 plus scientists
- 6 aircraft
- Multiple field sites
- Multiple mobile vans

- Data to be shared among all participants of MILAGRO

ASP G-1 Research Aircraft Facility Layout

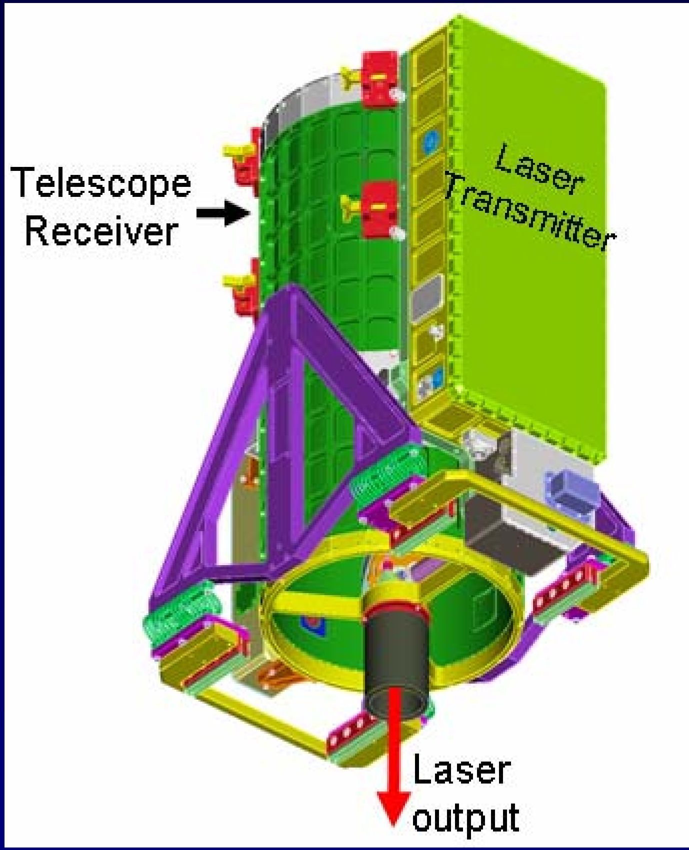


PCASP, CAPS – PNNL, BNL: Senum, Hubbe
State – PNNL: Hubbe
PTRMS - EMSL: Alexander, Ortega
AMS - Aerodyne, EMSL: Alexander, Jayne
Peroxides - SUNY, BNL: Lloyd, Bowerman
VOCs – York: Hubbe, Rudolf
PILS – BNL: Lee

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)



MILAGRO Measurement Sites

Mobile site   Fixed site   Other measurements

MAX-Mex Participants and Instrumentation

T0 Supersite

Mexico City IMP

MET
RADIATION
AEROSOLS

ANL	Aethalometer (7 channel)	BC Aersosol absorption
ANL	Multi-angle Absorption	BC Aersosol absorption
ANL	Nephelometer 3 wavelength	particle scattering
ANL	Nephelometer 1 wavelength dry	dry particle scattering
ANL	Nephelometer 1 wavelength wet	wet particle scattering
ANL	Filter Sampler	OC/EC, humic like substances
ANL	Open path NIR TDLAS	NH3
ANL	Filter Sampler	14C, 40K, 210Pb, 7Be, 210Po, 210Bi,
ANL	RB Meter	UVB
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

Field Campaign Period

MAX-MEX/MILAGRO Began March 1, 2006
with Data Taken to March 29, 2006

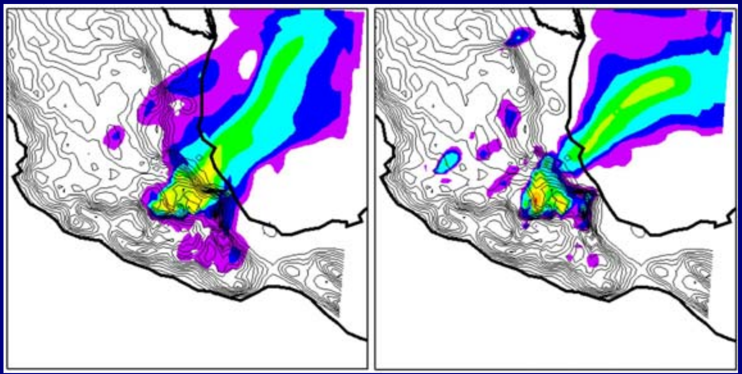
Forecast Support for Aircraft Operations

DOE leadership in forecast support

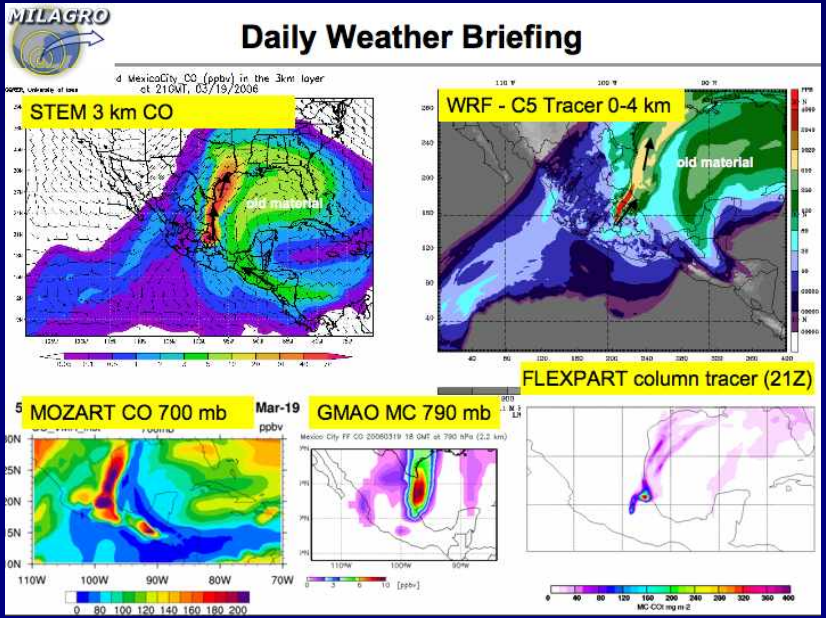
- Pre-field campaign activities to help identify surface sampling sites and dominant pollutant transport pathways
- Organized set of models (local, regional, and global scale) used during MILAGRO
- Lead forecasting team to develop daily briefings to support principal investigators in planning research aircraft flights
- Daily briefings disseminated to remote scientists via NCAR field catalog

