Aerosol remote sensing with MISR: Current and future directions

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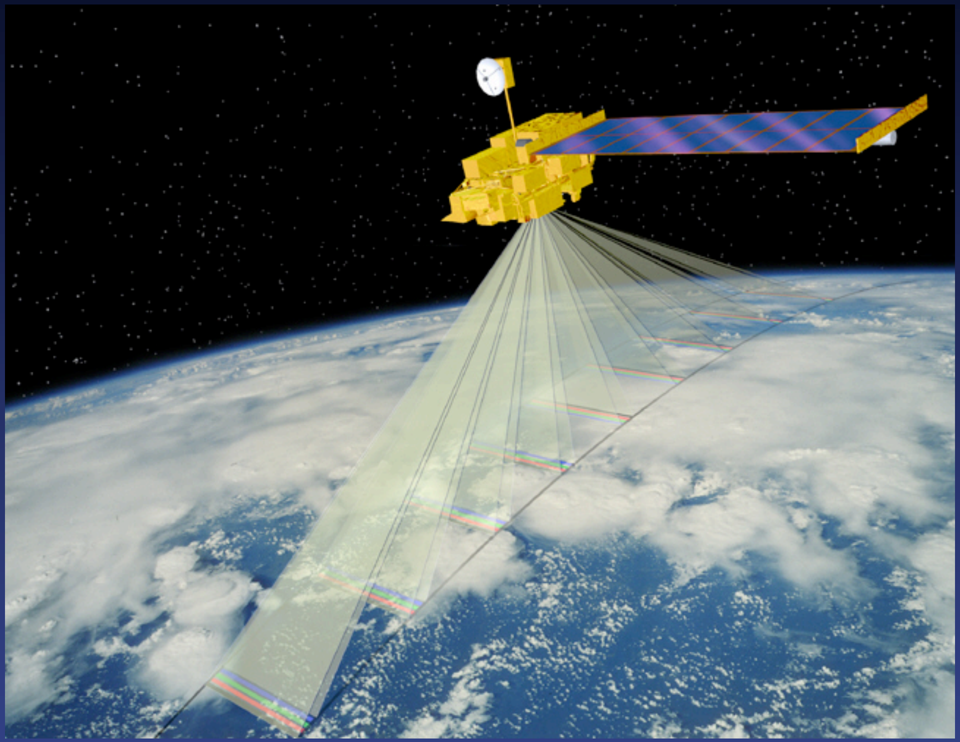
MISR observation and data analysis strategy



MISR provides global, multi-angle observations at moderately high spatial resolution over a wide range of angles

9 view angles at Earth surface: 70.5° forward to 70.5° aft

275 m - 1.1 km sampling

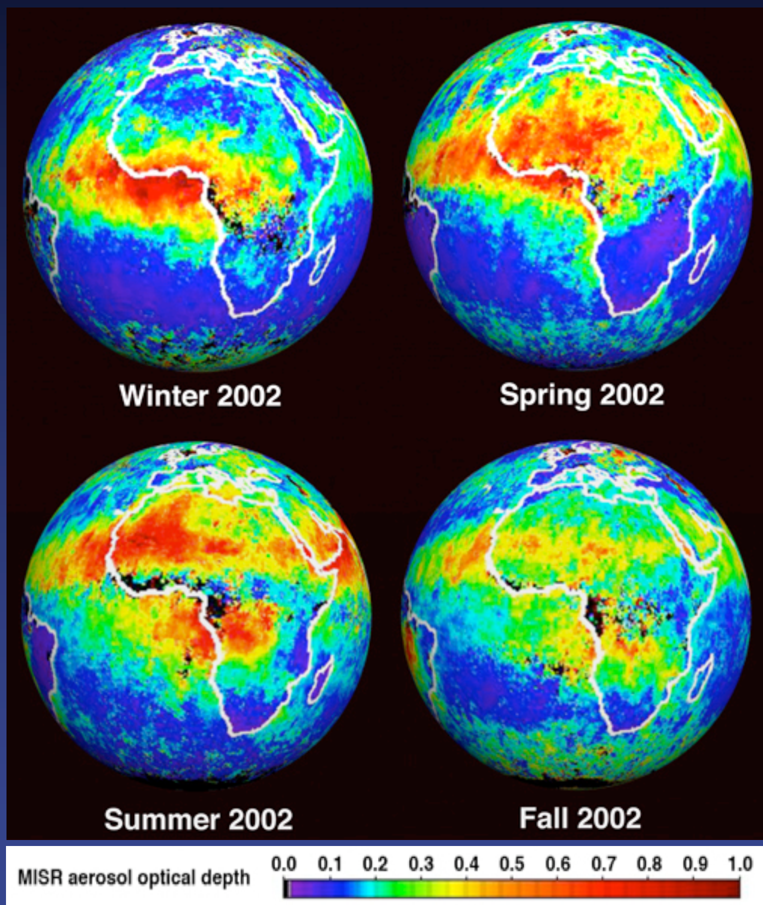
Multiple spectral bands at each angle: 446, 558, 672, 866 nm

400-km swath: 9-day global coverage

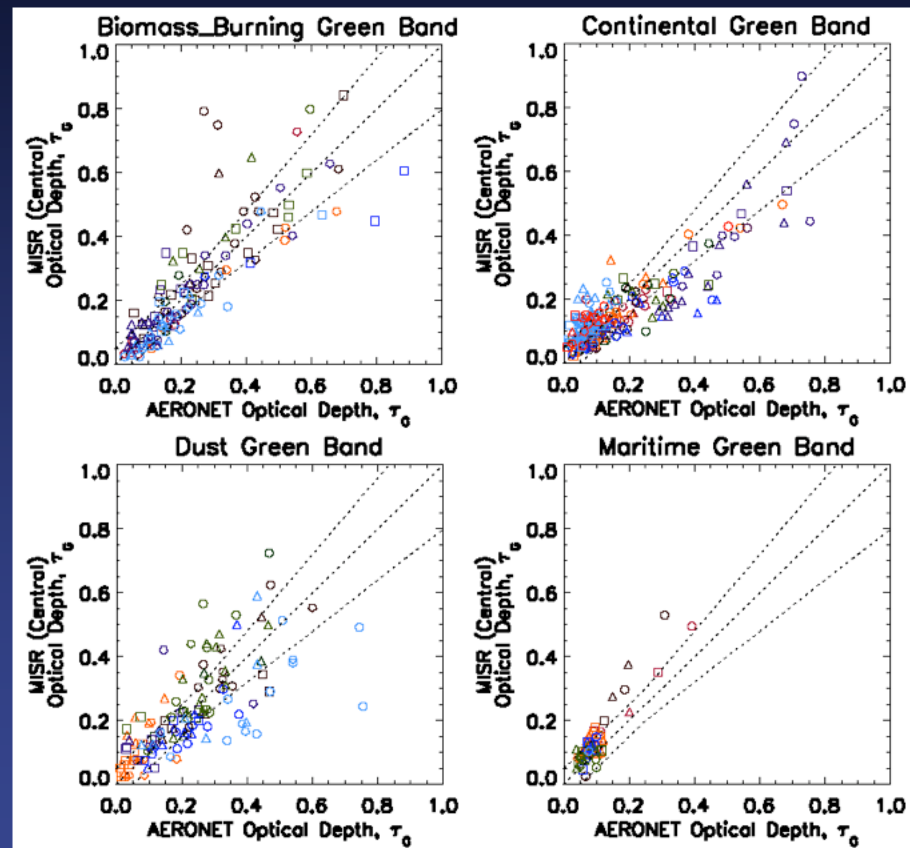
7 minutes to observe each scene at all 9 angles

These data are being explored in two ways:
-- Analyzing global, standard products generated by "operational" algorithms
-- Case studies using research algorithms

