The NASA Micro-Pulse Lidar Network: MPLNET

Aerosol Lidar Profiles for AeroCom Studies

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Judd Welton, Tim Berkoff

CALIPSO Validation Activities:
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NASA SMART-COMMIT Field Deployments:
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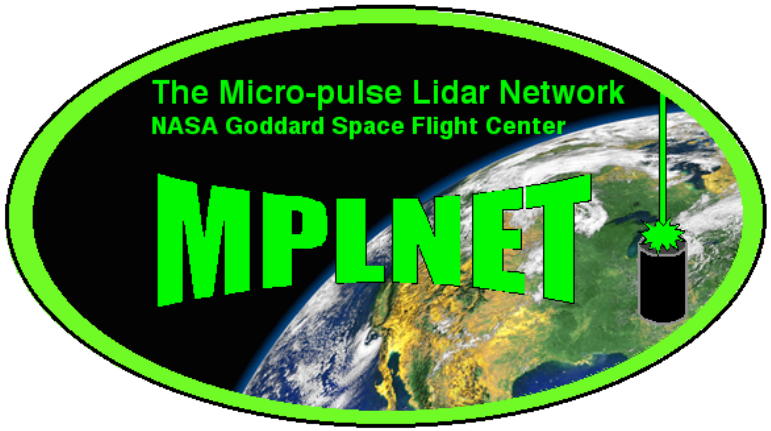
Jack Ji, 613.2

Site Operations & Science Investigations
…. many network partners around the world



MPLNET is funded by the NASA Radiation Sciences Program and the Earth Observing System

The NASA Micro-Pulse Lidar Network: MPLNET

Overview and Current Status

Objective: Long-term, local - regional - worldwide aerosol and cloud profile observations using common instrument & data processing in a federated network

Currently:

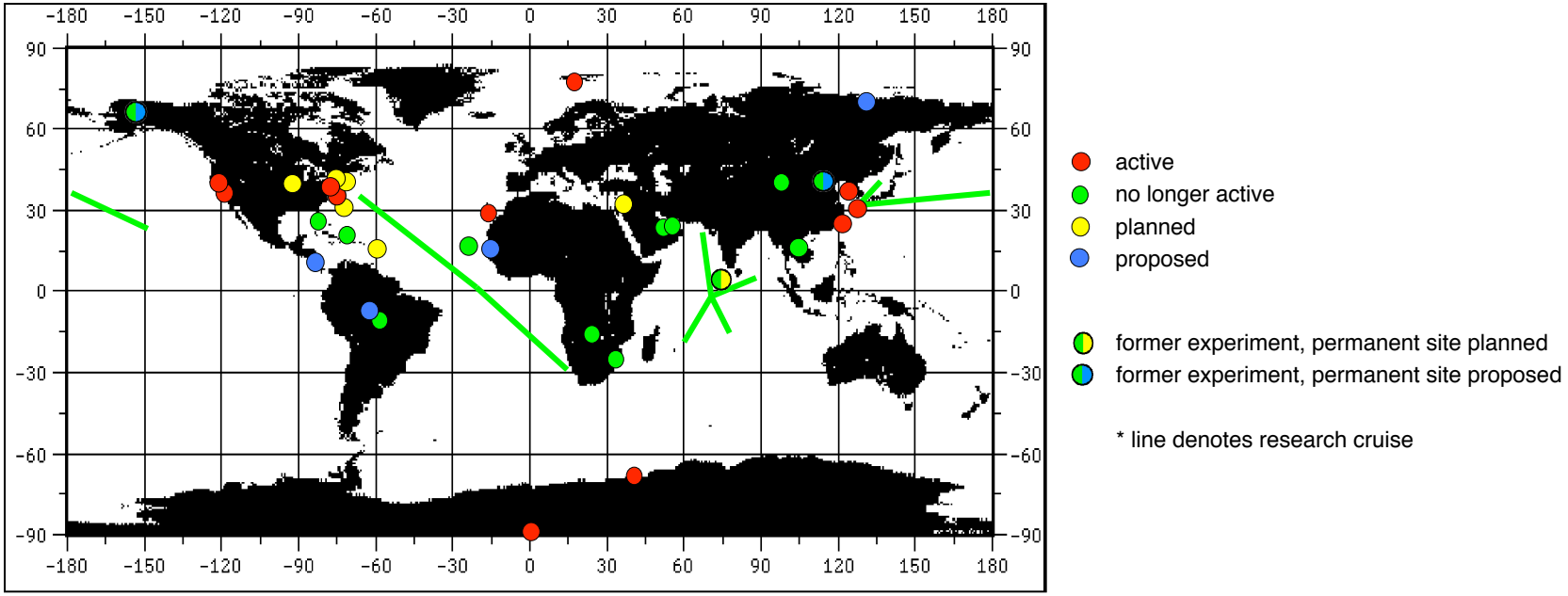
11 active sites
6 planned sites (in preparation)
6 proposed sites (funding dependent)
12 sites no longer active (mostly field campaigns*)
1 Ocean cruise (two cruises pre-dating MPLNET are available)

* Most campaigns utilize SMART-COMMIT platform (Tsay et al. 613.2)

Goddard team + 11 Partners compose MPLNET:

NASA LaRC
NOAA ESRL
Naval Research Lab - Monterey
Japan's National Institute of Polar Research
Spain's Instituto Nacional de Técnica Aeroespacial - INTA
4 US Universities
2 Korean Universities
1 Taiwan University

other partners pending



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Instrumentation

- **Micro-pulse Lidar Systems (MPL)**
  - compact & semi-autonomous
  - 523 or 527 nm wavelength
  - PRF 2500 Hz
  - eye-safe, output energy in μJ
  - small FOV, no multiple scattering

- **Sunphotometer**
  - Sites & Experiments: NASA Aerosol Robotic Network (AERONET) sunphotometers by Cimel
  - Handheld Microtops sunphotometer used on ocean cruises

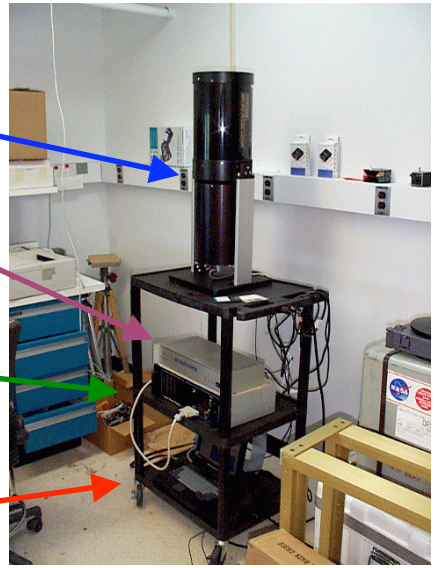
- **Original MPL Design (Type 1-3)**

Transceiver:
20cm Cassegrain Telescope on top
Laser Head, Detector, Optics below

Scalar Unit:
Data at 30, 75, 150, 300 m vert. res.

