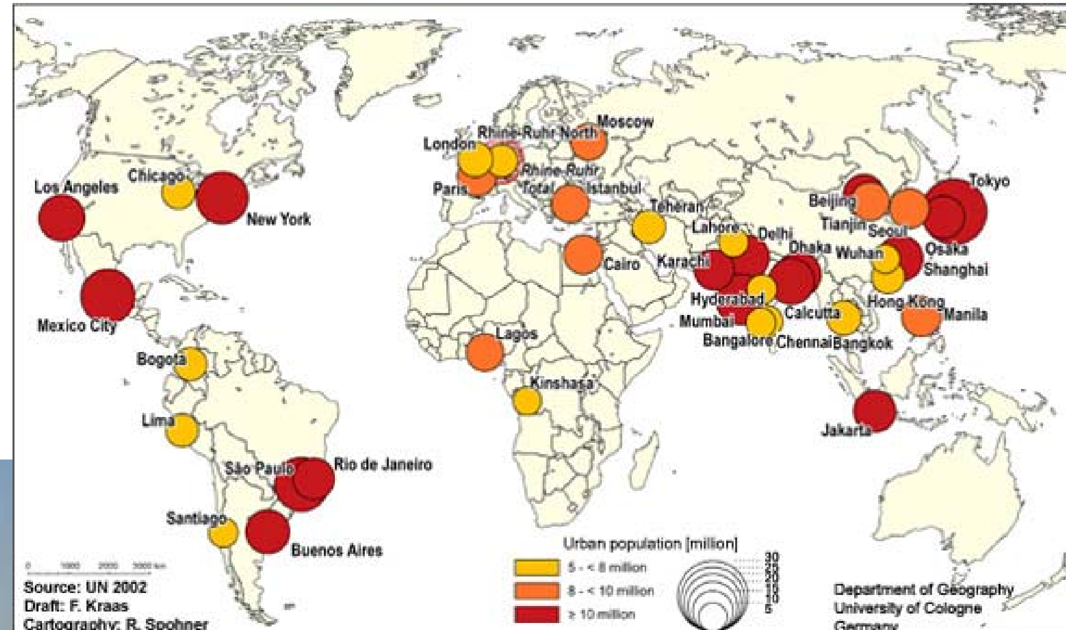
Megacities: Mexico City and Houston as Potential Field Sites

Nancy Marley and Jeff Gaffney

Argonne National Laboratory



Aerosol Radiative Forcing – You Need to Determine:

Optical Properties -(Size, Chemical Composition as Function of Size, Optical Constants, Etc.)

Sources - (Natural and Anthropogenic)

Lifetimes - (Size and Hygroscopicity)

Position in Atmosphere (Vertical & Horizontal Distributions)

