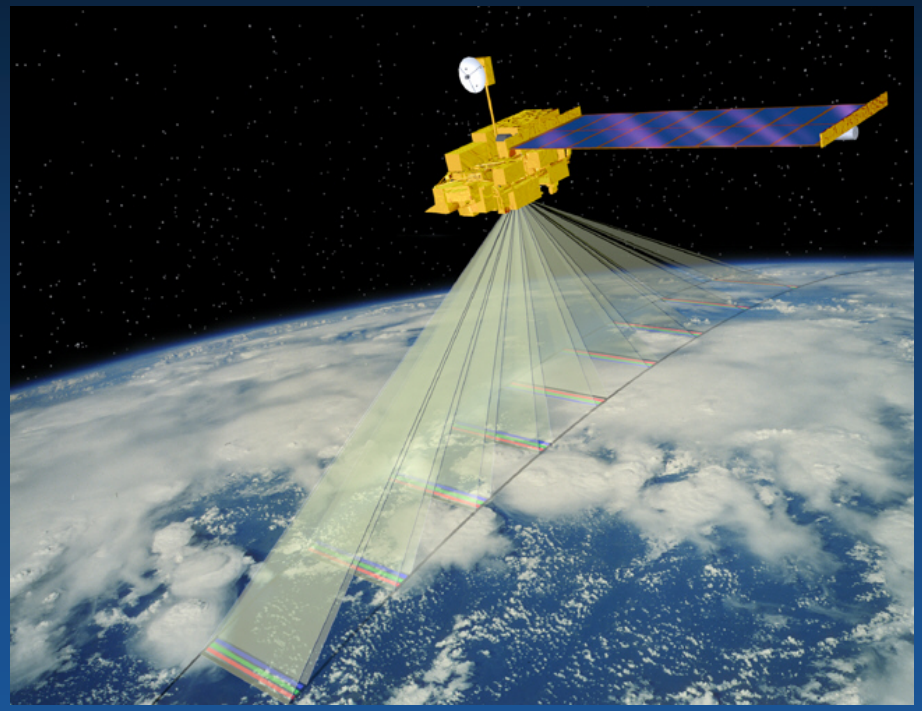
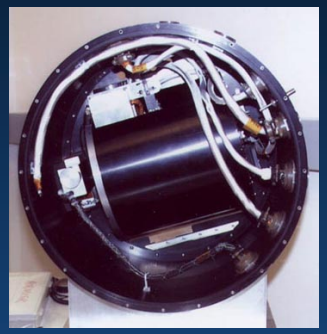
Perspectives on recent advances and future directions in multiangle remote sensing derived from MISR's first six years in Earth orbit