Laser Power Supply:
1 W Nd:YLF Laser Diode
(Doubled to 523nm on Head)

Laptop Computer:
Data Acquisition, Storage (1 min res)



- **New MPL Design (Type 4)**

Available from Sigma Space Corp.

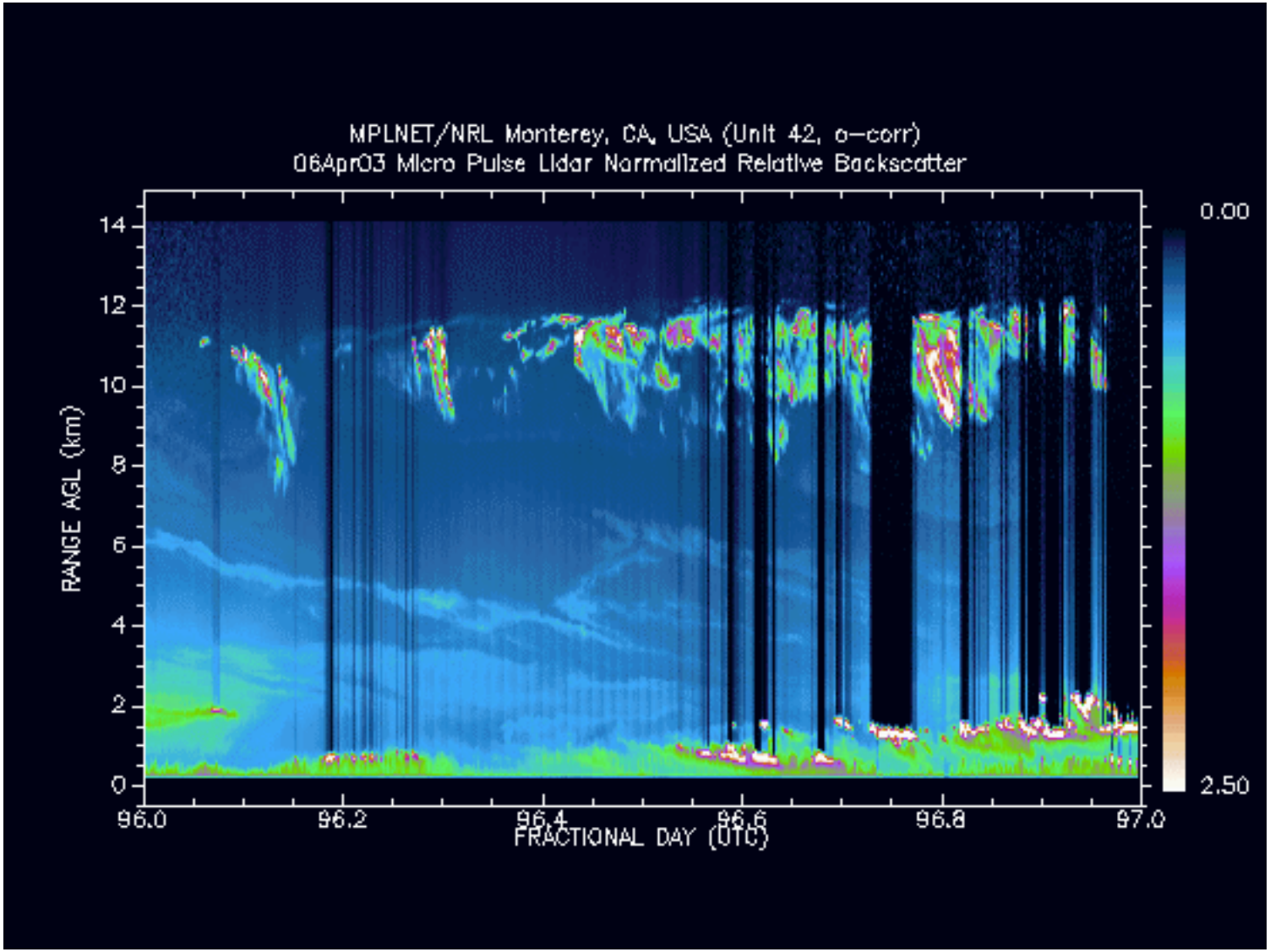
Basic System Specifications:
Same optical design, and similar wavelength and output energy, and temporal/spatial resolution. Still eye-safe & autonomous

Improvements:
- More rugged design
- Improved laser supply creates longer lifetime and control of laser via computer
- Multi-channel data system
- Fiber coupled detectors

* The MPL and MPLNET recently won a Technology Transfer award from the Federal Laboratory Consortium

The NASA Micro-Pulse Lidar Network: MPLNET

Example of Level 1 Data



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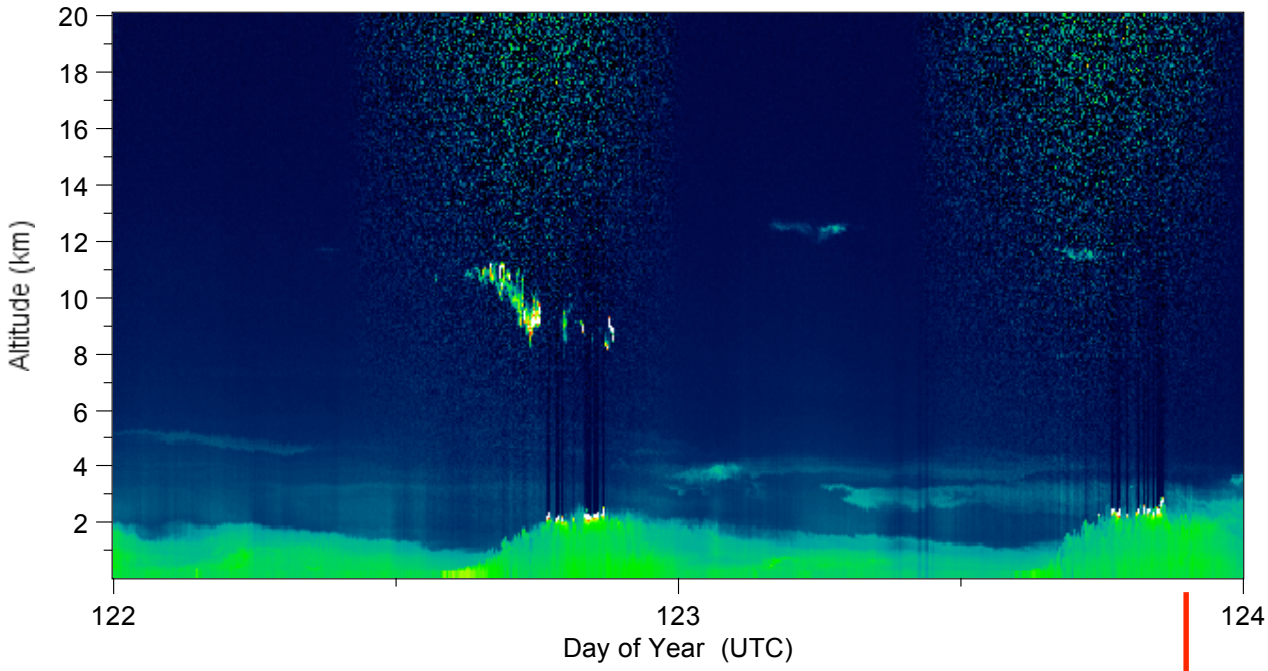
Data Retrieval: Aerosol Extinction Profile