Aerosol sensitivity over many surface types



AOT over Land & Water,
Including Bright Desert

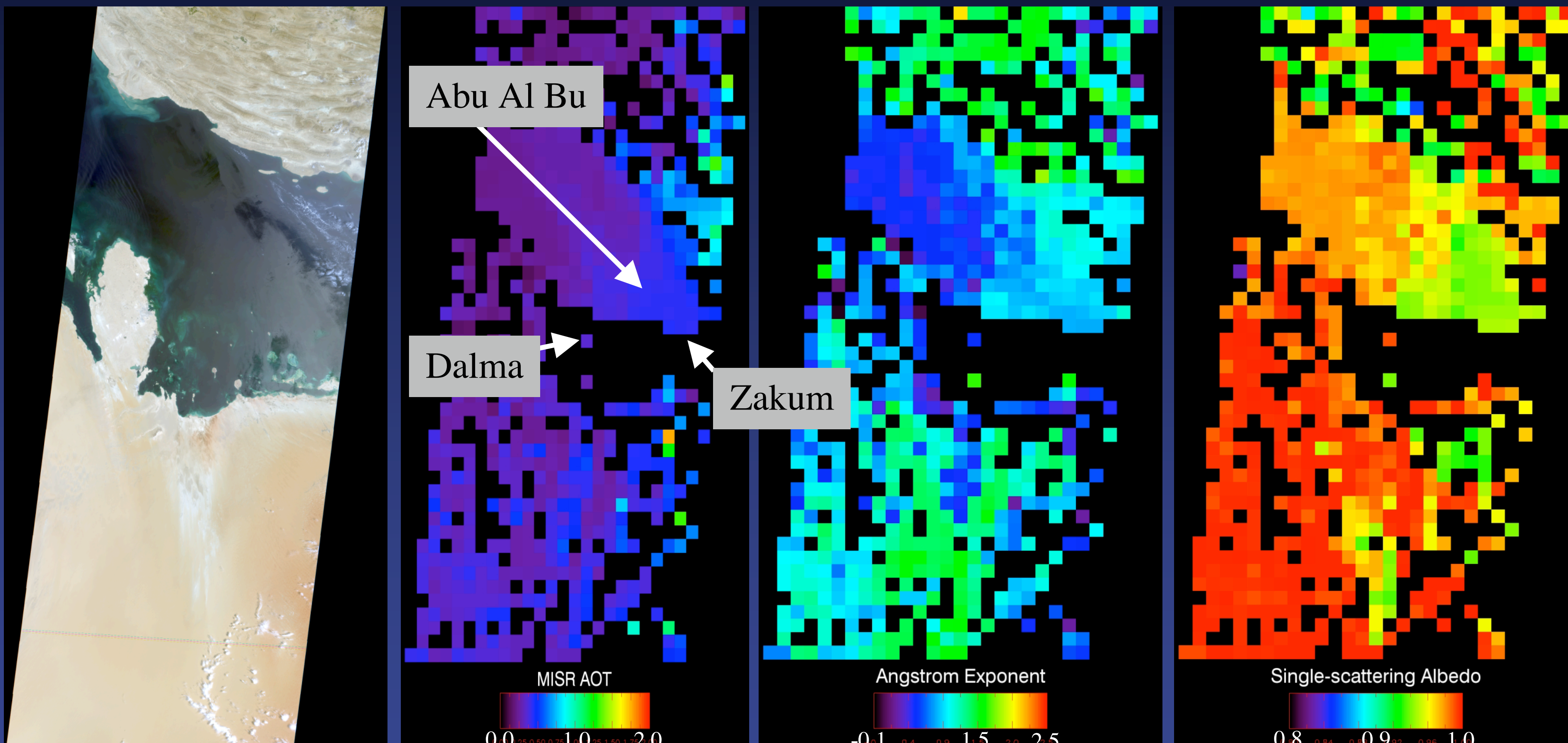


MISR-AERONET AOT Comparisons
Stratified by Expected Aerosol Type

Aerosol Air Mass Type Identification

UAE-2 Campaign MISR Data + AERONET Site Locations

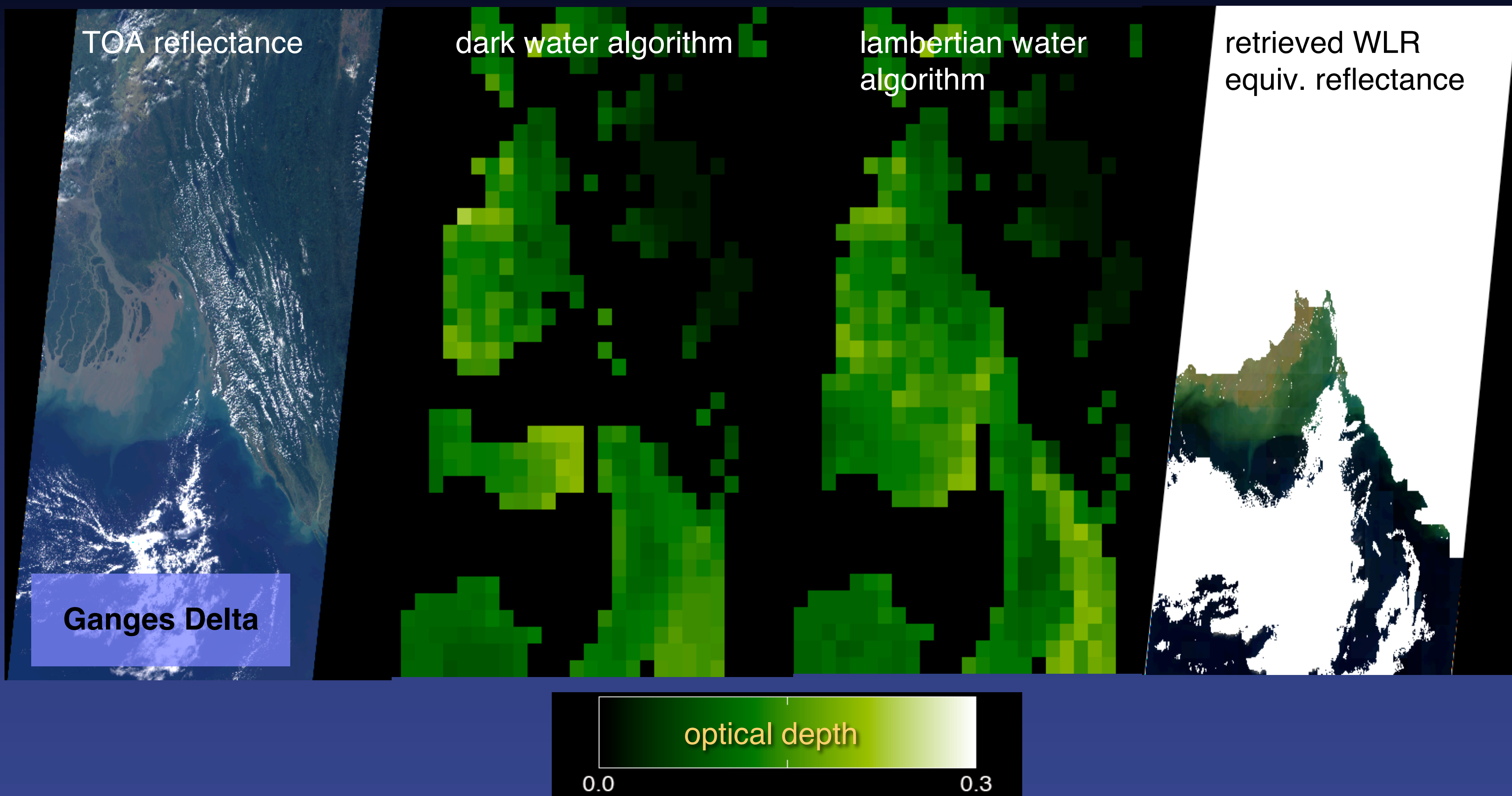
September 01, 2004 Orbit 25032 Path 162 Blocks 68-73 V16



