Breakout Group 3:
Aerosol Optical Properties & Radiative Effects

Co-Chairs:
Phil Russell,
Jim Barnard, Nancy Marley, Yohei Shinozuka

Second MILAGRO
Science Meeting
15-18 May 2007
Mexico City

Breakout Group on Aerosol Optical Properties & Radiative Effects

Summary of potential papers*

- **Grouped into 5 categories:**

	Papers
- Comparisons	2
- Local m^3 closure of size distribution, composition, scattering, absorption, f(RH), CCN concentration	2
- Local column radiation closure	4
- Upscaling from land based and in-situ aircraft to satellites, local to regional	10
- Validation and comparison of remote sensing measurements	18
Total	36

*Updated Mar 2007 for INTEX-B Meeting

Breakout Group on Aerosol Optical Properties & Radiative Effects

Plan re potential papers

- **Send current list to MILAGRO email list after this meeting**
  - **Request updated titles, authors**
  - **Request planned submission date**
    (Reminder: Planned ACP publication date is Dec 2008)
  - **Recommend that authors circulate drafts among breakout group members before submission (Sasha)**

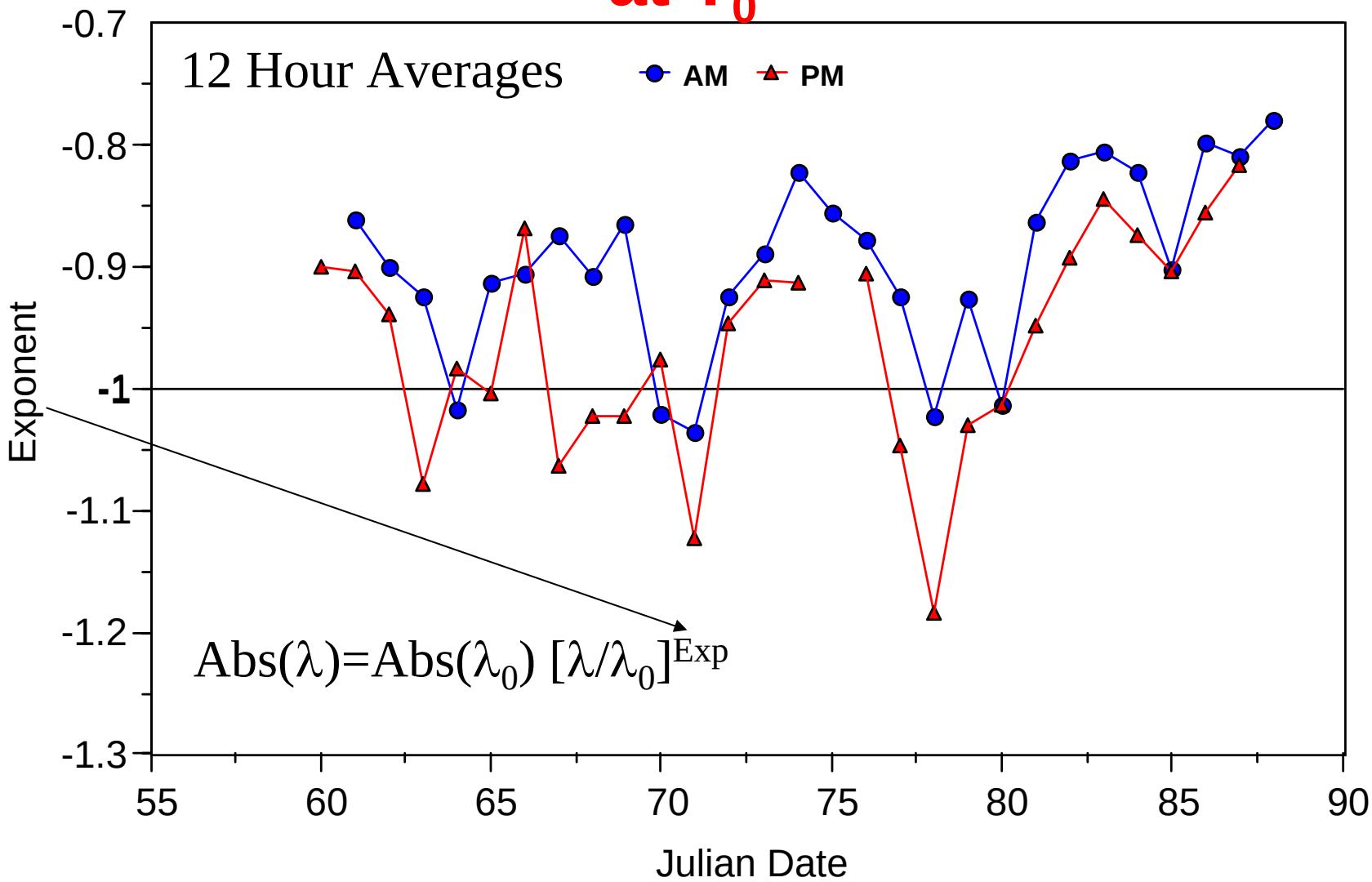
Breakout Group on Aerosol Optical Properties & Radiative Effects

Major findings (nuggets):

- **Absorption of Mexico City aerosol is frequently different than expected from the black carbon 1/λ dependence (N. Marley, P. Arnott).** This fits with:

- At T_0 BC particles are coated with organics (T. Onasch, Slowik, Dubey): TEM (Adachi), SPMS (Moffet).
- Absorption amplification on A/C (Shinozuka, Clarke et al.)
- SSA decrease in near UV (Jim Barnard, Rainer Volkamer)
- Plotting data by wavelength dependence of absorption and scattering produces clustering, with clusters probably dependent on sources and ageing (Clarke)
  - enhanced UV absorption observed in afternoon
  - enhanced near IR absorption observed some mornings

Wavelength dependence of aerosol absorption at T_0



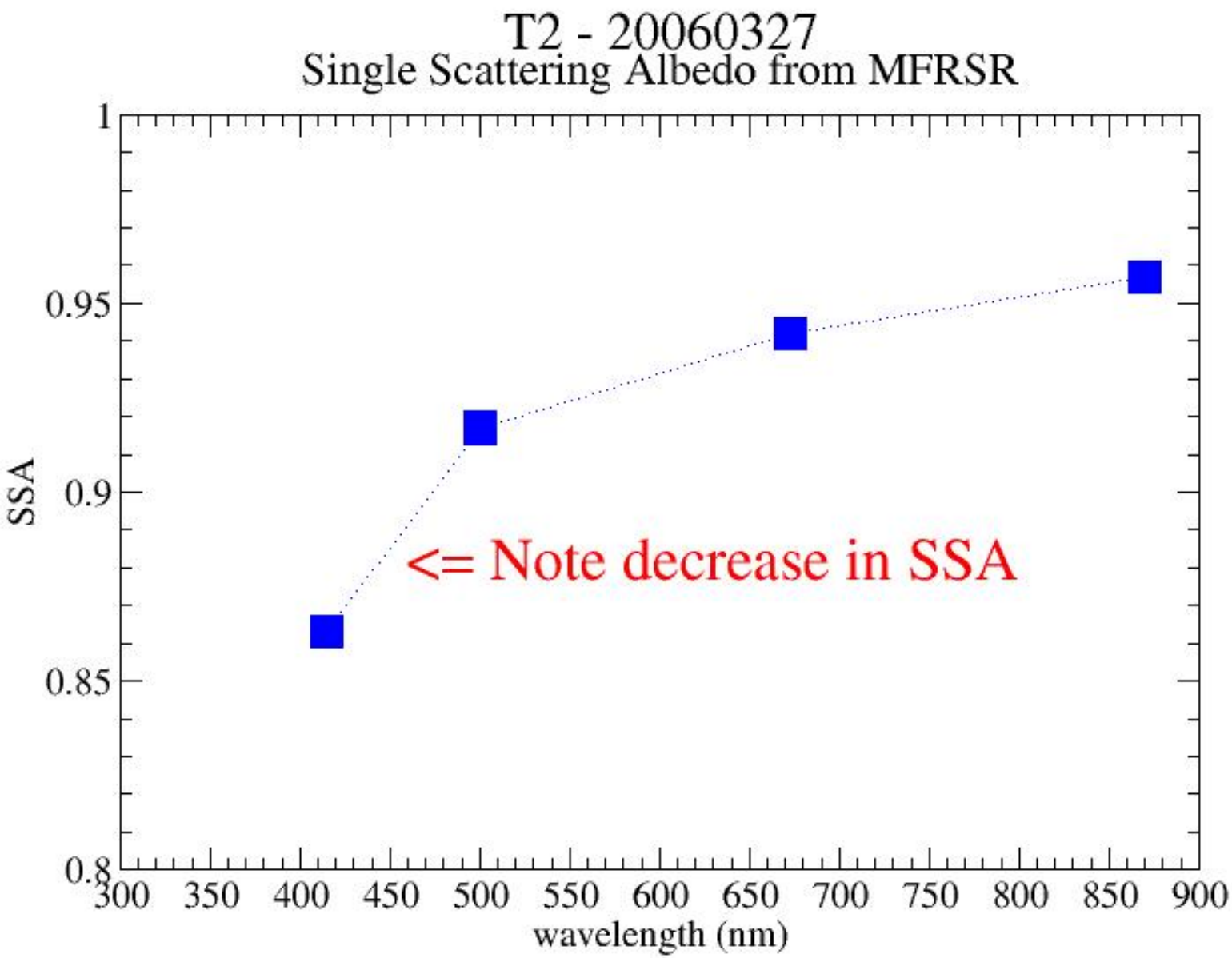
March 1 – 29 (Day 60 – 88), 2006

N. Marley et al.

Evidence of enhanced absorption in UV and near-UV from ϖ_0 measurements

Jim Barnard, PNNL

Rainer Volkamer, UCSD

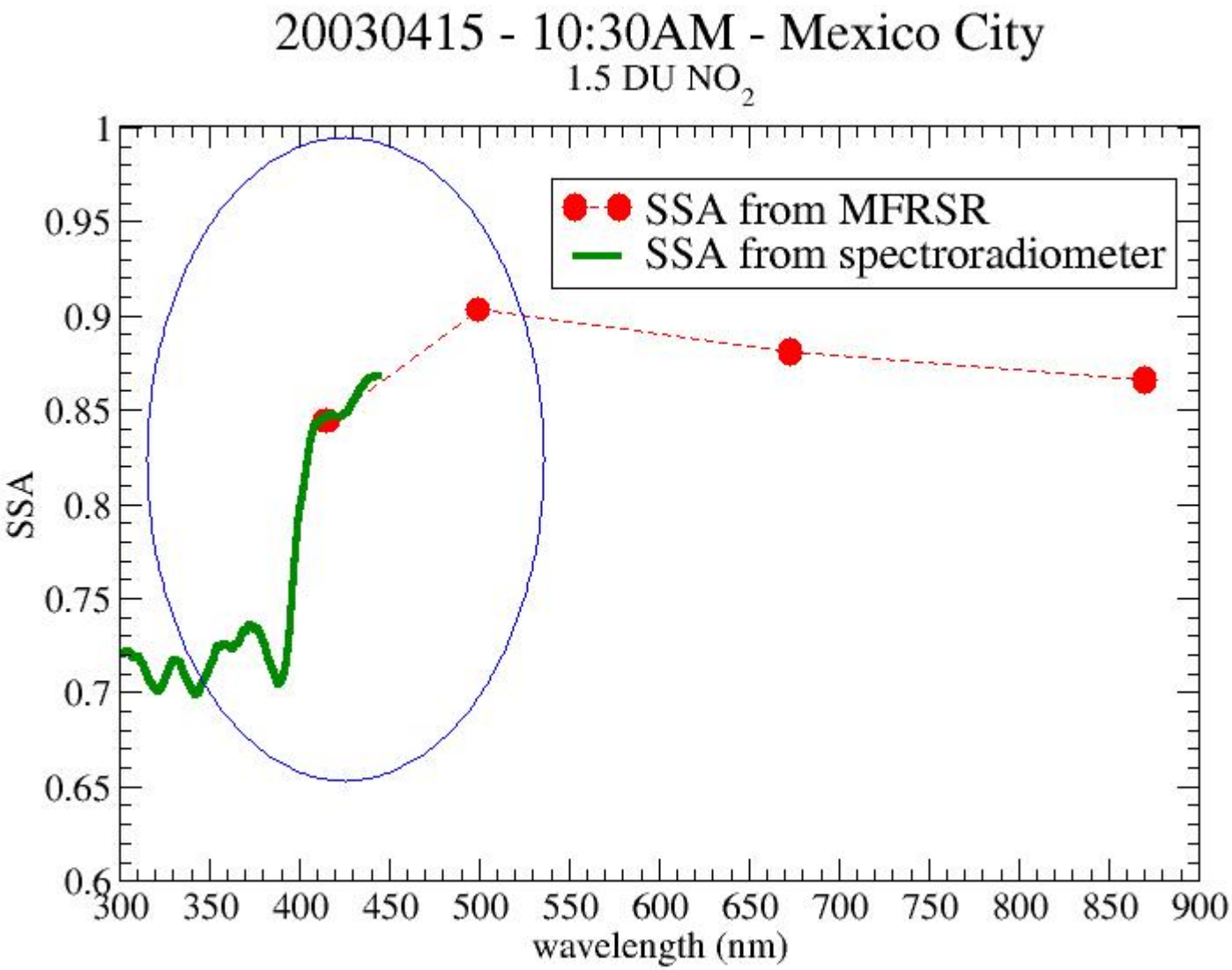

T2 - 20060327
Single Scattering Albedo from MFRSR
SSA
1
0.95
0.9
0.85
0.8
300
350
400
450
500
550
600
650
700
750
800
850
900
wavelength (nm)
<= Note decrease in SSA

¿ Preguntas ? (Questions)

Is this decrease in ϖ_0 seen at other sites and at other times?

Is this decrease seen by different instruments?

¡Sí!