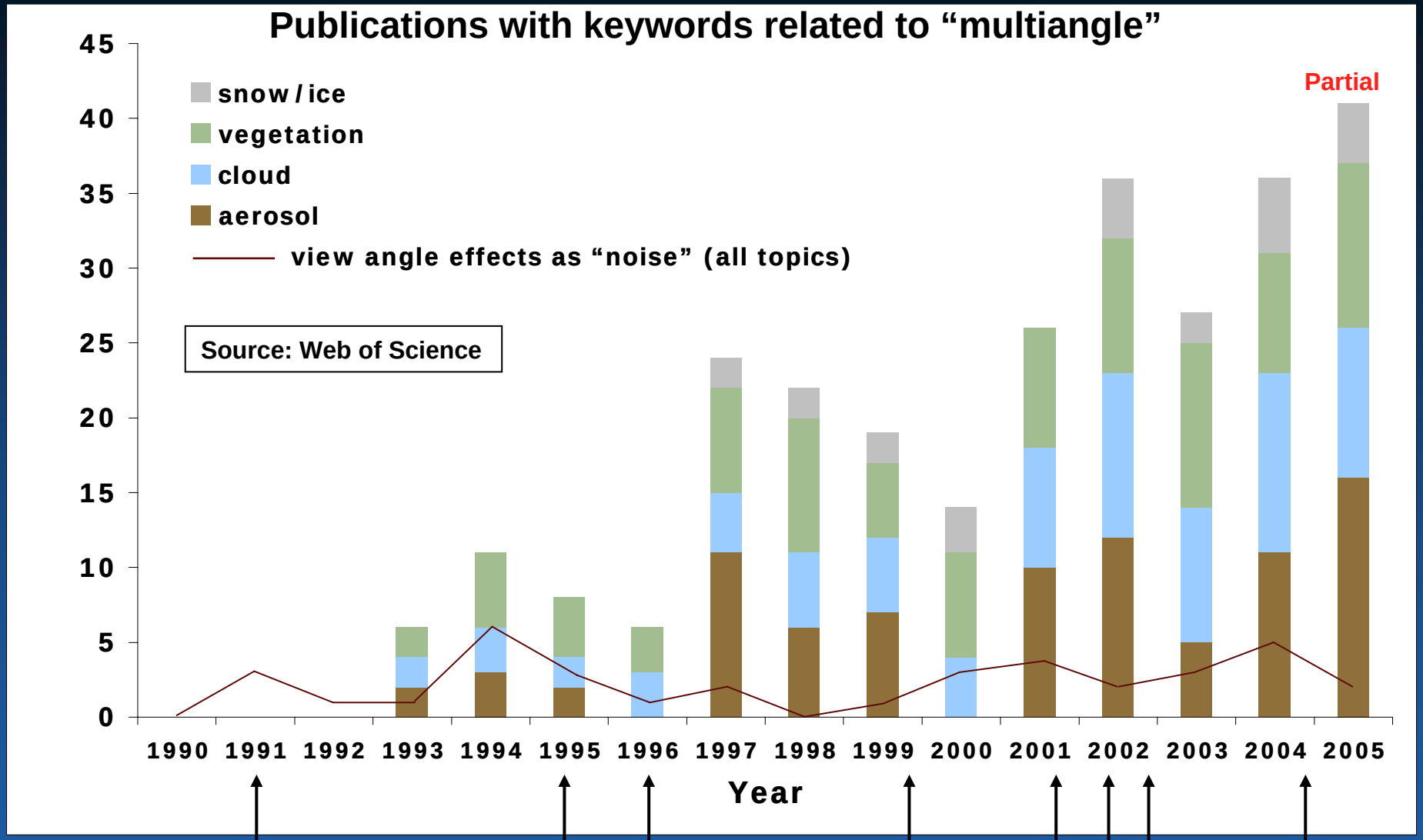




David J. Diner and the MISR Science Team

IWMMM-4, Sydney, Australia
20-24 March 2006

Multiangle/off-nadir sensing: Evolution from noise to signal



Launch

ATSR-1

ATSR-2

POLDER-1

MISR

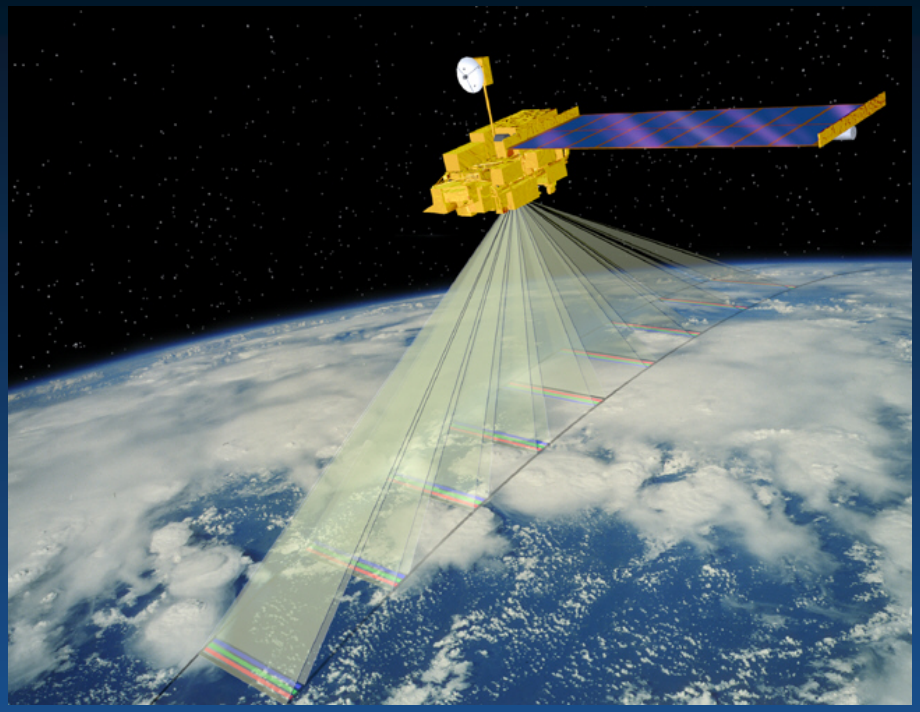
PROBA/ CHRIS

AATSR

POLDER-2

PARASOL

Illustrations of multiangle capabilities: MISR



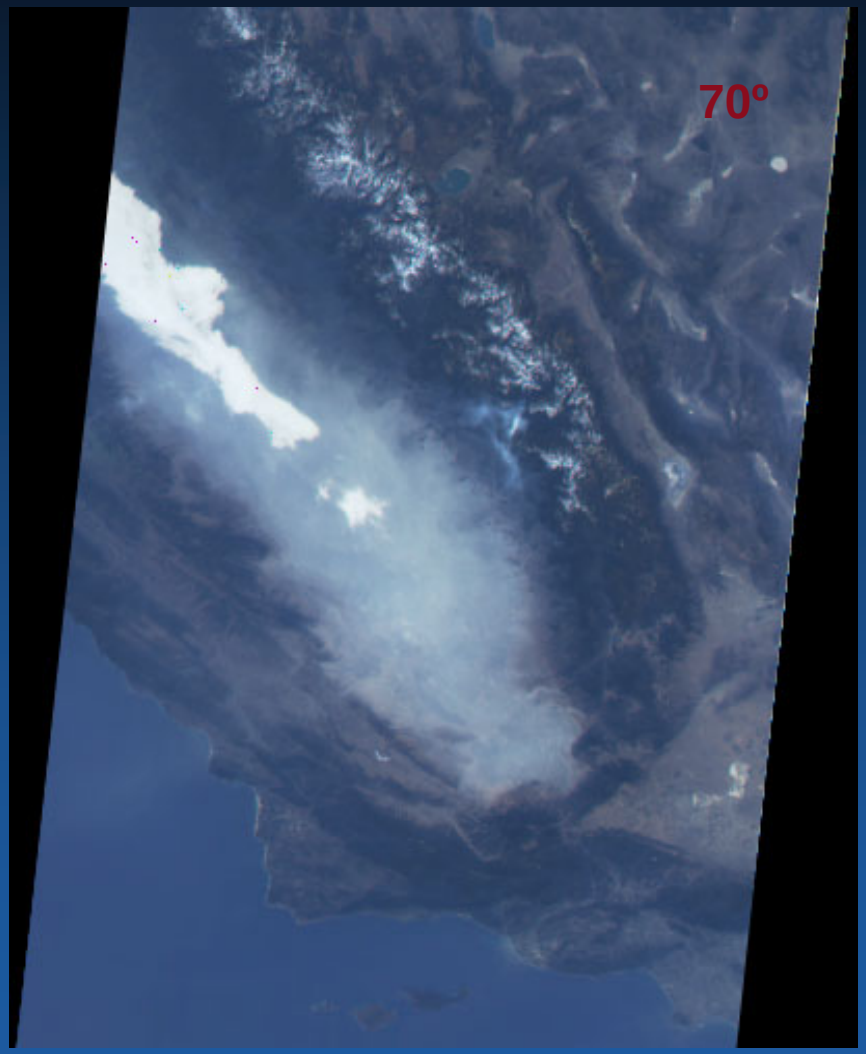
Terra launch
12/18/99

9 view angles at Earth surface:
70.5º forward to 70.5º backward of nadir

Four spectral bands at each angle:
446 nm ± 21 nm 558 nm ± 15 nm
672 nm ± 11 nm 866 nm ± 20 nm

Spatial resolution:
275 m - 1.1 km

Complete zonal coverage
9 days at equator 2 days at poles

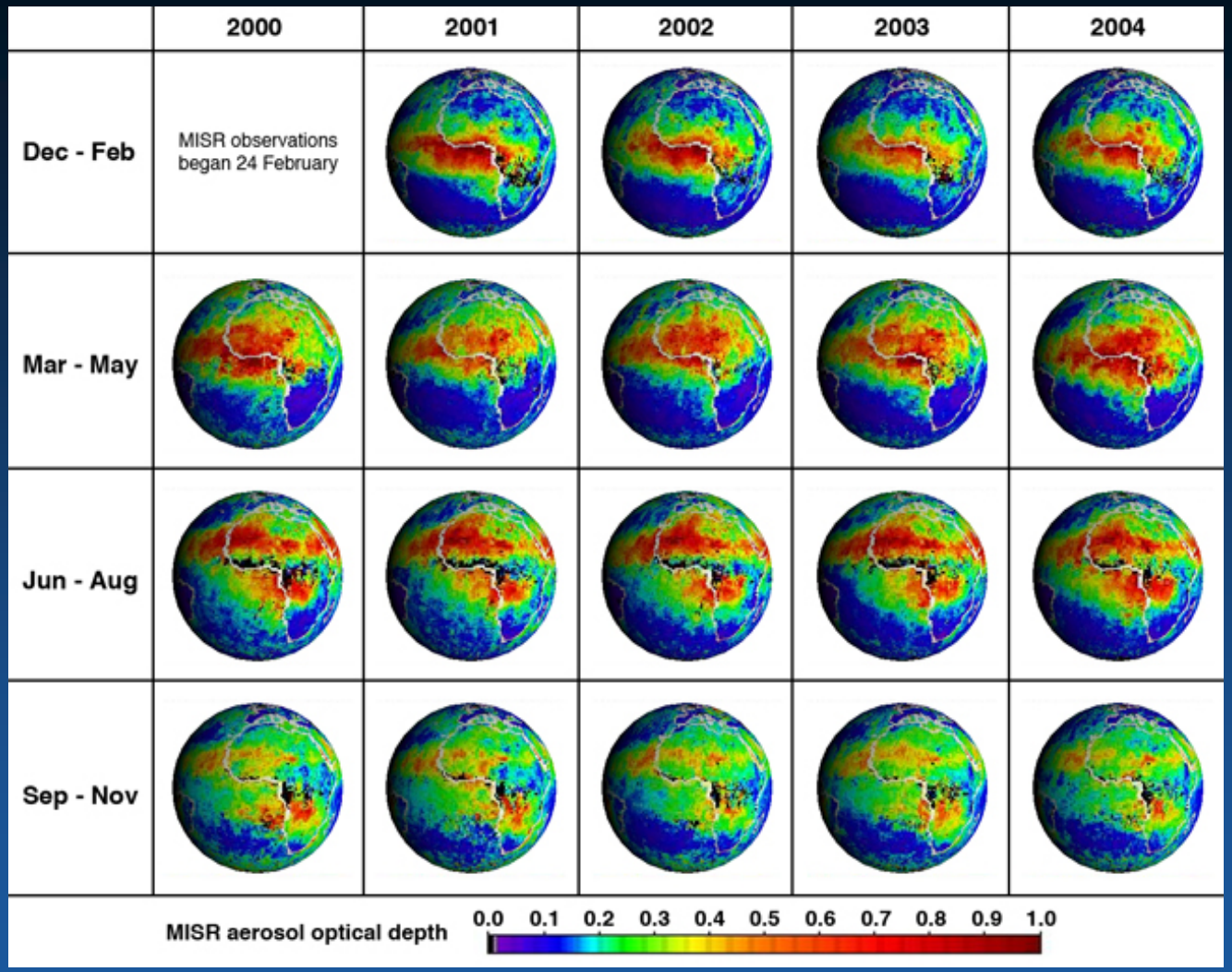


State-of-the-art multiangle, multispectral imagery

Absolute radiometric uncertainty 4%
Relative radiometric uncertainty 2%
Temporal stability 1%
Geolocation uncertainty 50 m
Camera-to-camera registration < 275 m

Credit: Carol Bruegge, Nadine Chrien, Veljko Jovanovic, Wedad Abdou, Ralph Kahn, Jim Conel, Mark Helmlinger, Roger Davies, John Martonchik

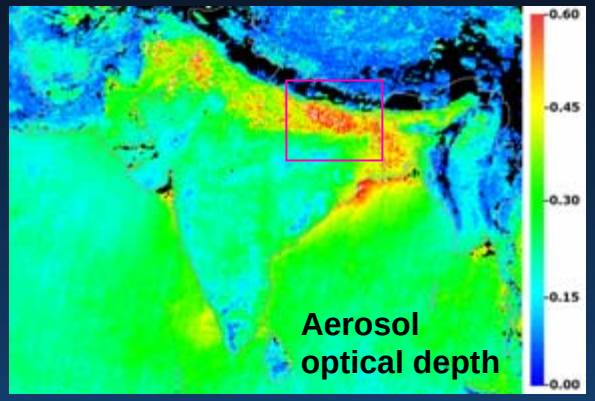
Multiangle aerosol retrieval over land and water

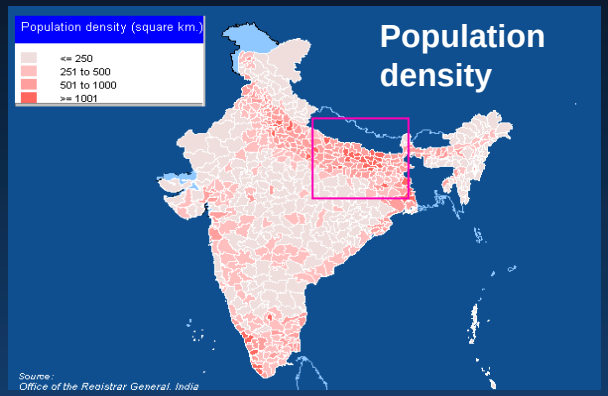


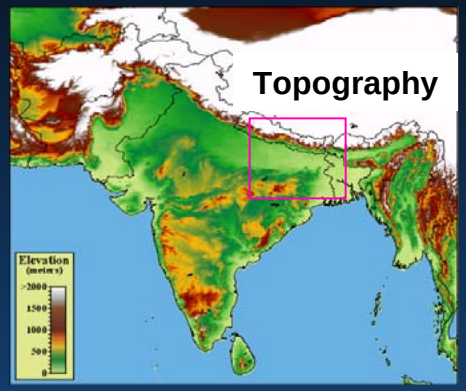
Separation of surface and atmospheric signals based on **angular signature** works over many surface types, including bright deserts.