MISR Nadir Image | **MISR AOT** | **Angstrom Exponent** | **SSA**

Dustier Air Masses have **Lower ANG** and **Higher SSA** Than Polluted Ones

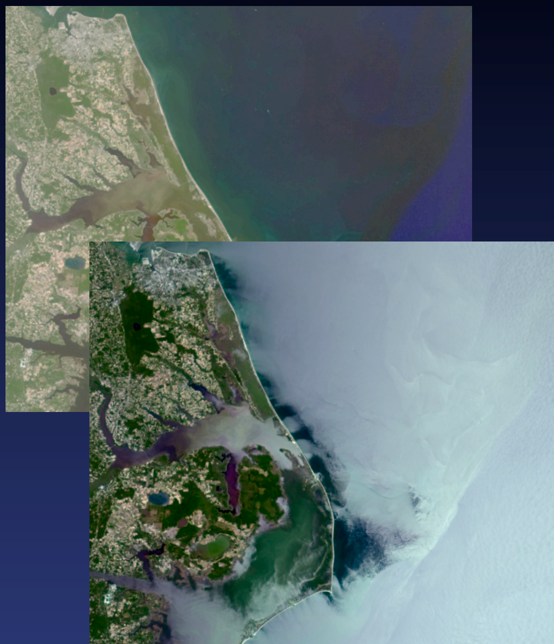
Multi-angle retrievals over Case 2 waters

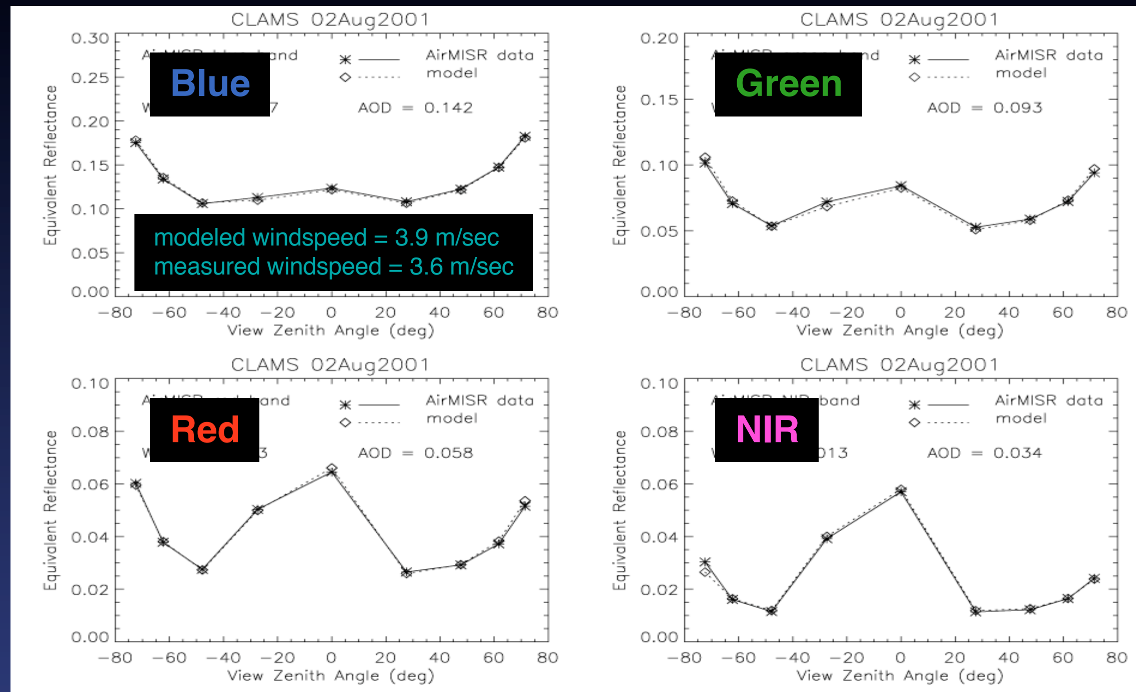


Multiangle views allow characterizing water-leaving radiance (WLR) by its **angular shape** instead of limiting retrievals to cases where WLR = 0.

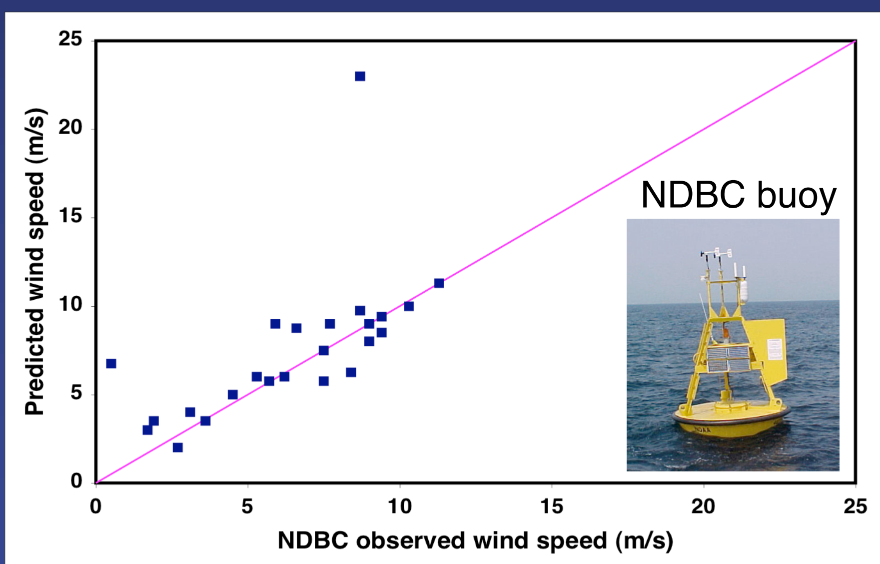
Credit: John Martonchik

Sunglint as a source of information on surface wind speed





AirMISR data over the Chesapeake Lighthouse 8/2/2001

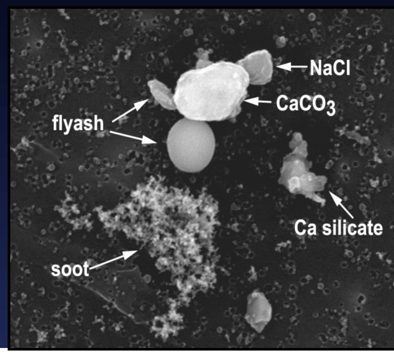


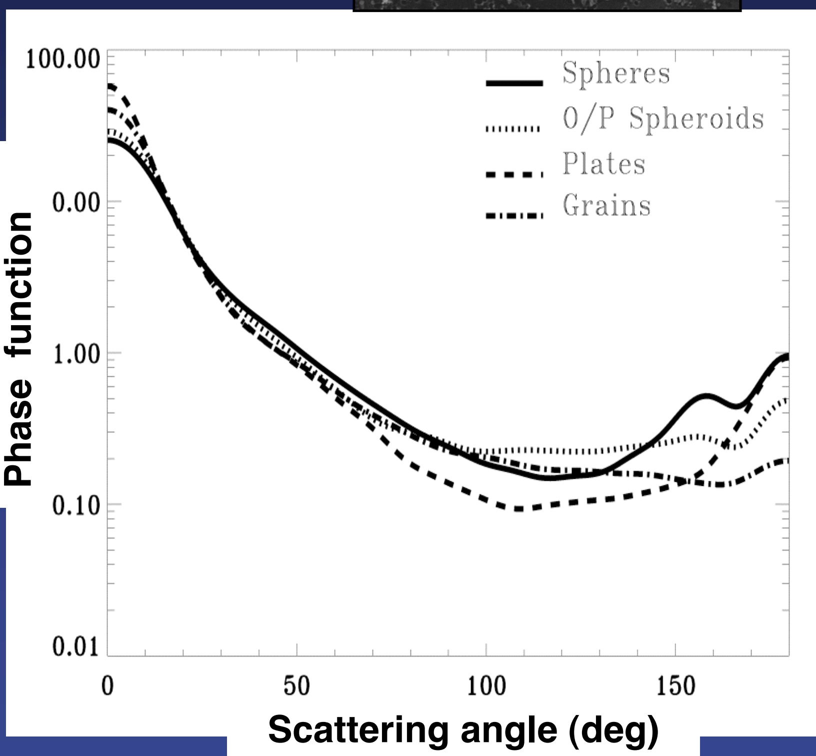
Possible Operational Algorithm For White Cap Assessment over Ocean