20030415 - 10:30AM - Mexico City
1.5 DU NO2
SSA from MFRSR
SSA from spectroradiometer
SSA
wavelength (nm)
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
300
350
400
450
500
550
600
650
700
750
800
850
900

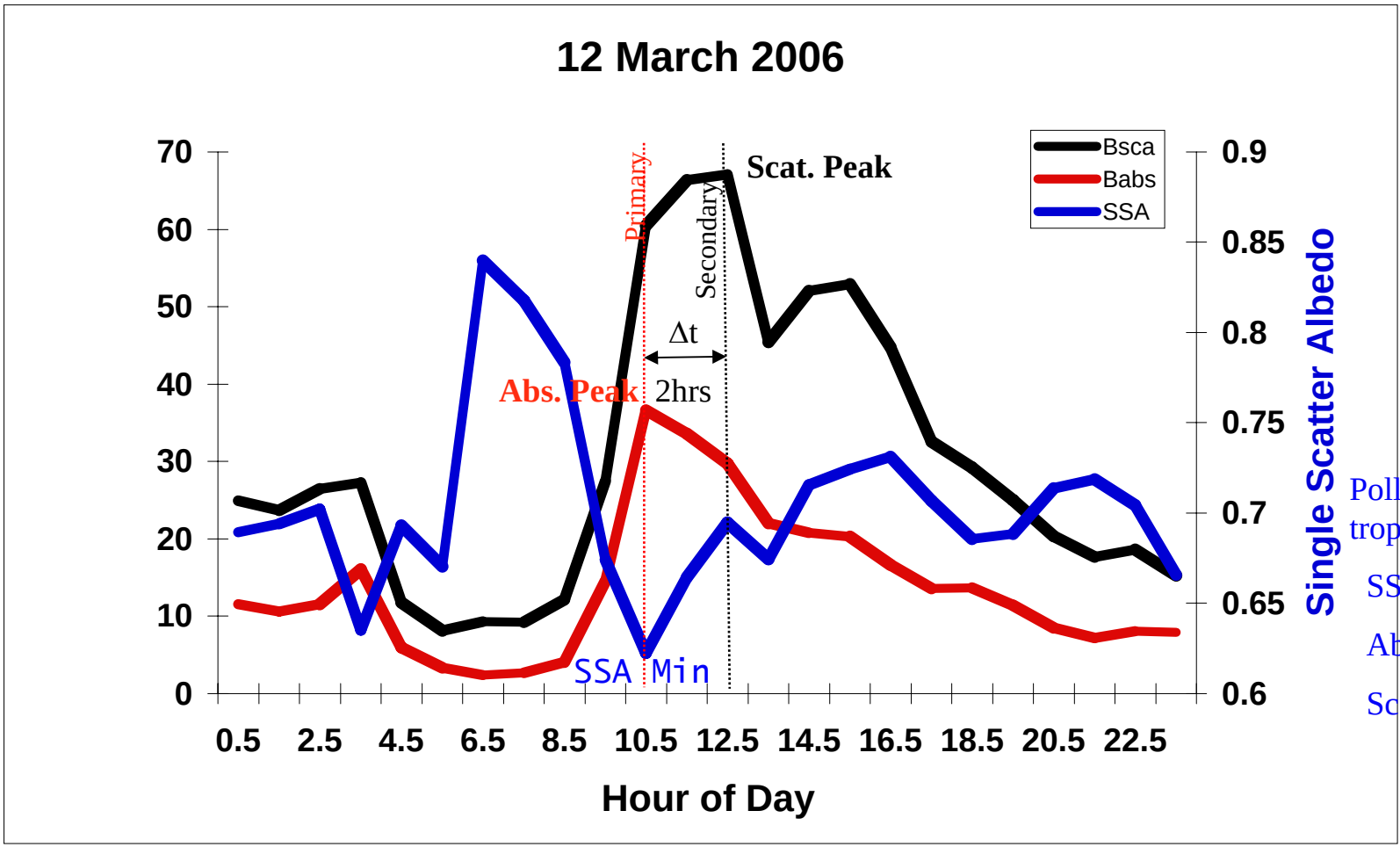
Breakout Group on Aerosol Optical Properties & Radiative Effects

Major findings (nuggets):

- **Delayed scattering at Picos Tres Padres indicates secondary organic aerosol formation (Mazzoleni, Dubey)**
  -Mechanism developed by simultaneous measurements and modeling of gas-phase precursors (Herndon et al)

- **Average SSA of surface aerosol at the surface in Mexico City Valley surveyed extensively by the Aerodyne-LAPA is ~0.7 (absorbing), consistent with fresh soot (SSA~0.3) coated by scattering organics (Mazzoleni, Dubey)**

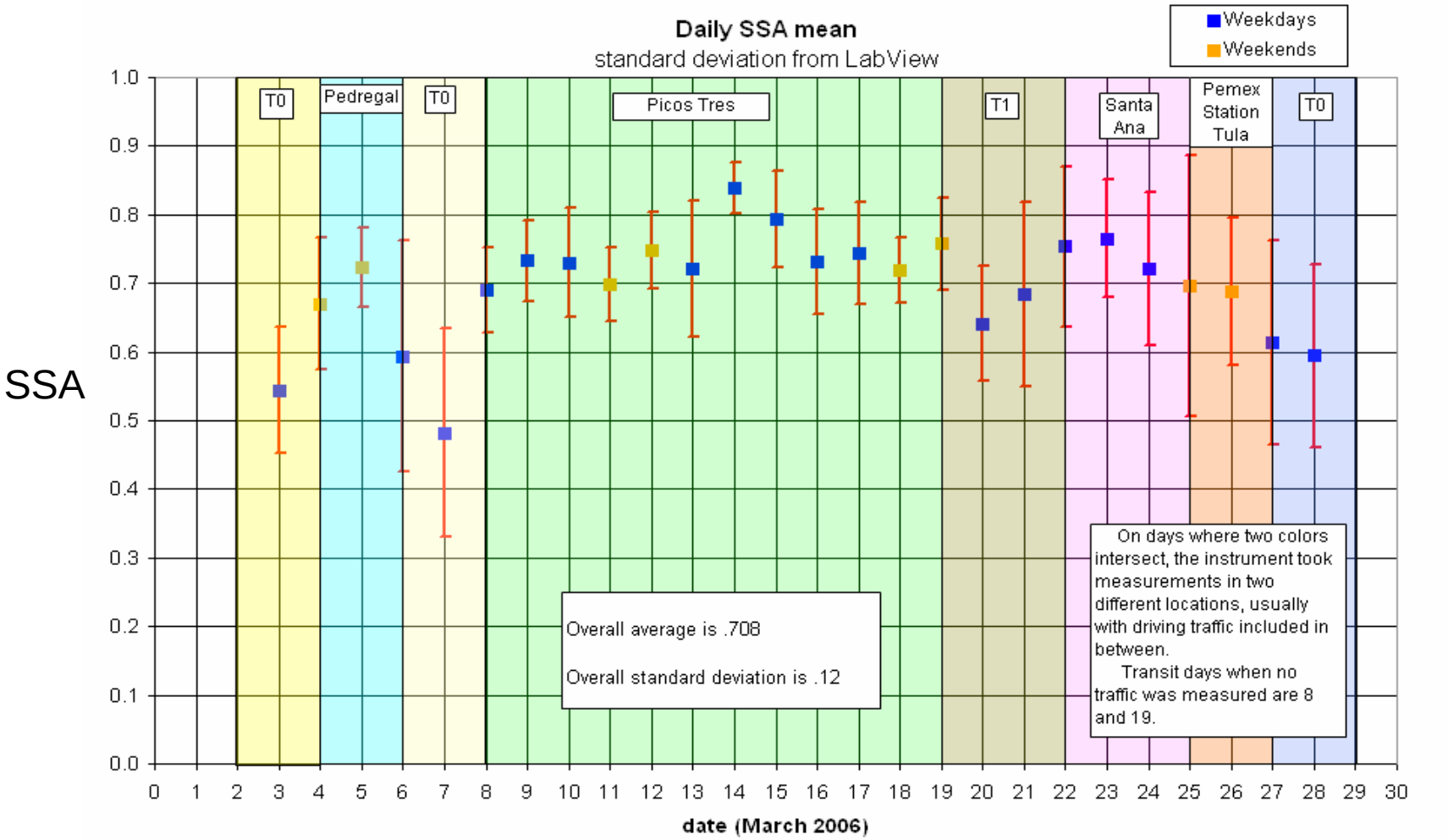
Picos de Tres Padres: March 12 2006
Los Alamos PhotoAcoustic (781nm)



Absorption rises faster than scattering and peaks earlier in morning. Delayed scattering is likely from secondary aerosol formation (Herndon et al).

Mazzoleni, Dubey et al

Survey of Single Scatter Albedo (781nm) of Mexico City Aerosols by LosAlamosPhotacoustic on Aerodyne Van



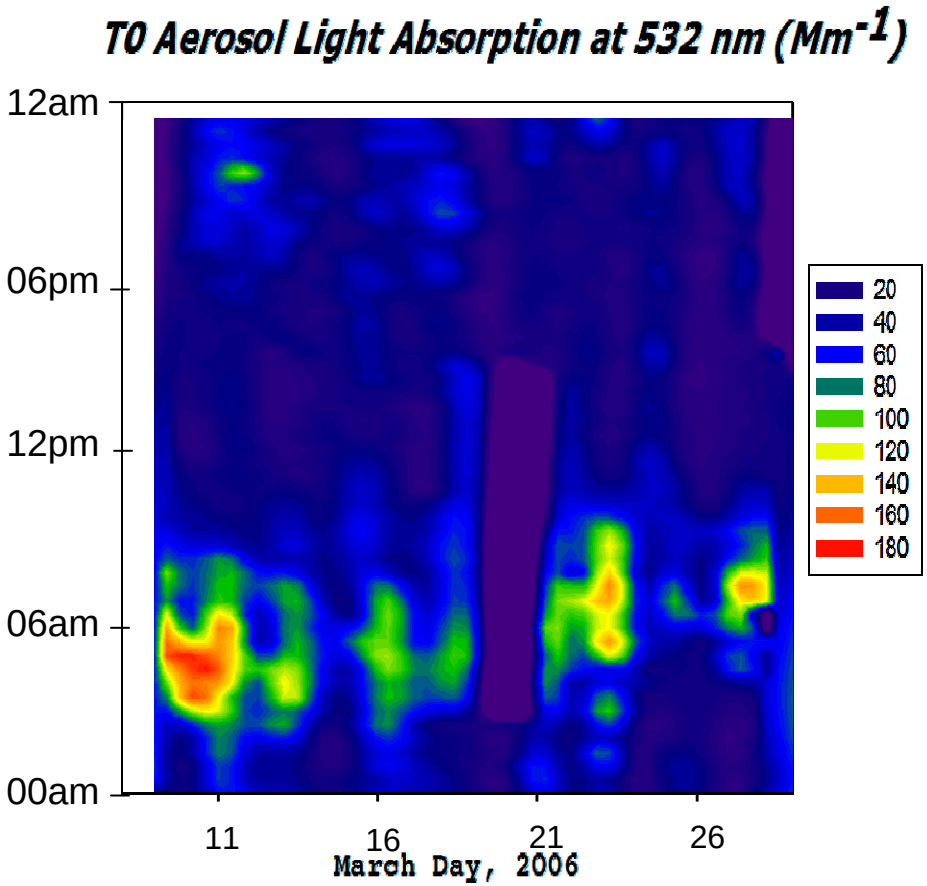
Average SSA of 0.7 indicates highly absorbing aerosols in the Mexico City. Probably soot (SSA~0.3) coated with organics/sulfate with high SSA~1.

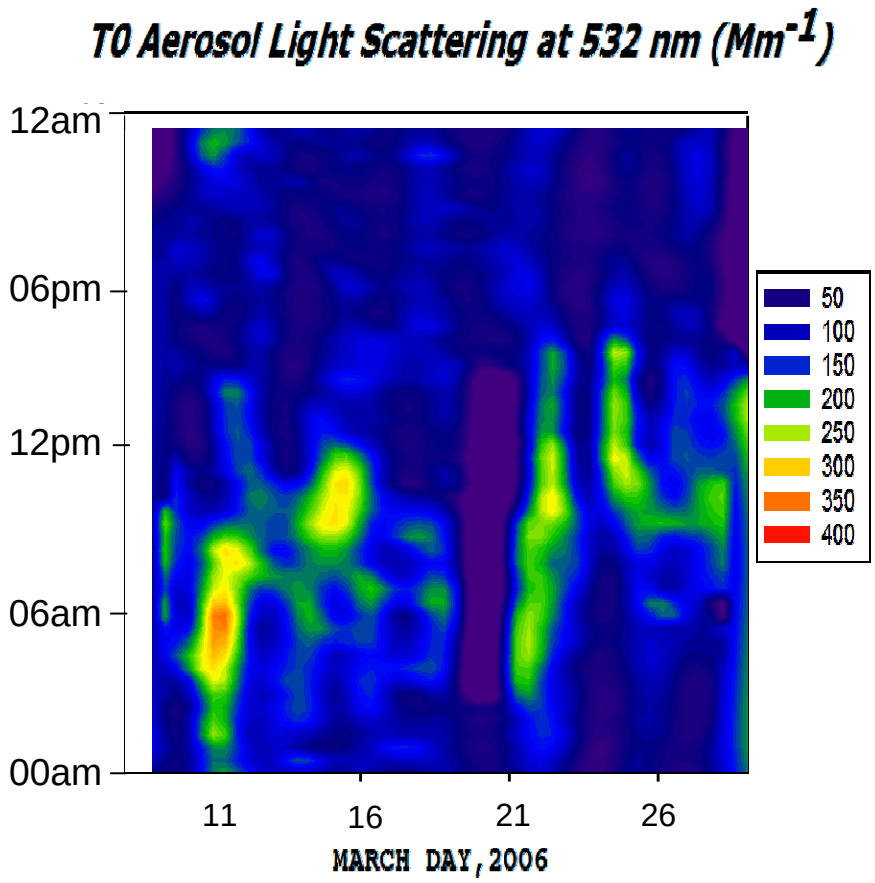
Mazzoleni, Dubey et al

Mexico City: Confluence of complex meteorology and air pollution - Photoacoustic measurements of aerosol light absorption and scattering at four sites in and near Mexico City

Lupita Paredes-Miranda & W. Patrick Arnott
Atmospheric Sciences Program
University of Nevada Reno, Physics Department MS/220
AMS Student Chapter Presentation, Nov. 09, 2006