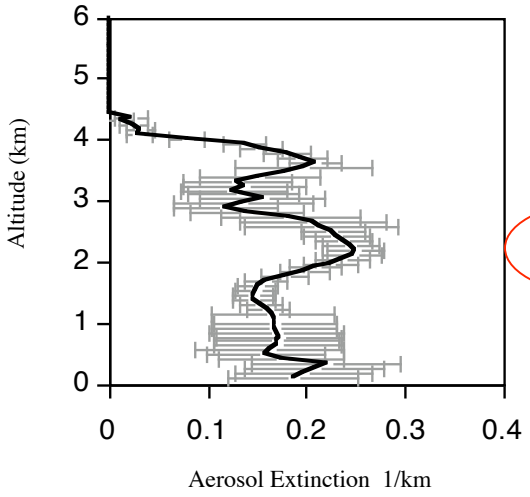
MPLNET:
Combined Active Lidar and Passive Photometer

Continuous MPLNET lidar observations

PBL structure & evolution readily apparent



Retrieved Aerosol Extinction Profile



AOD: 0.714 ± 0.01

C: 180 ± 9 $\frac{km^3 \cdot sr}{\mu J \cdot \mu s}$

Sa: 64 ± 4 sr

AERONET column Aerosol Optical Depth (AOD) observation used as constraint to retrieve vertical profile of aerosol extinction from the MPL

Aerosol extinction-to-backscatter ratio is calculated, this parameter is required for satellite retrieval of extinction

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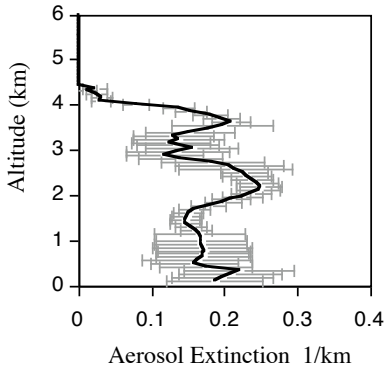
Data Retrieval: Level 1, 1.5, 2, and 3 Data Products

Level 1
Signals

Level 1.5



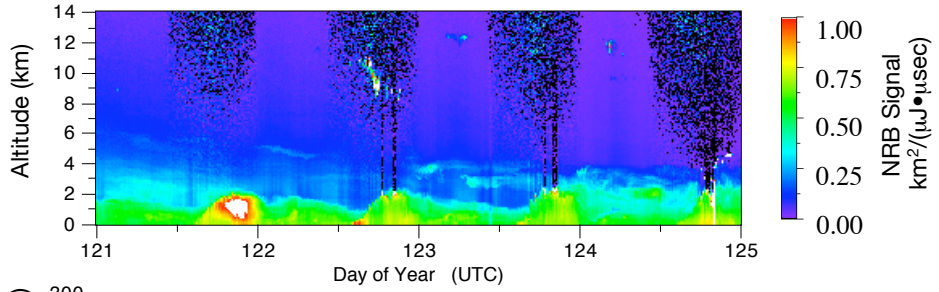
AOD: 0.714 ± 0.01

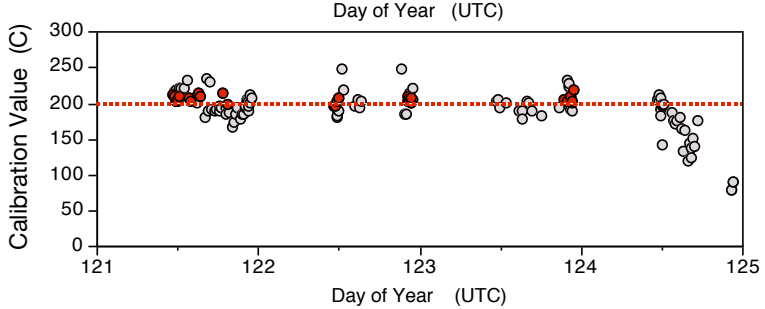
C: $180 \pm 9 \ \frac{km^3 \cdot sr}{\mu J \cdot \mu s}$

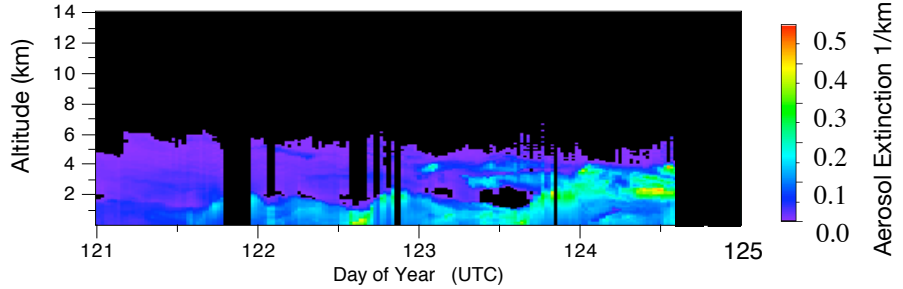
Sa: $64 \pm 4 \ sr$

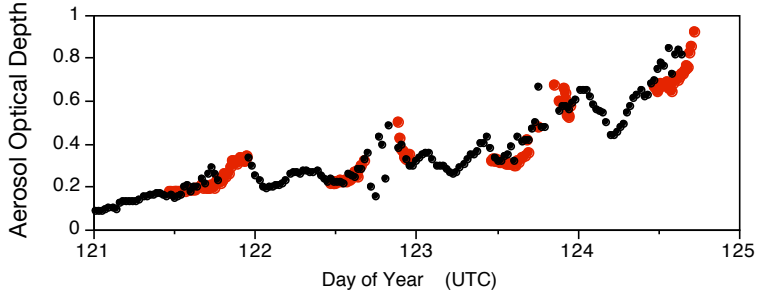
Level 2
Calibrations, Quality Assured Data

Level 3
Continuous Extinction Profiles & AOD









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Validation of MPLNET Aerosol Products

How well do state-of-the-art techniques measuring the vertical profile of tropospheric aerosol extinction compare?