2000-2002 MISR-retrieved surface wind speed compared to NOAA National Data Buoy Center (NDBC) measurements (13 sites)

Credit: Enrique Gonzales, David Fox, Ralph Kahn, John Martonchik

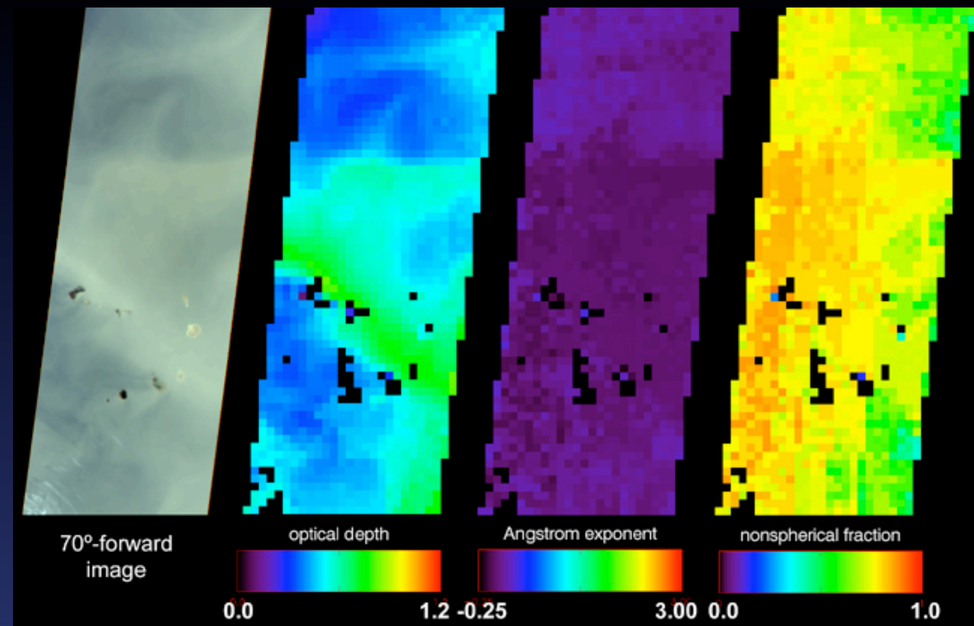
Distinguishing aerosol particle shapes



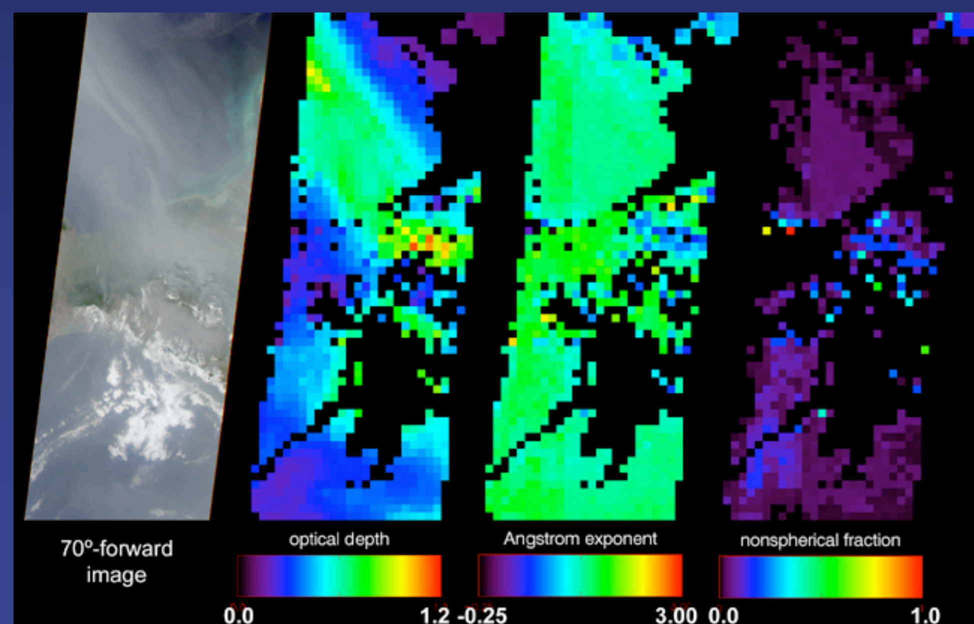


Spheres, Spheroids, Plates, Grains

Credit: Olga Kalashnikova



Large, non-spherical Dust near Cape Verde

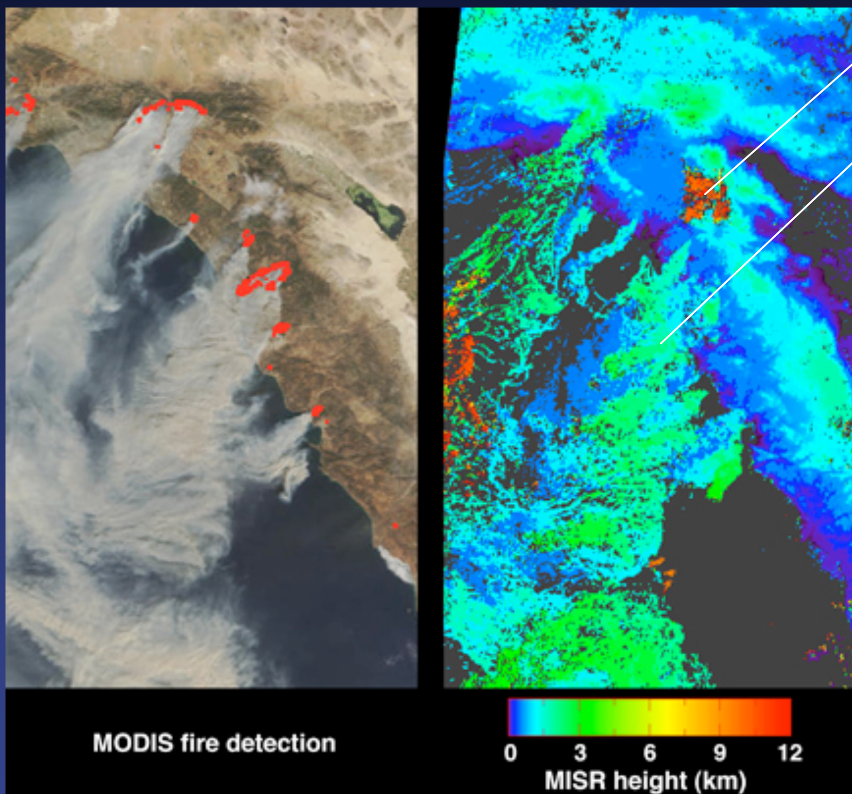


Medium, spherical BioBurn over Gulf of Mexico

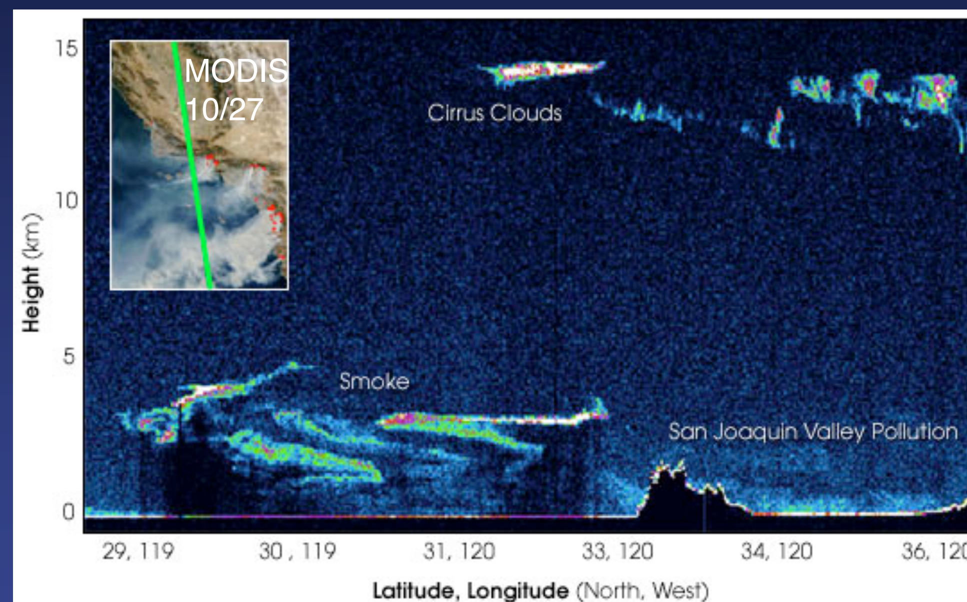
Passive/active mapping of smoke plumes & aerosol injection heights