TO Site Mexico City, Aerosol Optics for 532 nm

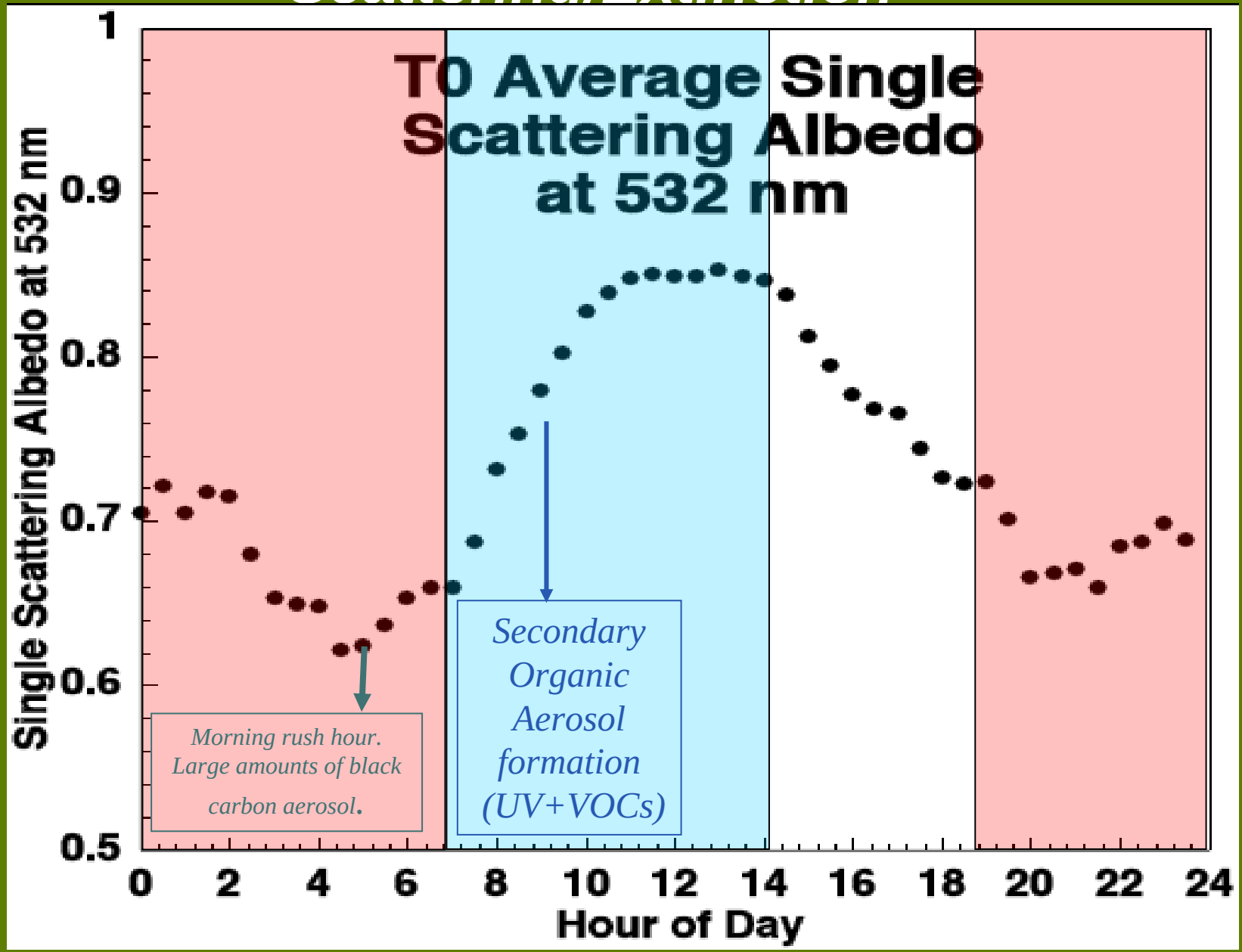




Aerosol Absorption: *Note the day to day variability in the peak absorption, probably due to meteorology.*

Aerosol Scattering: *peaks later in the day than absorption, due to dust, OC, secondary organic aerosol, and inorganics.*

Average Single Scattering Albedo: Scattering/Extinction



SUMMARY

•Peak gaseous absorption is approx. 2 hrs later in the day than peak particle absorption. Peak 30-minute-average aerosol absorption in Mexico City was 180 Mm^{-1}. Heating effects on BL dynamics are likely.

•Daily single scattering albedos vary between 0.6 and 0.85 at 532 nm at the T0 site. Transportation dominates aerosol optics in the morning and secondary OC is important in the afternoon. Dust is also important at the T1 site.

Aerosol Optics, Clarke et al. C-130, DC-8

HIGEAR
Hawaii Group for Environmental Aerosol Research

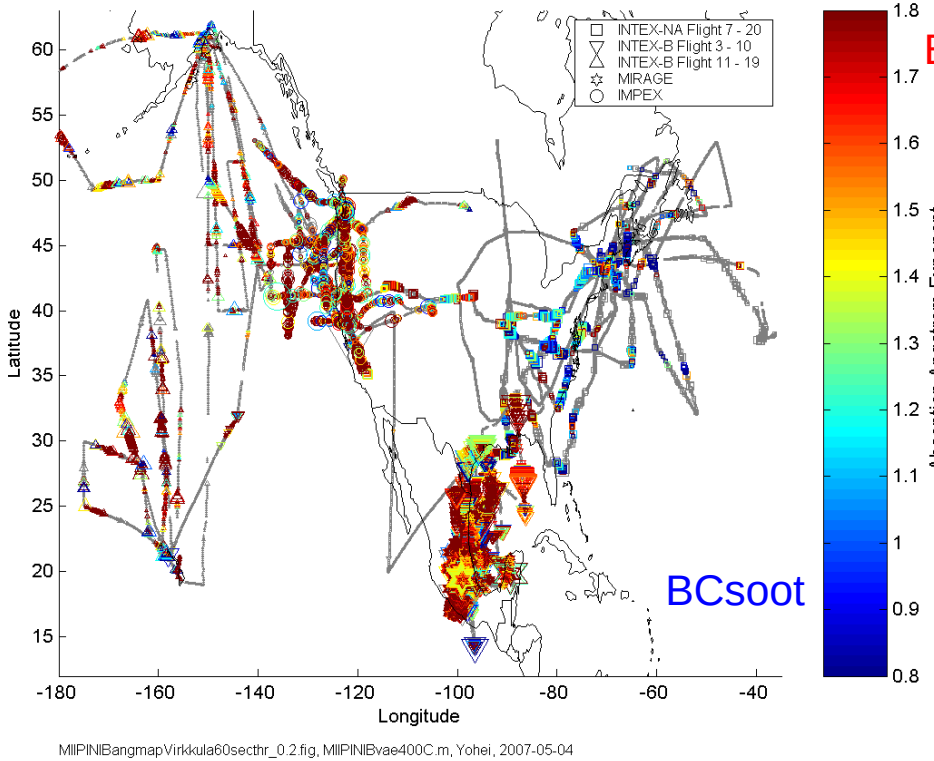
- Fig 1 Variation in aerosol spectral absorption and single scatter albedo over North America form INTEX-A, INTEX-B, IMPEX and MILAGRO
- Fig 2 Wavelength dependence of light scattering rapidly maps our pollutions and dust contributions to aerosol optics. (Total and Submicron at 450, 550, 700nm)
- Fig 3 Wavelength dependence of Light absorption is function of OC and Dust Concentrations
- Fig 4 f(RH) or Gamma (humidity dependence of light scattering) {DC-8} provides understanding of evolution in optics of MC aerosol under increasing humidity

Photo courtesy Cam McNaughton

Regional Differences in Aerosol Optical Properties over North America

Color: Absorption Angstrom

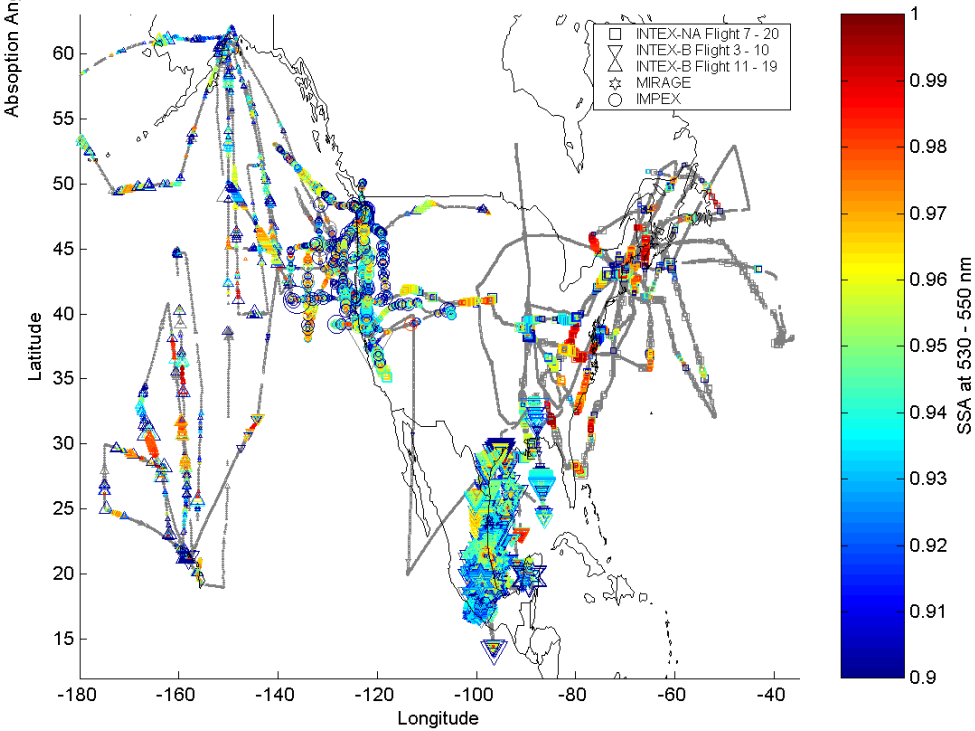
Wavelength Dependence of Absorption



MIIPINIBangmapVirkkula60secthr_0.2.fig, MIIPINIBvae400C.m, Yohei, 2007-05-04

BC & OC biomass

Color: Single Scatter Albedo



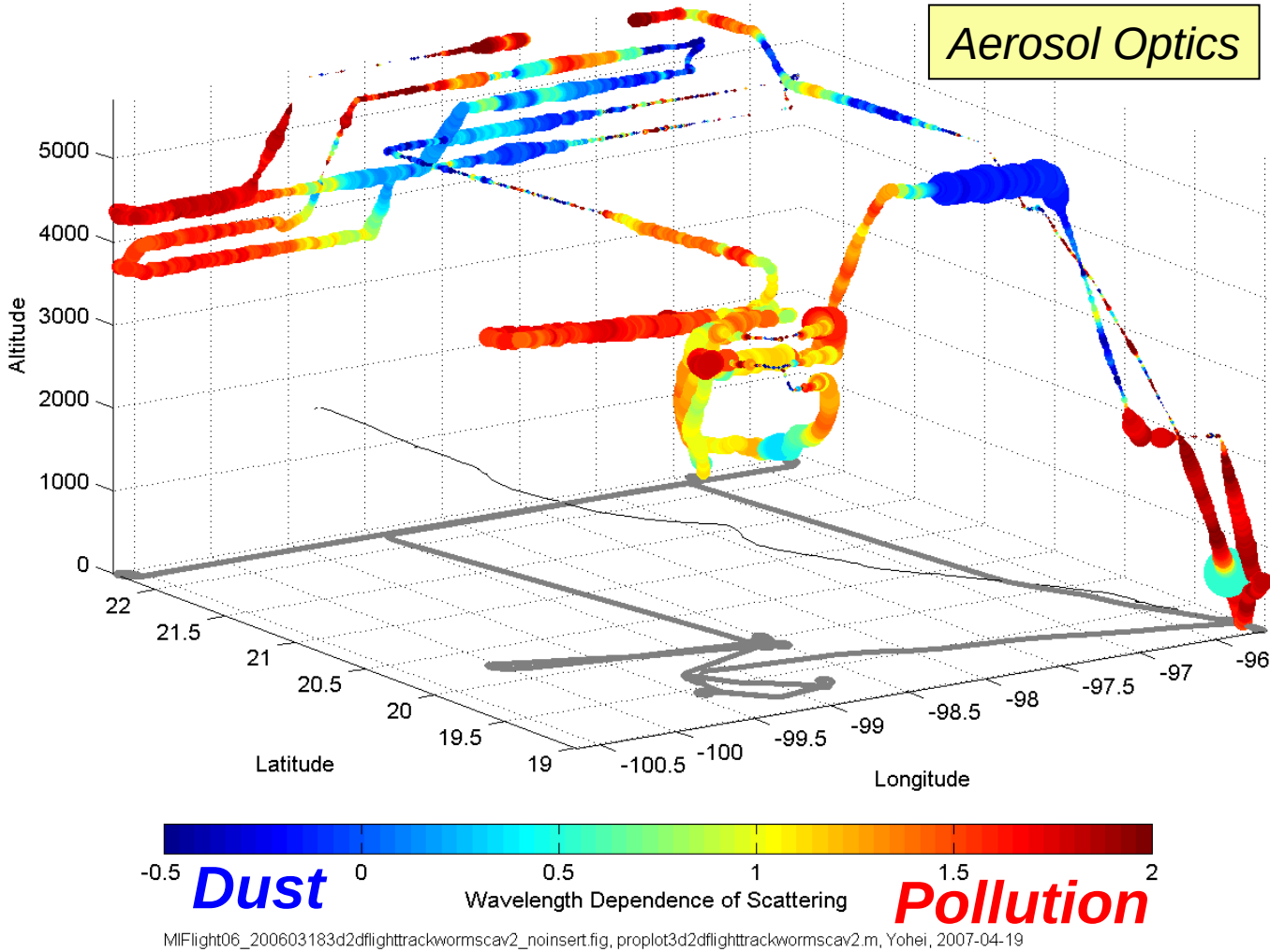
MIIPINIBssamapVirkkula60secabsthr_0.2.fig, MIIPINIBvae400C.m, Yohei, 2007-05-04

Average over 60-sec.,Absorption > 0.2 Mm-1, Scattering > 2 Mm-1, marker size proportional to absorption

Yohei Shinozuka

Spectral signature in scattering for Dust and Pollution over Mexico City environs can be linked to satelite and model products