B. Schmid, R. Ferrare, C. Flynn, R. Elleman, D. Covert, A. Strawa, E. Welton, D. Turner, H. Jonsson, J. Redemann, J. Eilers, K. Ricci, A. G. Hallar, M. Clayton, J. Michalsky, A. Smirnov, B. Holben, and J. Barnard, *J. Geophys. Res.*, 111, D05S07, doi:10.1029/2005JD005837, 2006.

Aerosol Extinction & Optical Depth profiles compared in most comprehensive study to date:

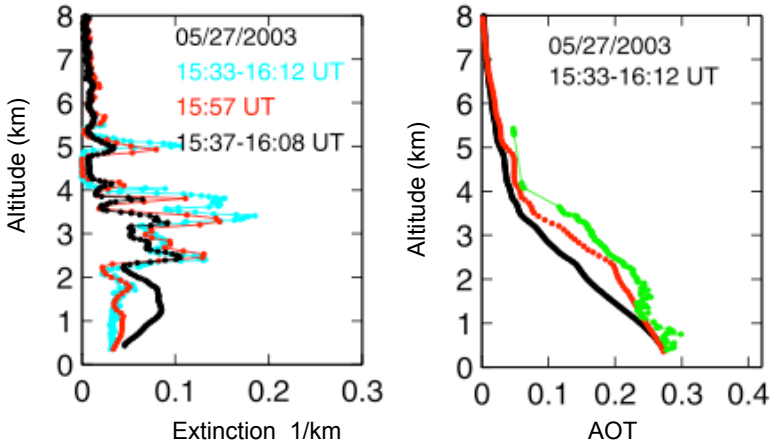
- MPLNET (column AOT anchored to AERONET)
- MPL from ARM
- Airborne Ames Sunphotometer (AATS)
- Airborne nephelometer & absorption photometer
- Airborne cavity ring-down system (Cadenza)
- Ground-based Raman lidar (CARL)

AATS used as truth
- AATS is most direct measure of AOT profile
- AATS Column AOT within 2% of AERONET

AATS-14 shown above

Example Comparisons from study (25 Days total).
Also surveyed past 7 field campaigns of such work.

MPLNET
MPL ARM
Neph/PSAP
AATS



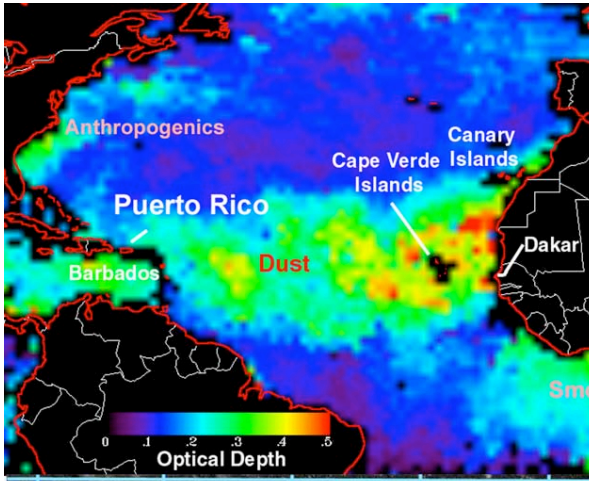
Summary of Study Results: MPLNET among best performers

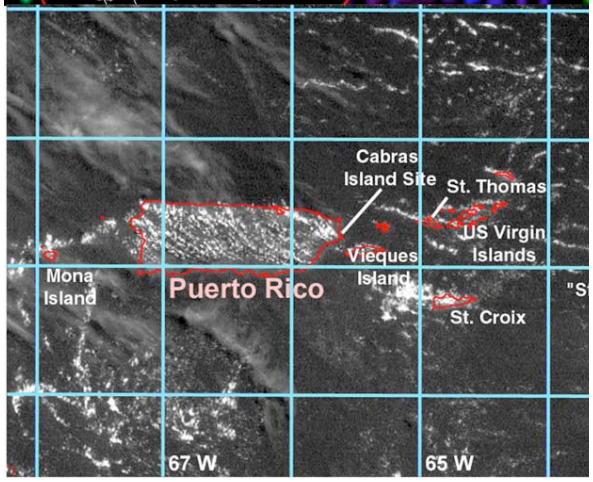
Instrument (visible wavelengths, ~520 nm)	Bias Error relative to AATS
Cadenza	- 13%
Neph / PSAP	- 15%
MPLNET	+ 13%
MPL ARM	+ 24%
CARL (Raman)	+ 54%
Neph / PSAP Mean from 7 Campaigns	- 17%
Size Dist. Derived Mean from 3 Campaigns	- 18%
MPLNET Mean from 5 Campaigns	< + 20% (work in progress)