Veracruz Forecasting Team

DOE / ASP pre-field campaign modeling of aerosol transport patterns

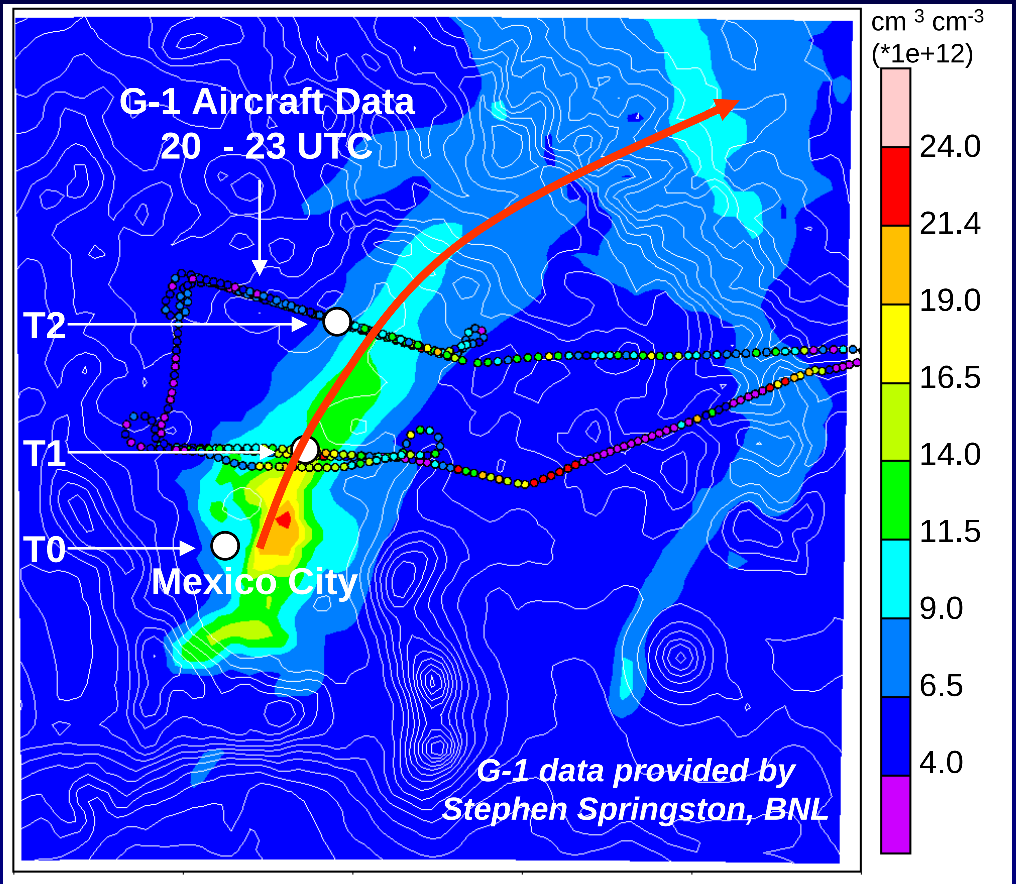


Example Briefing Material Available at
http://catalog.eol.ucar.edu/cgi-bin/milagro/report/index

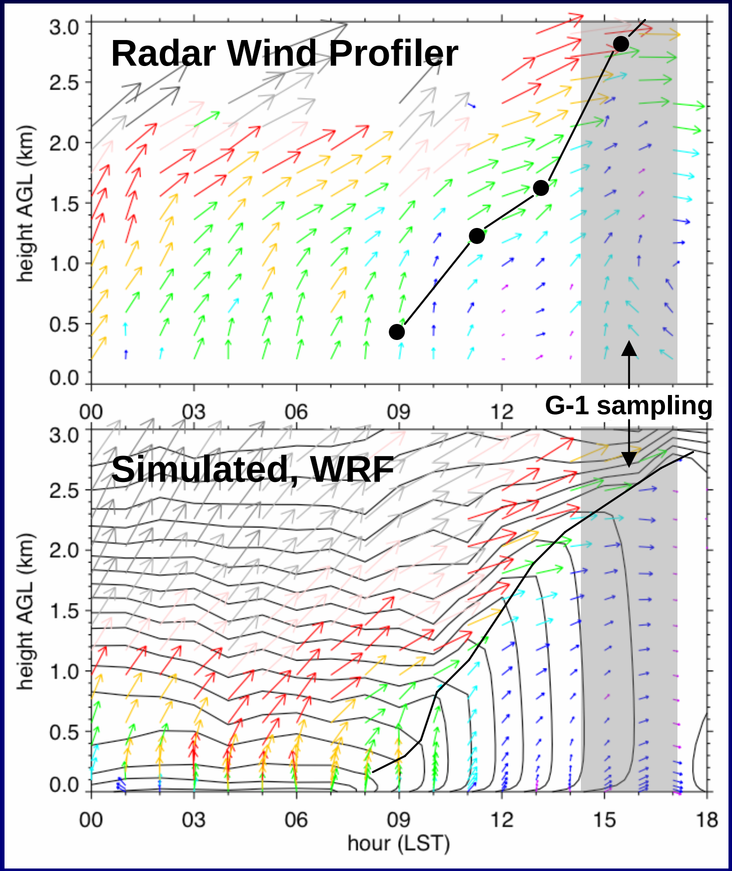


Sampling Strategy a Success

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



Wind Profiles and PBL at T1, 20 March



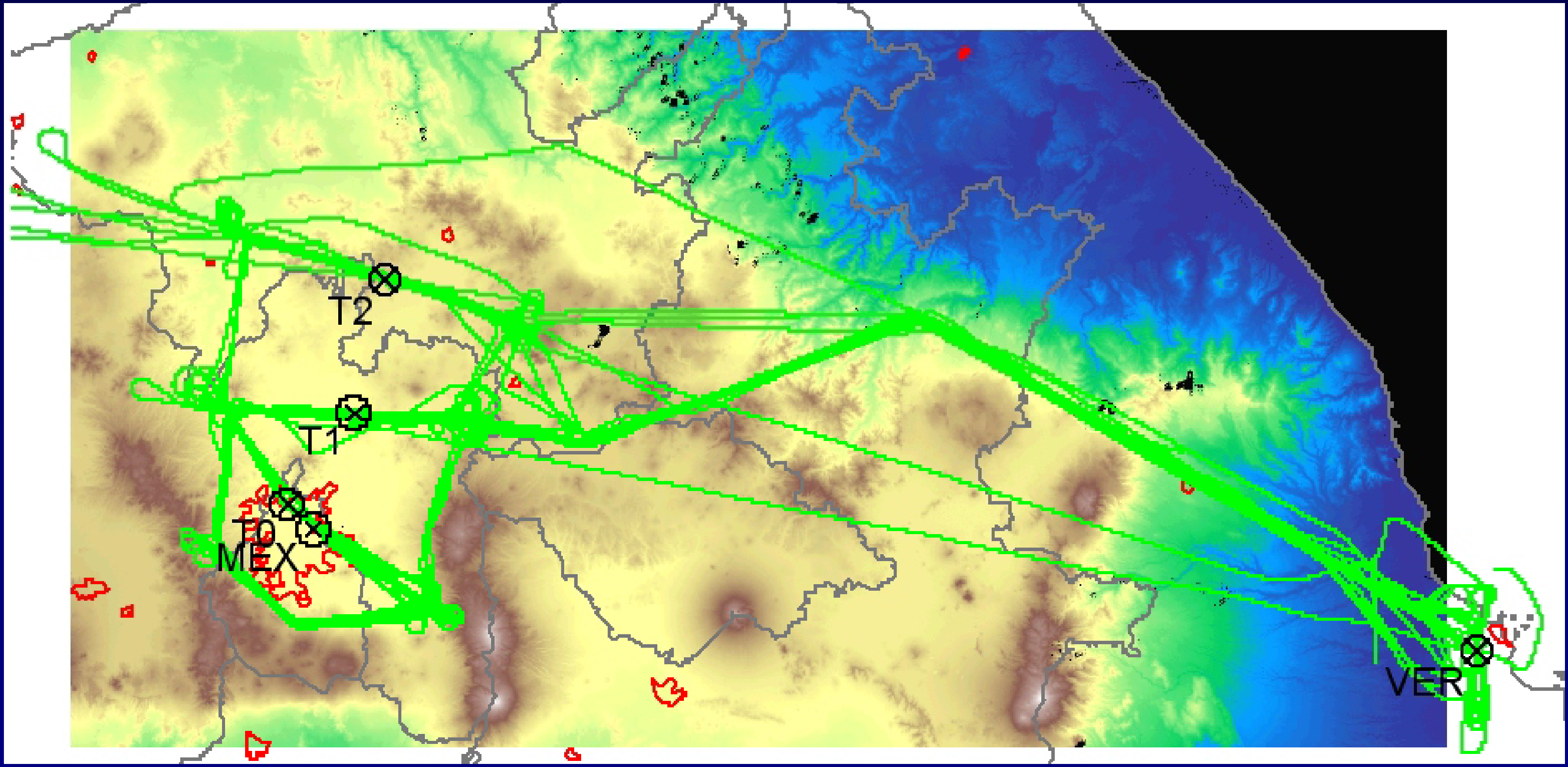
- T1/T2 transport scenario occurred on 4-5 days during March 2006.
- Simulated downwind plume in good agreement with observations.

- Strong ambient SW flow aloft decreases during day.