Aerosol Optics



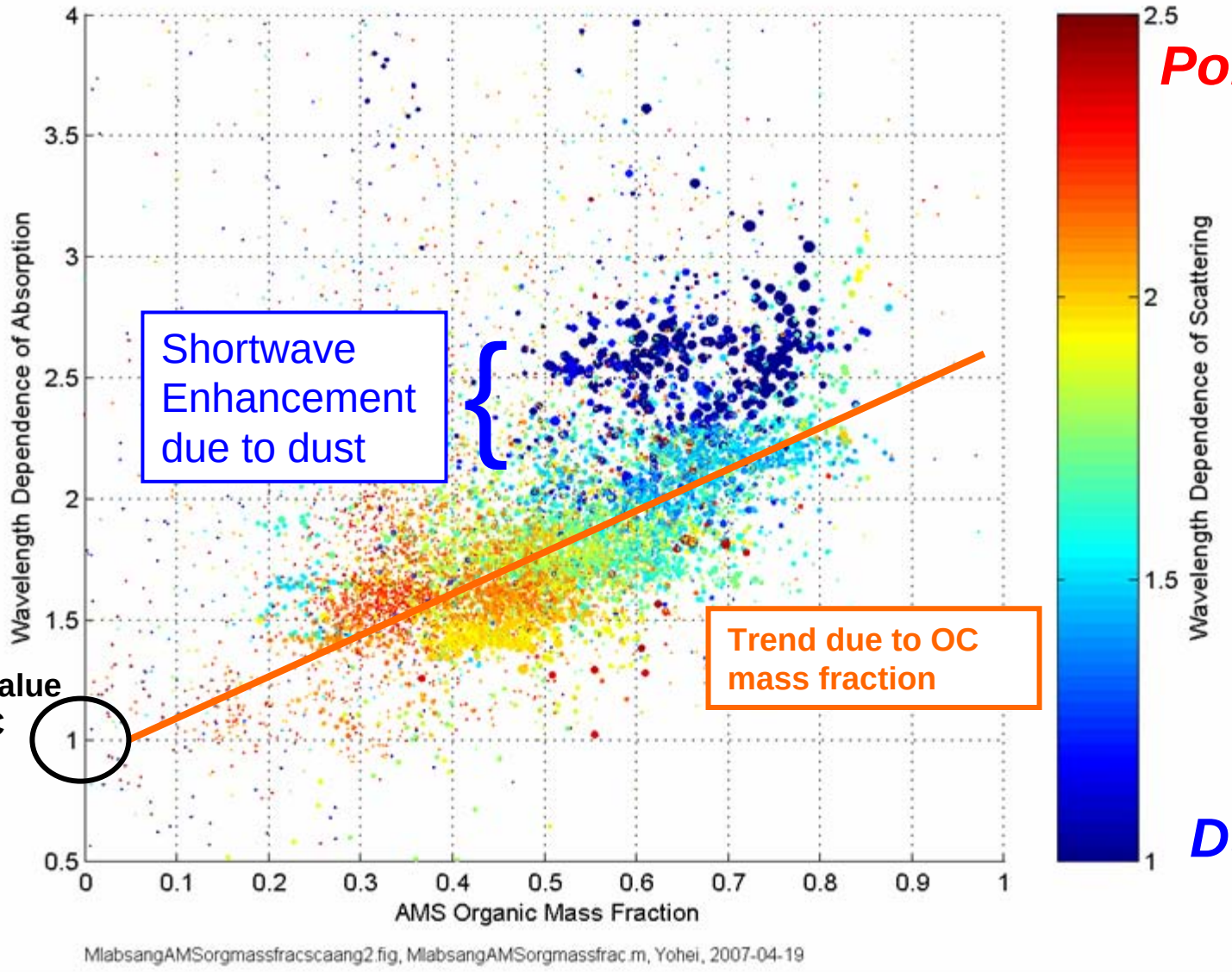
MIFlight06_200603183d2dflighttrackwormscav2_noinsert.fig, proplot3d2dflighttrackwormscav2.m, Yohei, 2007-04-19

HIGEAR
Hawaii Group for Environmental Aerosol Research

Wavelength dependence of light scattering (angstrom Exponent) provides continuous indication of coarse dust and fine pollution aerosol.

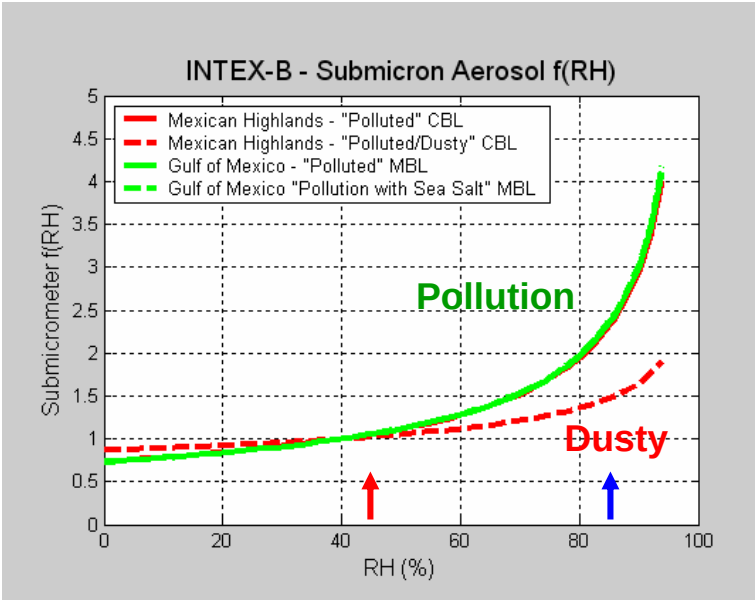
Wavelength dependence of absorption over Mexico is linked to both the organic carbon component (AMS - J, Jimenez, P. DeCarlo) and dust.
Model and remote sensing implications for SSA etc.

Aerosol Optics



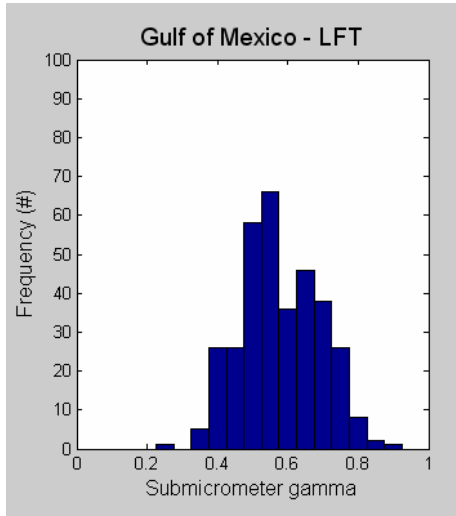
The role of humidity in modifying optical properties such as SSA when transported from dry to humid environment (eg. Mexico City to the Gulf of Mexico)

Aerosol Optics



HIGEAR
Hawaii Group for Environmental Aerosol Research

DC-8 Measured f(RH) at 45% and 85%RH yields Gamma or scattering response to RH increase

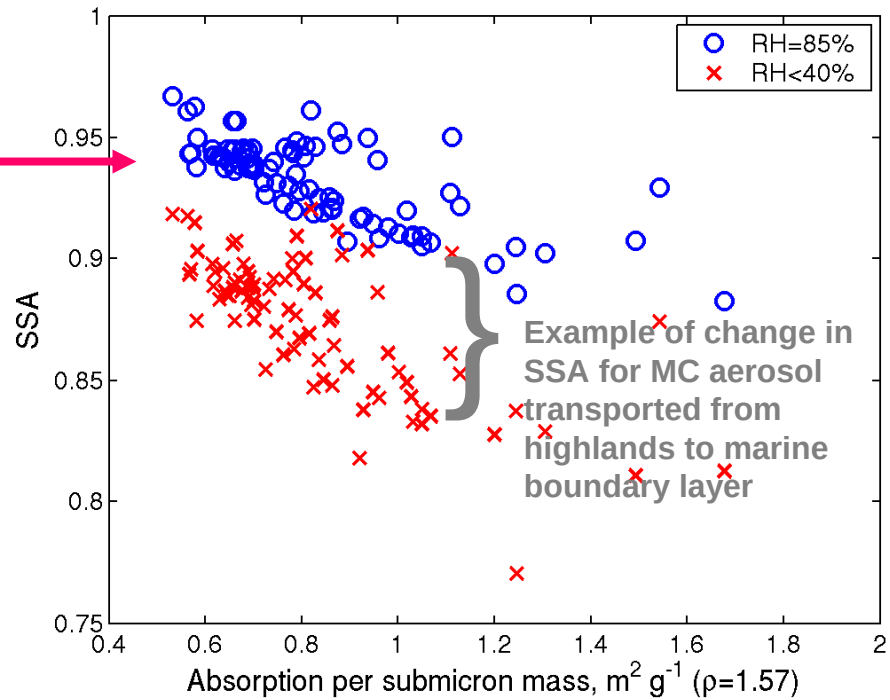


Implications for Satellite or model products

The single scatter albedo (ratio of scattering to sum of absorption and scattering) can change as air mass humidifies during evolution.

The red symbols are for dry (45%RH) as experienced near MC and the blue are for the same aerosol at 85%RH as may be experienced over the Gulf of Mexico as a function of absorption per submicron mass.

The "wet" SSA is much higher than the measured dry SSA values and are more tightly clustered about a line. This reveals the coupling between the chemistry (ions), absorption and optical properties.

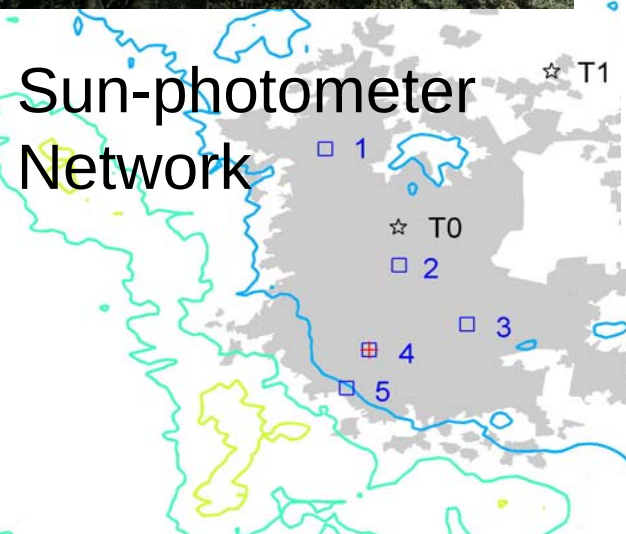


Breakout Group on Aerosol Optical Properties & Radiative Effects

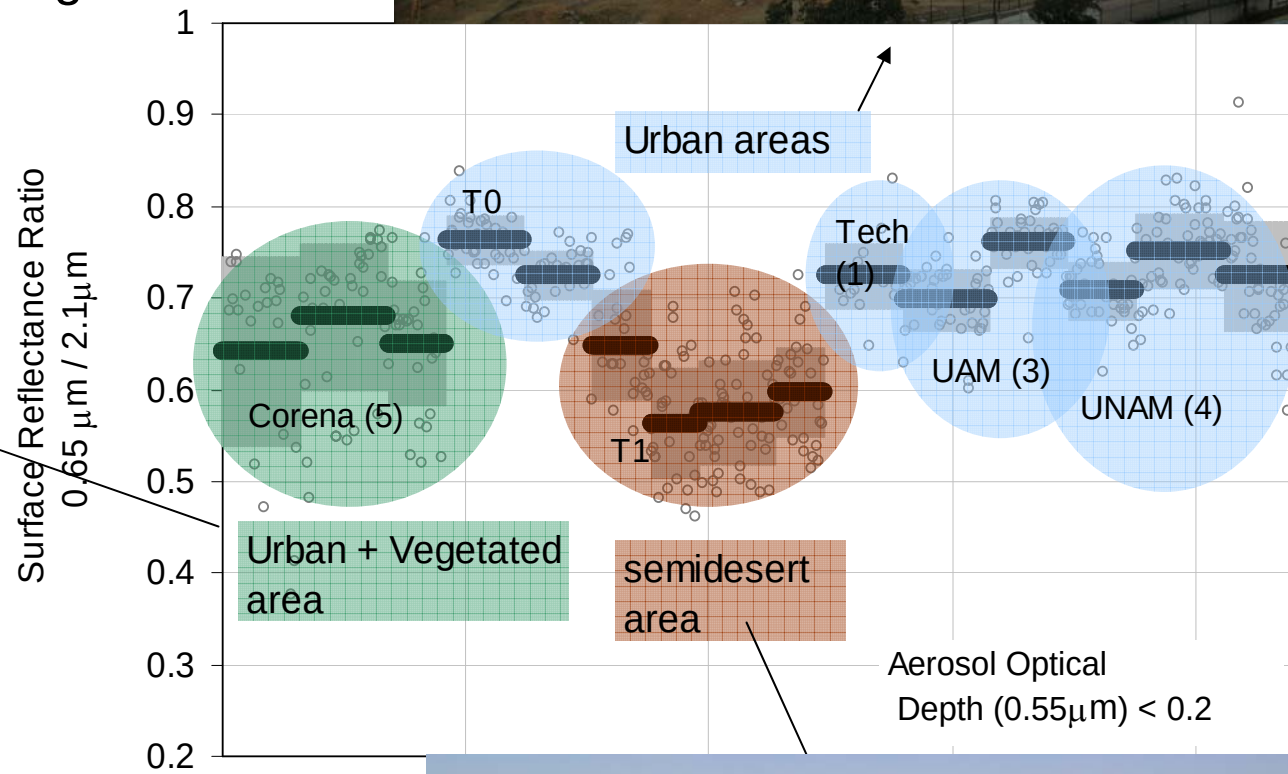
Major findings (nuggets, cont'd):

- Sun photometer (Microtops) network that operated during MILAGRO experiment helped to raise the importance of a better estimation of surface reflectance over urban area (is converging to higher values than assumed nowadays). This assumption can improve the AOD satellite products (MODIS algorithm with finer spatial resolution). (Castanho)
Needs to be compared to more direct albedo & BRDF measurements by CAR, RSP, SSFR.
Also check consistency between MC & other urban areas.