cirrus

smoke

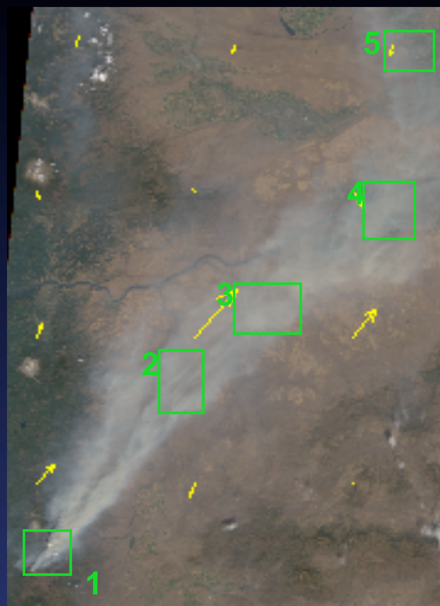


MODIS fire occurrence
MISR aerosol plume & cloud height
Terra 26 October 2003

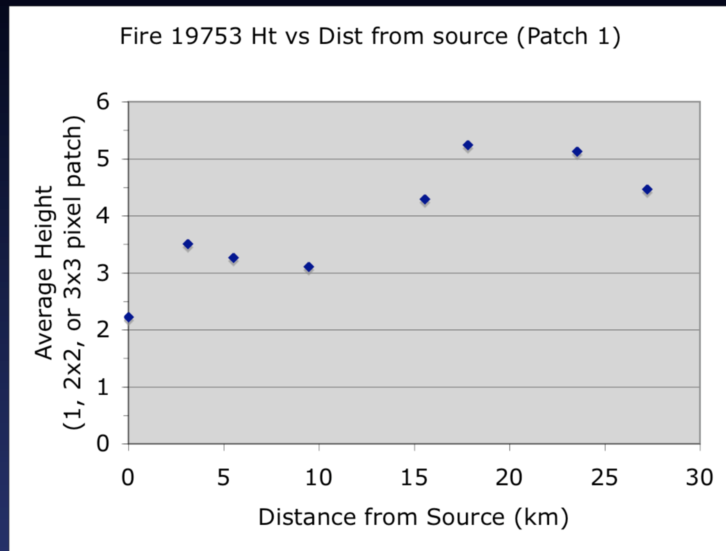


GLAS LIDAR vertical profiles
28 October 2003

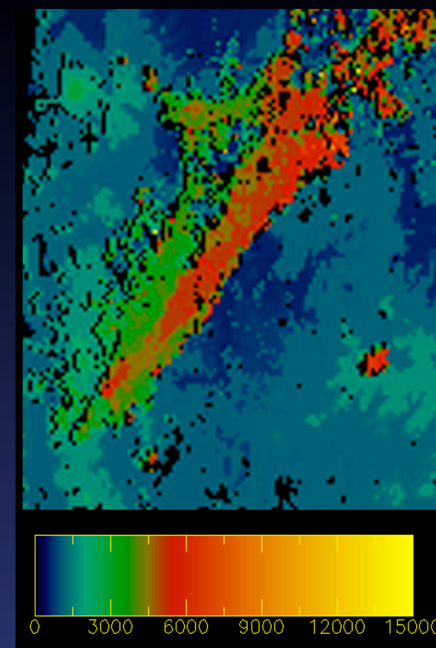
Aerosol plume physics



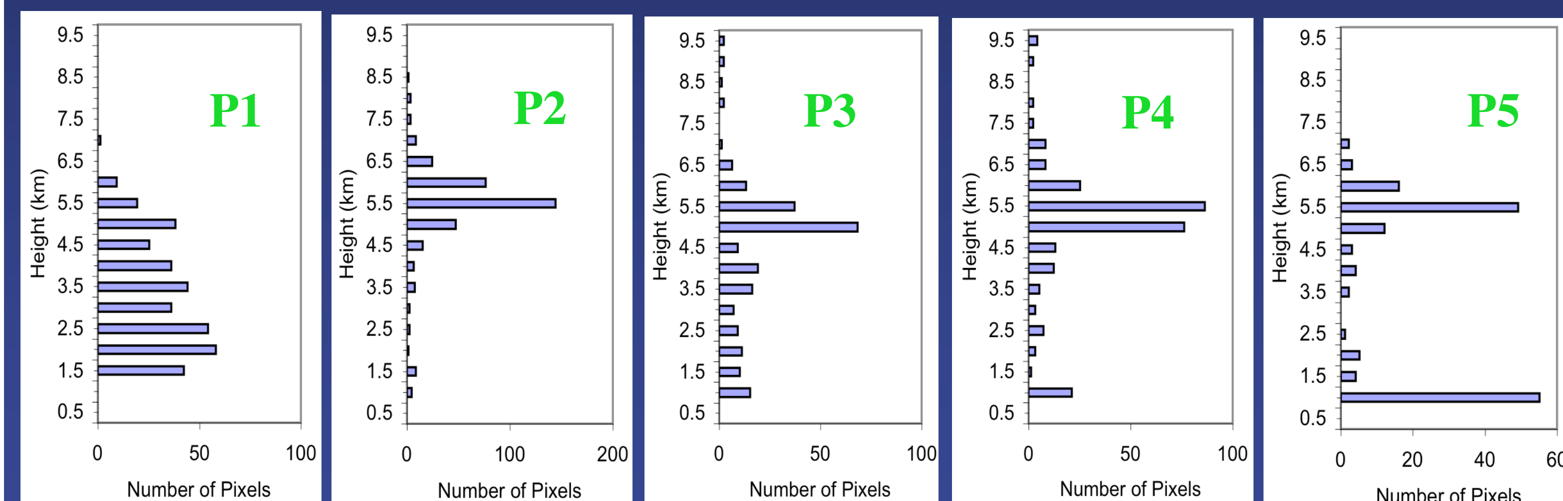
B&B Complex Fire, OR
4 September 2003



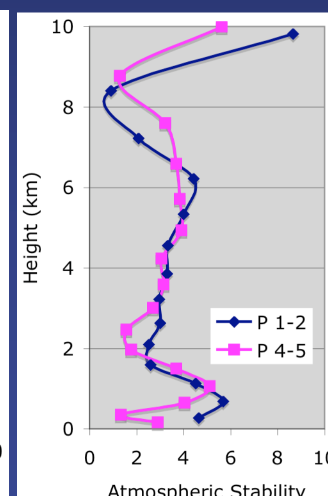
Near-source Fire Plume Rise



MISR Stereo Height

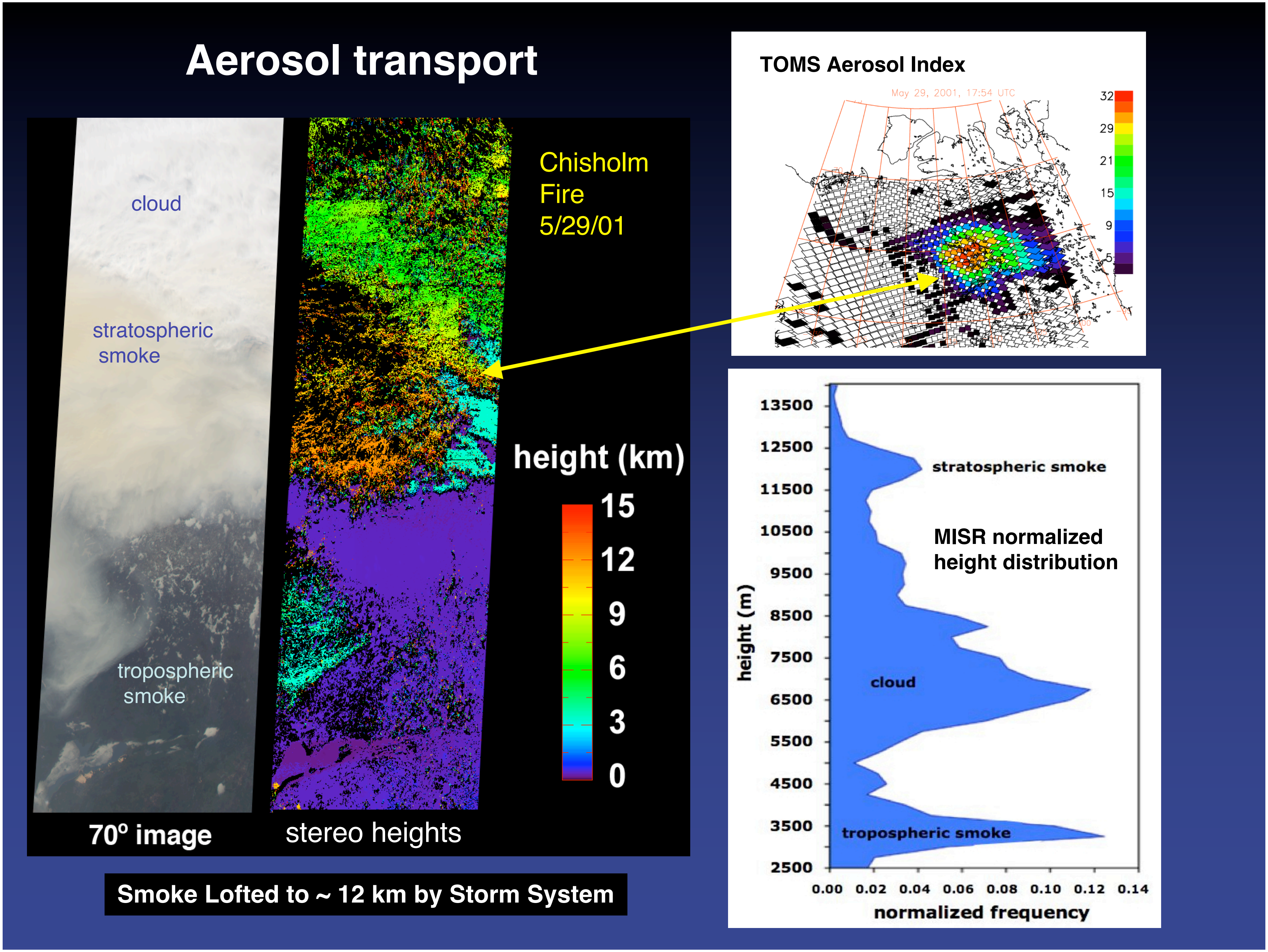


MISR Stereo Height Histograms for Patches Progressively Downwind



Atm. Stab. Profile

From: Kahn et al., JGR, submitted



Aerosol transport
cloud
stratospheric smoke
tropospheric smoke
70° image
stereo heights
Chisholm Fire 5/29/01
height (km)
15
12
9
6
3
0
Smoke Lofted to ~ 12 km by Storm System
TOMS Aerosol Index
May 29, 2001, 17:54 UTC
32
29
21
15
9
5
MISR normalized height distribution
stratospheric smoke
cloud
tropospheric smoke
height (m)
13500
12500
11500
10500
9500
8500
7500
6500
5500
4500
3500
2500
0.00 0.02 0.04 0.06 0.08 0.10 0.12 0.14