J. Fast, PNNL

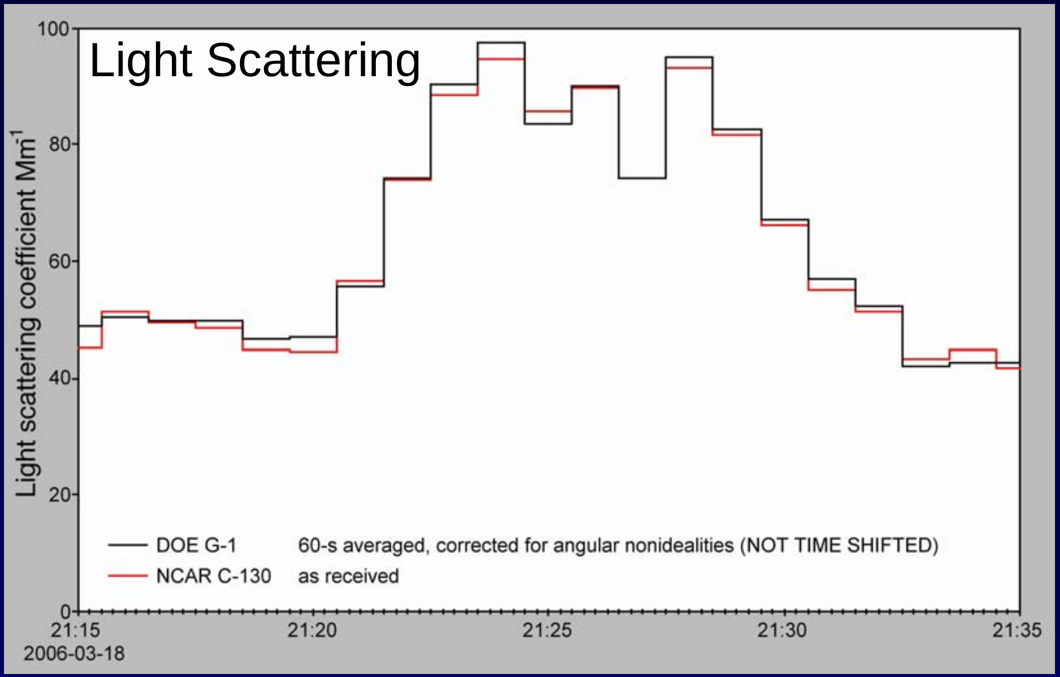
G-1 Flights

15 Flights, 48 hours Flight Time
Over-flights of T0 (12), T1(37), T2 (23)



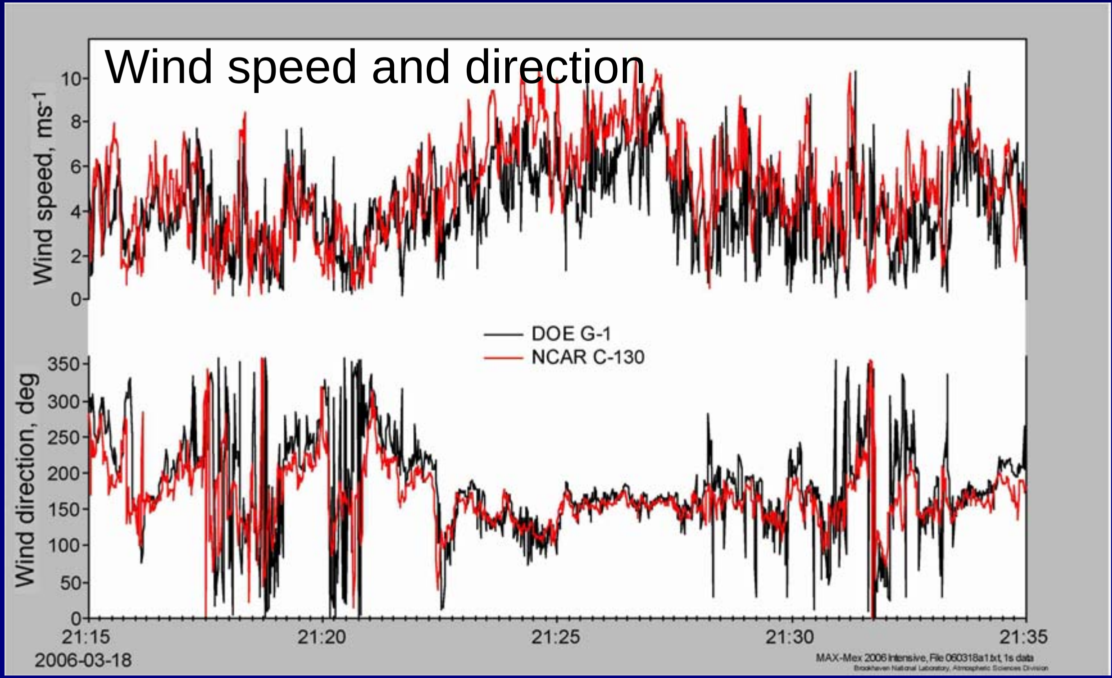
S. Springston, L. Kleinman, BNL

Aircraft Intercomparisons



Aircraft instrument intercomparisons provide high confidence in the measurements.

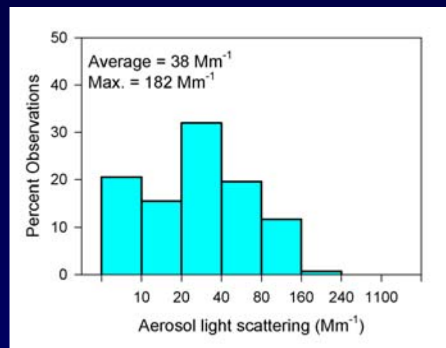
DOE G-1 and NSF C-130 wing-to-wing intercomparisons show excellent agreement.

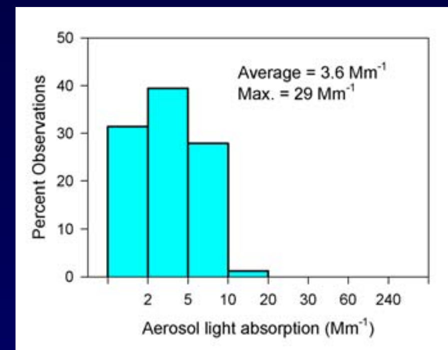


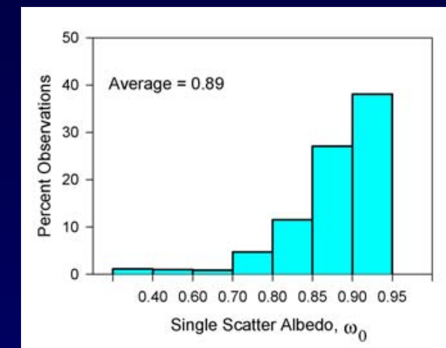
Aerosol Optical Properties

Scattering | Absorption | Single Scatter Albedo

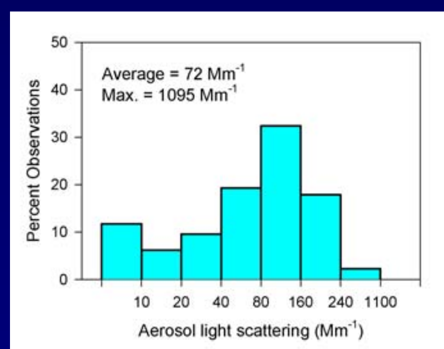
Eastern U.S. (2002, NEAQS)