NEED TO MINIMIZE MEASUREMENT UNCERTAINTIES

– NEED REASONABLE AEROSOL LOADINGS

- SENSITIVE and SELECTIVE INSTRUMENTATION

URBAN AREAS – *HIGH AEROSOL LOADINGS*

MAJOR SOURCES OF BOTH PRIMARY AND SECONDARY AEROSOLS to REGIONAL & GLOBAL SCALES

ASP HAS CONSIDERABLE HISTORY IN URBAN FIELD WORK

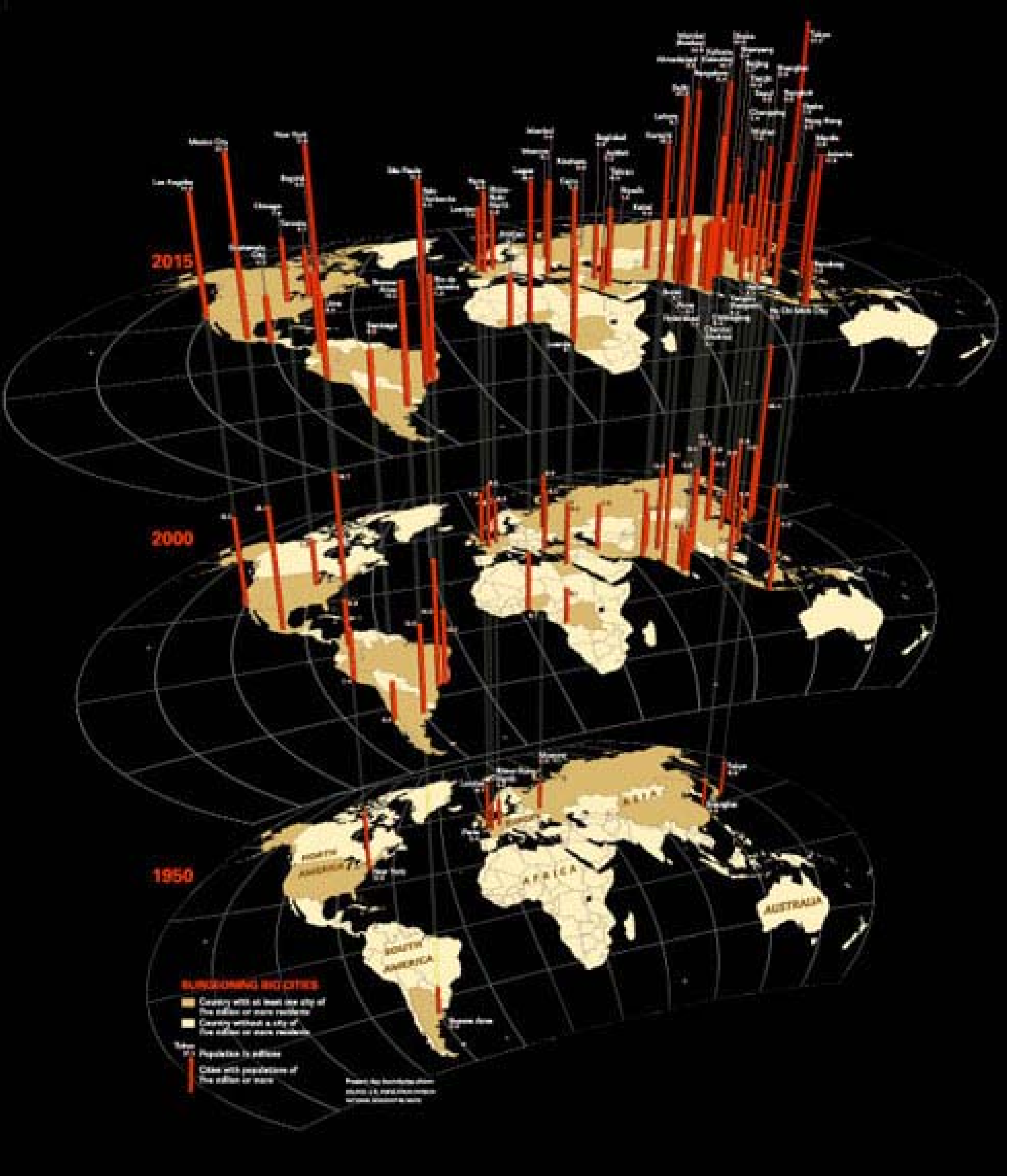
Mexico City – Aerosol Study – 1997

Northeast Oxidant and Particle Study (NEOPS), Philadelphia– 1999

Phoenix, AZ 1998, 2001

Texas Air Quality Study, TexAQs 2000 (**Houston)**

Mexico City Megacity 2003 – MCMA 2003 (MIT)



MEGACITIES

➢*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 ½ urban by 2025

MEGACITIES AND MINI-MEGACITIES MAJOR SOURCES OF AEROSOLS AND GREENHOUSE GASES

THESE SOURCES WILL BE CHANGING OVER TIME AS THE CITIES DEVELOP AND THE TECHNOLOGIES EVOLVE

CARBONACEOUS AEROSOLS (ORGANIC & BLACK CARBON)

SULFATE, NITRATE – *FOSSIL FUEL COMBUSTION*

BLACK CARBON – *DIESEL AND TWO-CYCLE ENGINES, ETC.*

SECONDARY ORGANIC AEROSOLS – *FOSSIL AND BIOGENIC*

NEED TO BETTER CHARACTERIZE THE EMISSIONS

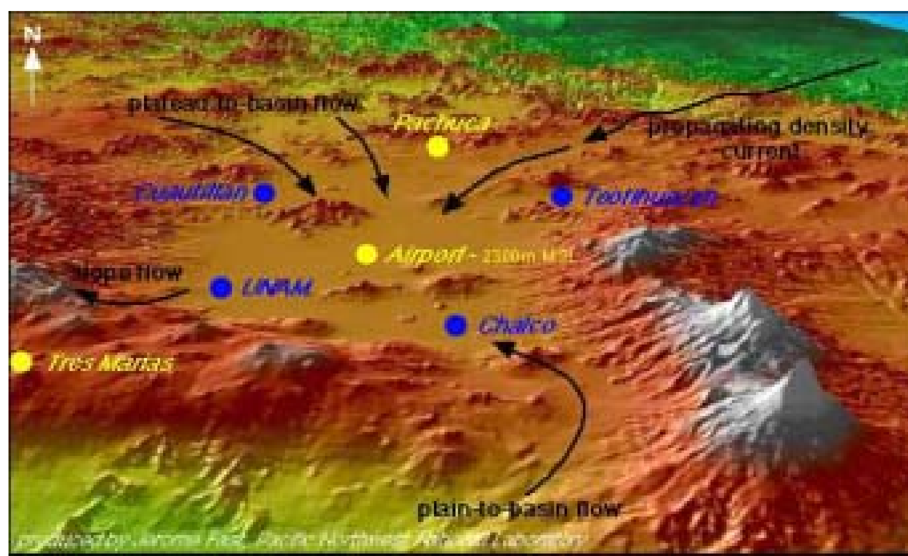
AND THEIR PROPERTIES (SIZE, ETC.)

MEGACITIES - TOP TEN

	Population	
Megacity	1991	2000
Tokyo, Japan	27,245,000	29,971,000
Mexico City, Mexico	20,899,000	27,872,000
Sao Paulo, Brazil	18,701,000	25,354,000
Seoul, South Korea	16,792,000	21,976,000
New York, USA	14,625,000	14,648,000
Osaka, Japan	13,872,000	14,287,000
Bombay, India	12,101,000	15,357,000
Calcutta, India	11,898,000	14,088,000
Rio de Janeiro, Brazil	11,688,000	14,169,000
Buenos Aires, Argentina	11,657,000	12,911,000

TARGET OF OPPORTUNITY - MEXICO CITY

- 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**



Mexico City 1997

LOTS OF AEROSOLS – ON A DAILY BASIS!

> 50 $\mu g/m^3$ PM-2.5

50% Organic and Black Carbon (Soot)

