MEASURING AEROSOL POLLUTION FROM SPACE: CAPABILITIES, LIMITATIONS, AND NEXT STEPS

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**With contributions from the Satellite Aerosol, and Satellite Aerosol Validation Communities



OMI Near UV Aerosol Products

Extinction AOD



AI

MODerate-resolution Imaging Spectroradiometer [MODIS]

- NASA, Terra & Aqua
 - launched 1999, 2001
 - 705 km polar orbits, descending
 (10:30 a.m.) & ascending (1:30 p.m.)
- Sensor Characteristics
 - 36 spectral bands ranging from 0.41 to 14.385 μm
 - cross-track scan mirror with 2330 km swath width
 - Spatial resolutions:
 - 250 m (bands 1 2)
 - 500 m (bands 3 7)
 - 1000 m (bands 8 36)
 - 2% reflectance calibration accuracy
 - onboard solar diffuser & solar diffuser stability monitor



Improved over AVHRR:

- Calibration
- Spatial Resolution
- Spectral Range & # Bands







MODIS Fire & Smoke Observations Idaho, August 23, 2000



- MODIS observes **AOT**
- •Also **Fire Brightness Temperature** (even through smoke) --> fire radiative energy --> related to rate of biomass consumption
- Observes at 10:30 am/pm and 1:30 am/pm ±40 min. local time

Multi-angle Imaging SpectroRadiometer



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- <u>Nine</u> CCD push-broom <u>cameras</u>
- <u>Nine view angles</u> at Earth surface: 70.5° forward to 70.5° aft
- Four spectral bands at each angle: 446, 558, 672, 866 nm
- Studies Aerosols, Clouds, & Surface

MISR Monthly Global Aerosol Mid-VIS AOT





January 2005

Five Years of <u>MISR</u> Global Aerosol Products

	2000	2001	2002	2003	2004				
Dec - Feb	MISR observations began 24 February								
Mar - May									
Jun - Aug									
Sep - Nov									
MISR aerosol optical depth 0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0									

127 MISR- AERONET & 113 MODIS-AERONET Coincident AOT Comparisons Over Land; March, June, and September 2002



Pollution Aerosol Concentrated in Ganges Valley near Kanpur, India (MISR)



MISR mid-visible AOD [Winter, 2001-2004; white --> AOD >0.6] NCEP Winds + Topography [Black=surface; Red=850 mb; contours=vertical, solid=subsidence]

See also: Krol et al. Poster, Session 3; Muller & Sole-Chamarro Poster, Session 2

DiGirolamo et al., GRL, 2004

Using MISR and chemical transport models to map particulate air pollution

• Epidemiologists want to know the concentrations of small airborne particles ($PM_{2.5}$ aerosols) near Earth's surface, especially in urban areas and near pollution sources.

• MISR measures column-average aerosol amount & type, globally, ~ once per week.



• Liu et al. [*JGR 2004*] used two multi-layer aerosol numerical transport models to relate MISR-measured column-average quantities to near-surface values.

• Comparisons between the MISR-driven model values of $PM_{2.5}$ and those measured at Environmental Protection Agency sites, show high quantitative & spatial correlation.

See also: Liu, Franklin, and Koutrakis Poster, Session 2

Smoke from Mexico (MISR) 2 May 2002

<u>Aerosol:</u> Amount Size Shape



Medium Spherical Smoke Particles

Dust blowing off the Sahara Desert (MISR) 6 February 2004



Oregon Fire (B&B Complex) Sept 04 2003 Orbit 19753 Blks 53-55 MISR Aerosols V17, Heights V13 (no winds)



Plume Periphery: Higher AOT, Lower ANG, Lower SSA than Background

Plume Core: Too Thick & Variable for Standard AOT Retrieval

Kahn, et al., JGR, submitted

Oregon Fire Sept 04 2003 Orbit 19753 MISR Stereo Heights V13 (no winds)



0

5

10

15

Distance from Source (km)

20

25

Patch 1 Detail

Atmospheric stability derived from NCEP re-analysis

Kahn, et al., JGR, submitted

30

MISR height analysis of World Trade Center plume 12 September 2001



MISR Stereo-Derived Elevations in four patches progressively downwind of the WTC, used to help model both fire characteristics and plume evolution