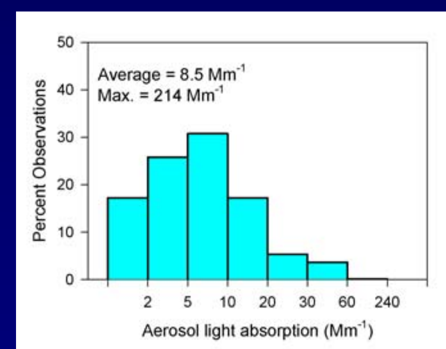


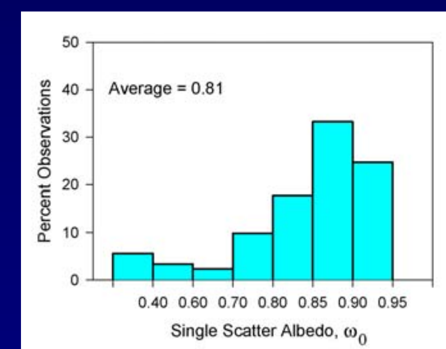




Mexico City Basin







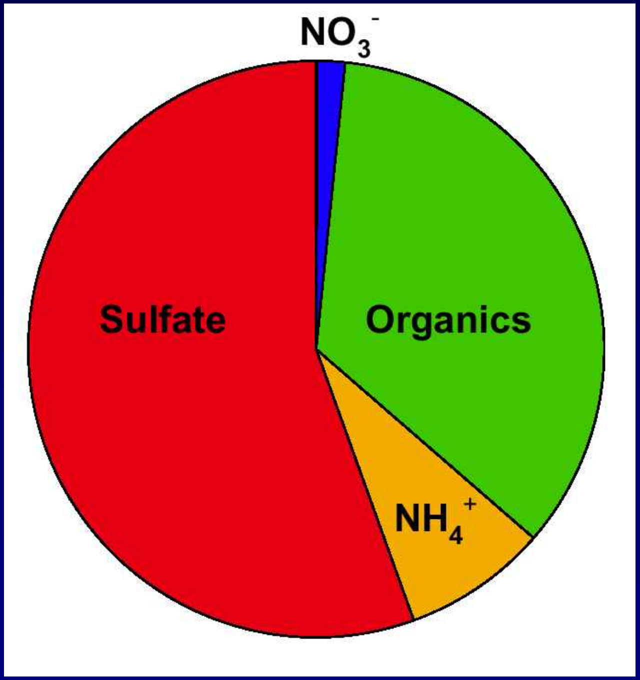
- Light scattering, absorption were 2 times Eastern U.S.
- Urban area routinely surpassed peak U.S. values
- Higher proportion black carbon in Mexico aerosol
- Mexico aerosol is warming ($\omega_0 < 0.85$), U.S. cooling

S. Springston, L. Kleinman, BNL

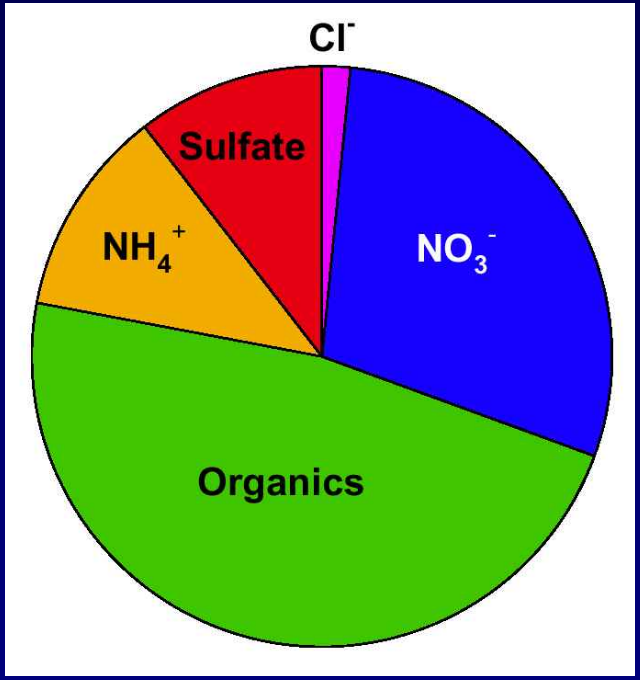
Aerosol Composition Comparison

Aerosol Mass Spectrometer Measurements from G-1

Eastern U.S. Regional Pollution



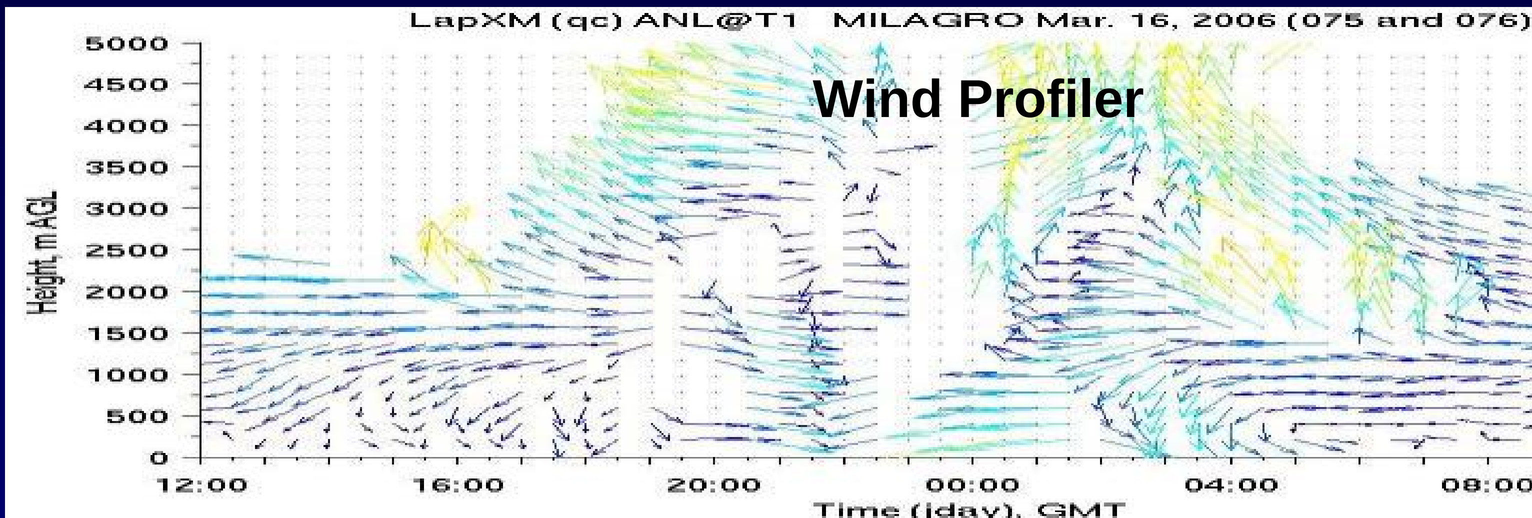
Mexico City Urban

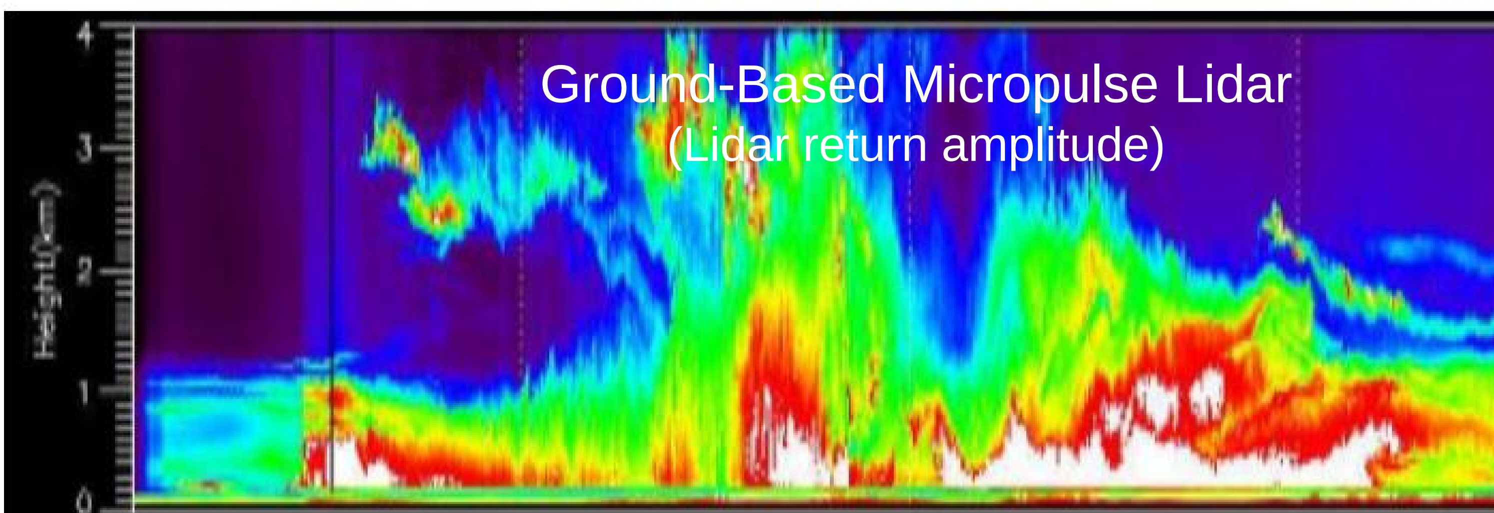


- Eastern U.S. episodes - sulfate dominated
- Mexico urban aerosol - organic dominated, with nitrate