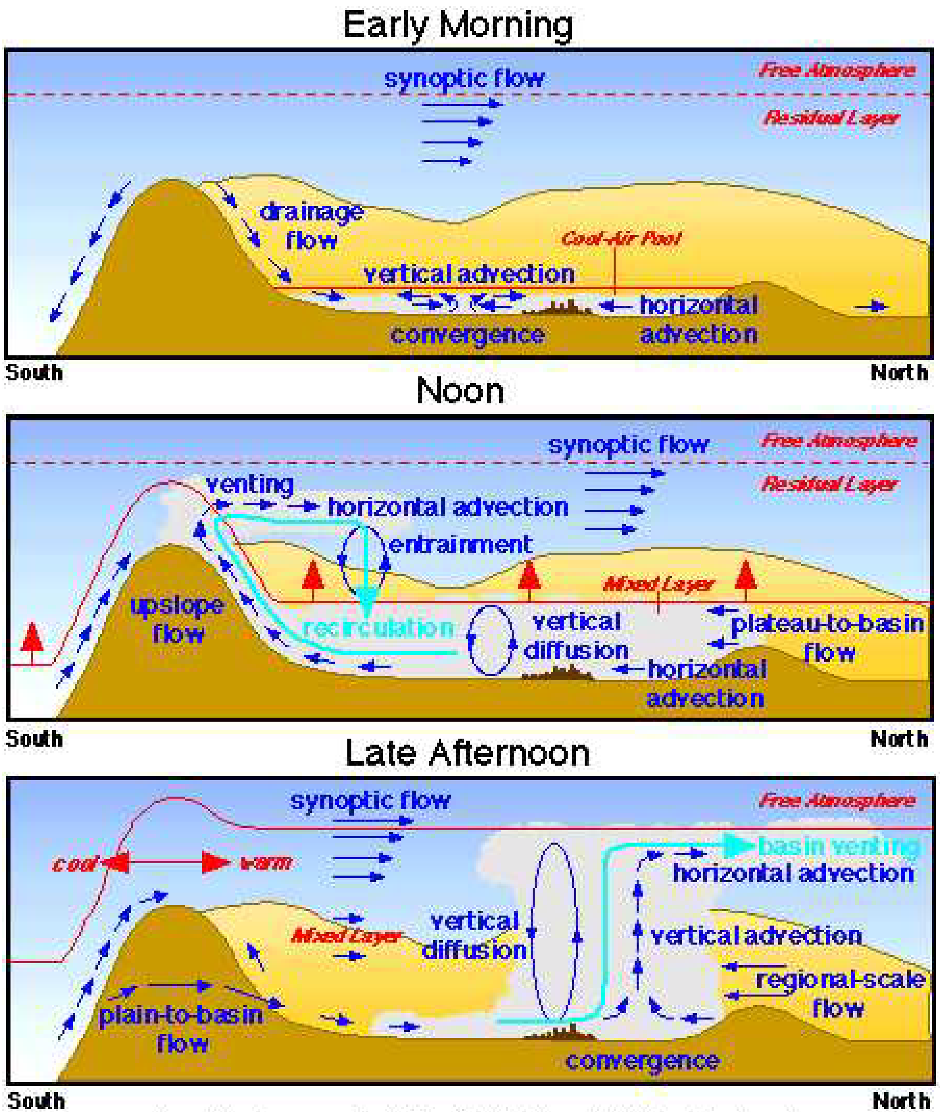
Fast NO to NO_2 Conversion & NH_4NO_3 Production

NH_3 Important!

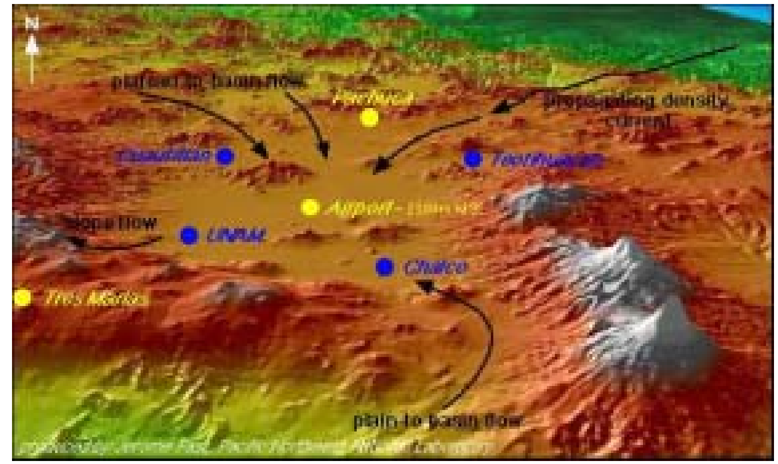
NH_3 Sources?

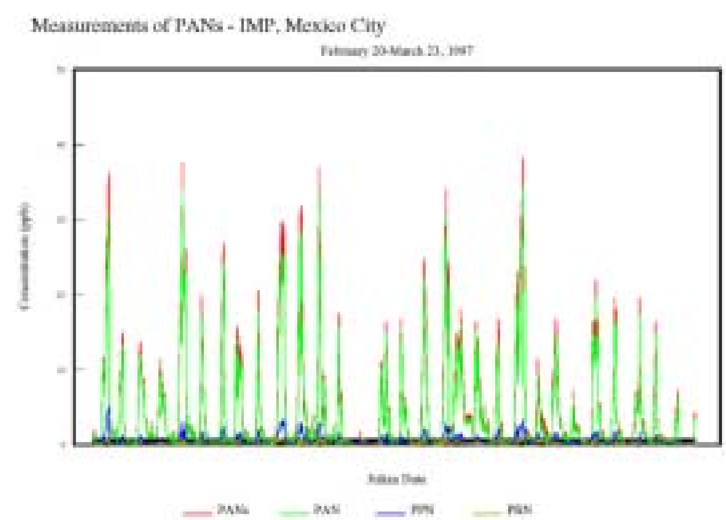
Mexico City 7:50 am 2/21/97

ASP METEOROLOGY – SHOWED STRONG DIURNAL TRANSPORT IN MEXICO CITY BASIN! TYPICAL?



produced by Jerome Fast, Pacific Northwest National Laboratory





MEXICO CITY MEGACITY 2003 – APRIL

Collaborative Effort with MIT – Luisa and Mario Molina

Mexico City Metropolitan Area 2003 (MCMA) Study

NARSTO Effort

Preliminary Findings of Note:

High Levels of Black Carbon – *Not Washed Out in Rain Event!*

Important – Regional Climate Implications

Obtained Radiation Data as well as Comprehensive Aerosol and Gas Phase Data Sets

Aerosol Mass Spectrometers (Aerodyne)

DOAS, LIDAR, TDLAS, MFRSR instrumentation

High Levels of Ammonia – Anti-correlated with NH_4NO_3

New Cars – NH_3 Sources!