normalized frequency

The Aerosol Global Interactions Satellite (AEGIS) concept

passive sensor heritage

MISR | MODIS | AATSR | APS | POLDER | TOMS

active sensor heritage

GLAS | CALIPSO

+ **Technology developments**

ruggedized electro-optic retardance modulators for high-accuracy, self-calibrated polarization imaging

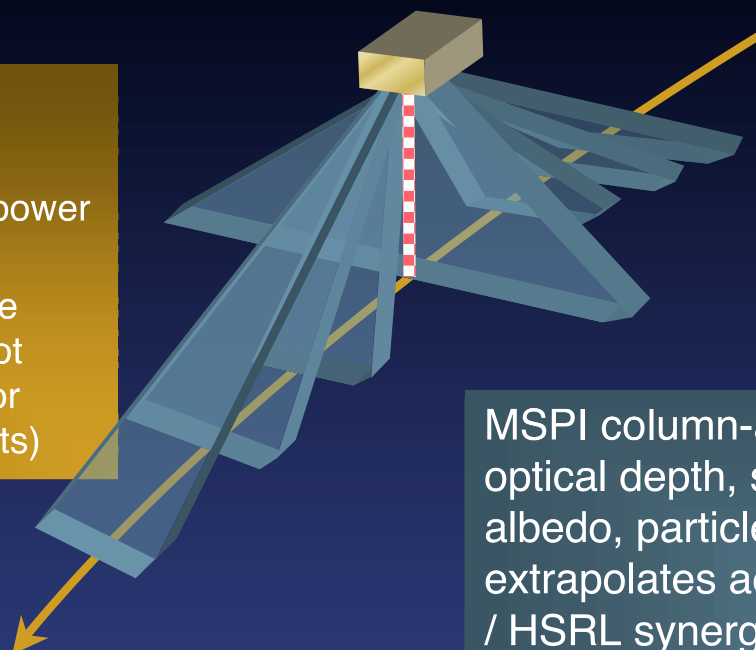
355-nm laser output & receiver channels; scalable frequency-agile laser source suitable for space

Multiangle SpectroPolarimetric Imager

High Spectral Resolution Lidar

Parameter	MSPI	HSRL
View angle range	Nadir to 70°, fore and aft	Nadir
Spectral range	Intensity: 380 - 2130 nm Polarization: 650, 1610 nm (0.5% uncertainty in DOLP)	HSRL: 355, 532 nm Backscatter only: 1064 nm Polarization: all three λ
Spatial resolution of derived aerosol products	Horizontal: 1-2 km Vertical: 200 m for plumes	Horizontal: 20 km Vertical: 120 m (backscatter), 900 m (extinction)
Global coverage time (swath width)	Multiangle: 4 days (700 km) "Nadir": 1 day (2650 km)	NA (100 m)