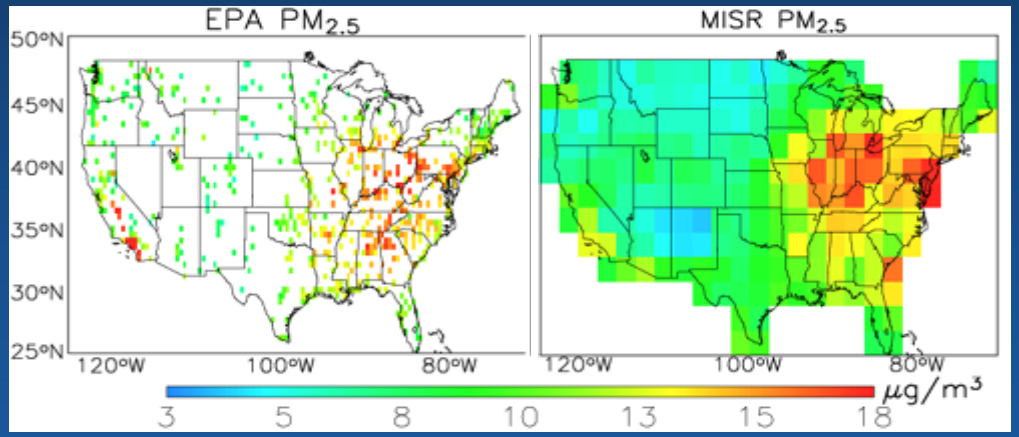
MISR seasonal maps of Saharan dust sources

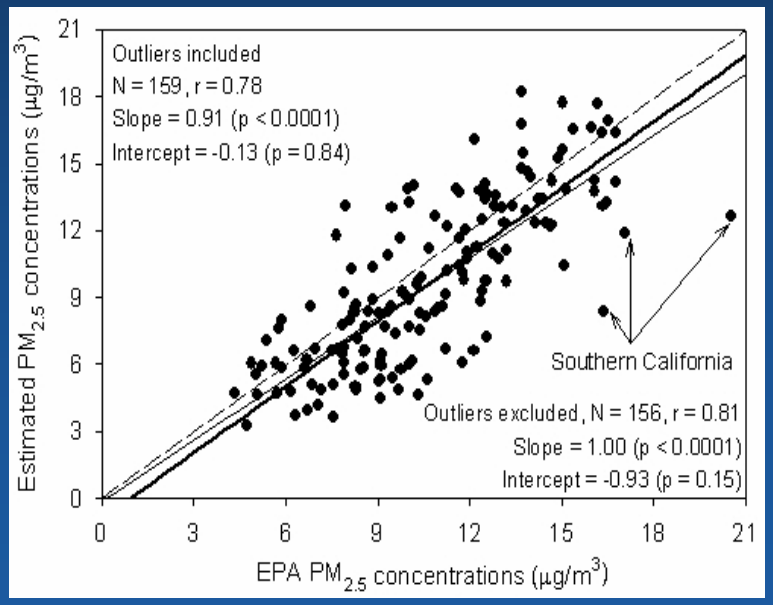
Observing concentrations of particulate air pollution