April 2003 Intensive Field Measurement Campaign

Supersite at CENICA (Ixtapalapa)

- ❑ Fixed Site Aerosol Mass Spectrometer (Aerodyne)
- ❑ Tall flux tower (Washington State University)
- ❑ UV-VIS DOAS (University of Heidelberg/MIT)
- ❑ LIDAR (University of Berlin/MIT)
- ❑ Tethered balloon (CENICA)
- ❑ Vertical atmospheric radiosondes (IMP/MIT)
- ❑ Fast GC with Luminol detection method - PAN, NOx
- ❑ Aethalometer - Black Carbon
- ❑ Tunable-diode laser system for NH_3
- ❑ VOC Canister sampling
- ❑ Fast GC with OLEFIN Detector- isobutene
- ❑ Nitroarenes (Arey, Atkinson, UCRiverside)
- ❑ Organic Carbon/Elemental Carbon (LBNL)
- ❑ MFRSR & Aerosol Characterization (PNNL)
- ❑ PTRMS/Aerosol Mass Spectrometer– VOCs (PNNL)

POOLING RESOURCES THROUGH COLLABORATIVE FIELD WORK!

MCMA 2003 – MIT/AERODYNE MOBILE LAB

SPATIAL INFORMATION

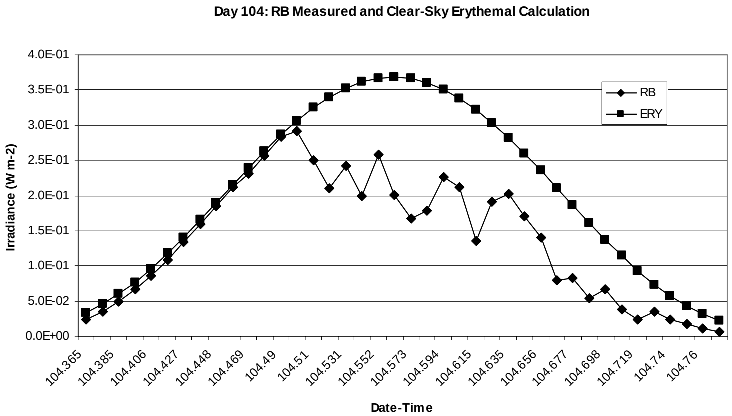
- NH_3/HNO_3 /HONO/HCHO QC-TILDAS (Aerodyne)
- AEROSOL MS
- Chemiluminescent NOy instrument (MIT)
- PTR-MS (MSU)
- Real-time Canister/Cartridge Autosampler (WSU)
- PAN/NO_2
- AETHALOMETER (LBNL)

BLACK CARBON – PRIMARY AEROSOL

Strong Absorber of Short Wave And Long Wave Radiation.

DIESELS

BIOMASS
BURNING

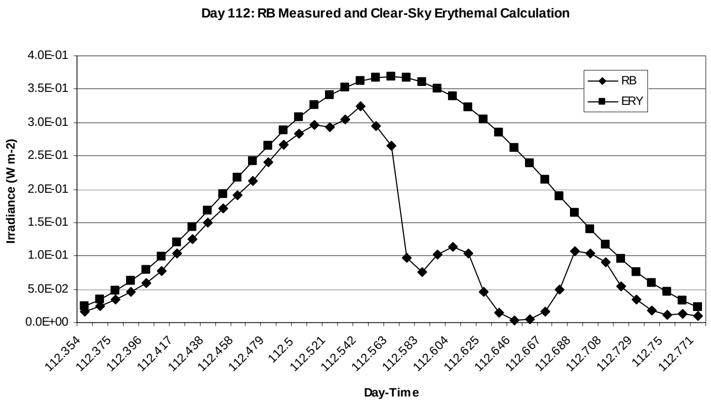


PHOTOCHEMISTRY EFFECTS

BC Absorbs Actinic Radiation

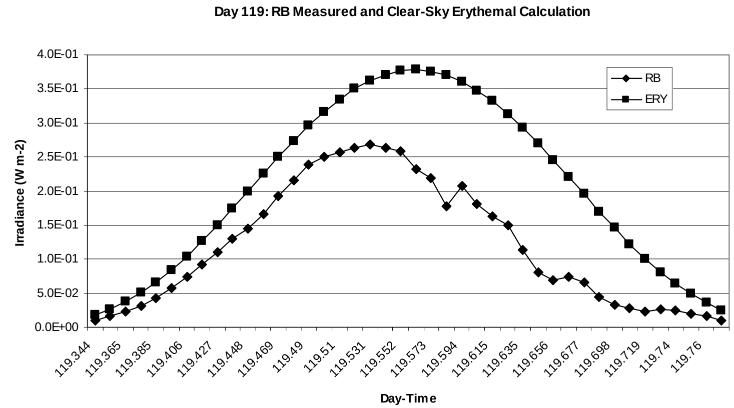
Modeled UVB vs. Robertson-Berger Meter

Cloud Effects (Added Bonus!)



April 22 – Julian Date 112 – RAIN EVENT

UV-B at zero!



Early morning – Black Carbon

CH_2O, NO_2, etc. → Ozone

IMPORTANCE OF PHOTOCHEMICAL FEEDBACKS

Less UV from BC absorption

Reduced Secondary Greenhouse Gas Formation (e.g. O_3)

Increased Lifetimes of Other Greenhouse Species (e.g. RH, CO)

Reduced Rates of Formation of Sulfates, Nitrates, Secondary Organic Aerosols

Biota Effects as Well – CO_2 Uptake – Evapotranspiration, etc.

Others?

AETHALOMETER

Optical Method Developed by DOE ASP Supported Research

Commercial Instrument

Seven Wavelengths

1-2 Minute Time Resolution

Semi-Continuous Operation

BC Data – 30 days – Aethalometer – Mexico City April 2003

Daily Average - **5000 ng m^{-3}** (Std dev. 1500 ng m^{-3})

Daily Maximum Ave **14300 ng m^{-3}** (Std dev. 6100 ng m^{-3})