Layering of Aerosols aboveT1

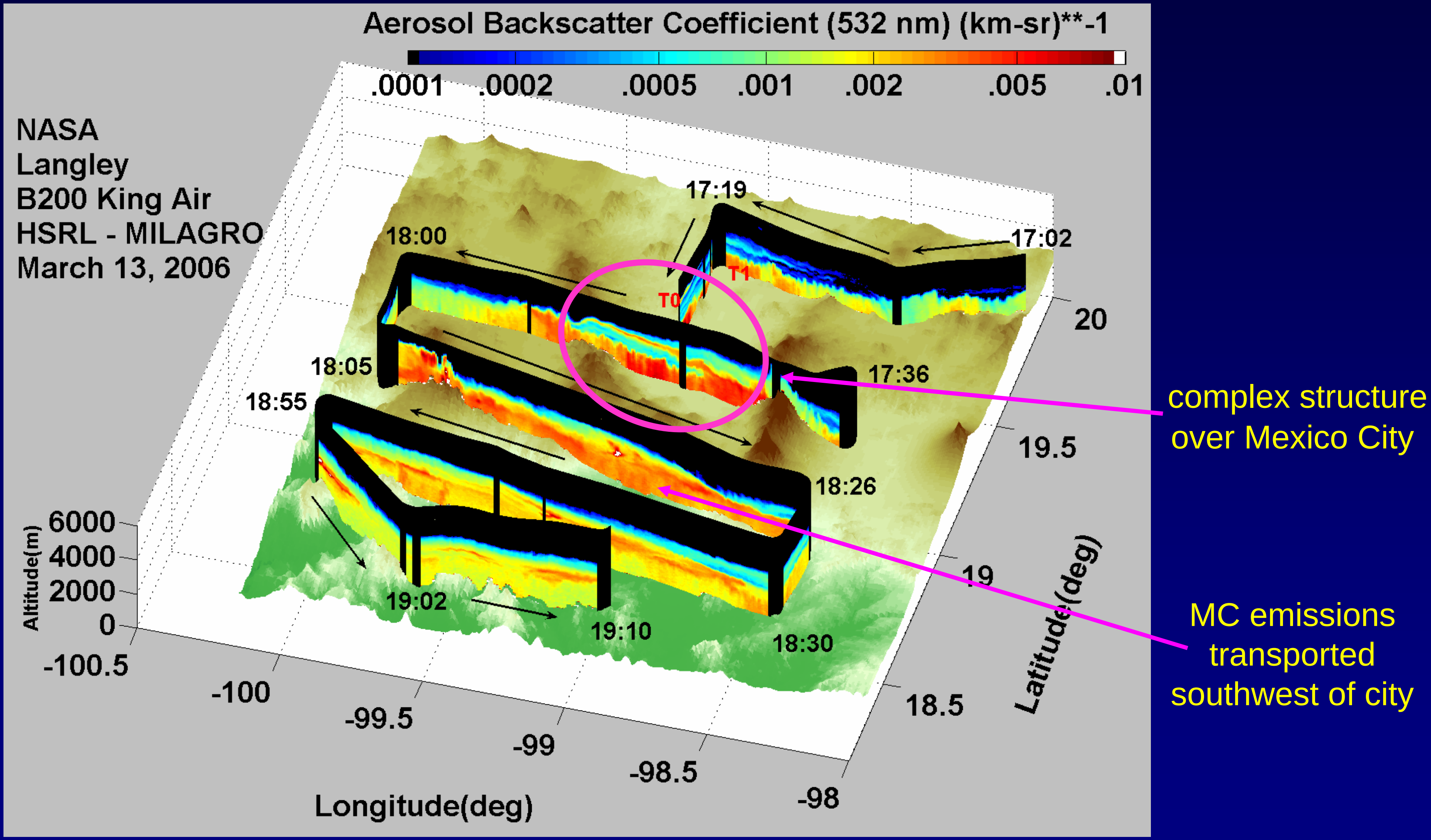
Aerosols lofted from Boundary Layer into Lower Troposphere