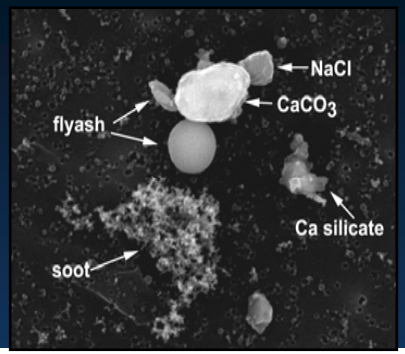


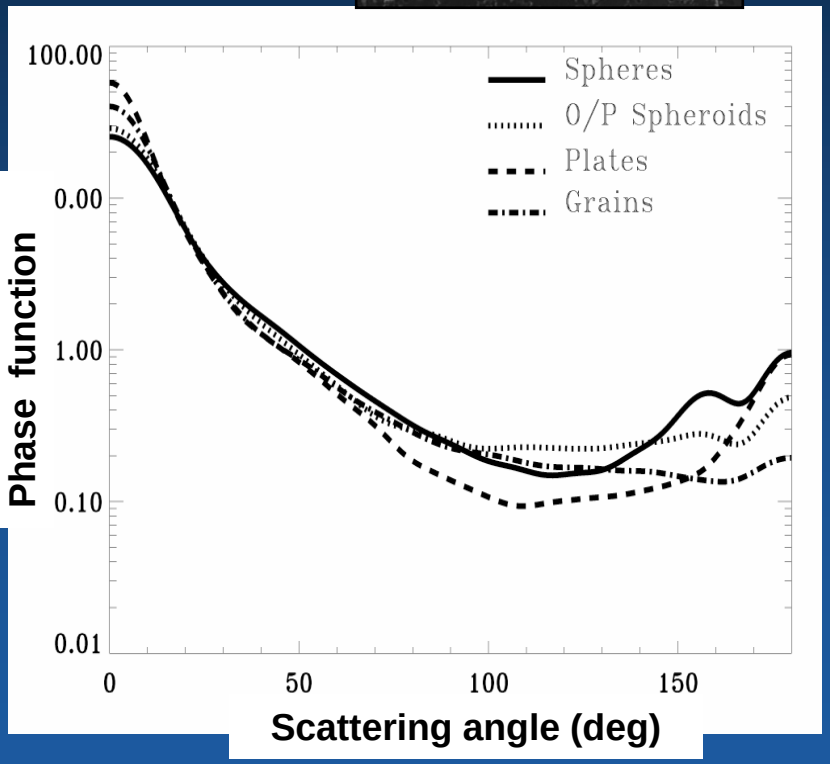


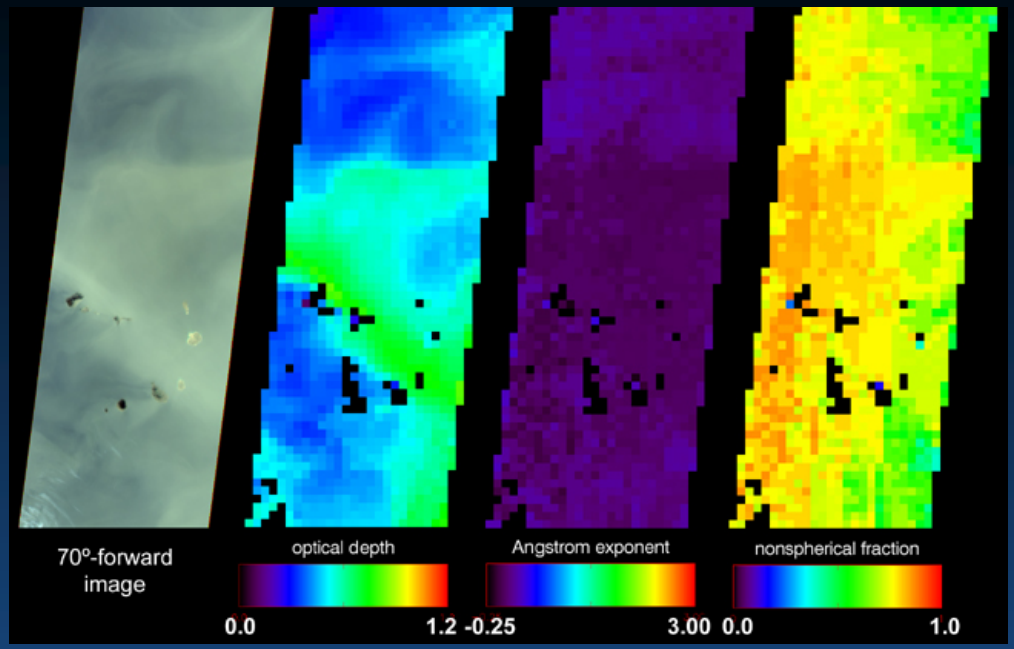


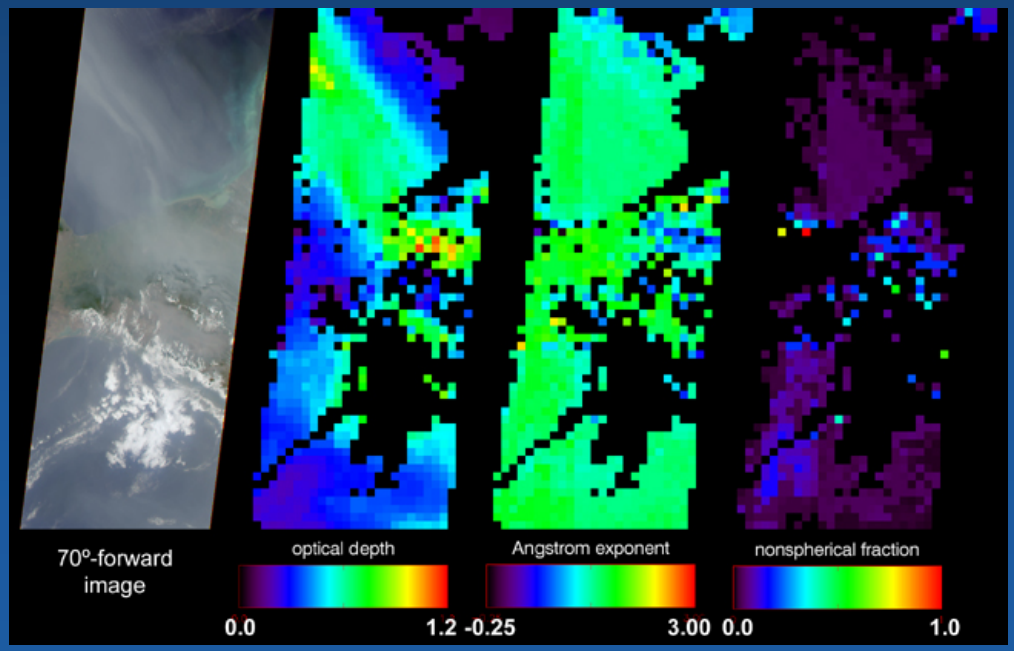
Credit: Larry Di Girolamo, Yang Liu

Distinguishing aerosol particle types



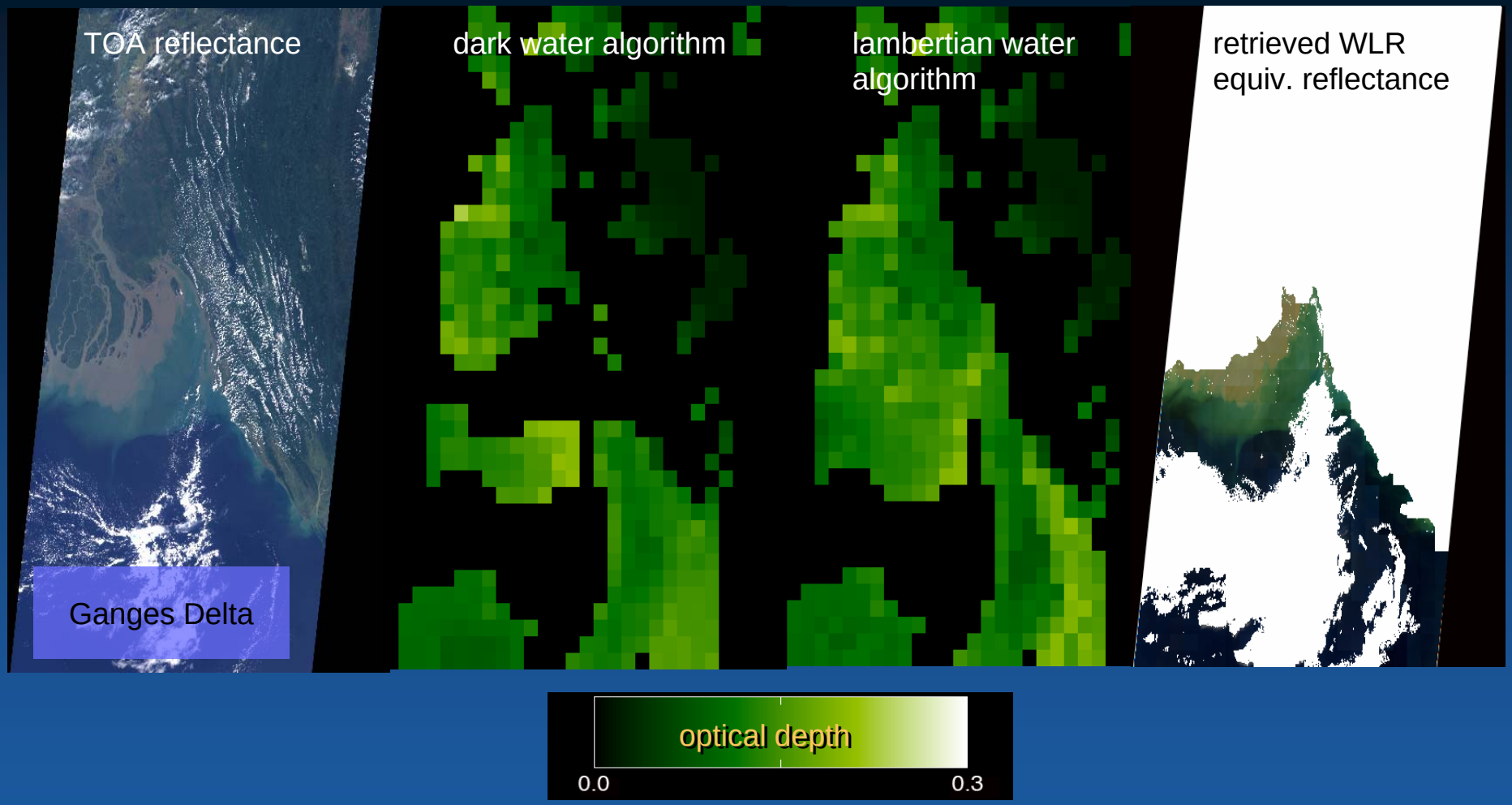






Credit: Olga Kalashnikova, Ralph Kahn

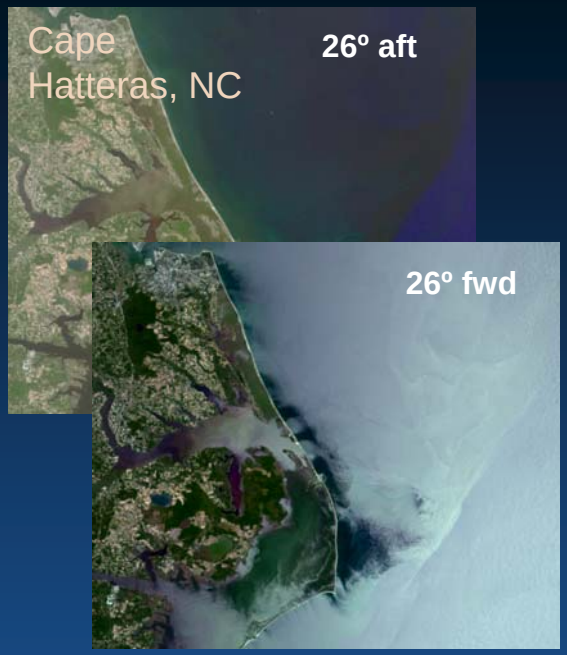
Multiangle aerosol/water-leaving radiance retrieval

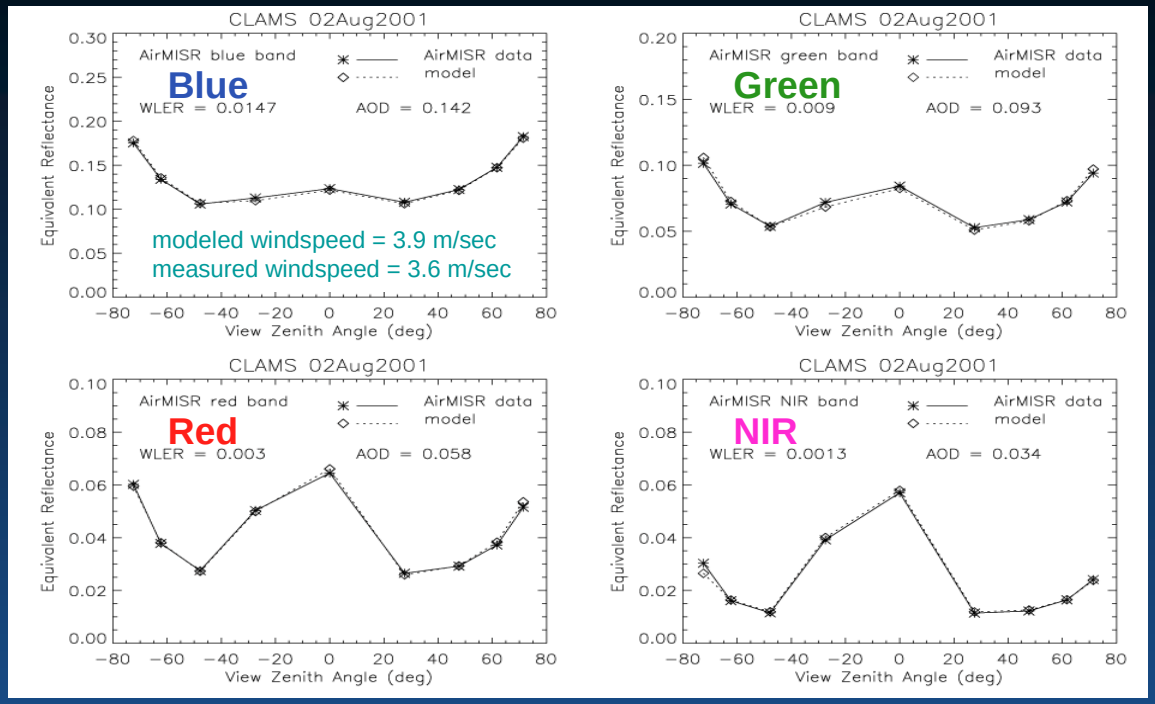


Multiangle views allow characterizing water-leaving radiance (WLR) by its **angular shape** instead of limiting to cases where WLR = 0.