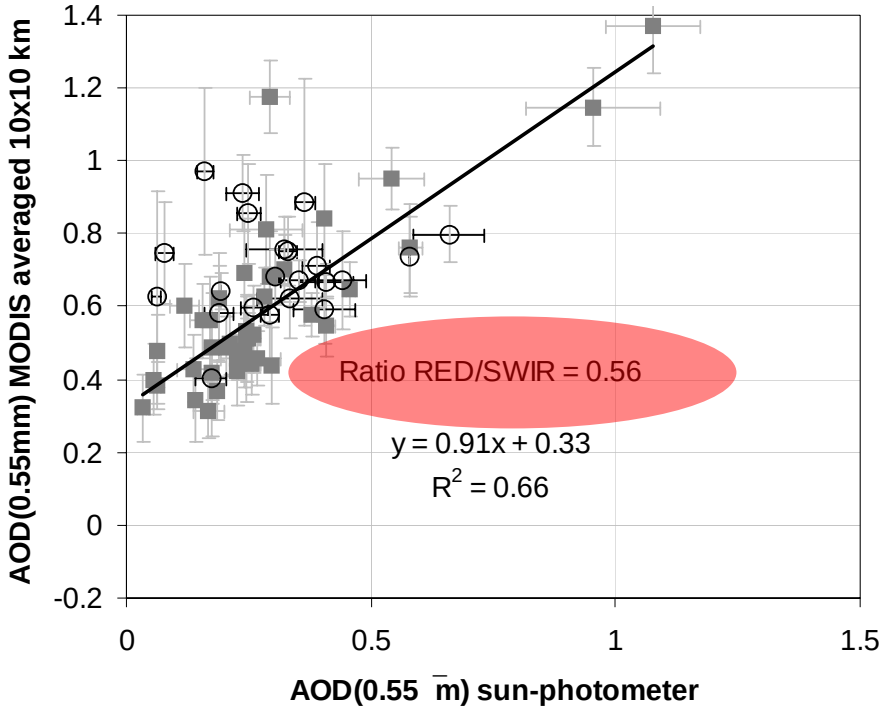
Surface reflectance ratio between visible and short-wave infrared wavelengths varies as a function of surface cover and scattering angle. The urbanized area in Mexico City shows on average values around 0.73

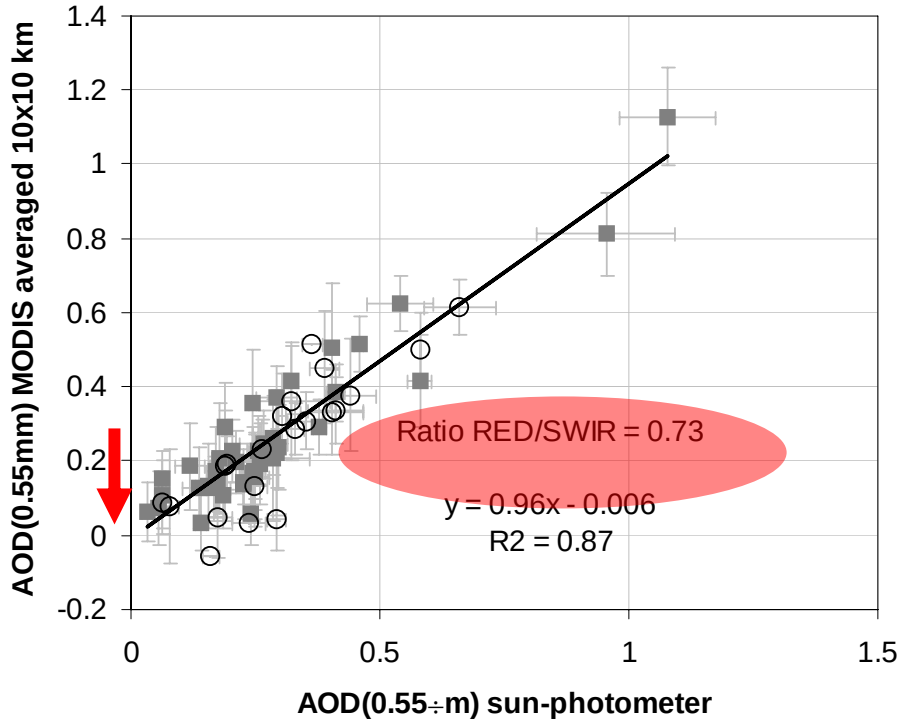


Sun-photometer Network



Milagro / MCMA – 2006 / Castanho - MIT



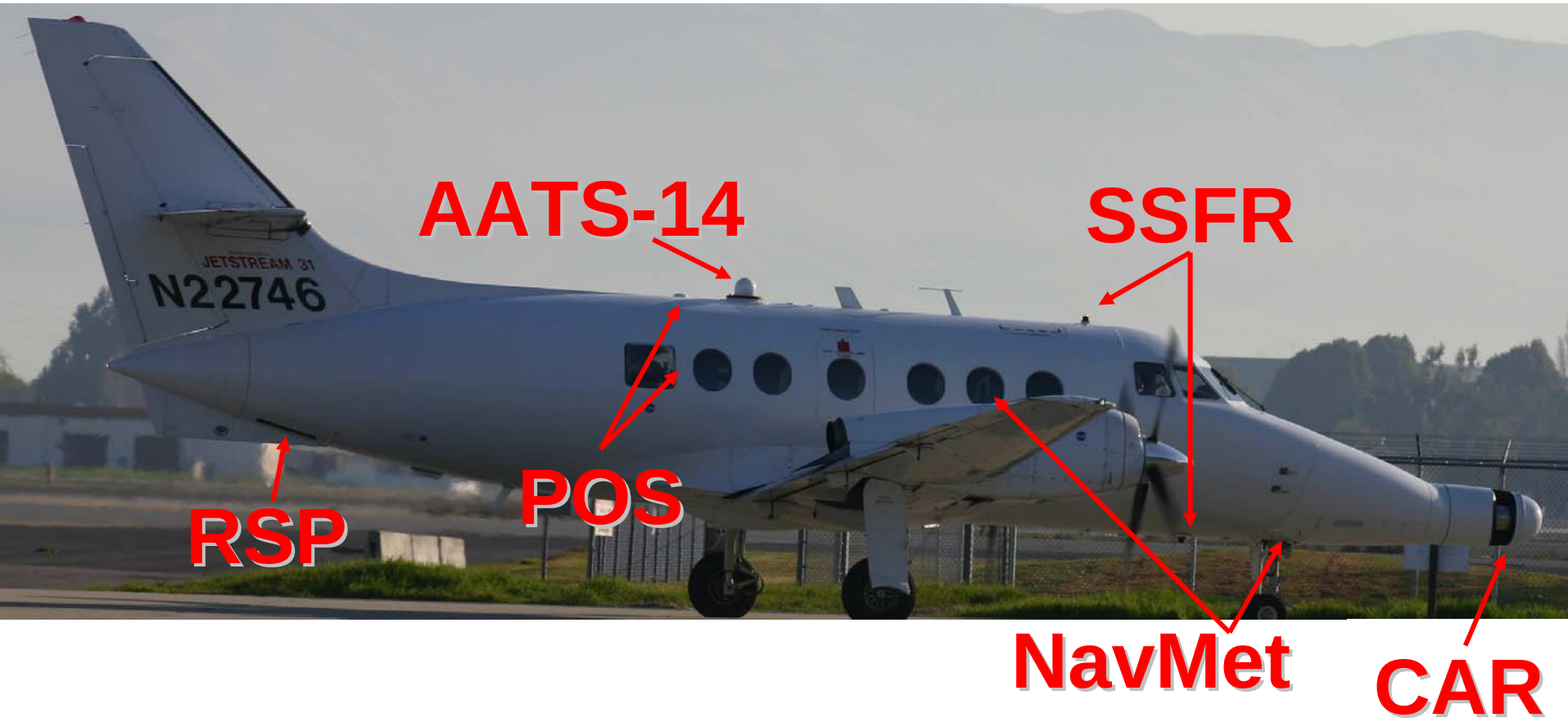


Plots show the MODIS AOD retrieved in this work with 1.5km spatial resolution over Mexico City compared to the sun photometer AOD measurement.

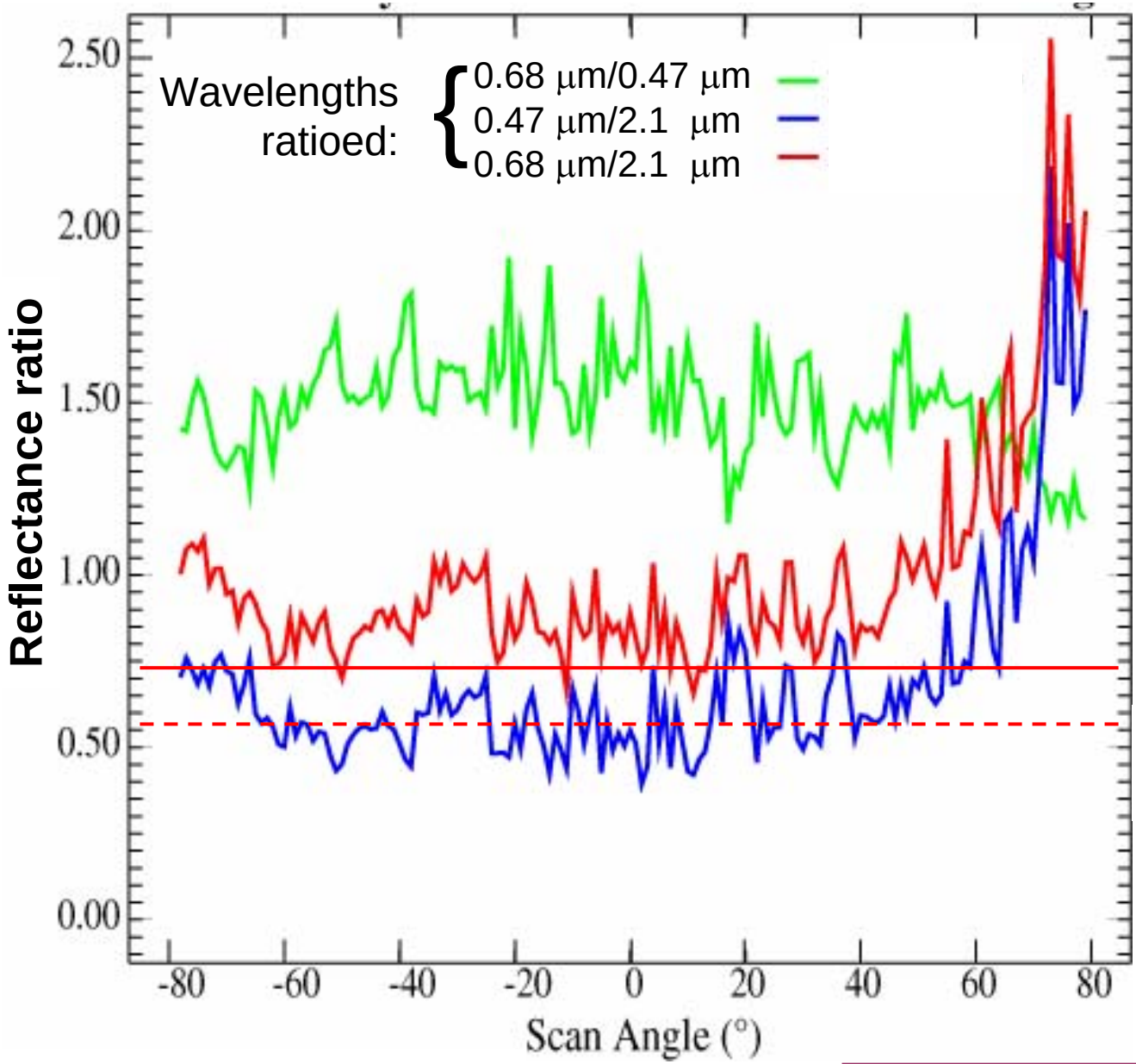
Open dots are data from sun-photometer network/Milagro experiment 2006, and gray squares are data from CIMEL/AERONET from 2002 until 2005. The assumption on the surface reflectance ratio (visible and shortwave infrared wavelengths) makes all difference on the AOD retrieval with MODIS over the Mexico City urban area as shown in these two figures. The surface ratio of 0.73 shows to significant improvement on the validation of the retrieval in the region.

Milagro/ MCMA-2006 / Castanho - MIT

Several J31 instruments measure surface albedo (SSFR) and BRDF (RSP & CAR)



Mexico City BRDF Ratios from CAR on J-31*



Castanho 0.73

MODIS Std 0.56

*~0.5 km AGL, Principal Plane

Gatebe, King et al.

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Synopsis to date:

- Several techniques indicate that, in the visible, Mexico City surface is more reflective than assumed in the standard MODIS AOD retrievals.

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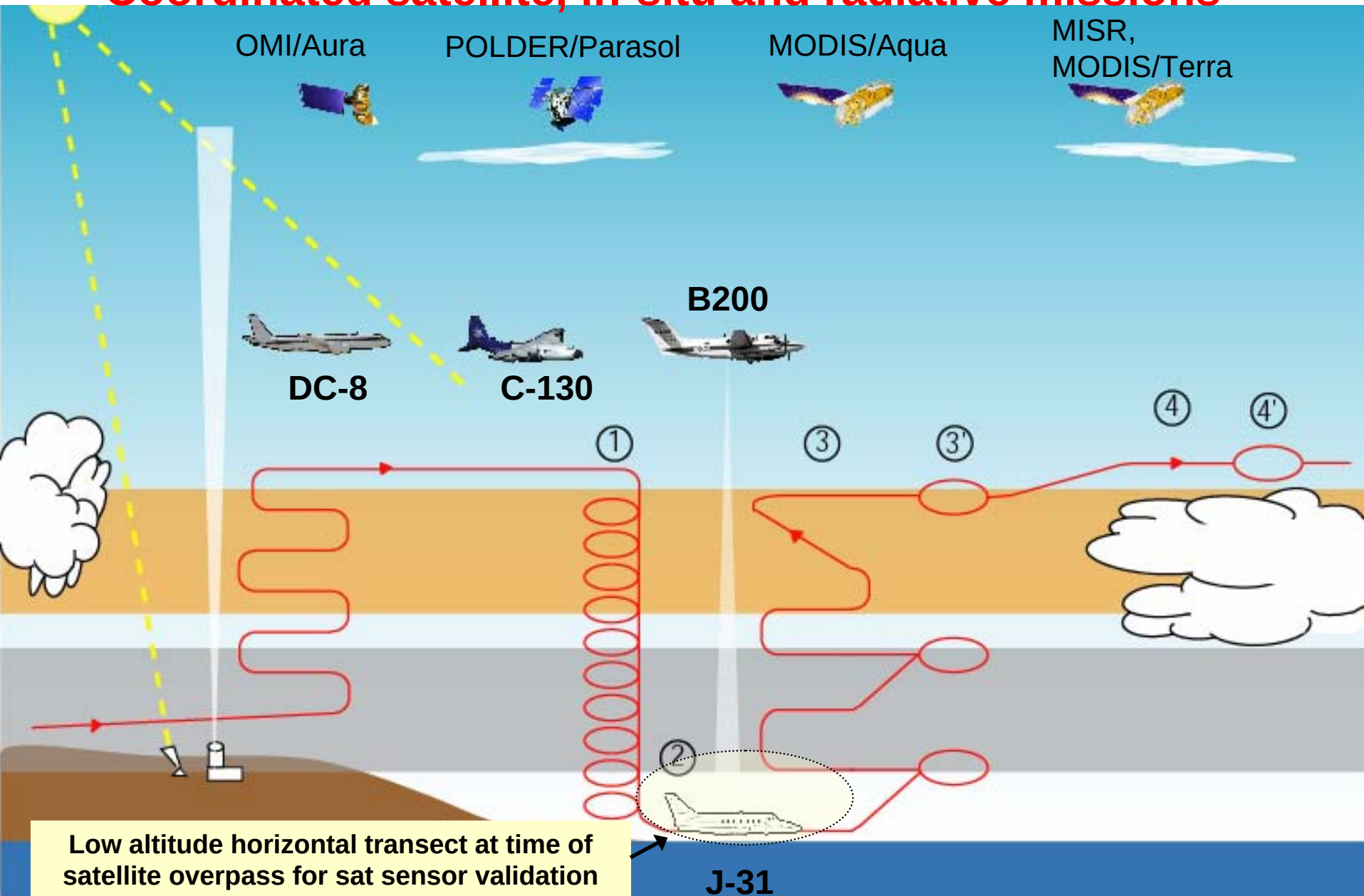
Major findings (nuggets, cont'd):

- Over the Gulf of Mexico, comparisons between aerosol optical depth (AOD) measurements from several satellite instruments and the J-31 aircraft have revealed a wide range of results,
  - some agreement better than expected
  - some significant discrepancies.