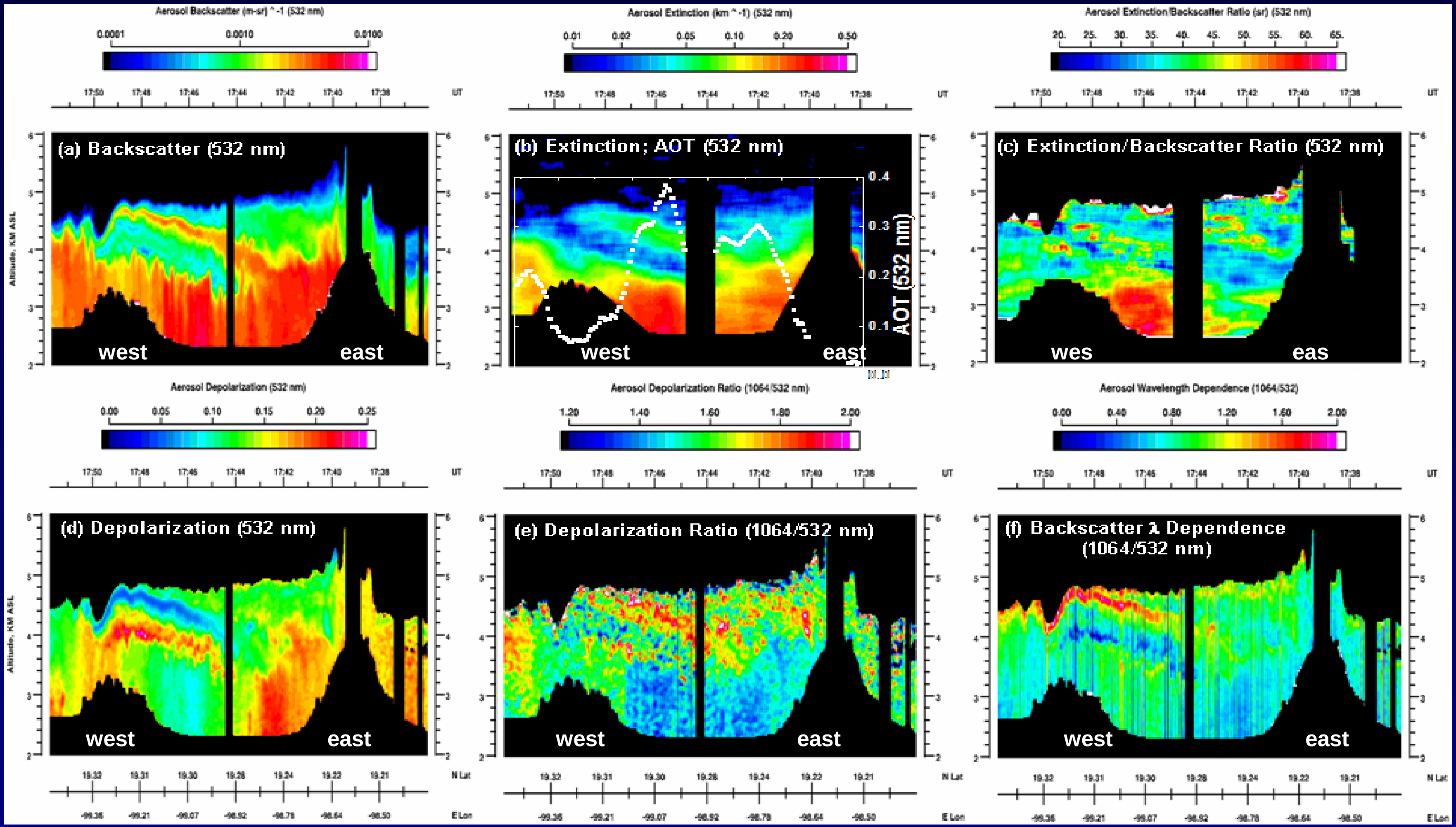
R. Coulter, ANL

Spatial Distribution of Aerosol Properties



C. Hostetler, NASA

Horizontal Distribution of Aerosol Types

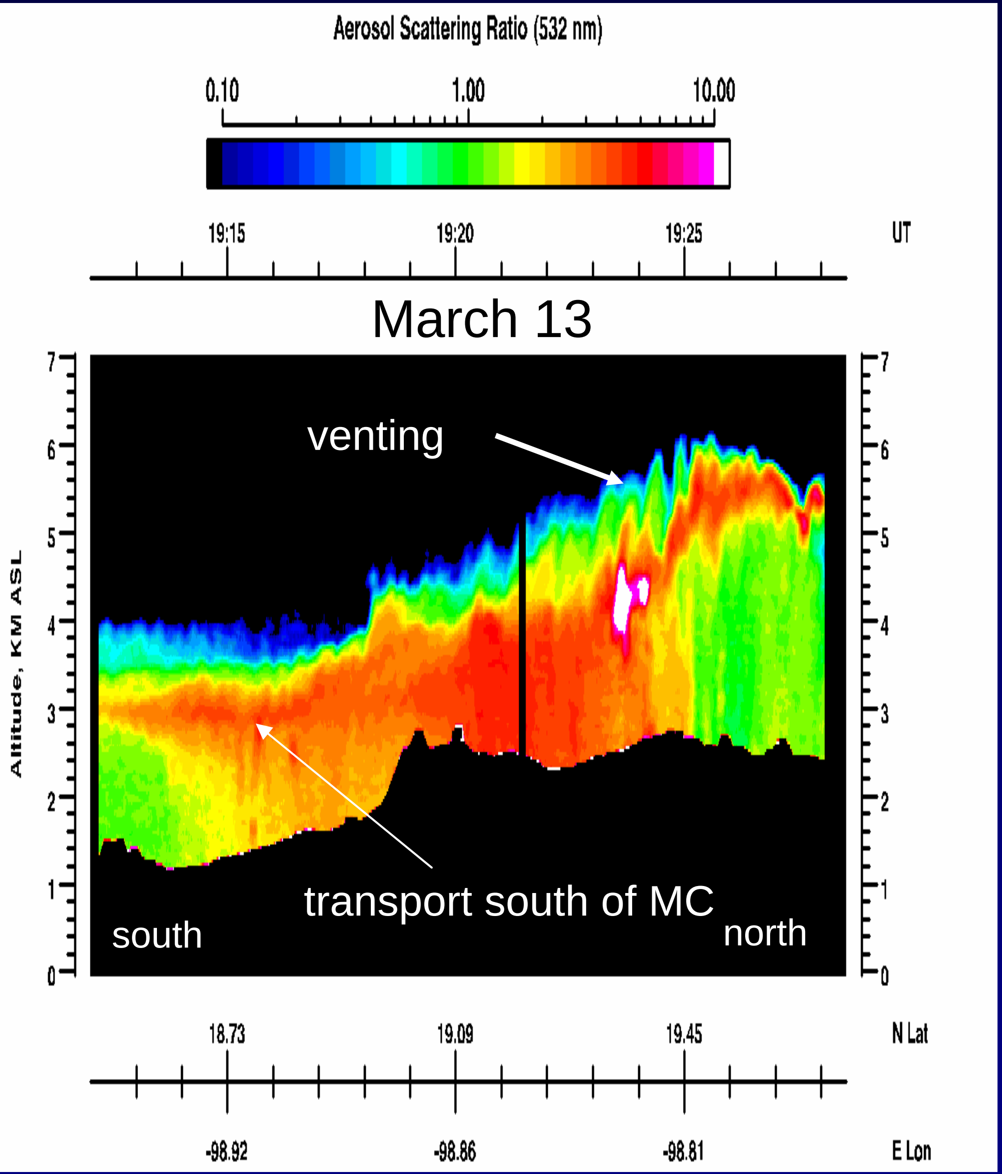


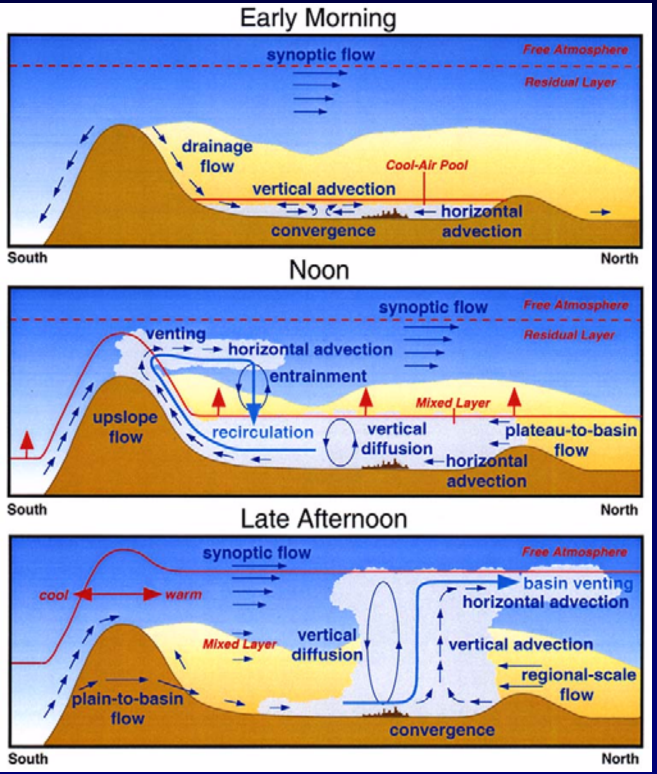
Western part of city- high extinction/backscatter ratio, high wavelength dependence, low depolarization – urban aerosol.

Eastern part of city - low extinction/backscatter, low wavelength dependence, high depolarization – dust.