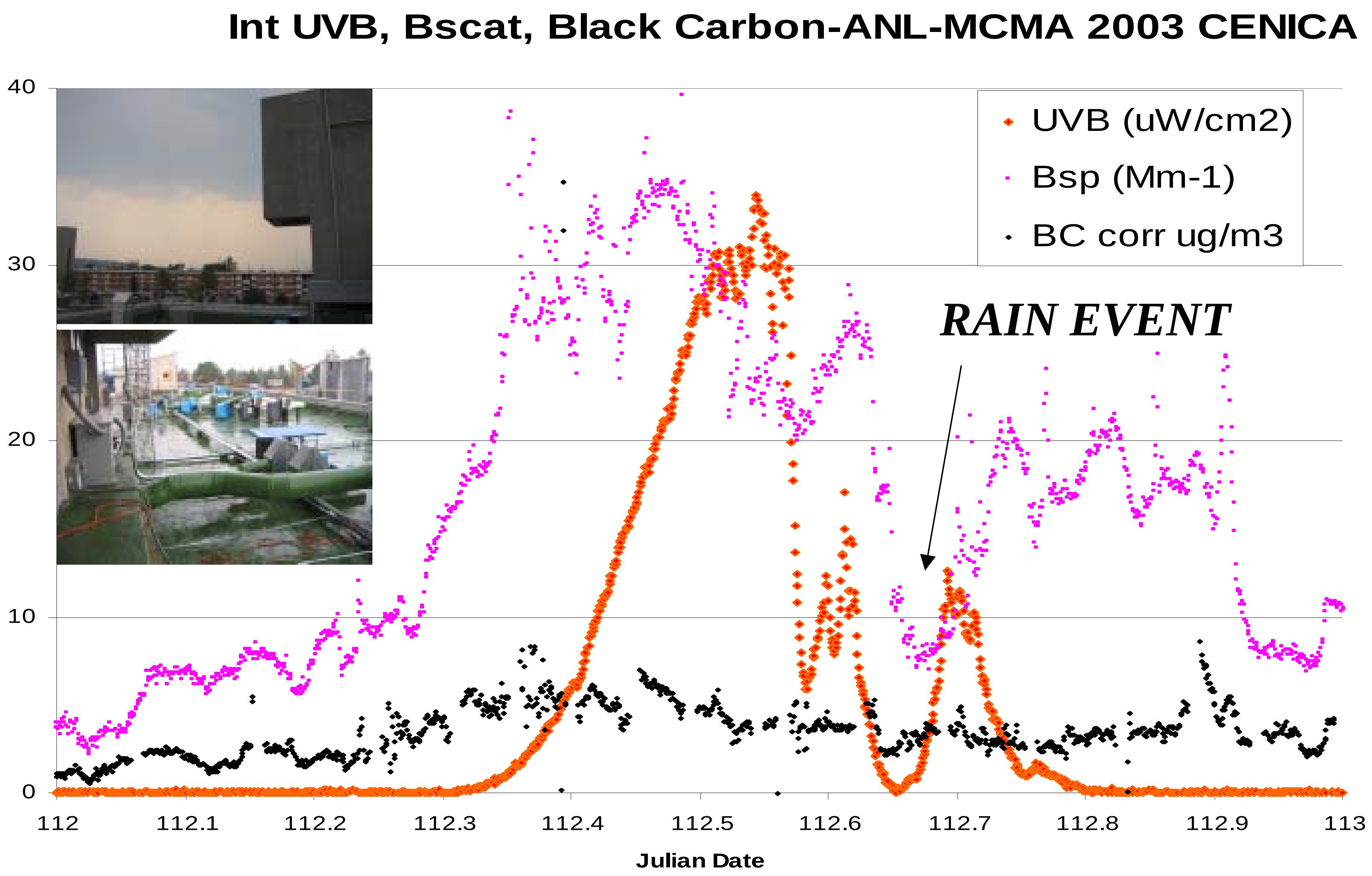
Daily Minimum Ave **1800 ng m^{-3}** (Std dev. 850 ng m^{-3})

PREVIOUS WORK in 1997 Ave **PM-2.5 was 50 μg m^{-3}**

10 % BC estimated from thermal analyses compares very well with this work.

DATA TAKEN DURING HOLY WEEK – SHOWS BC REDUCED

April 22, 2003



Most Models – BC Treated Same as Hygroscopic Aerosols

Lifetimes from 2-7 days

This work and other data indicates BC has longer lifetime.

Models Typically Underestimate Black Carbon and Organic Carbon (Secondary Organic Aerosols) by Factors of 3-4 (or more) (Chung & Seinfeld 2002).