Reasons for this behavior are being investigated. (Redemann, Livingston, Russell)

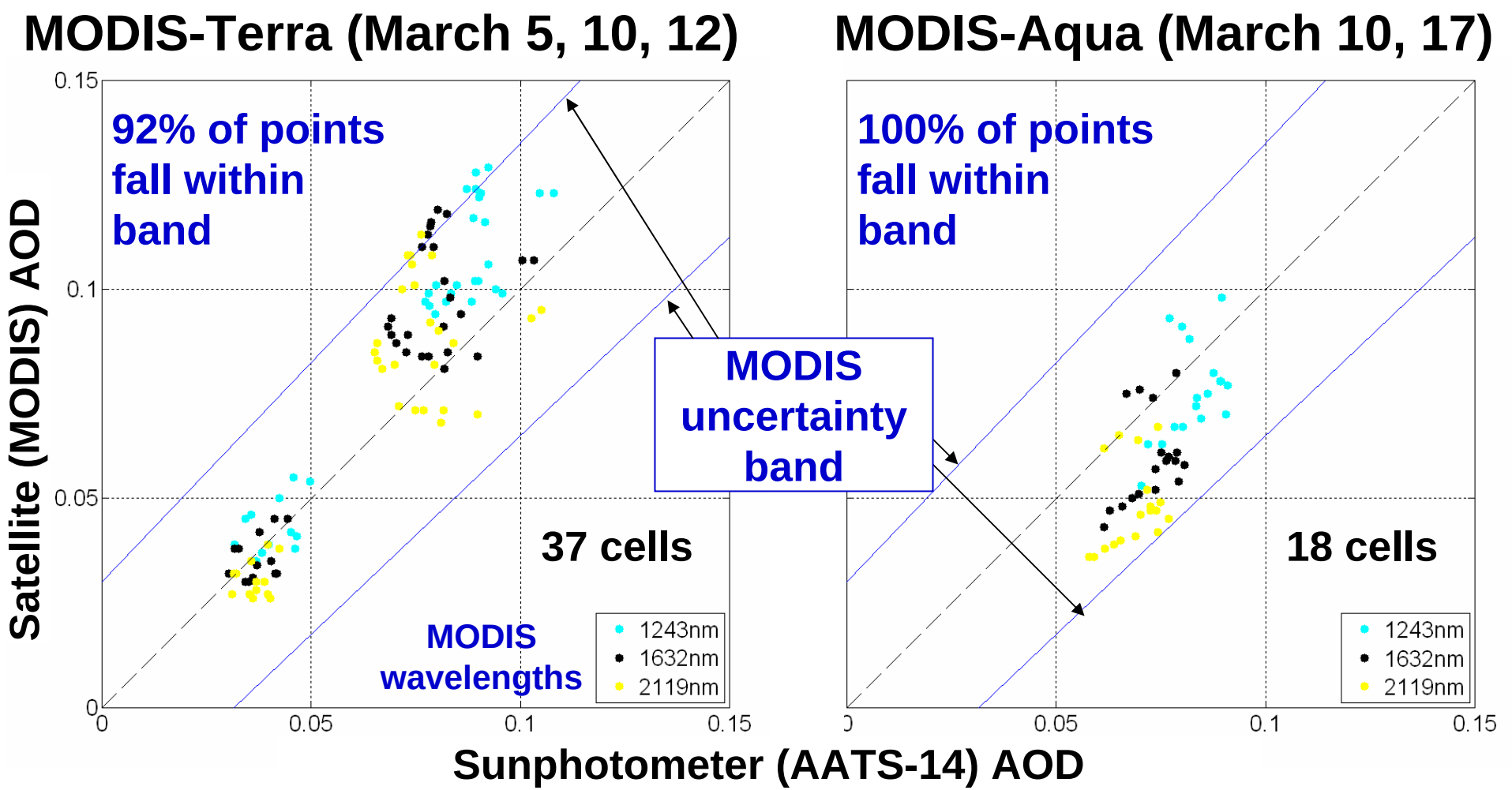
J31 flight patterns:

Coordinated satellite, in-situ and radiative missions



AOD Comparisons, MODIS vs AATS

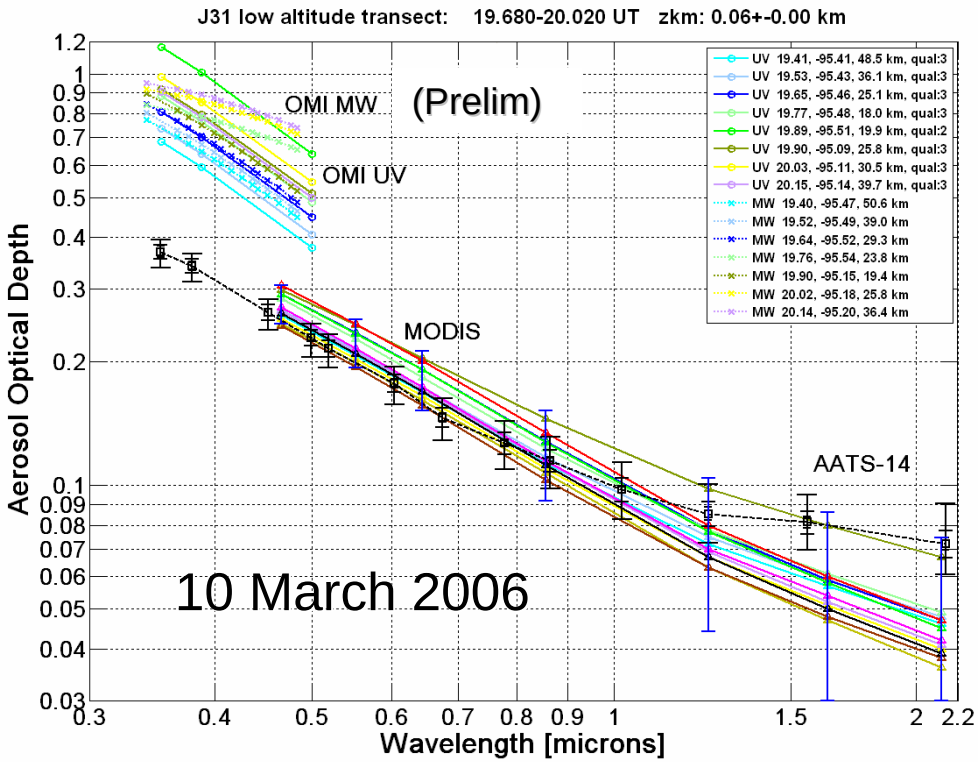
Gulf of Mexico, INTEX-B/MILAGRO, 2006

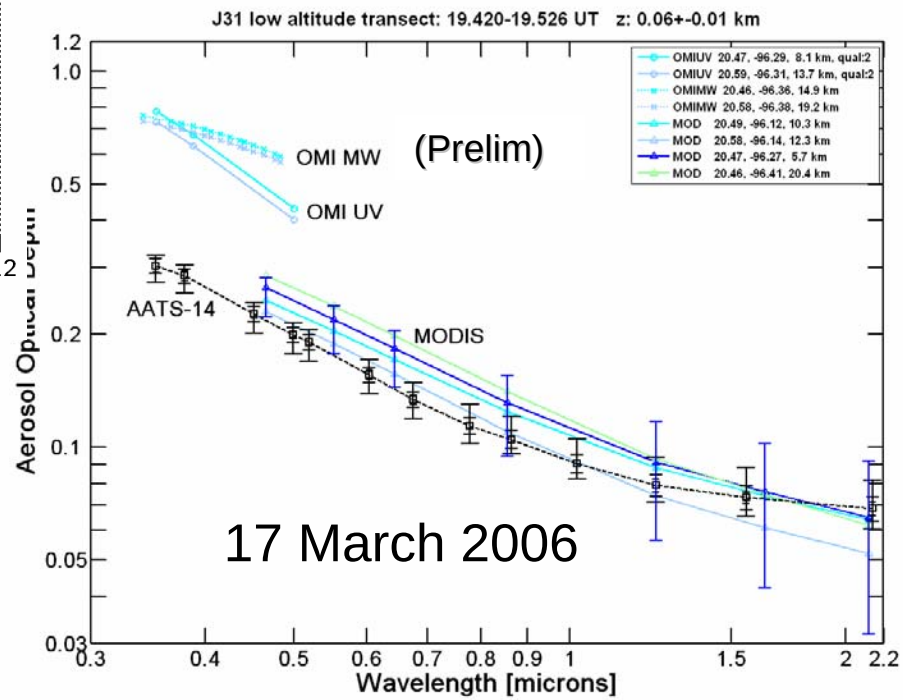


Agreement at MODIS SWIR wavelengths is better than expected, because the number of points falling within the uncertainty band exceeds 66%, which is the expected fraction if the MODIS uncertainty (±0.03 ±0.05AOD) is ±1σ.

AOD Comparisons, OMI vs AATS vs MODIS

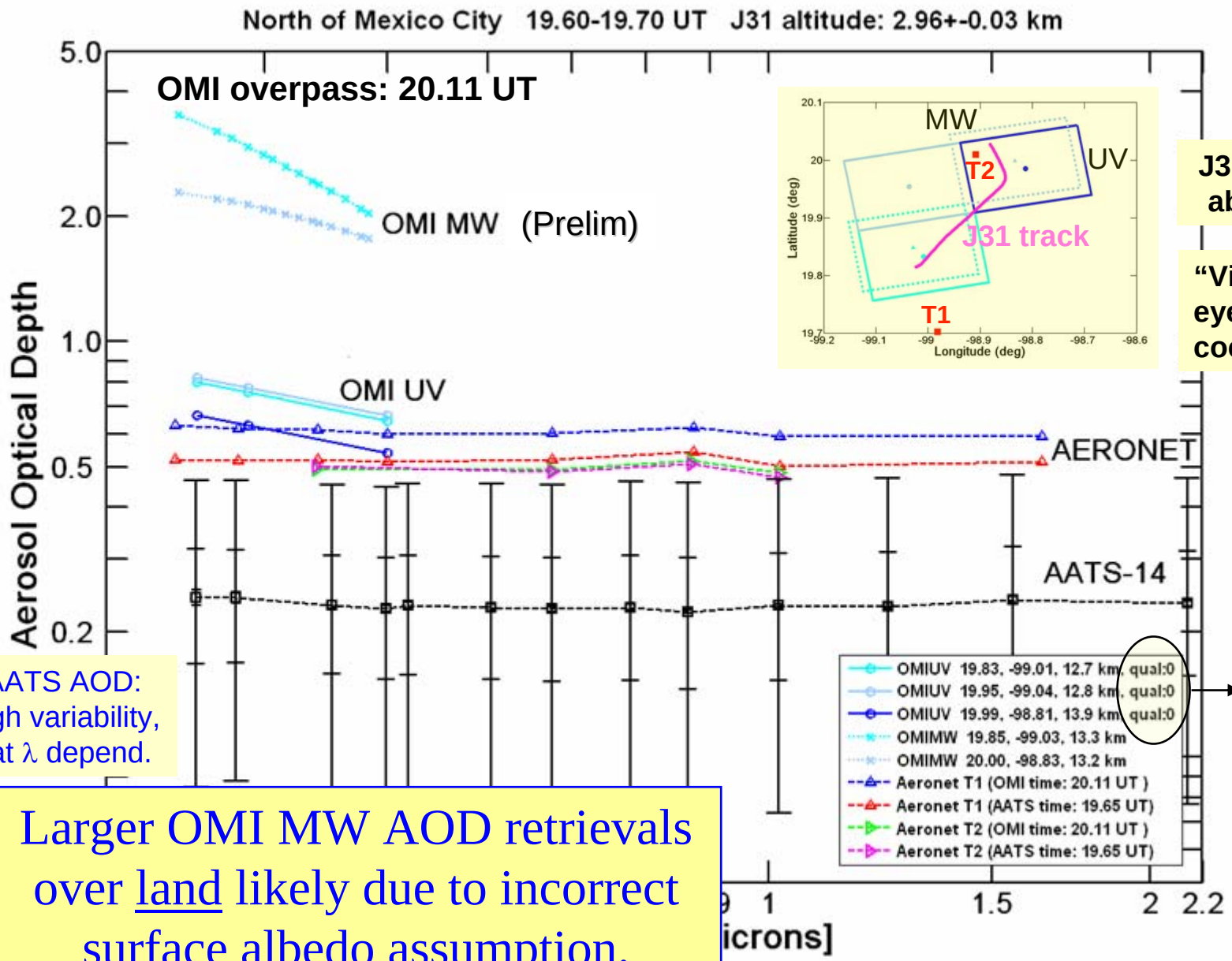
Gulf of Mexico, INTEX-B/MILAGRO, 2006





Larger OMI AOD retrievals over water likely due to cloud contamination.