LaRC Airborne HSRL Measurements, Mexico City, March 13, 2006

Aerosol Venting into Free Troposphere



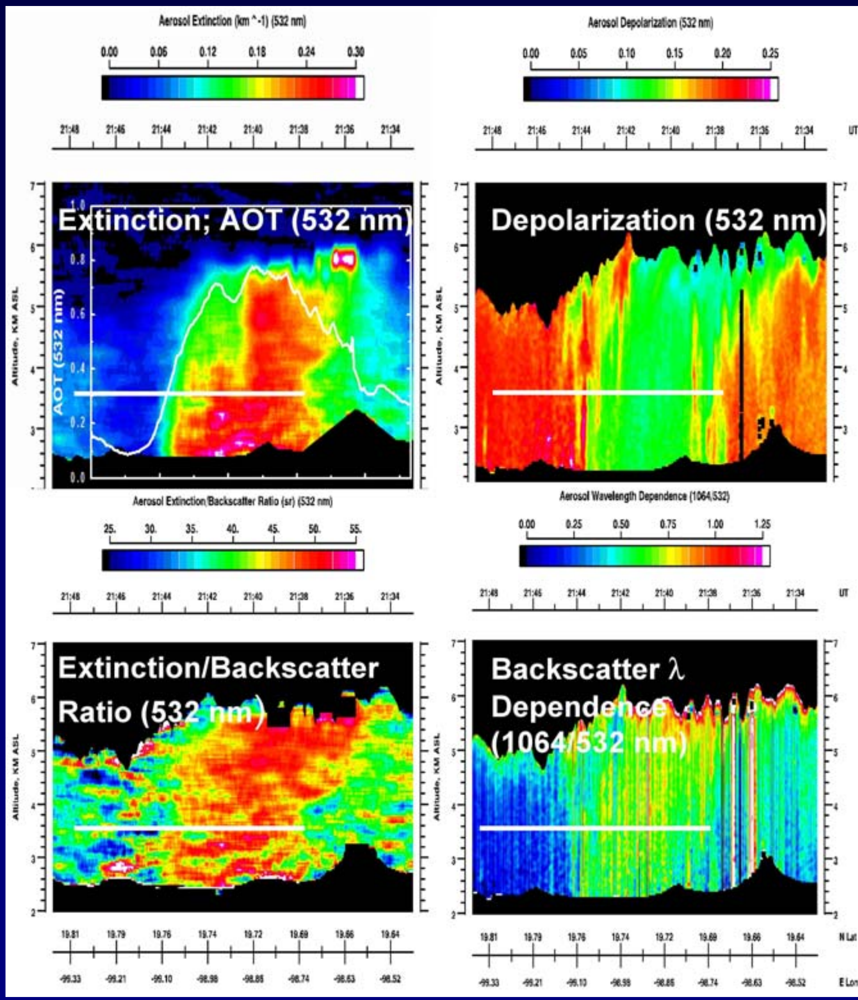


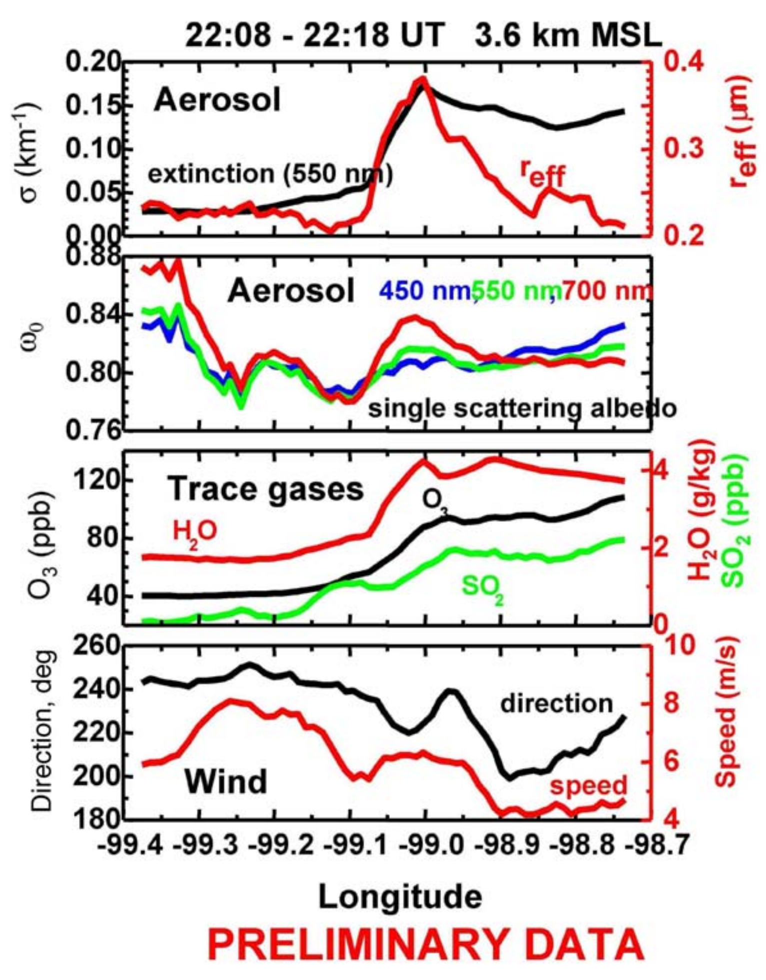
- Lidar measurements confirm earlier DOE / ASP modeling studies
- Models are being used to determine the effect of venting on aerosol evolution and radiative forcing

C. Hostetler, NASA; J. Fast , PNNL

Lidar Data Provide Vertical Context for In-situ Measurements

March 9, 2006

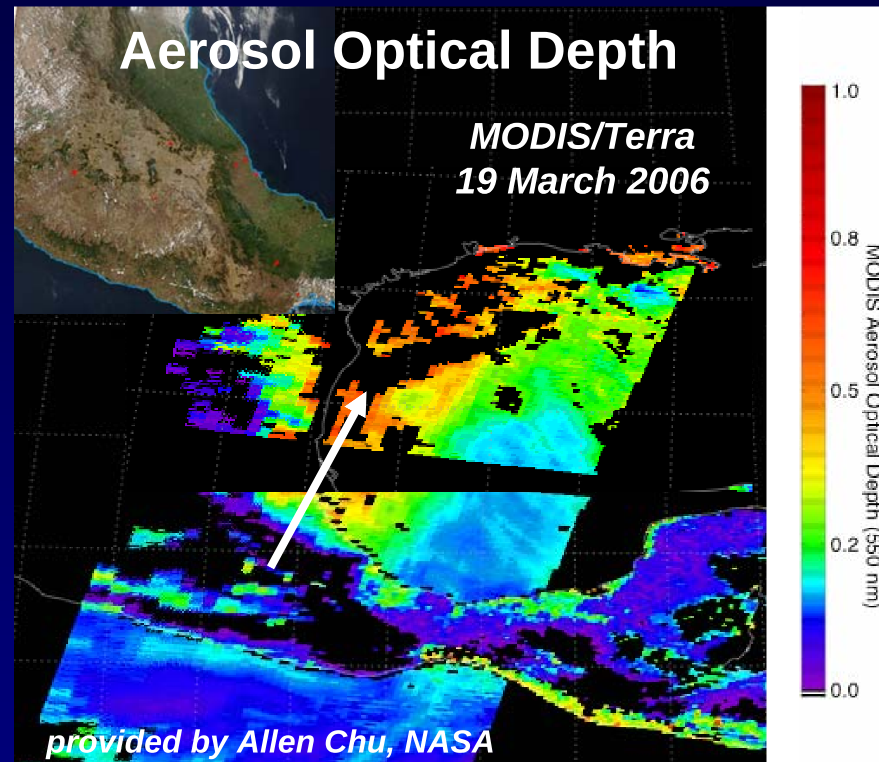




- HSRL and G-1 measurements show changes associated with MC pollution

Use of Satellite Measurements

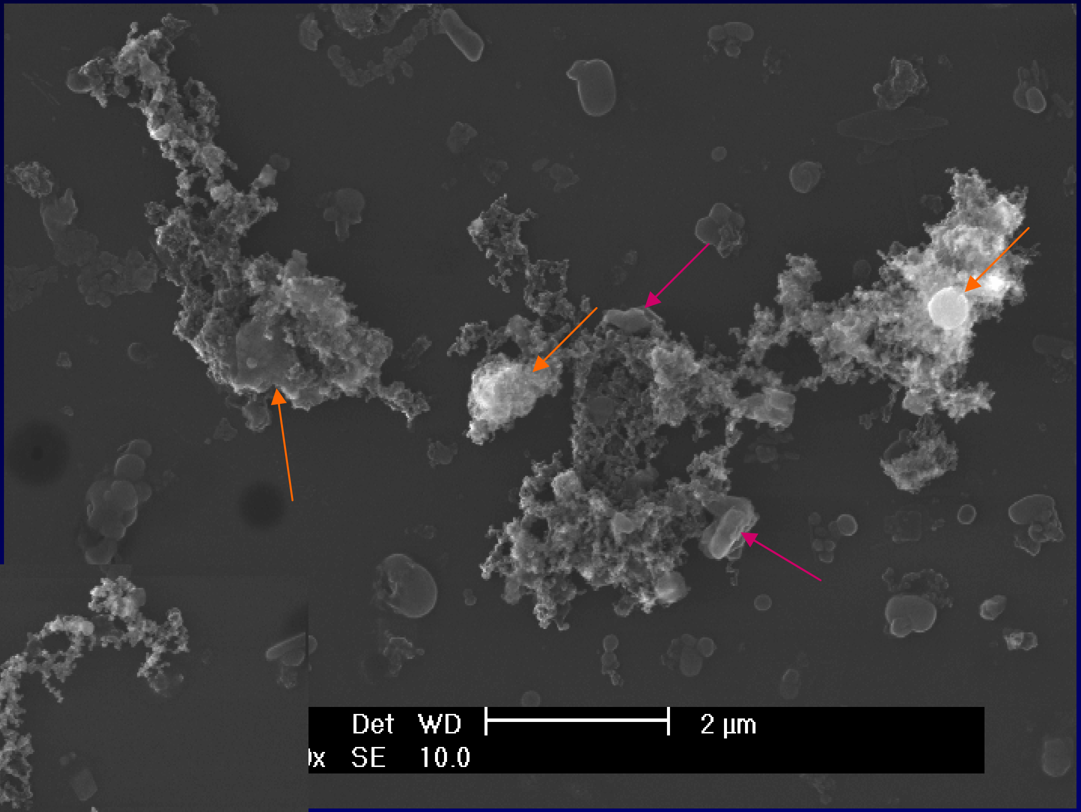
Satellite and Aircraft Intercomparisons for Biomass Burning and Dust Events