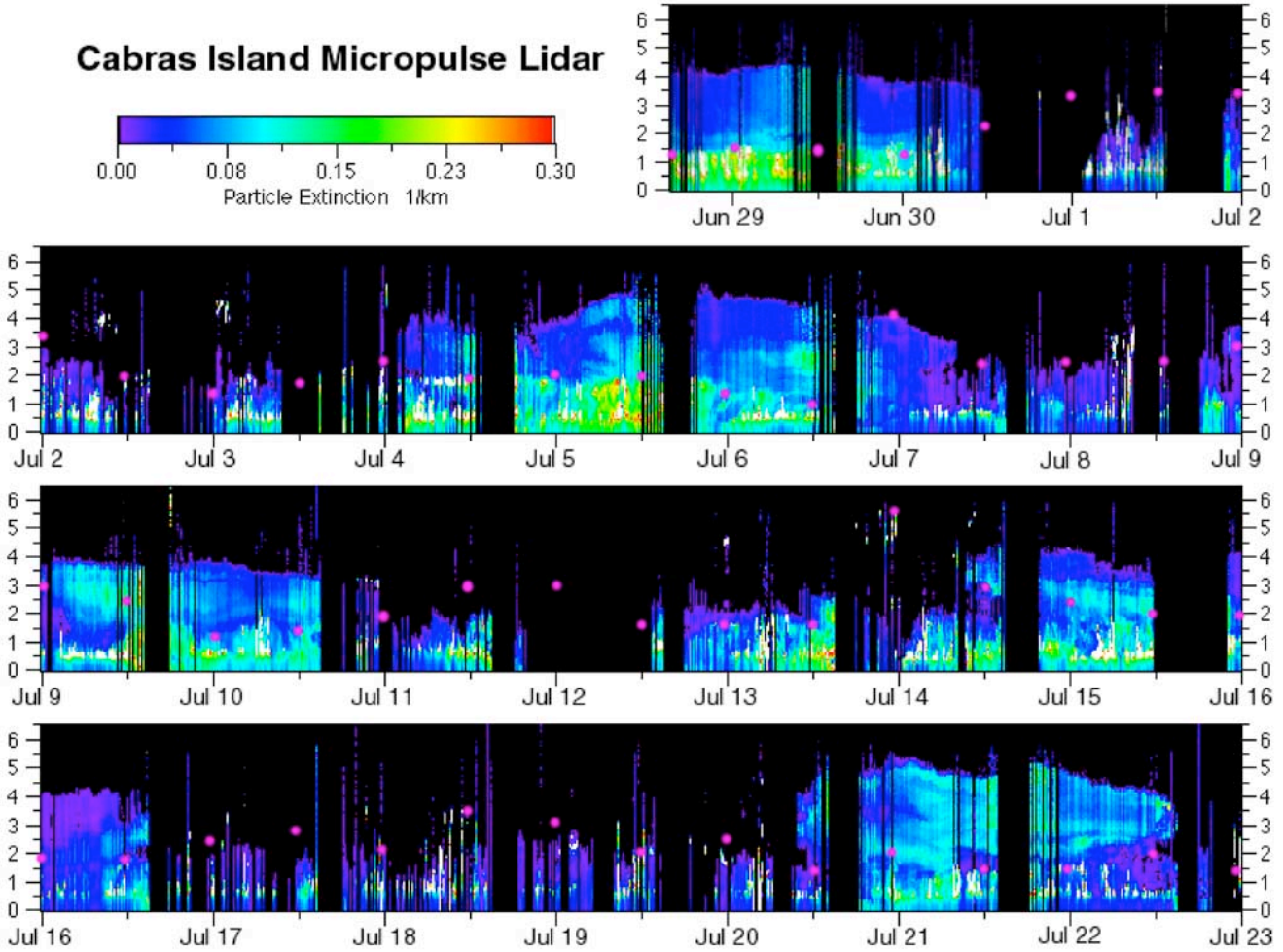
Conclusion: state-of-the-art techniques remain 15 - 20% uncertain
MPLNET meets or exceeds that target range

Observations of Saharan Dust Transport

Reid et al., *JGR*, 2003: Puerto Rico Dust Experiment (PRIDE) in 2000







Pink dots indicate MBL heights from nearby radiosonde

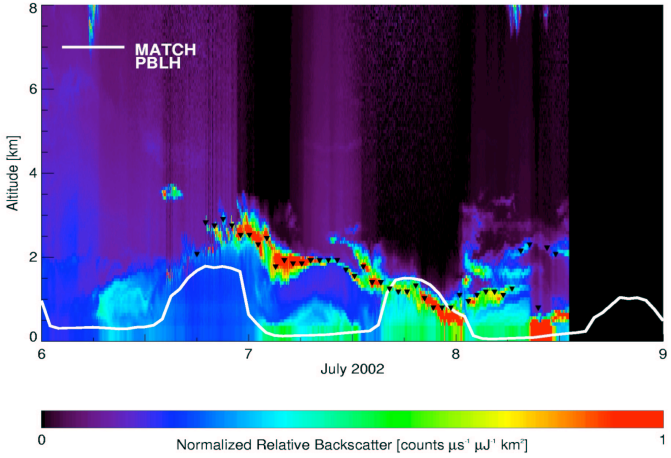
The NASA Micro-Pulse Lidar Network: MPLNET

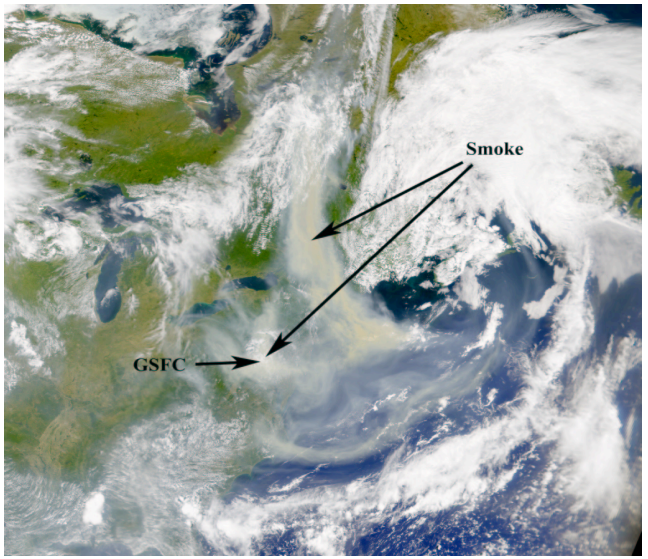
Relevant Publication/Science Results

Using Lidar to help constrain aerosol transport models:
Canadian smoke over Washington DC in 2002 (A Code Red Event!)

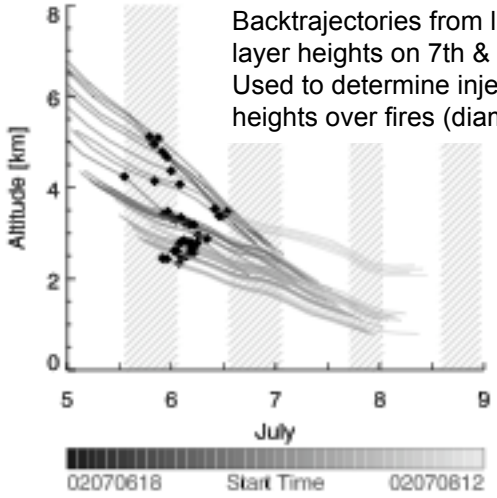
Colarco et al., *JGR*, 2004

MPLNET



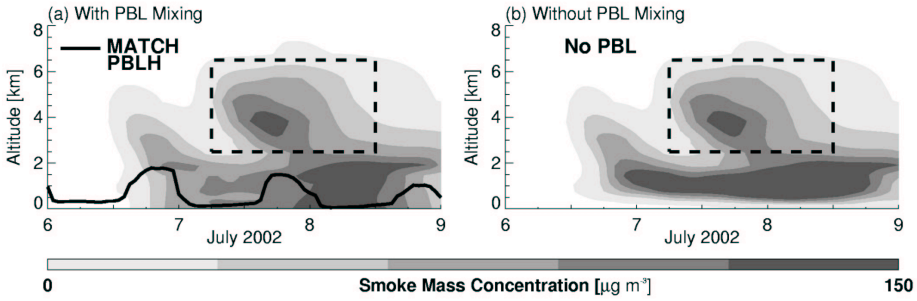


CARMA Model



Backtrajectories from lidar layer heights on 7th & 8th Used to determine injection heights over fires (diamonds)