19 March 2006 *(over land)*



J31 ~450-750 m above surface

"Visibility poor; eyes burning in cockpit…"

AATS AOD: high variability, flat λ depend.

highest quality

Larger OMI MW AOD retrievals over land likely due to incorrect surface albedo assumption.

Larger OMI AOD retrievals over water likely due to cloud contamination.

Larger OMI AOD retrievals over land likely due to incorrect surface albedo assumption.

Still to be investigated: effect of MILAGRO- measured wavelength-dependent SSA in UV.

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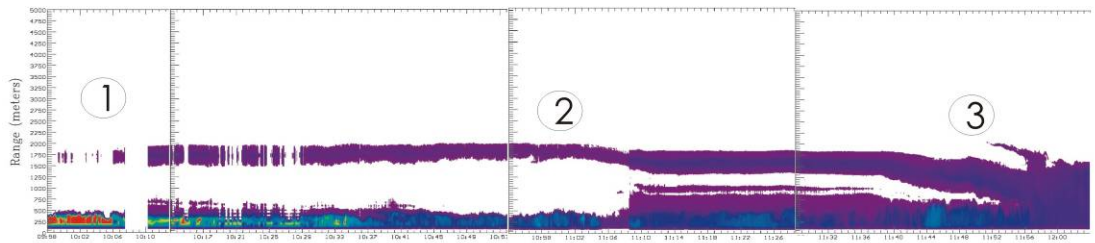
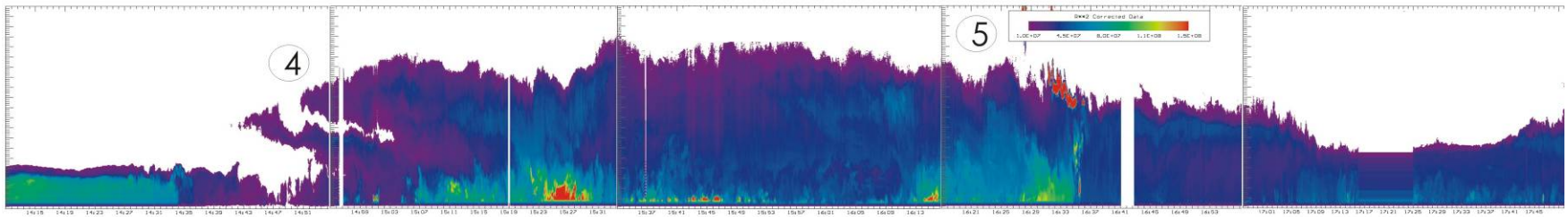
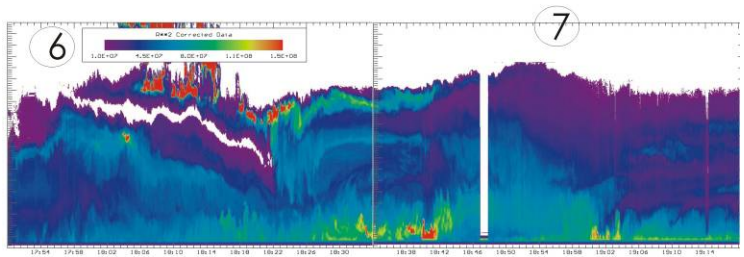
Major findings (nuggets, cont'd):

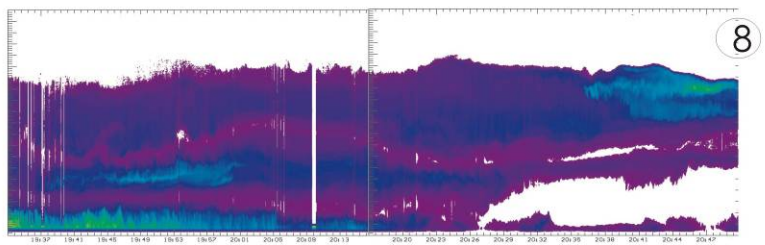
- Over land, air & ground lidars show abrupt changes in BL depth. Similar rapid changes seen in airborne AOD transects (Eichinger, Lewandowski, Hair, Livingston). What causes these? Individual convective plumes? "River" advection from different sources in complex terrain?

Abrupt Changes in the Boundary Layer
13 Mar 2006

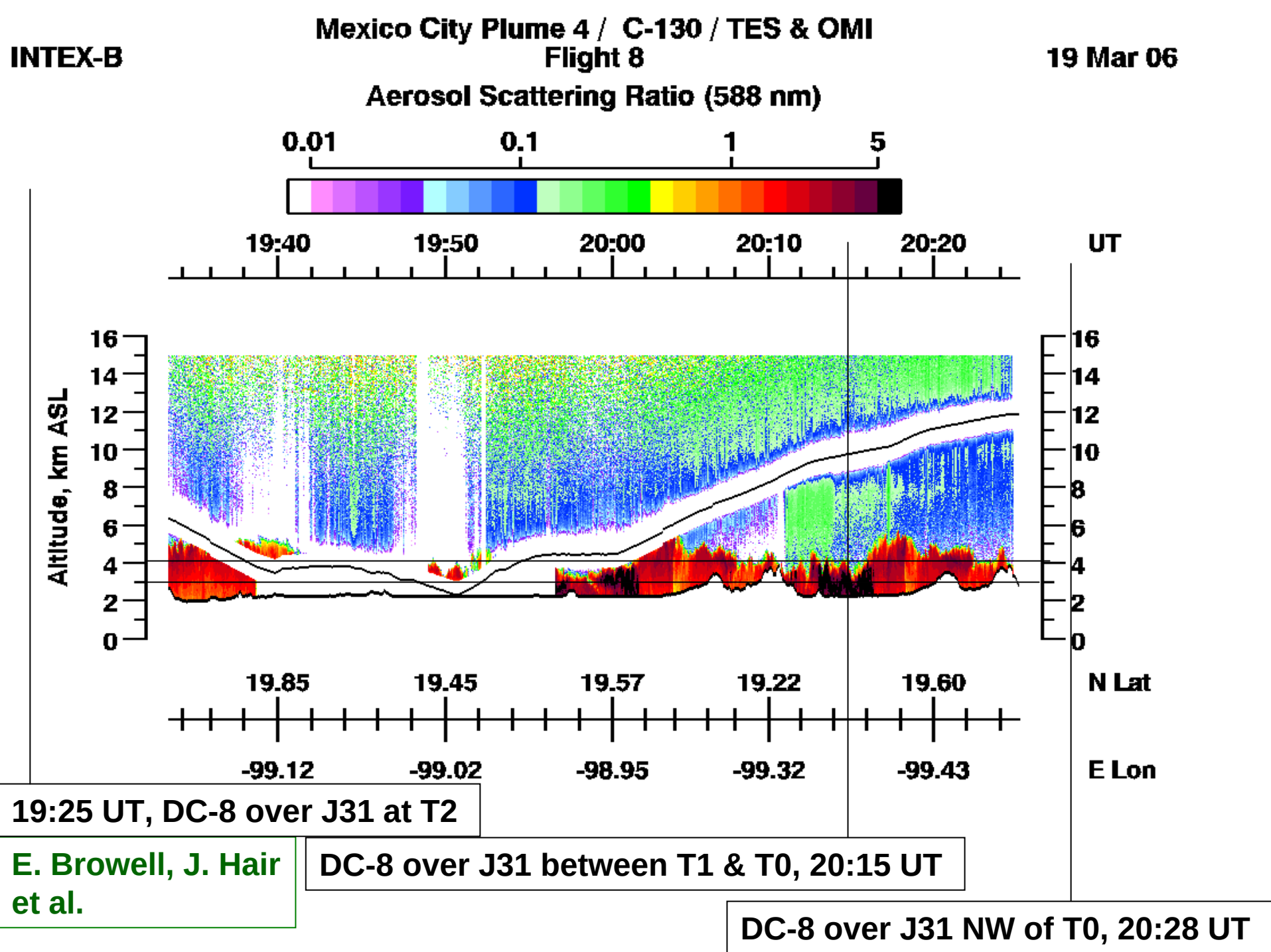








Eichinger et al.



E. Browell, J. Hair et al.

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Unanswered questions our data and models can address:

- How do AERONET-retrieved SSA spectra compare to all the other SSA results?
- Can the observed enhanced UV absorption be correlated with the weather changes? (organics/sulfate and SSA variation)
- What are organic aerosols' refractive indices and densities, hygroscopicity, mixing state?

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Unanswered questions our data and models can address:

- How do surface albedo or reflectance results from J-31 SSFR & RSP compare to the results from MODIS-sunphotometer and CAR?

- How to integrate different measurements of dust (polarimetry, satellite, microphysics, optics, coarse chemical components, lidar)?

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Unanswered questions our data and models can address:

- What microphysical property information do MISR and MODIS data contain about urban pollution plumes over land?

- How do we integrate satellite regional scale aerosol optical depth and air mass type spatial distributions with suborbital measurements and regional transport models?

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Unanswered questions our data and models can address:

- How can we best identify plumes in studies of evolution?
  - Can we differentiate between contrails and cirrus from multiangular, multispectral data? (Try adding tempearature and moisture data)
  - How can we identify subvisible cirrus?

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Cross-cutting issues:

- **What's responsible for the enhanced UV absorption? Organics? Gas?**

- It's important for UV satellite AOD retrievals (OMI, TOMS) + many other issues

- **Comparison of AOD from satellite (fine spatial resolution, i.e., 1.5 km) with PM2.5 concentration measured at RAMA stations. This also includes the lidar information on the aerosol layer heights.**

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Cross-cutting issues:

- How do we distinguish between Megacity & Regional (background) effects for:
  - aerosol radiative forcing
  - trends,
  - less ozone than expected,
  - reduction of reactive VOCs with time,
  - PANs, …

(Be explicit in defining regional/background: boundary layer vs. free troposphere, etc.)

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Cross-cutting issues:

- What data and models can provide accurate clocks to quantify evolution of aerosol physical, chemical and optical properties? (From VA Beach mtg: Don Blake putting together 1-pager; peroxide concentrations?)

End of Presentation

Remaining Slides are Backup

Breakout Group on Aerosol Optical Properties & Radiative Effects

-Future collaborations (within the breakout group & beyond):

J31 RSP-AATS:
- Validate RSP retrieved spectral optical depth
Atmospheric correction of low altitude measurements to provide accurate surface polarized BRDF

J31 RSP-AATS-SSFR: Evaluate remote sensing methods (RSP + lidar) for determining the aerosol radiative forcing profile against the measured spectral optical depth and radiative flux profile

J31 CAR-AATS: Retrieve BRDF and aerosol optical properties simultaneously from combined data sets: CAR, AATS, and AERONET.

Continue/extend satellite validation studies: OMI, MODIS, MISR, POLDER

DC-8/J31 AATS: Does DC-8 lidar-observed convective plume structure predict AATS-observed AOD variability?

King Air B200/J31: Compare more extinction profiles (x flights)

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Future collaborations (beyond the breakout group)

- Clocks, evolution of aerosol properties
- Ask modelers for their consensus on priorities (Steve Ghan, Greg Carmichael, others). Did they get optics right: mass absorption efficiency, SSA after humidification based on chemistry? What processes are most important? Regional vs global.

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Future collaborations (beyond the breakout group)

- Background lidar, MISR, other vertical profile measurements for March 6 plumes. Collaboration with Bob Yokelson, Ernesto Alvarado
- Impact/interaction of aerosols on/with photochemistry (including ozone production), radiation, surface reactions and cloud?

Breakout Group on Aerosol Optical Properties & Radiative Effects

Future collaborations (beyond the breakout group)

- BC vs. organic effects on SSA spectra (esp UV)
- Comparison of AOD from satellite (fine spatial resolution, i.e., 1.5 km) with $PM_{2.5}$ concentration measured at RAMA stations. This also includes the lidar information on the aerosol layer heights.

Breakout Group on Aerosol Optical Properties & Radiative Effects

Scope of Group:

--in situ measurements (optics, size, composition, mixing state, single particle properties, consistency of all these)

-- spectral radiation, at surface & in vertical profiles (& closure with in situ measurements)

--comparison to satellite observations

--aerosol effects on clouds

Second MILAGRO Science Meeting
15-18 May 2007
Mexico City

Breakout Group on Aerosol Optical Properties & Radiative Effects

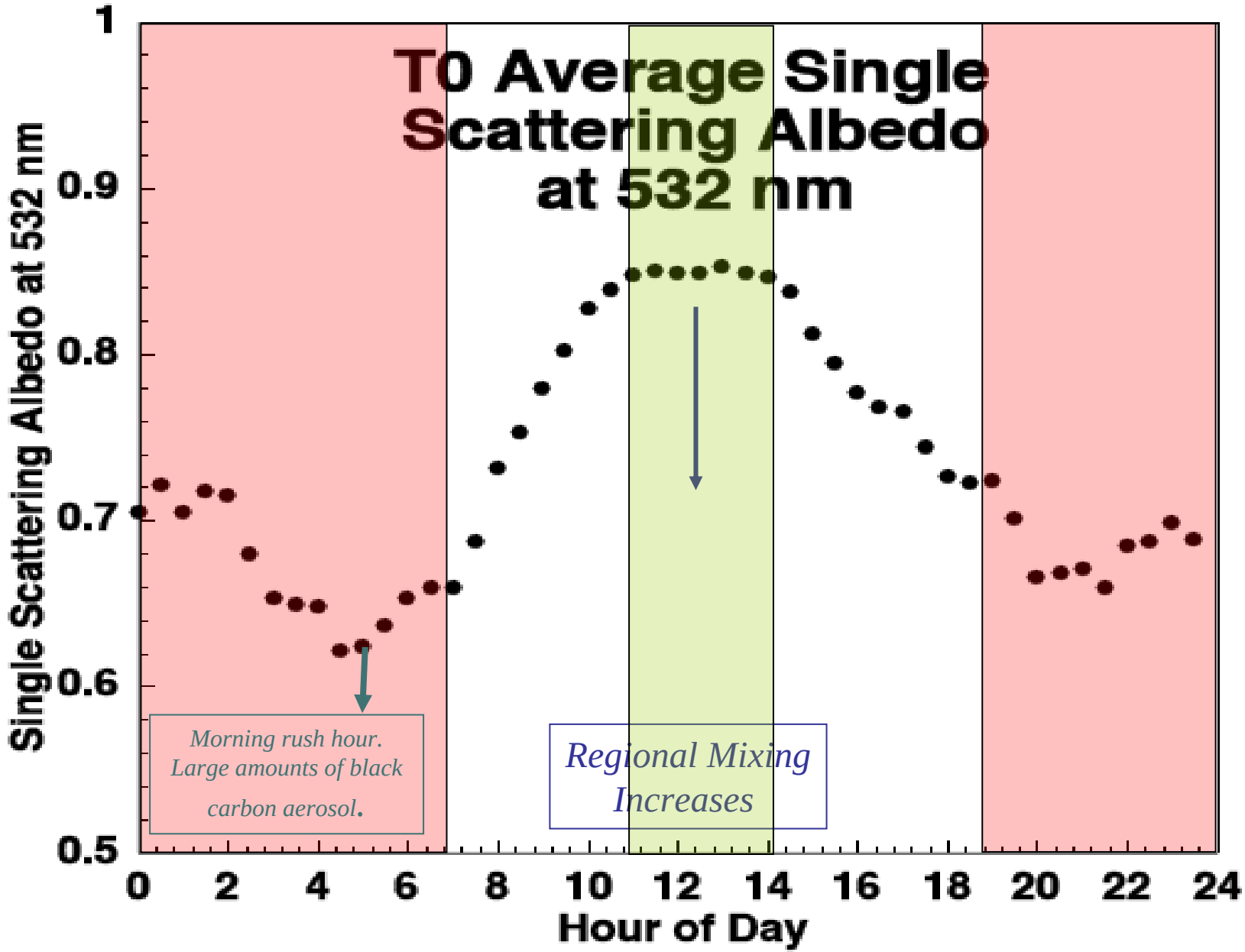
- **Purposes of breakout groups (agenda):**