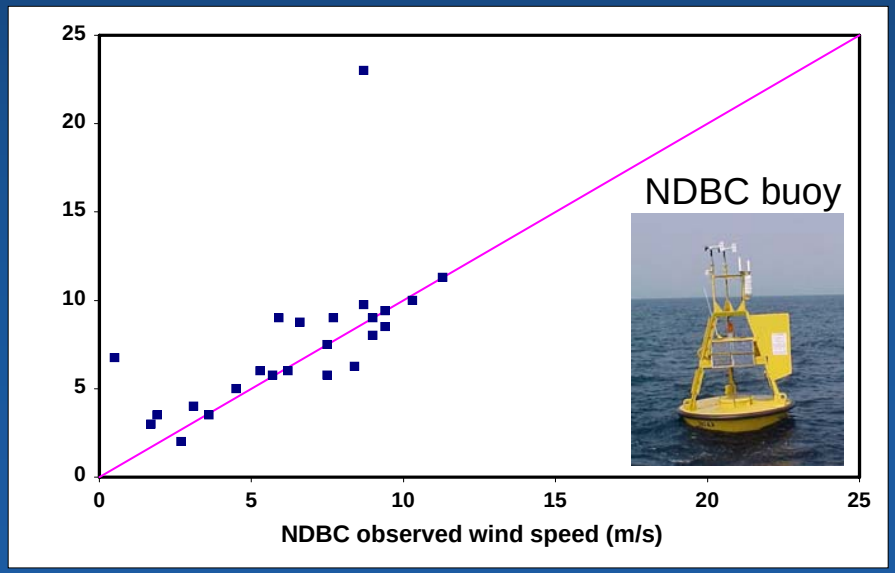
Credit: John Martonchik

Sunglint as a source of information on surface wind speed





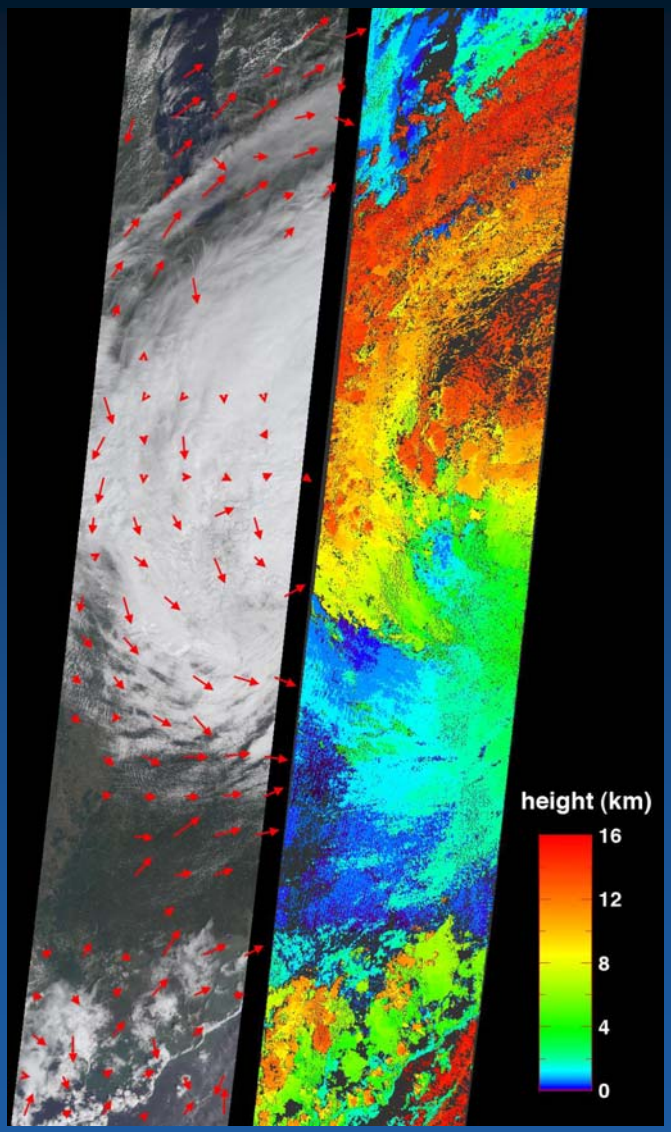
AirMISR data over the Chesapeake Lighthouse 8/2/2001



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

Credit: Enrique Gonzales, David Fox

New climate data records: geometric cloud heights and height-resolved cloud motion winds



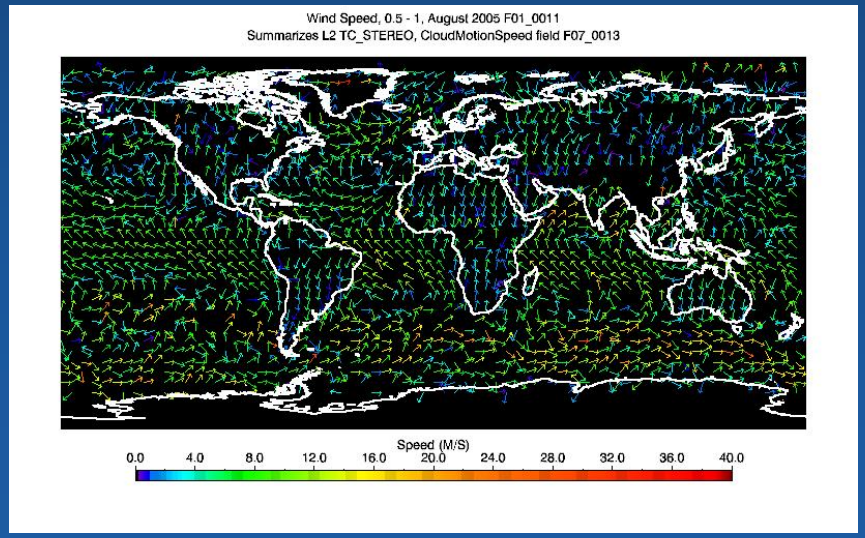
Hurricane Katrina 8/30/05

MISR stereoscopic cloud heights

- derived from purely geometric approach
- completely automated, globally
- independent of radiometric calibration, atmospheric temperature profiles, and cloud emissivity
- instantaneous accuracies of 500 m - 1 km, validated against ground-based radar/lidar

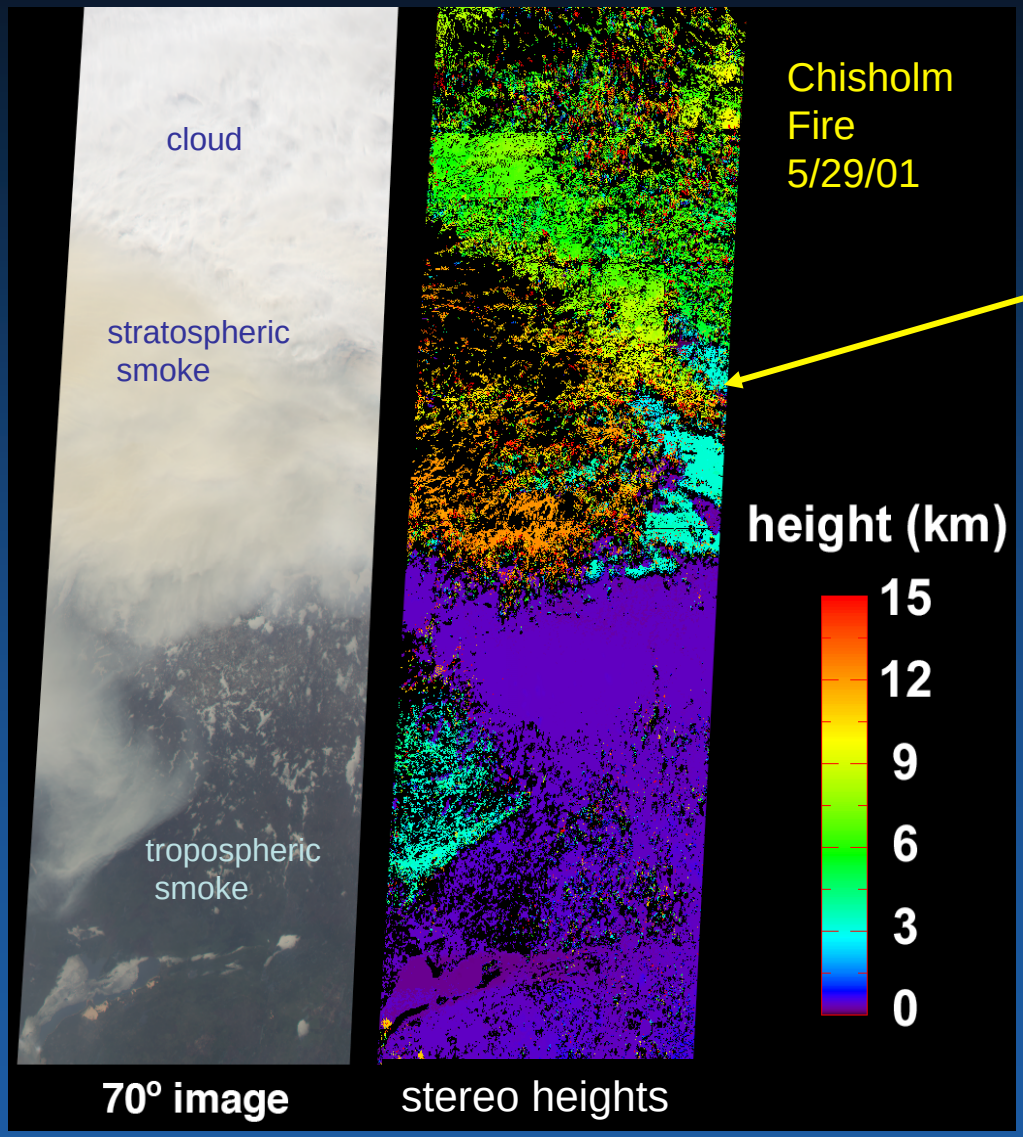
MISR cloud motion wind vectors

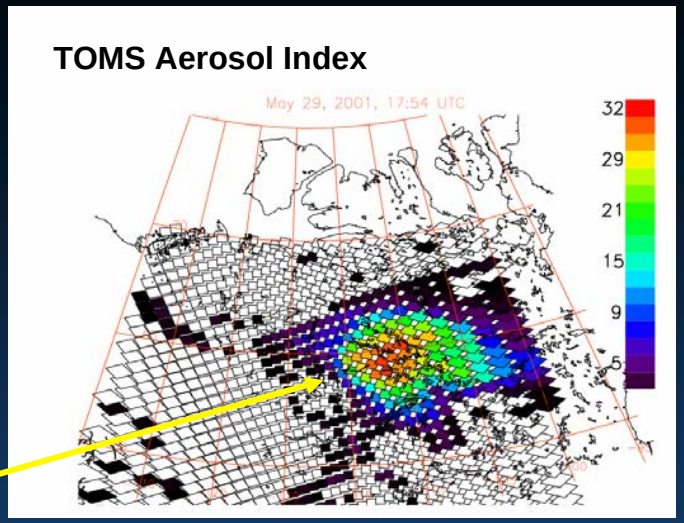
- stratified by height; 300 m height resolution
- estimated uncertainties based on fore-aft consistency checks: 1-3 m/s