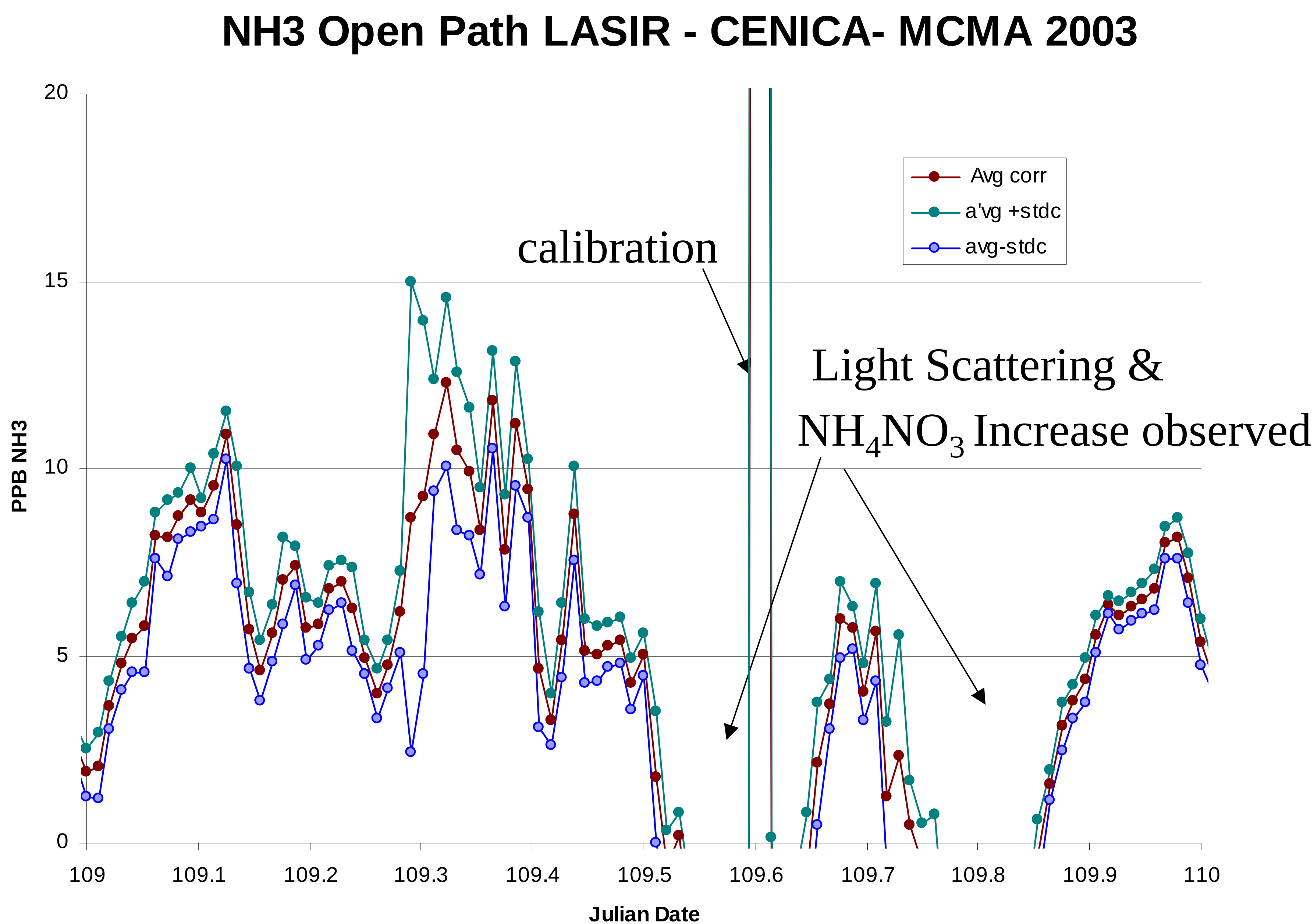
NEED TO ADDRESS AGING OF BC

Mexico City Plume

AMMONIA – IMPORTANT IN FORMATION OF AEROSOLS

TUNABLE DIODE SYSTEM – NEAR-IR LINE – 0.8 PPB DETECTION LIMIT

TELESCOPE/REFLECTOR SYSTEM – 244 M PATH


NH3 Open Path LASIR - CENICA- MCMA 2003
PPB NH3
Julian Date
0
5
10
15
20
109
109.1
109.2
109.3
109.4
109.5
109.6
109.7
109.8
109.9
110
Avg corr
a'vg +stdc
avg-stdc
calibration
Light Scattering &
NH_4NO_3 Increase observed

Preliminary Observations from Mexico City Megacity 2003 – MCMA 2003

Importance for Regional and Global Climate

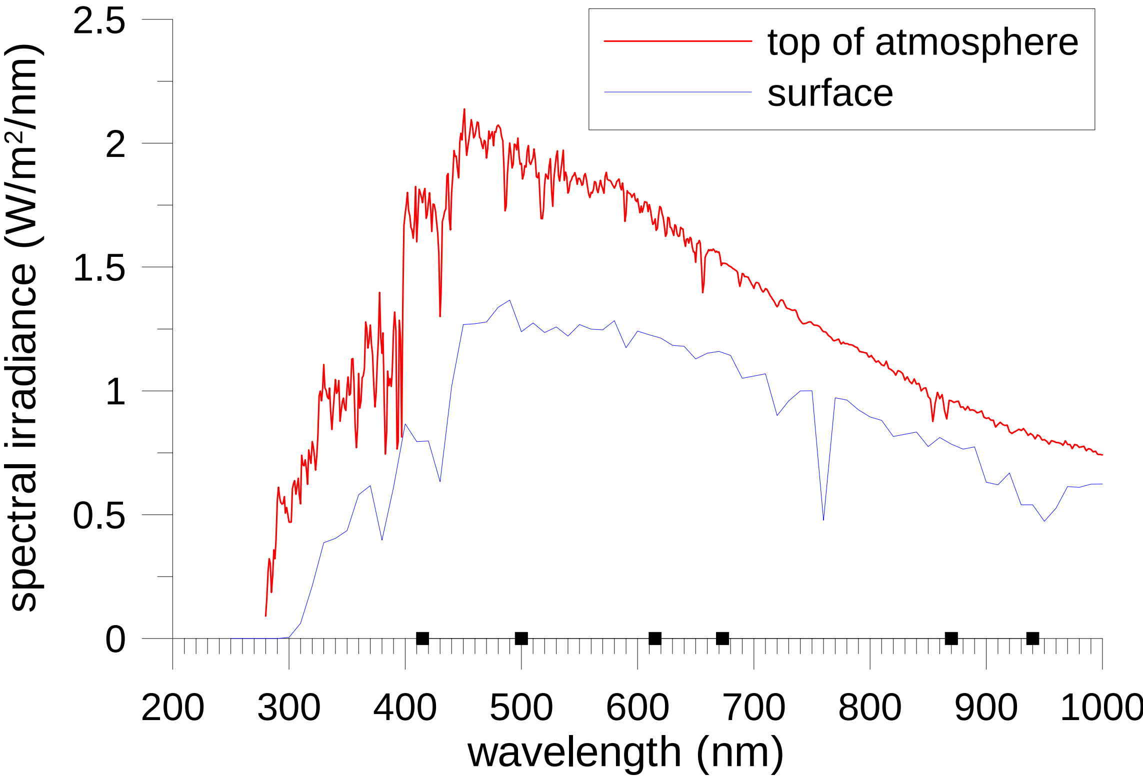
MEXICO CITY MAJOR SOURCE OF BC and NH_4NO_3

BC Can Heat as Well as Scatter – So BC Acts as Greenhouse Species (Hansen et al, 2000; Jacobsen, 2000, etc.)