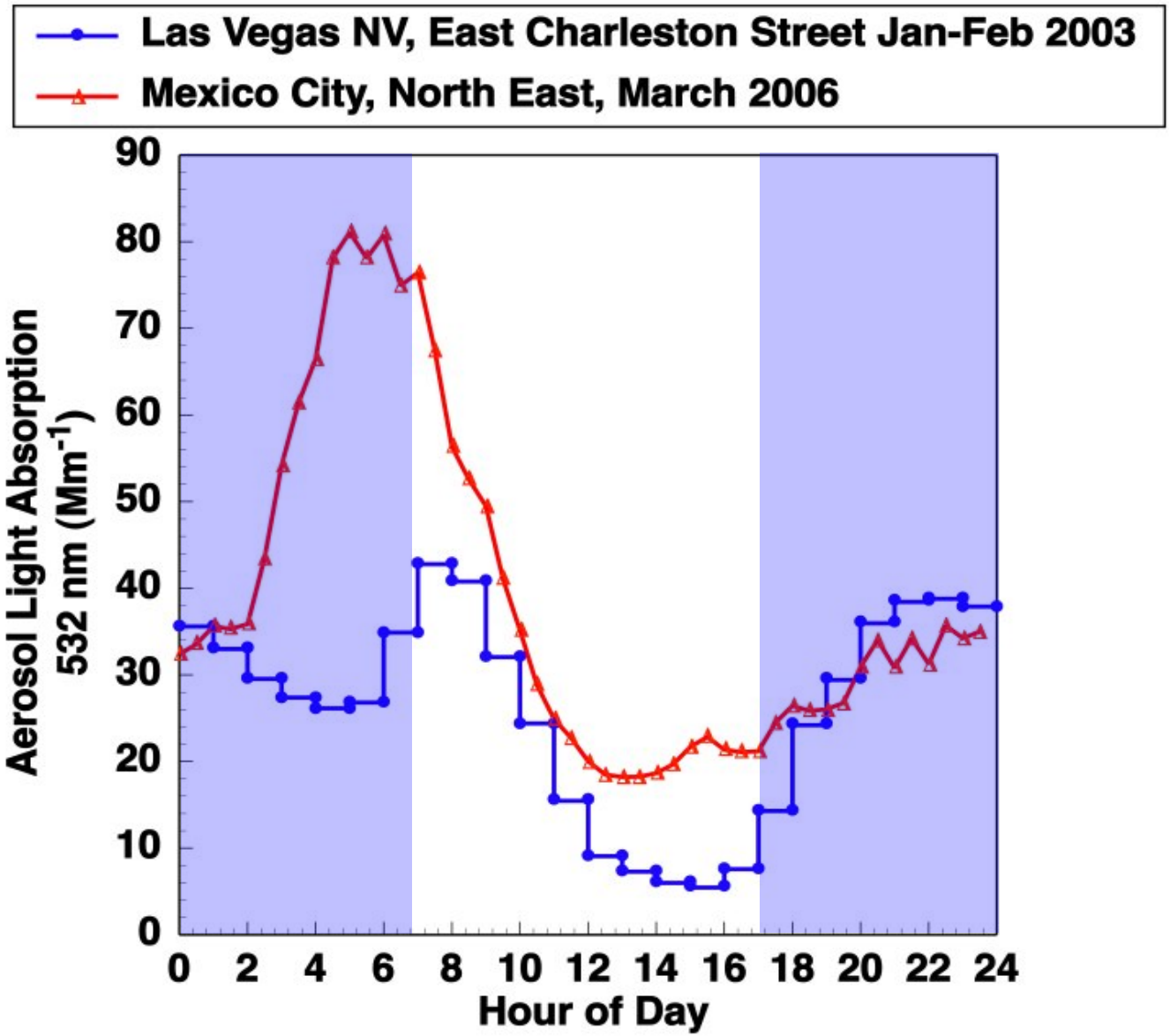
Identify nuggets (major findings) & major unanswered questions our data and models can address

Generate a draft list of potential papers (helped by the posters)

Identify cross-cutting issues

Identify future collaborations (within the breakout group & beyond)


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.
Regional Mixing Increases



Vegas: February 1, 2003

Sunrise: 6:42 am

Sunset: 5:07 pm

Lat N 35.2

Long W 115.2

City width 11 miles E-W

Wind Speed Ave 2.4 mph W-SW

Mexico City: March 15, 2006

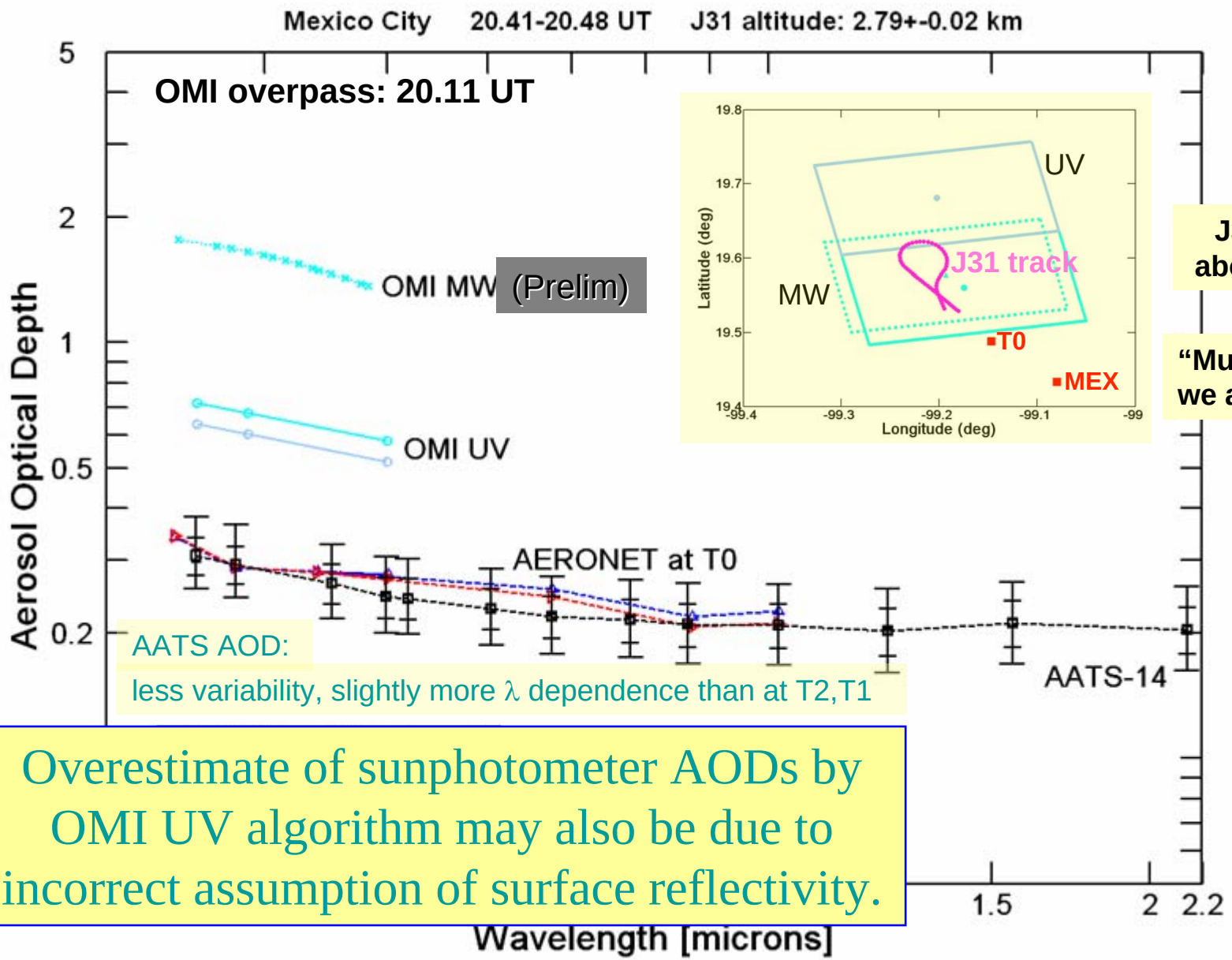
Sunrise: 6:45 am

Sunset: 6:45 pm

Lat N 19.49

Long W 99.15

19 March 2006 *(over land)*



AATS AOD:
less variability, slightly more λ dependence than at T2,T1

J31 ~450 m above surface

"Much clearer as we approach T0."

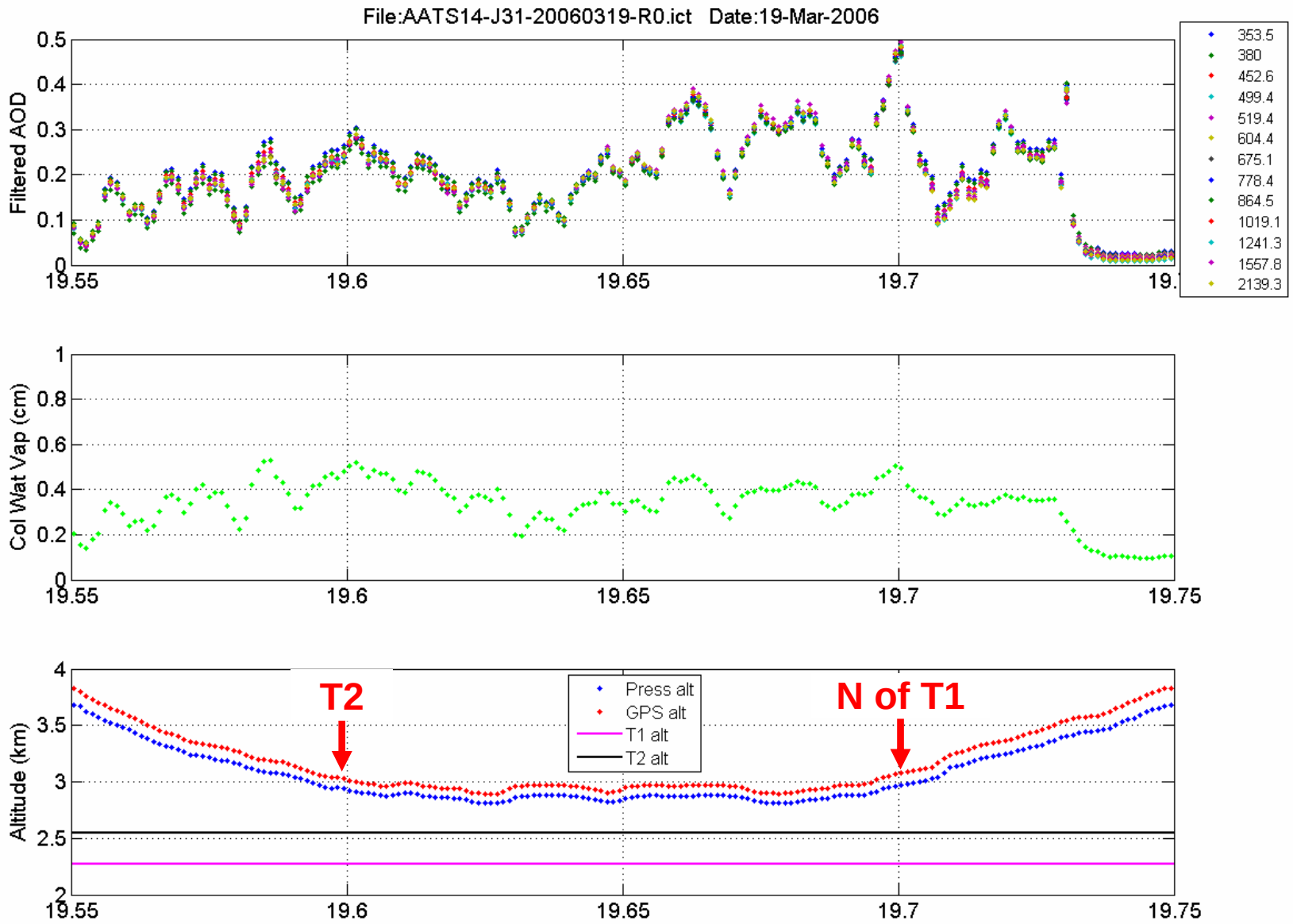
Overestimate of sunphotometer AODs by OMI UV algorithm may also be due to incorrect assumption of surface reflectivity.

Route Traveled in Previous Slide

13 Mar 2006

Eichinger et al.

NNE of Mexico City



“Visibility poor. Eyes burning in cockpit.”

Livingston et al.