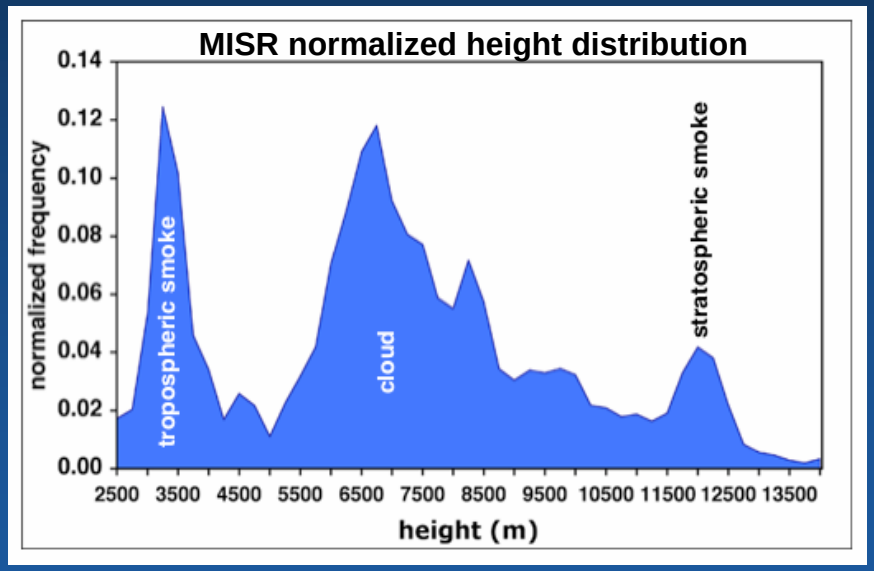


Monthly mean winds August 2005
0.5-1 km altitude

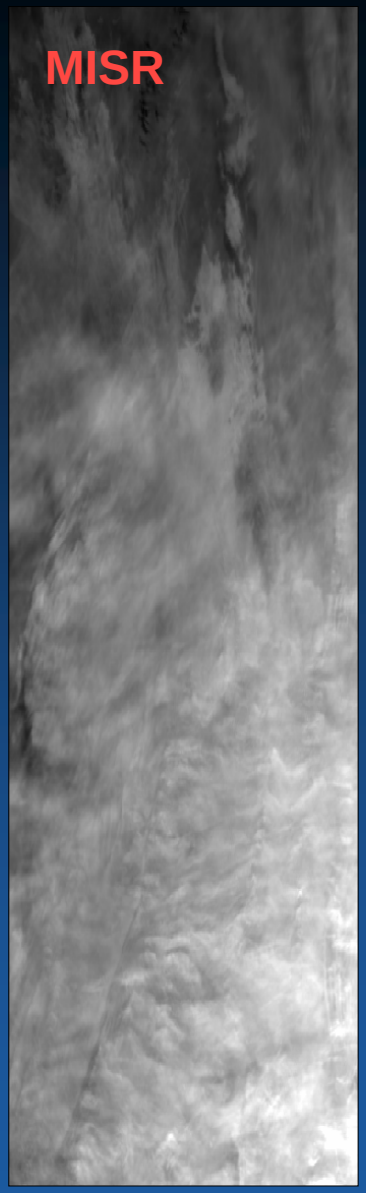
Aerosol transport

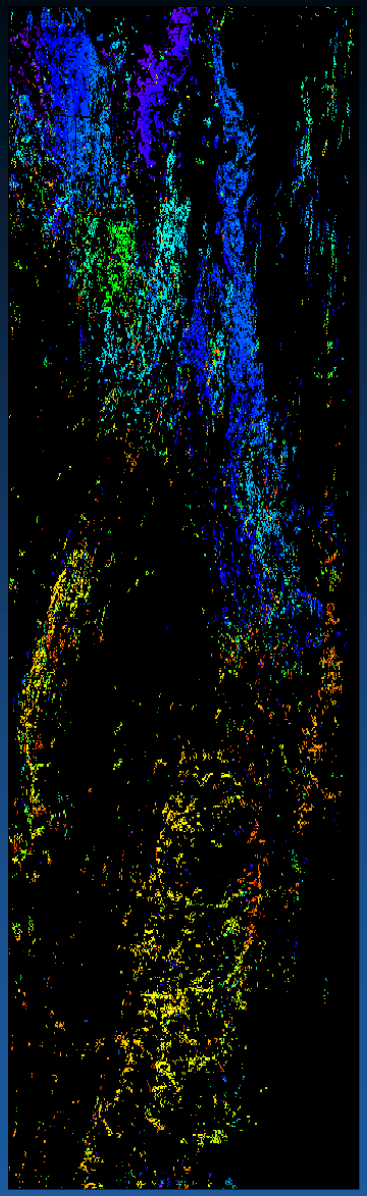


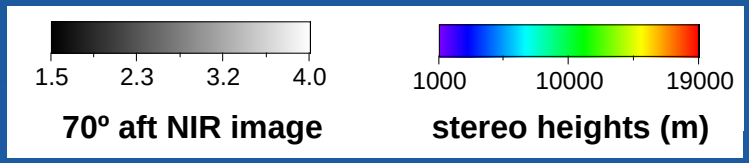


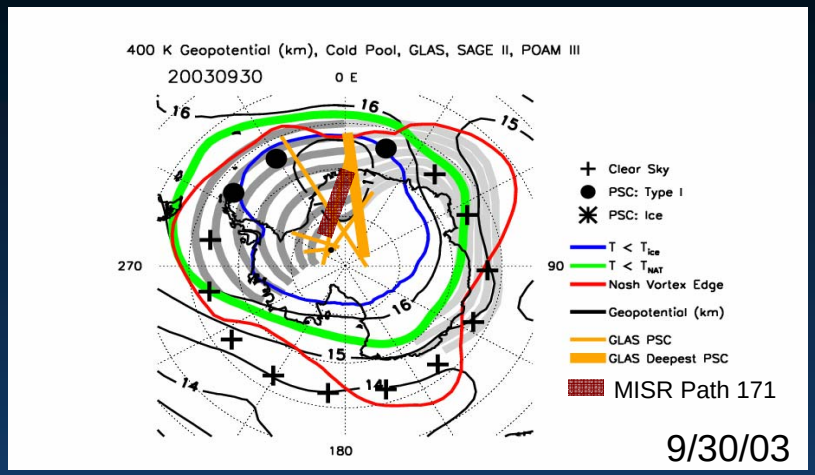


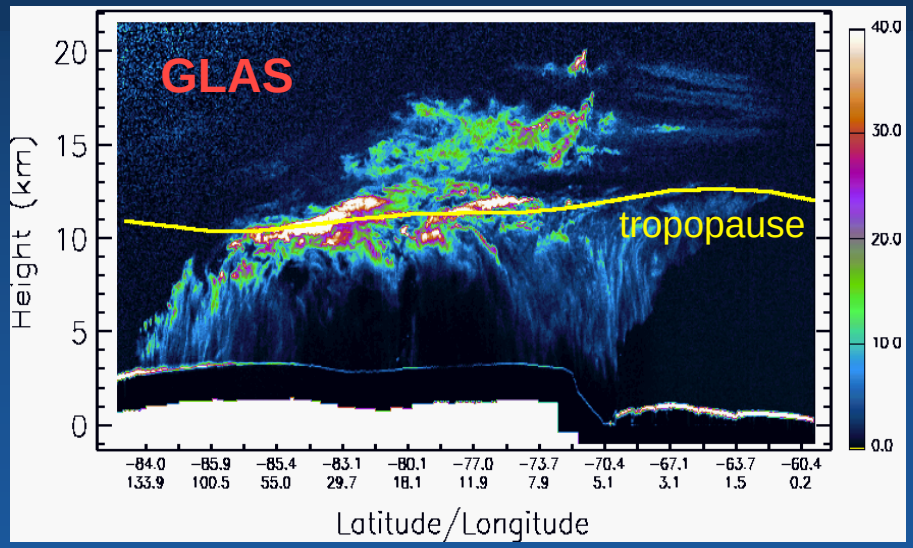
Type II Polar Stratospheric Clouds







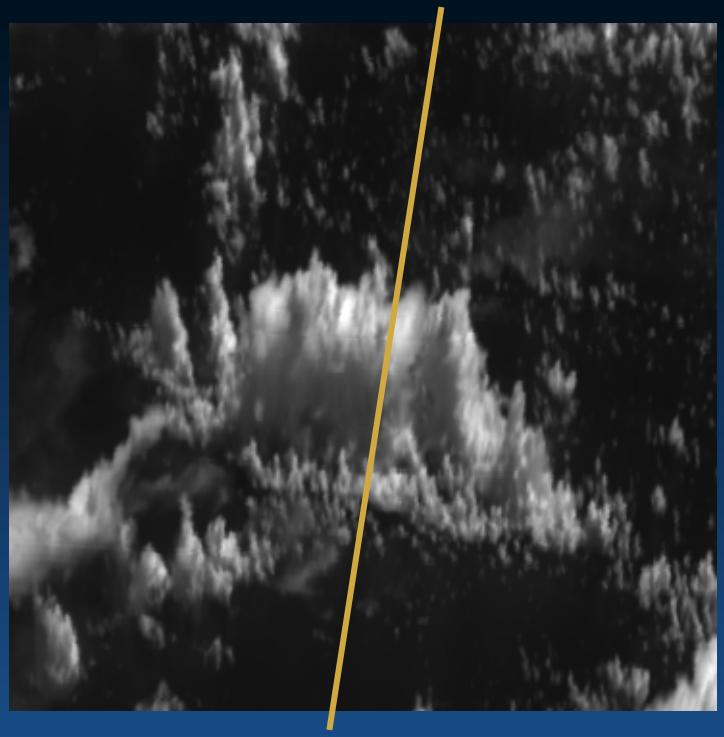


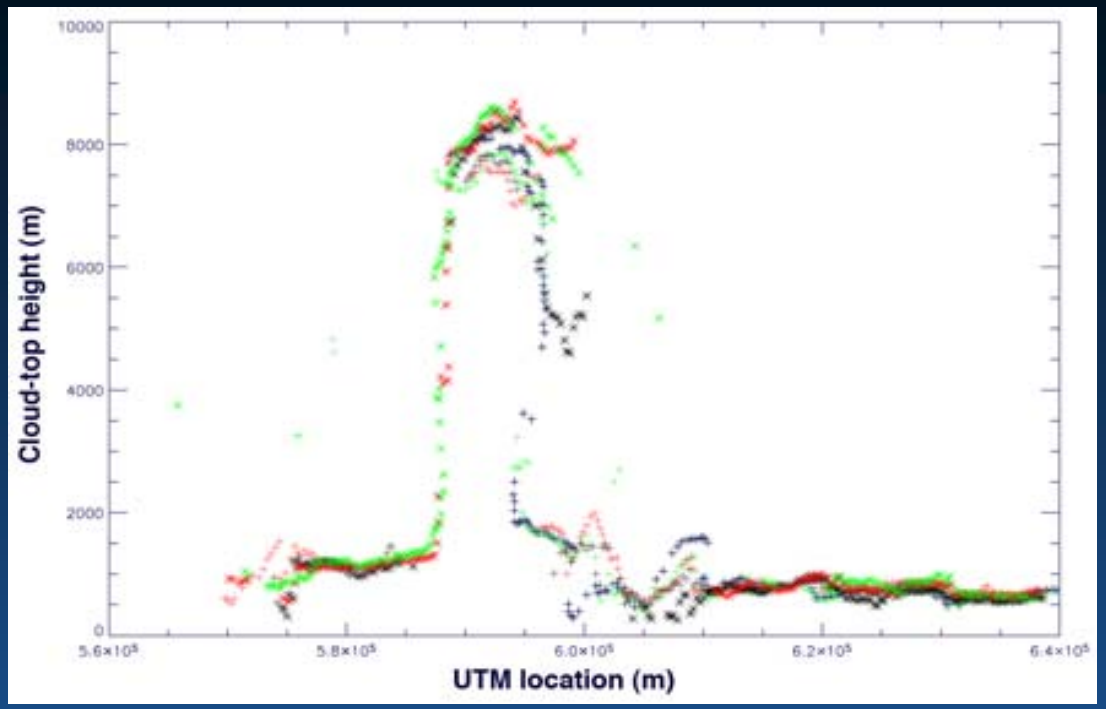


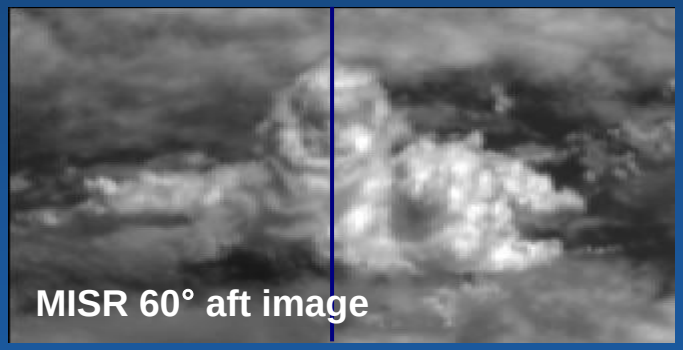
Mode and standard deviation of PSC height distributions (14 - 20 km) show **MISR-GLAS agreement to within 1 km.**

Credit: Larry Di Girolamo, Michael Fromm, Steve Palm

3-D reconstruction of convective clouds







	nadir only	nadir+60°
cloud vertical extent	no information	10.5±0.8 km
extinction coefficient	no information	8–22 km^{-1} (higher at base)
cloud optical depth	> 60	150±30

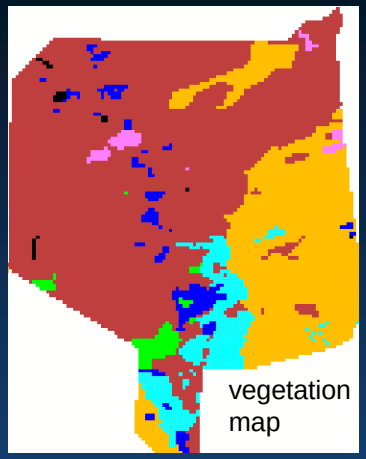
Oblique views of cloud sides make possible observation and vertical integration of cloud column properties in a way that is impossible from nadir views.