BC Direct Effect – Semi-Direct Effect (Change in Relative Humidity)

NH_4NO_3 – Direct and Indirect Effects – Scattering

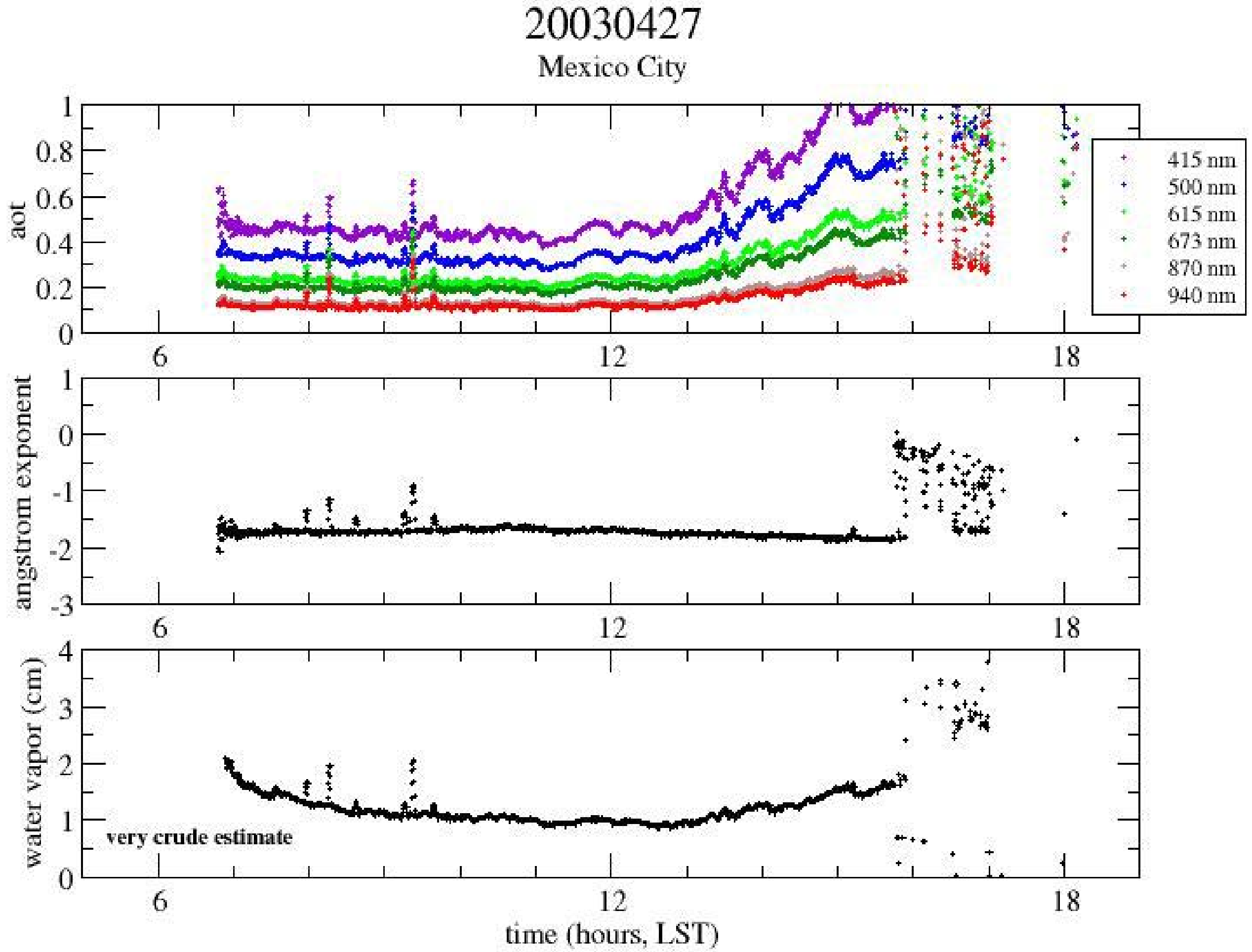
MFRSR Solar Radiation



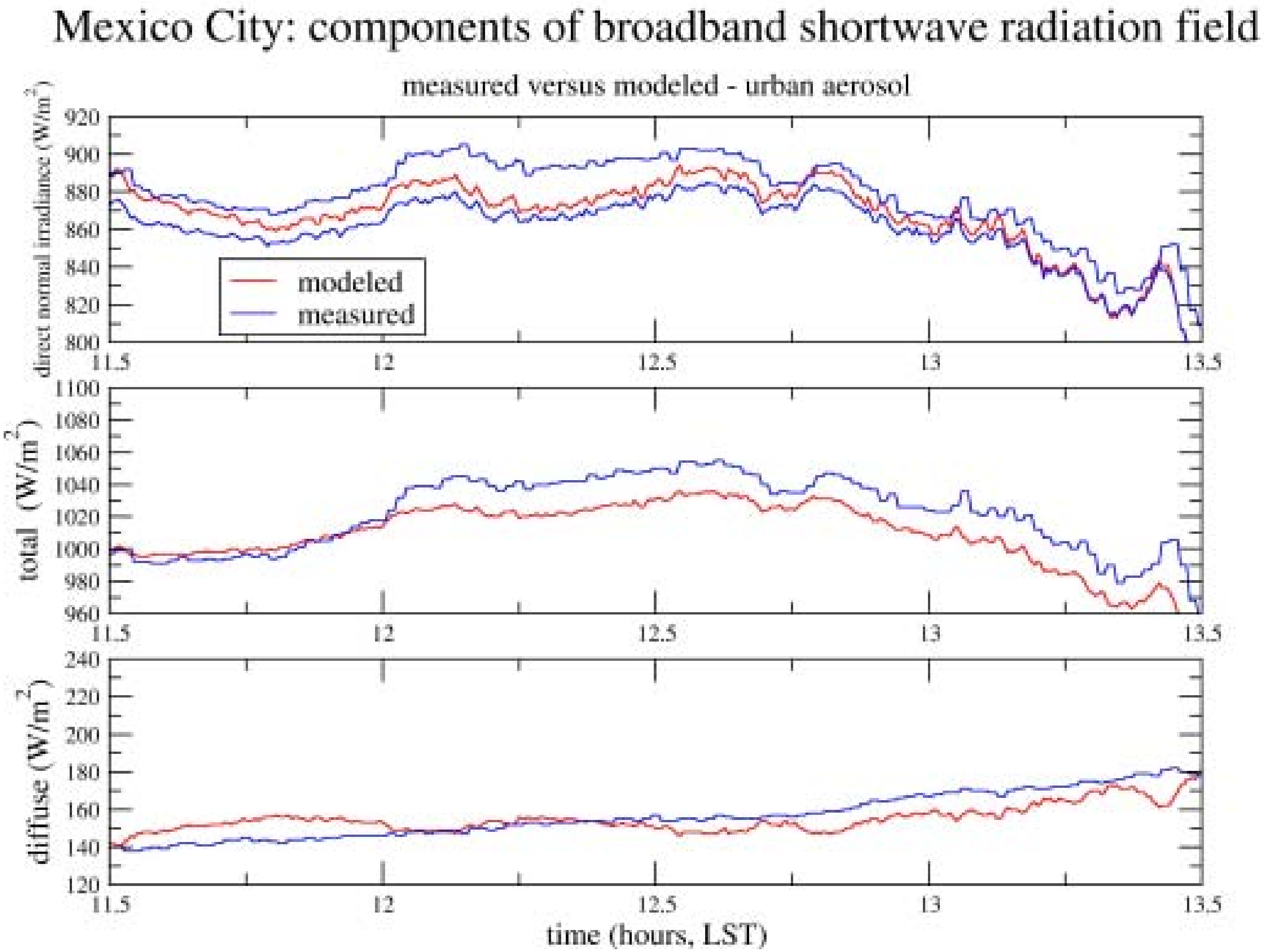
MFRSR – Visible and

UV Channels

Aerosol Optical Thickness



Run Measured vs Modeled experiment (narrowband to broadband)



We get excellent agreement for $\varpi_o = 0.80$ for diffuse radiation

Broadband Fluxes (W/m^2)

	Modeled	**Measured**	Error
direct	867	878	1.3%
diffuse	155	157	1.3%
total	1009	1022	1.3%

SINGLE SCATTERING ALBEDO REFLECTS BC IMPACT!

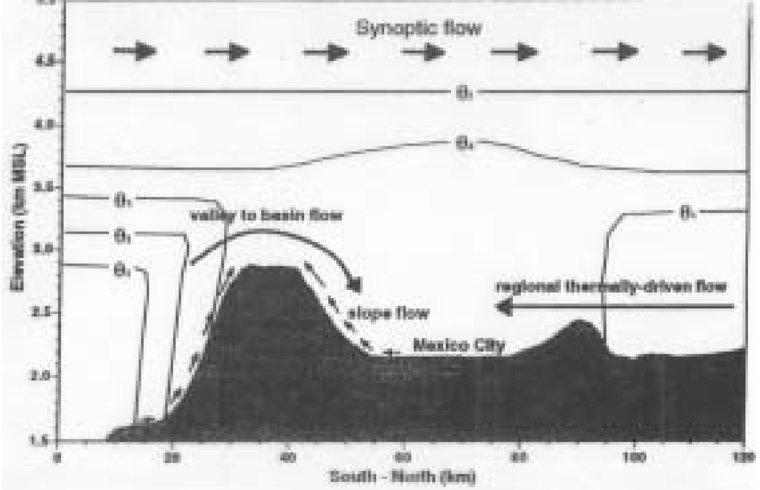


Figure 2. Schematic diagram of possible contributions to local flow patterns in the Mexico City area.

ASP Meteorologists

Showed Regional

"Flushing" of Basin

In Mexico City 1997
Study .