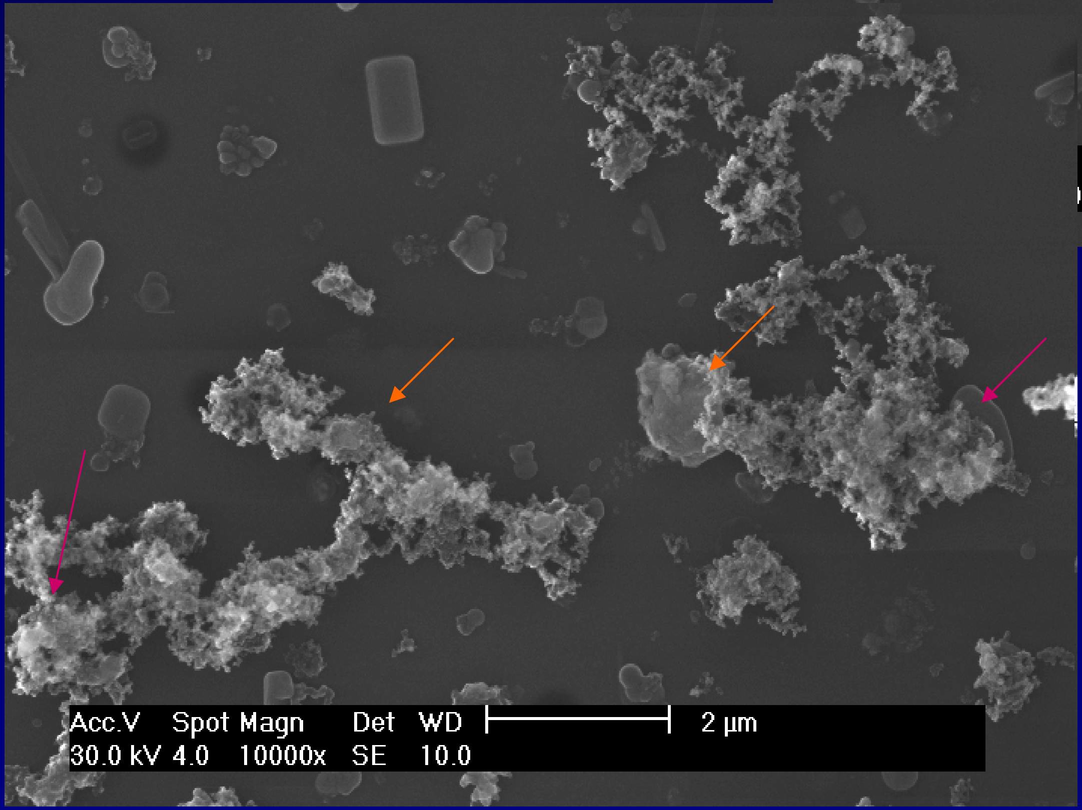


- Very dry conditions contributed to higher-than-normal biomass burning events.
- Mixing of anthropogenic and biomass burning particles.

- 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.

Scanning Electron Microscopy Images of Particles at T0

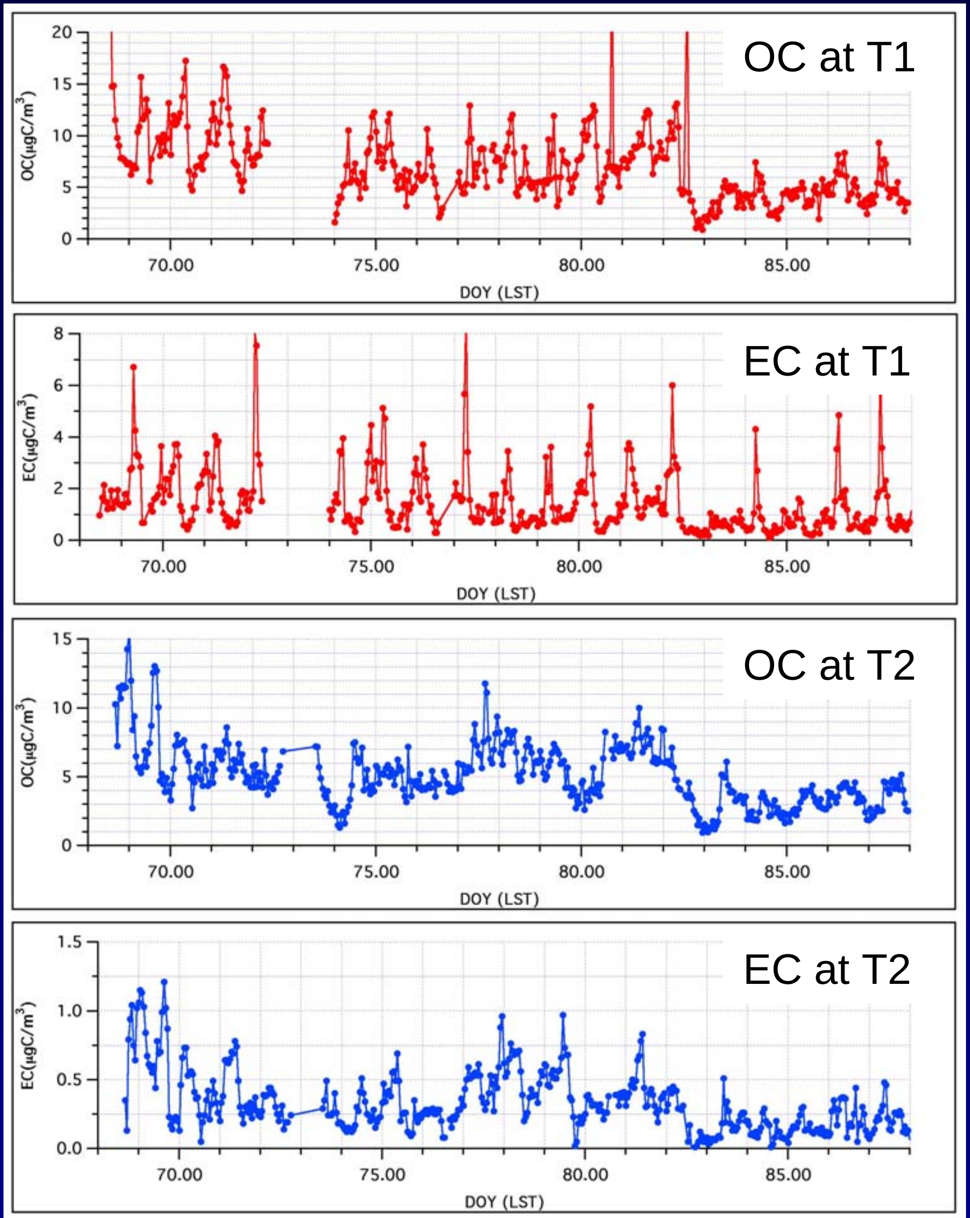




CaO inclusions and S-rich inclusions in soot particles

Y. Desyaterik, R. Hopkins, M. Gilles and A. Laskin; PNNL, LBNL

EC and OC Measurements at T1 and T2



Organic Carbon / Elemental Carbon Measurements at T1 and T2

EC - Tracer of Transport

OC - Tracer of Secondary Organic Aerosols

Higher concentrations and stronger diurnal variations at T1 than T2 as expected.

Data will be compared to optical data and aerosol composition.

C. Doran, J. Barnard, W. Shaw, PNNL

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:

Preliminary Data - September 2006

Final Data Sets – March 2007

MILAGRO Science Meeting – October 2006:

Preliminary Analyses

Begin Data Assessments for Publications

Acknowledgments

ASP MAX-MEX Science Team

Pilots and ASP Science Support personnel

MILAGRO Participants

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THE PROJECT WAS CARRIED OUT SAFELY WITH NO INCIDENTS.