AEGIS mission strategy



Low Earth orbital altitude (470 km)

- Minimizes HSRL power and mass
- Enables multiangle views by MSPI (not possible from L1 or geostationary orbits)

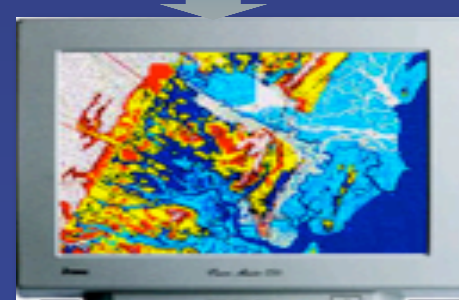
HSRL measures layer-wise profiles of aerosol properties (eff. radius, complex refractive index, shape, concentration), plus column optical depth

- Segregates near-surface and layer aerosol properties from total column

MSPI column-averaged aerosol sensitivity to optical depth, size distribution, single-scattering albedo, particle shape, refractive index extrapolates aerosol models derived from MSPI / HSRL synergy to broad swath

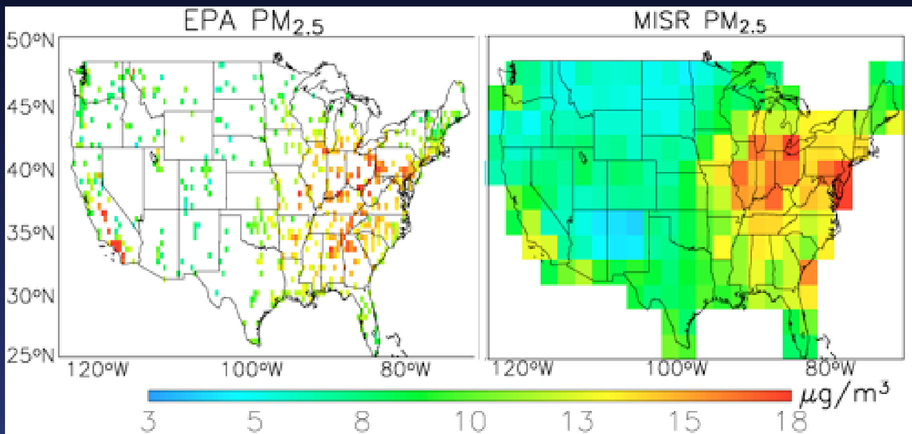
Stereo provides two-dimensional maps of aerosol plume injection and transport heights

Coverage enables integration with surface network, aircraft data, and assimilation models



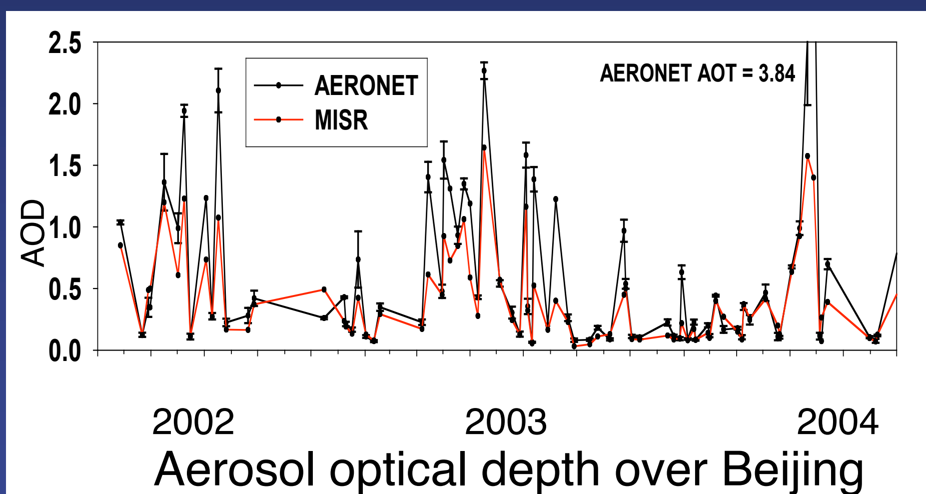
AEGIS contributions to global aerosol characterization

Example: Mapping particulate pollution



Today: Use of a transport model (GEOS-CHEM) relates MISR column AOD to surface $PM_{2.5}$ yielding good agreement with EPA surface data.

Future: HSRL will provide direct vertical profiles, and the combination of MSPI and HSRL will help sort aerosols by particle type.



Credit: Yang Liu

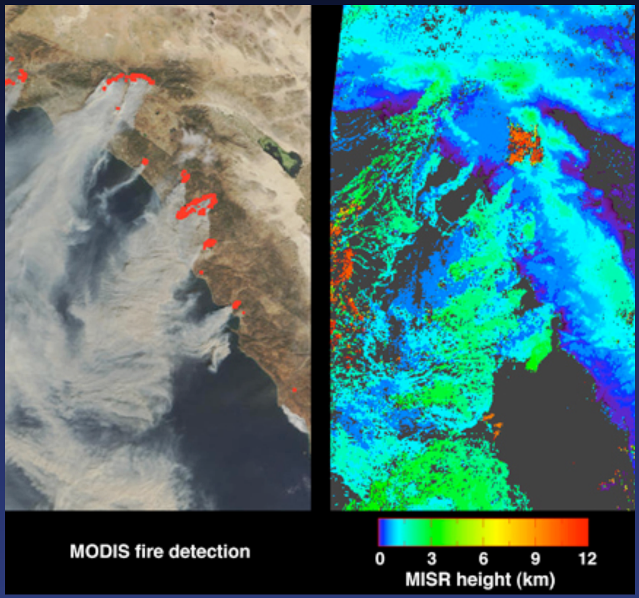
Today: MISR and AERONET optical depths over cities with high particulate levels (e.g., Beijing) are highly correlated;

In this example, MISR underestimates optical depth by 25-30%, most likely due to incorrect single scattering albedo.

Future: MSPI's greater sensitivity to single scattering albedo, coupled with HSRL, will provide much-improved particle models and aerosol type discrimination.

AEGIS contributions to global aerosol characterization

Example: Tracking aerosol transport in 3-D

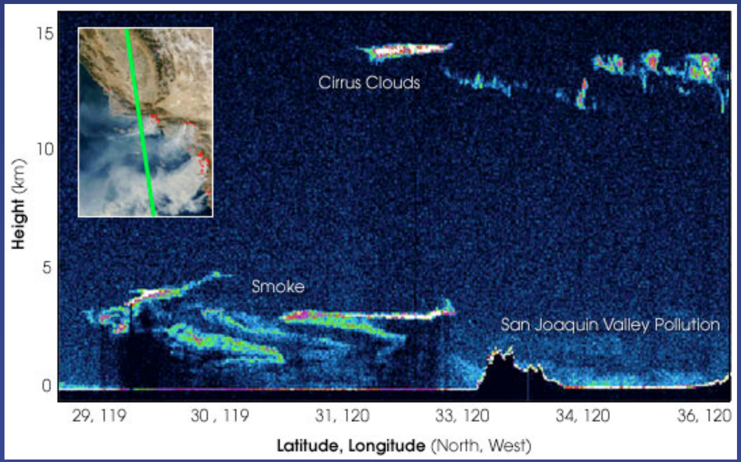


Today: MODIS provides near-daily horizontal coverage of aerosols and identifies active wildfire locations;

Automated MISR stereo retrievals map smoke (and dust) plume top heights;

MISR provides statistical aerosol injection information to calibrate transport models, but current narrow swath misses many events.