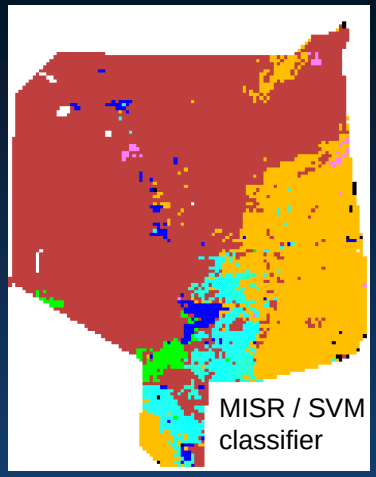
Credit: Roger Davies, Gabriela Seiz, Celine Cornet

Community type classification in arid lands

Jornada
Experimental Range

- Upland Grasses
- Playa Grasses
- Tarbush
- Mesquite
- Creosotebush
- Other Shrubs
- Not mapped

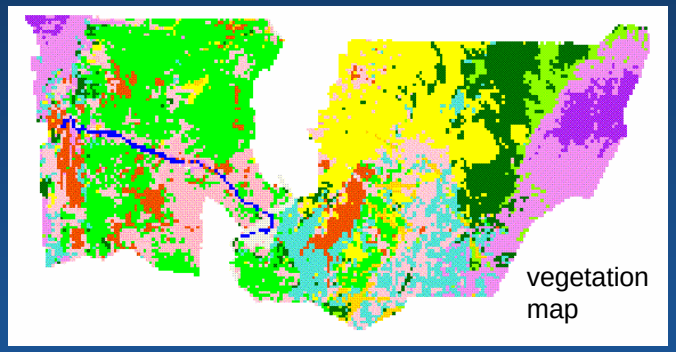


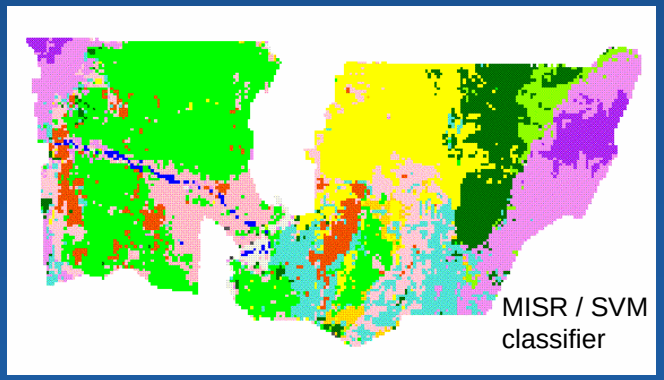


Overall classification accuracy increased from 45% (nadir only) to 77% (multiangle), using BRF models and a support vector machine (SVM) algorithm. For 5 of 19 classes, the improvement was 50 percentage points.

Sevilleta National Wildlife Refuge

- Not mapped
- Water or Wet Ground
- Barren or Sparsely Vegetated
- Great Basin Grasslands
- Transition Chihuahuan and Great Basin Grasslands
- Chihuahuan Desert Grasslands
- Transition Chihuahuan and Plains Grasslands
- Plains Grasslands
- Chihuahuan or Great Basin Lowland/Swale Grasslands
- Chihuahuan Desert Creosotebush Shrublands
- Great Basin Shrublands--Fourwing Saltbush/Br. Dalea
- Rocky Mountain Juniper Savanna
- Rocky Mountain Pinyon Woodlands
- Rio Grande Riparian Woodlands