Lidar used as constraint for deposition sensitivity study



MPLNET provides aerosol profile information useful to AeroCom:

- Multiple sites worldwide, data available from 2000-current
- Aerosol layer heights (day & night)
- Aerosol extinction and optical depth profiles (AERONET obs times)
    - level 3 extinction products possible (nighttime availability)
- common, standardized instruments, calibrations, & data processing
    - all files in netcdf (ascii upon request)
- extinction products have been validated multiple times
- MPLNET part of BAMGOMAS project (Aerosol data synergism)

MPLNET contributes to providing global aerosol profiles in other subtle ways……

Validation for satellite lidars: GLAS & CALIPSO

- direct validation of similar products
- help improve aerosol retrievals from space
- comparisons during overpasses provide unique spatial & temporal information

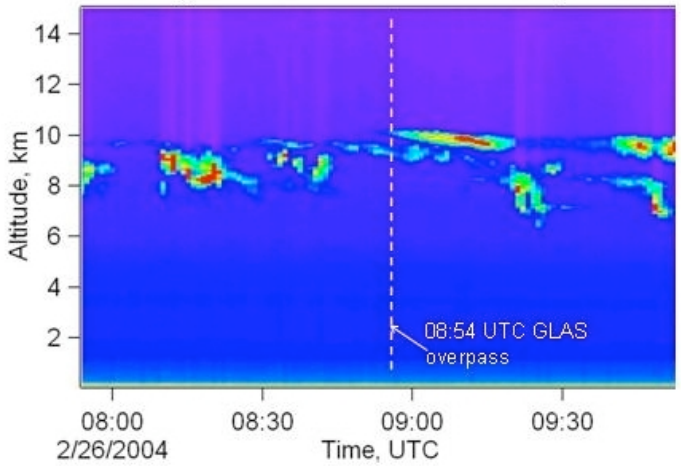
The NASA Micro-Pulse Lidar Network: MPLNET

Satellite Lidar Cal/Val: Direct Validation

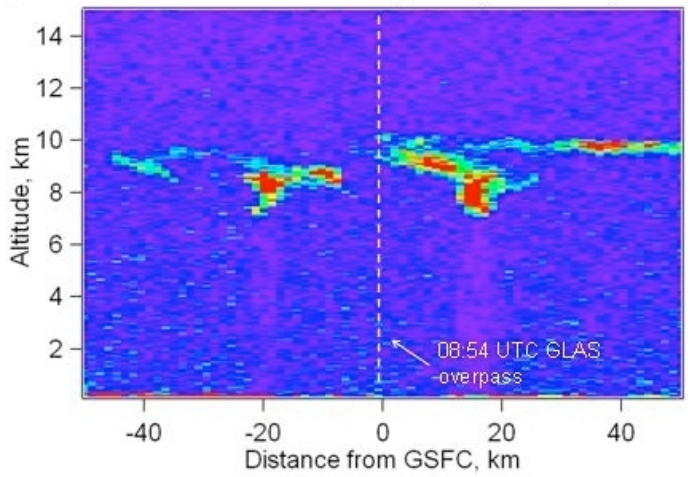
Direct Validation of GLAS Cloud Heights: Berkoff et al. (2005)

Result: extremely difficult due to differences in view geometry and temporal res

MPLNET ground-based observation (+/- 1 hour)

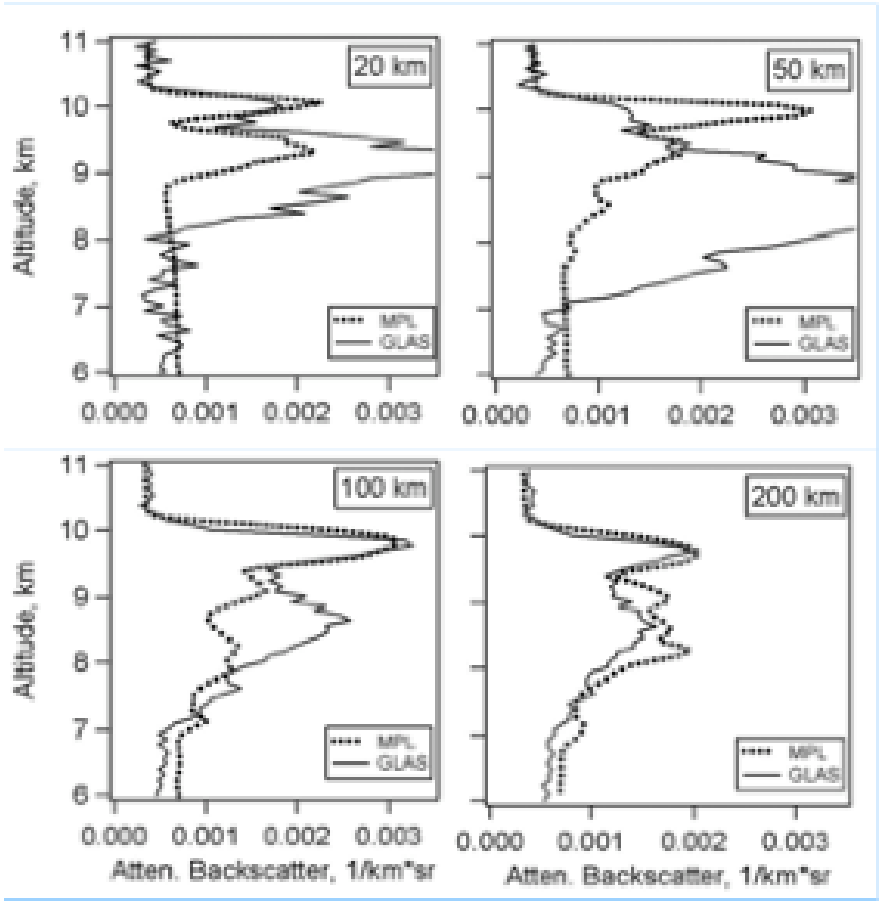


GLAS/IceSat Overpass (+/- 50 km)