Future: MSPI improves upon MISR stereo revisit frequencies by a factor of 2.



Today: GLAS (and in the near future, CALIPSO) lidar provides aerosol vertical layering along subsatellite transects;

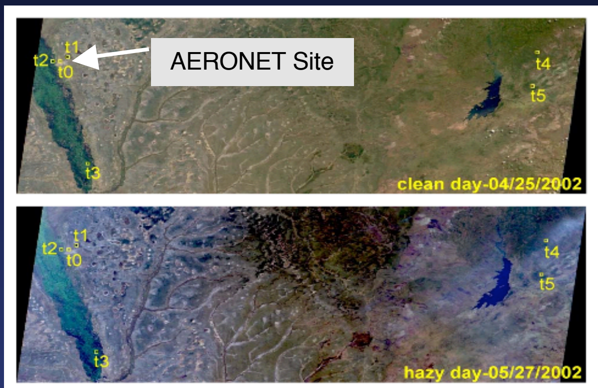
Direct determination of aerosol type in each layer is not possible, and quantitative extinction retrieval requires assumption of particle backscatter-to-extinction ratios.

Future: HSRL overcomes this limitation.

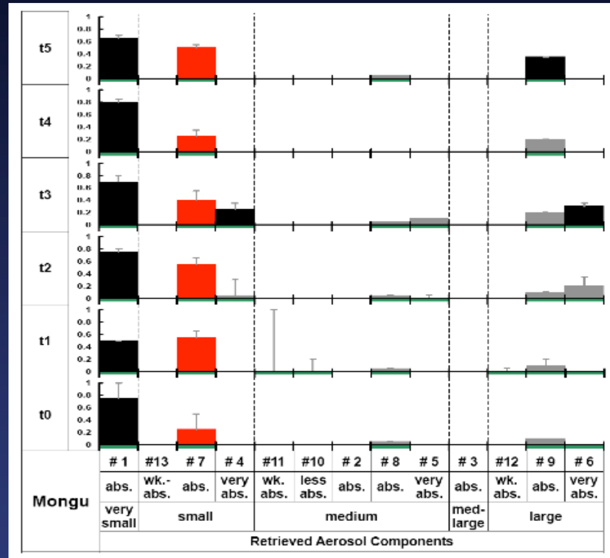
AEGIS contributions to global aerosol characterization

Example: Identifying particle microphysical characteristics

MISR data over Mongu, Zambia



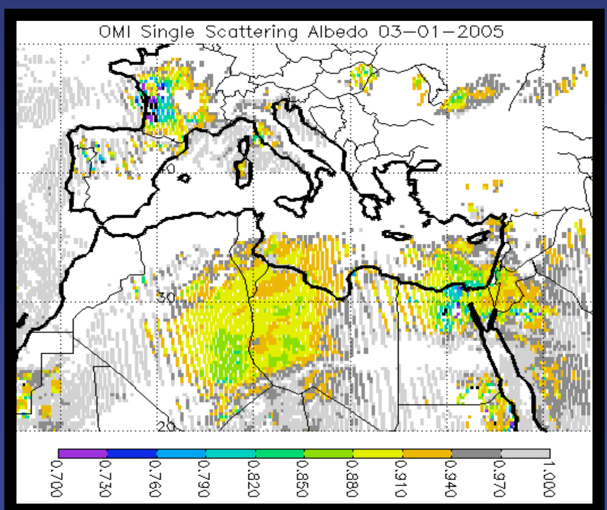
Credit: Wei-Ting Chen



Today: In this case study, MISR analysis retrieves particle sizes and single scattering albedo.

	MISR	AERONET
Size	0.15 - 0.22 μm	0.24 μm
SSA	0.84 - 0.85	0.83
AOD	0.3 - 0.4	0.34

Future: MSPI and HSRL build upon this capability.



Today: TOMS and OMI take advantage of Rayleigh-aerosol interaction and low surface albedo in the near-UV to retrieve single scattering albedo.

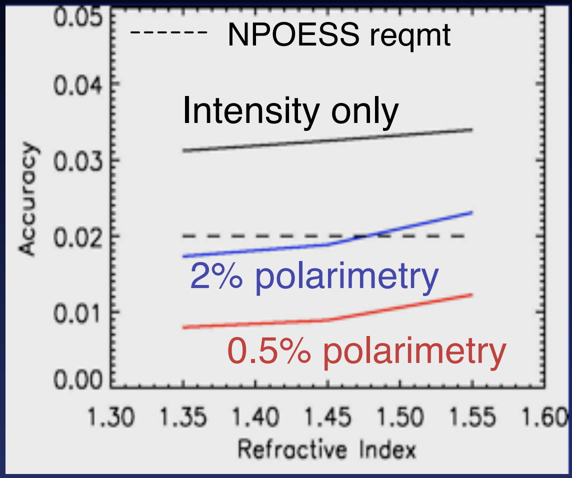
Future: MSPI provides near-UV data with high spatial resolution. Multiangle UV imaging could help disentangle effects of optical depth, single scattering albedo, and aerosol height.

Key MSPI and HSRL developments

Visible, near- and short-wave IR intensities yield particle size and shape, UV data constrain aerosol absorption, and accurate polarimetry is required for real refractive index and particle size variance.

Currently planned UV / polarization sensors (OMPS, APS) do not have high spatial resolution and / or global coverage.

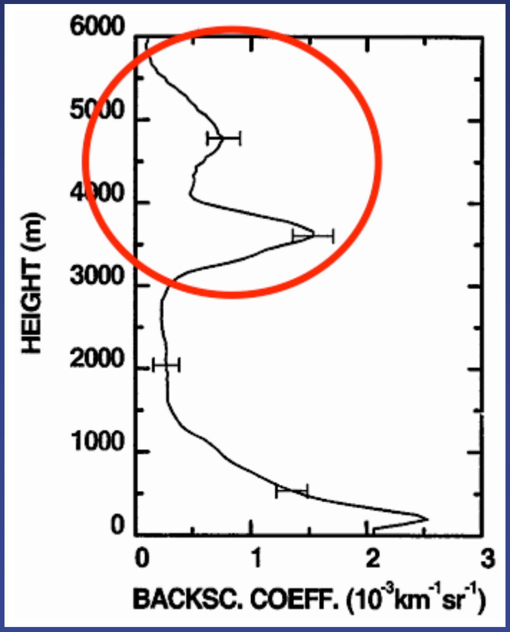
MSPI technology (high-performance optics, photoelastic modulators, and advanced focal planes) makes this feasible. Meeting 0.5% polarization is the biggest challenge.



Credit: Brian Cairns

Conventional backscatter lidars are not capable of profiling aerosol concentration or microphysical parameters and provide only limited information on particle type.

HSRL overcomes these limitations to provide size information and compositional proxies.



3-backscatter, 2 extinction lidar retrieval	aircraft in situ (r > 50 nm)
r_{eff} = 0.27±0.04	0.25±0.07 μm
n_r = 1.63±0.09	1.56
SSA = 0.81±0.03	0.79±0.02
volume conc. = 13±3	9±5 μm^3 cm^{-3}

This case study over Germany shows the benefit of a microphysics-capable lidar

Credit: Detlef Müller

Conclusions

Multiangle imaging at scales of 275 m - 1.1 km

- permits aerosol characterization over wide range of surface types, including source regions such as deserts and urban areas
- gives a 3-D perspective on complex scenes, enables retrieving plume heights
- provides particle type discrimination

Future multiangle instrument enhancements are envisioned

- increasing the spectral coverage from UV to shortwave IR
- Incorporating high accuracy polarimetric imaging
- widening the instrument swath

MISR aerosol data products are available
through the Langley Atmospheric Sciences Data Center DAAC
http://eosweb.larc.nasa.gov