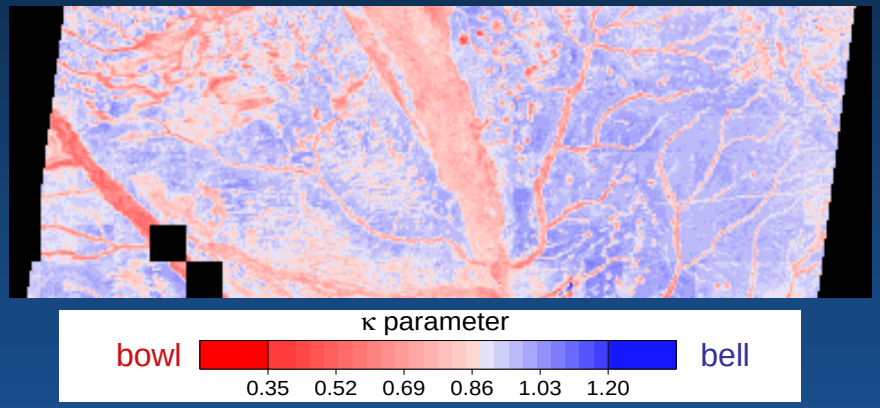


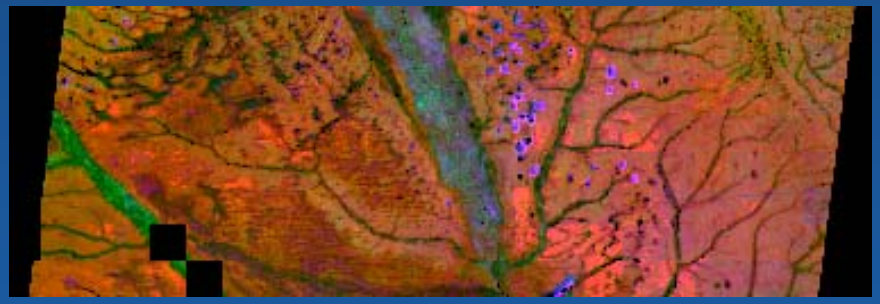


Credit: Mark Chopping

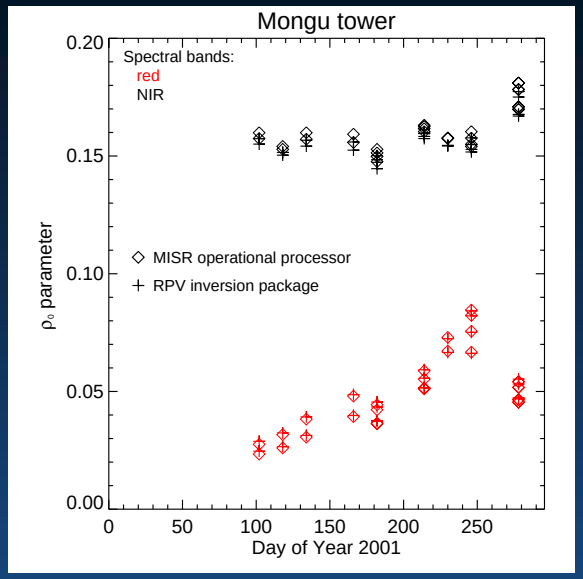
Semi-empirical BRF (RPV) analysis of canopy structure

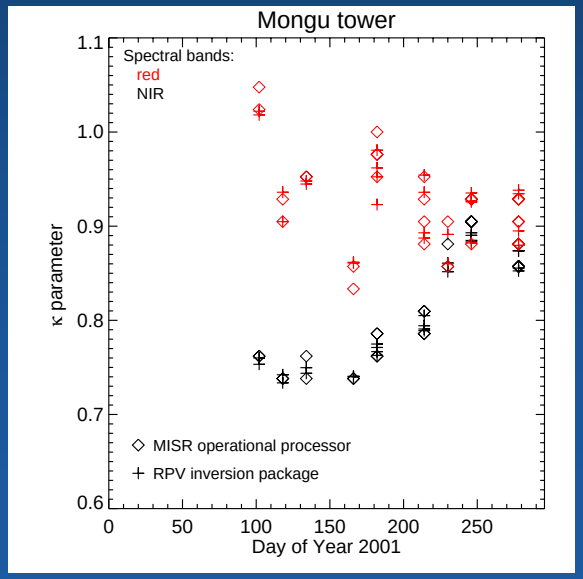
Spectral RGB composite of reflectance (ρ_0) parameter





Structural / spectral composite
Red: red band k-parameter (bowl -> bell)
Green: FPAR
Blue: NIR Θ parameter (back -> fwd scatter)



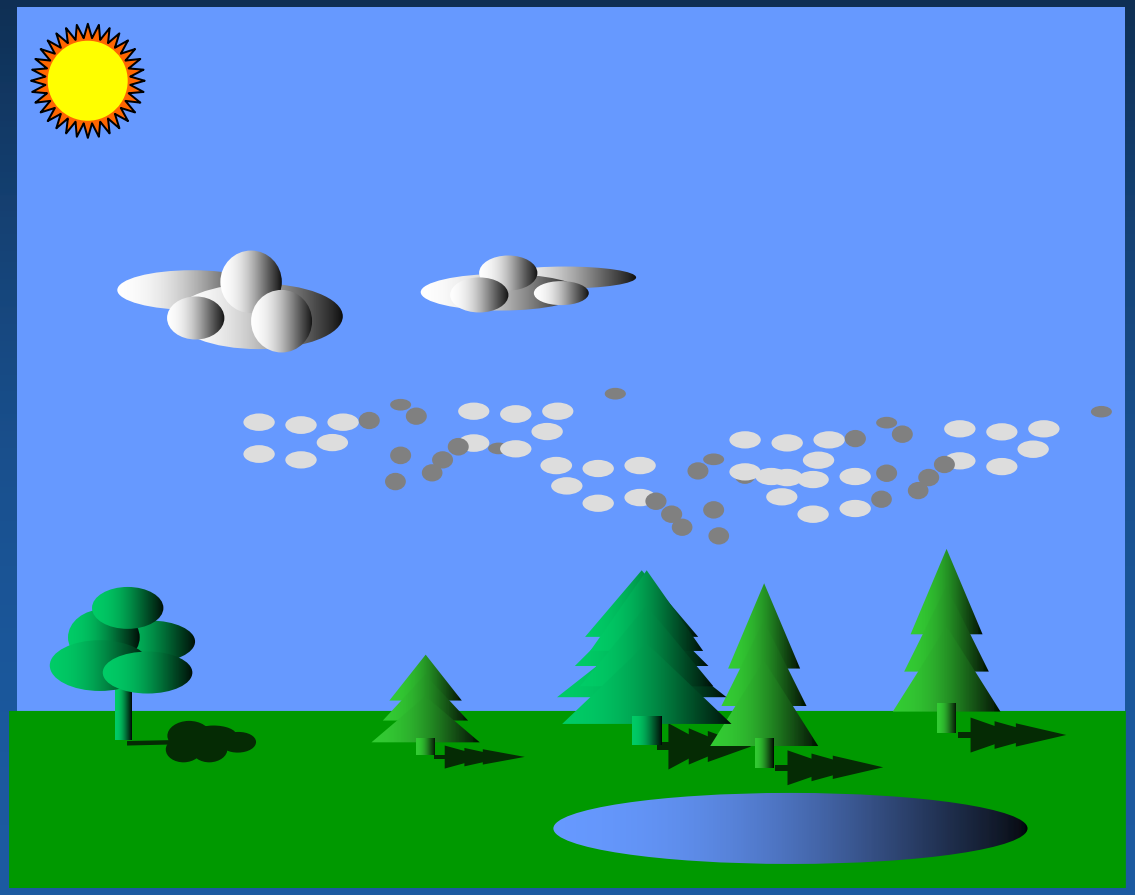


Work is now beginning on analyzing joint time series of parameters representing canopy greenness and clumping

Credit:
Bernard Pinty

Multi-angle imaging provides a rich perspective on our environment

--inferring structure of three-dimensional, spatially complex media
--partitioning solar energy among different vertical layers
--capturing scene dynamics (e.g., height-resolved cloud motion)
↗ No longer solely in the domain of active sensors (radar, lidar)



sunlight

clouds

aerosols

vegetation canopies

ground and water

Looking to the future

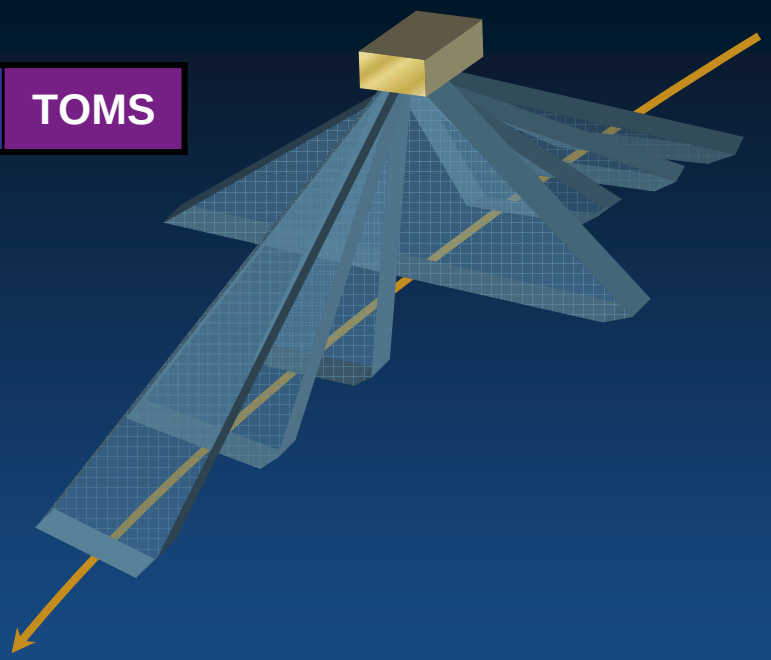
passive sensor heritage

MISR	MODIS	AATSR	APS	POLDER	TOMS

+ **Technology developments**

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

Multiangle SpectroPolarimetric Imager



Parameter	MSPI
View angle range	Nadir to 70º, fore and aft
Spectral range	Intensity: 380 - 2130 nm Polarization: 650, 1610 nm (0.5% uncertainty in DOLP)
Spatial resolution	Horizontal: 275 m - 1.1 km Vertical: 200 m for plumes
Global coverage time (swath width)	Multiangle: 4 days (700 km) “Nadir”: 1 day (2650 km)

Conclusions

Multiangle satellite data are an extremely rich source of information on atmospheric structure at both microphysical and macroscopic scales

Multiangle remote sensing provides a paradigm shift:

- use of land and water angular reflectance shapes—not brightness—to decouple aerosol/surface radiances (e.g., over bright deserts, Case 2 waters)
- sunglint utilization as opposed to avoidance
- geometrically-derived climate data records
- cloud/aerosol plume heights and 3-D cloud reconstruction from passive optical measurements

Looking to the future: opportunities and challenges

- advanced multiangle sensors—UV-SWIR spectral coverage, imaging polarimetry
- efficient multidimensional aerosol and 3-D cloud retrieval algorithms to facilitate operational application