Spatiotemporal Length-Matched Profiles

..... MPL ——— GLAS



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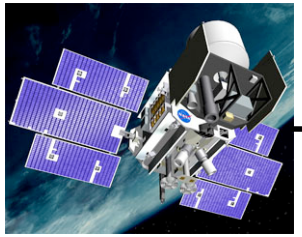
Satellite Lidar Cal/Val: Algorithm Development

The Lidar Ratio Problem for Satellite Lidar

MPLNET data will be used to construct look-up table



Geoscience Laser Altimeter System
Launch Date: 2003

Both missions use backscatter lidar. To obtain aerosol extinction and optical depth one must resolve the relationship between backscatter and extinction.

Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations
Launch Date: 2006

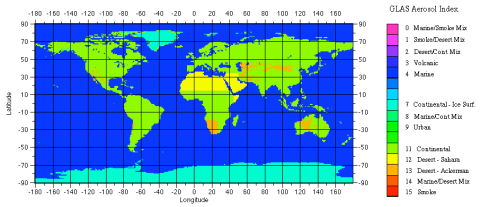
Aerosol Optical Depth Known:
Constrain lidar solution and calculate lidar ratio

1. Transmission loss method for elevated layer
2. AOD from coincident satellite data -> MODIS
3. AOD from ground instrument under orbit track

Lidar Ratio is required

$$S = \frac{\sigma(r)}{\beta(r)} = \frac{4\pi}{\omega_o P(180°)}$$

Lidar Ratio Look-Up-Table (LUT):



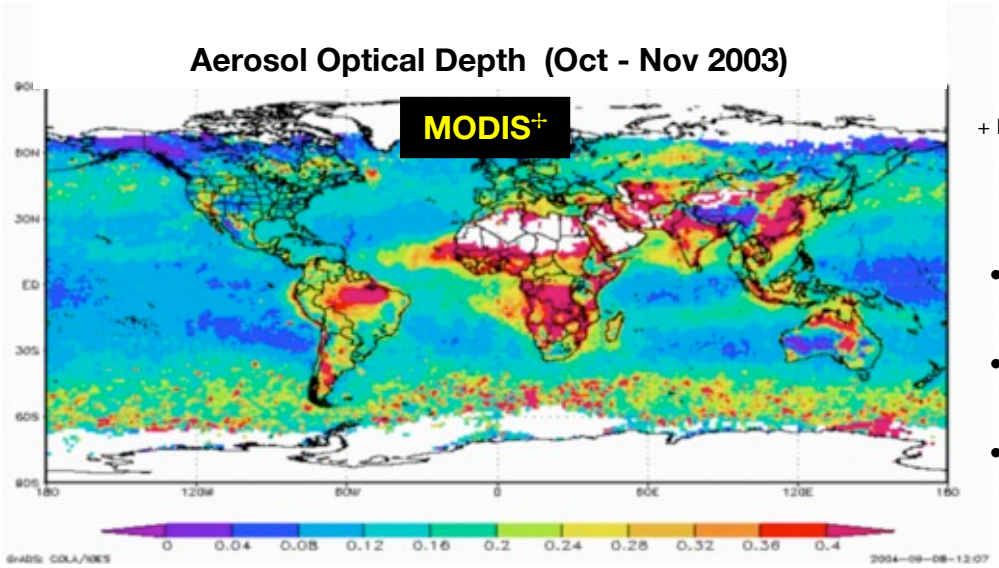
use values from ground measurements, and model calculations

Aerosol extinction profiles and layer optical depths

The NASA Micro-Pulse Lidar Network: MPLNET

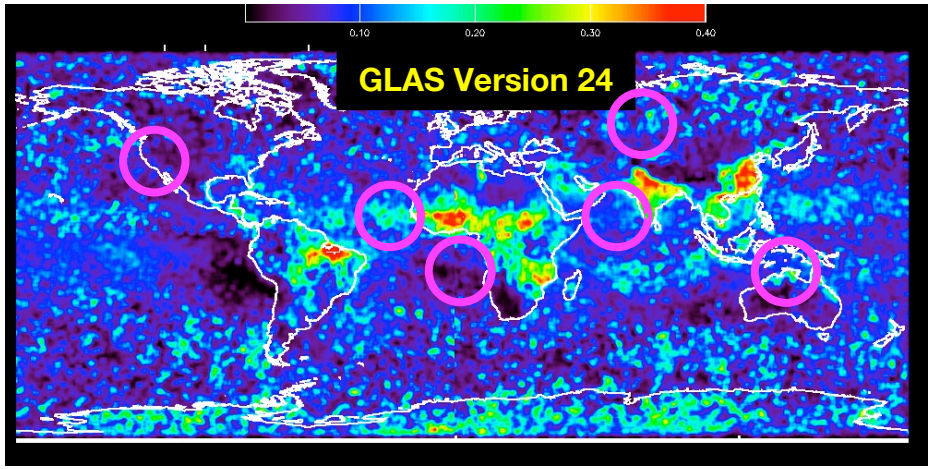
Satellite Lidar Cal/Val: Algorithm Development

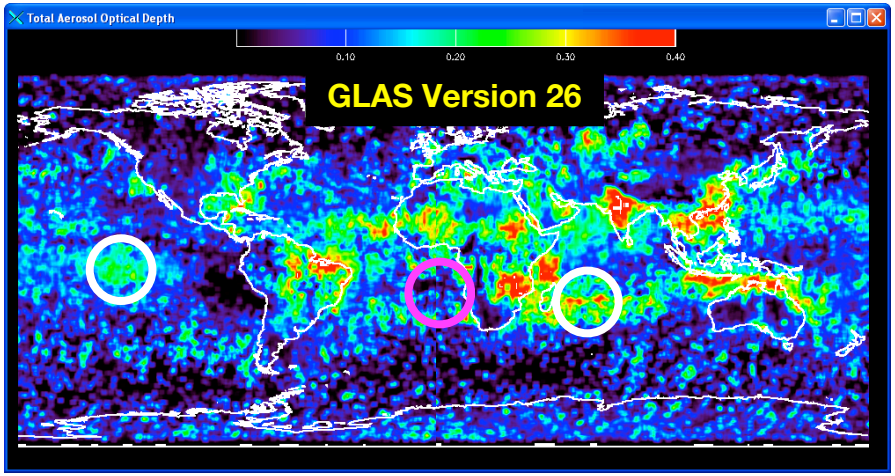
Illustration of the problem: Comparison of GLAS & MODIS AOD