See also: Stenchikov et al. Poster, Session 3

Stenchikov et al., JEFM, submitted





Field Campaigns: Satellite Aerosol Product Validation + MISR/MODIS Regional Aerosol Maps







Mongu, Zambia *Burning Season* April 27, 2002



From: Chen et al., JGR, submitted

UAE-2 Campaign MISR Data + AERONET Site Locations September 01, 2004 Orbit 25032 Path 162 Blocks 68-73 V16



Dustier Atmosphere has Lower ANG and Higher SSA Than Polluted Area

MISR Participation **INTEX-B / Milagro Campaign**

• Provide Regional AOT & Aerosol Type Maps

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- Validate MISR Land & Water Urban Aerosol Pollution Retrievals
- Test AEGIS multi-angle-spectral polariz. + Lidar Mission Concept

MISK Site	coverage	INTEX-B / Milagro Campaign			
Site	Date	Time (UTC)	Orbit	Path	Block
Gulf2,	Mar01,2006	16:52	32989	23,	70
Veracruz,	Mar01,2006	16:54	32989	23,	75
Gulf2,	Mar03,2006	16:40	33018	21,	70
Gulf1,	Mar03,2006	16:40	33018	21,	70
Gulf1,	Mar05,2006	16:27	33047	19,	70
Houston,	Mar06,2006	17:09	33062	26,	67
Mexico_City,	Mar06,2006	17:12	33062	26,	75
Veracruz,	Mar08,2006	17:00	33091	24,	75
Gulf2,	Mar10,2006	16.46	33120	22,	70
Gulf1,	Mar12,2006	16:34	33149	20,	70
Mexico_City,	Mar13,2006	17:19	33164	27,	75
Veracruz,	Mar15,2006	17:06	33193	25,	75
Houston,	Mar15,2006	17:03	33193	25,	67
Mexico_City,	Mar15,2006	17:06	33193	25,	75
Gulf2,	Mar17,2006	16:52	33222	23,	70
Veracruz,	Mar17,2006	16:54	33222	23,	75
Gulf1,	Mar19,2006	16:40	33251	21,	70
Gulf2,	Mar19,2006	16:40	33251	21,	70
Gulf1,	Mar21,2006	16:27	33280	19,	70
Houston,	Mar22,2006	17:09	33295	26,	67
Mexico_City,	Mar22,2006	17:12	33295	26,	75
Veracruz,	Mar24,2006	17:00	33324	24,	75
Gulf2,	Mar26,2006	16.46	33353	22,	70
Gulf1,	Mar28,2006	16:34	33382	20,	70
Mexico_City,	Mar29,2006	17:19	33397	27,	75

"Gulf 1" & "Gulf 2" are Paths E of Veracruz [Gulf 2 is within J31 Range, Gulf 1 is one hop]





R. �Kahn, MISR Aerosol Scientist

CURRENT STATE OF MISR-MODIS AEROSOL CAPABILITY

What we can do *routinely now* with satellite data

- AOT over water and land, except scattered <u>cloudy</u> regions, some <u>snow & ice</u> situations, <u>Case 2 water</u>
- M edium/large aerosol ratio; [MODIS; possibly dust from pollution from small particles]
- Spherical vs. Non-spherical [MISR; plates from grains from spheres at least in some cases]
- A erosol Layer Height [TOMS uv, GLAS, hopefully soon CALIPSO]
- A erosol Plume Height to ~0.5 km [MISR; mainly forest fire, volcano, and dust source regions]
- F ire Occurrence [MODIS, AVHRR and other instruments w/mid-IR channels]

What we can do *now in individual cases*, & with available satellite data, could do routinely

- 3-5 size bins [MISR; need to complete the validation]
- 2-4 single-scattering albedo groupings [MISR; need to complete the validation]
- Aerosol amount & properties over Case 2 waters [MISR; algorithm development underway]

There is more to be said about other of the newer satellite instruments as well: POLDER, CERES, GLAS, AIRS, (CALIPSO), (GLORY), etc.

For Air Quality: <u>Direct Downlink</u> <u>Rapid Processing</u> <u>1-3 km Spatial Resolution</u>