LIDAR AND AEROSOL DATA – BC, SULFATE, NITRATE, NH_3

Single Particle Mass Spectrometers, DOAS, etc.

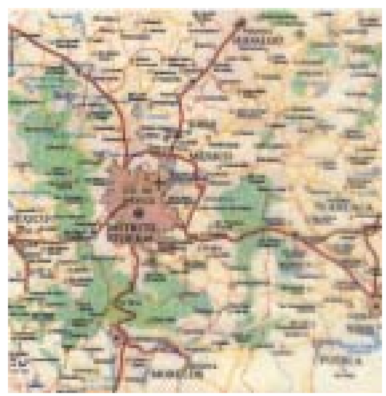
→Daily Flux Estimates of the Mexico City Plume!

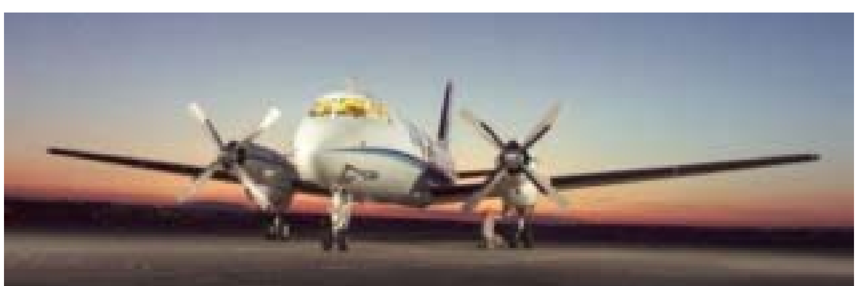
→Comparison to Modeled Emissions

→SPATIALLY CORRECT?

MEXICO CITY MEGACITY 2006

PLANNING INITIATED FOR JOINT AIRCRAFT
& GROUND BASED STUDY
COLLABORATION WITH
MCMA 2006 – MIT
MIRAGE 2006 - NSF





SOME FOCUS AREAS

• DETAILED CHARACTERIZATION OF A MEGACITY PLUME

INTEGRATED AEROSOL SOURCE STRENGTHS FROM A MEGACITY – FOR MODEL COMPARISON

NSF and DOE Aircraft

ASP Meteorology (RASS, SODARS, LIDARS)

Ground Based Measurements

SECONDARY AEROSOL FORMATION & AGING – DOWNWIND PLUME MEASUREMENTS – BLACK CARBON, ETC.

NIGHTTIME RADIATIVE FORCING – “SMUDGE POT”EFFECTS (Jacobsen 2002) – GROUND BASED MEASUREMENTS.