+ Image provided by the MODIS Online Visualization and Analysis System (MOVAS), NASA GSFC

- GLAS Images provided by Steve Palm, SSAI/GSFC
- **Original aerosol product shown in ver 24**
  - simple aerosol assignments (marine only over ocean, no transport)
- **Latest aerosol product shown in ver 26**
  - regional aerosol transport over ocean, poor altitude assignment

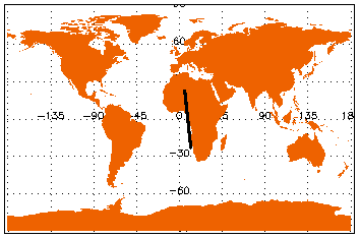




The NASA Micro-Pulse Lidar Network: MPLNET

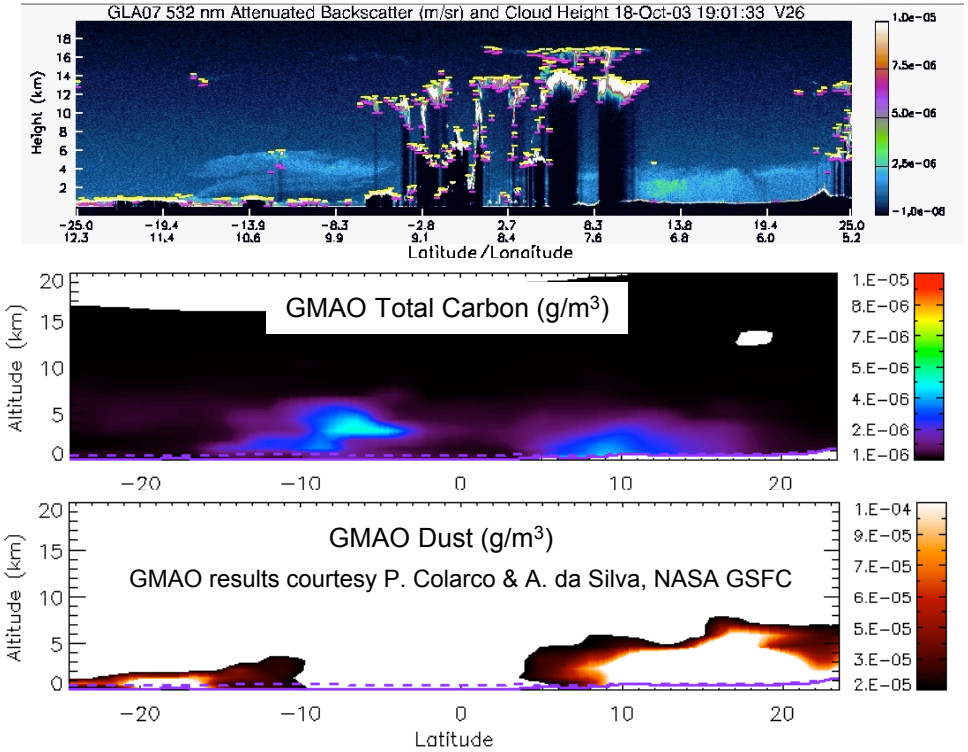
Satellite Lidar Cal/Val: Algorithm Development

Use aerosol transport models to help assign aerosol type (lidar observables also used: β, color ratio, depol)



after aerosol type is assigned, use lidar ratio from look up table database →

provide feedback on aerosol layer presence & height to model



Develop Aerosol Lidar Ratio Database: Groundbased data

Level 2 MPLNET & AERONET Results: Lidar Ratio vs Angstrom Exponent

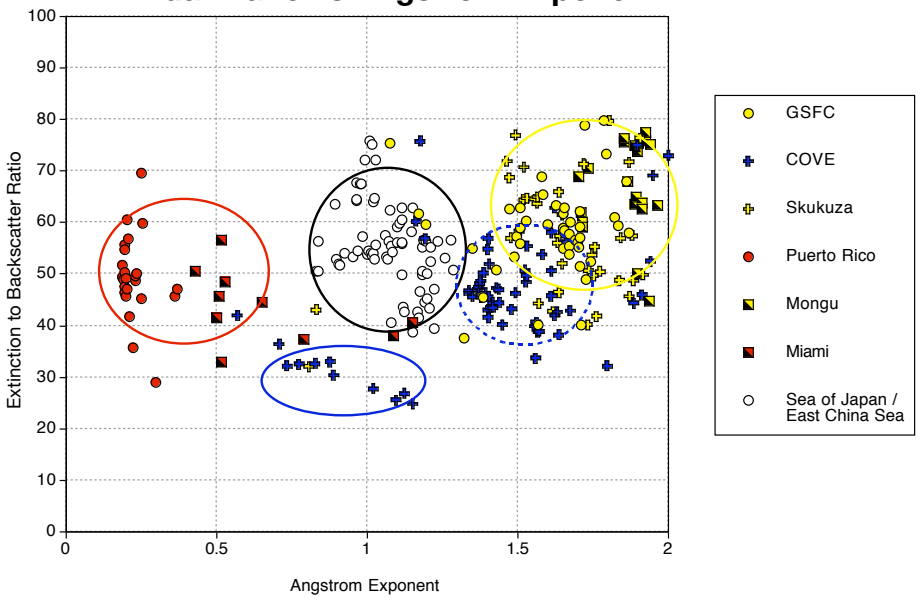


Table 1. Lidar Ratios (S) from Cattrall et al. (2005)[+]

Aerosol Type	Angstrom Exponent	S from AERONET	S from Literature
Urban	1.7 ± 0.2	71 ± 10 sr	64 ± 4 sr
Smoke	1.8 ± 0.2	60 ± 8 sr	64 ± 5 sr
Dust	0.1 ± 0.1	42 ± 4 sr	43 ± 6 sr
Asian*	1.2 ± 0.2	58 ± 11 sr	N/A
Marine	0.7 ± 0.4	28 ± 5 sr	29 ± 5 sr

[+] Cattrall, C., J. Reagan, K. Thome, and O. Dubovik, Variability of aerosol and spectral lidar and backscatter extinction ratios of key aerosol types derived from selected Aerosol Robotic Network locations, *J. Geophys. Res.*, **110**, D10S11, doi:10.1029/2004JD005124, 2005.
* Cattrall et al. refer to this type as Developing Nation