Seeing the Earth in 4-D

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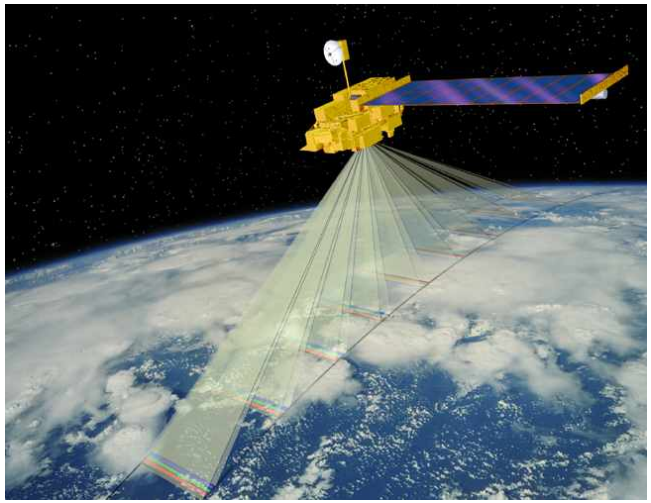
MISR on Terra spacecraft



MISR
Multi-angle Imaging SpectroRadiometer

1999 launch

Nine view angles: 70º forward to 70º backward

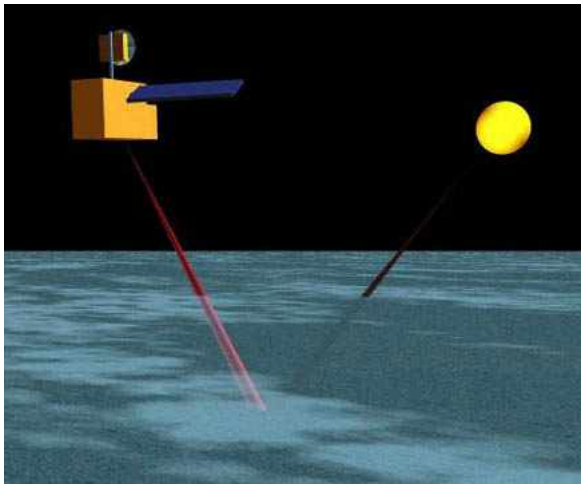
Four spectral bands: 446, 558, 672, 866 nm

275 m sampling

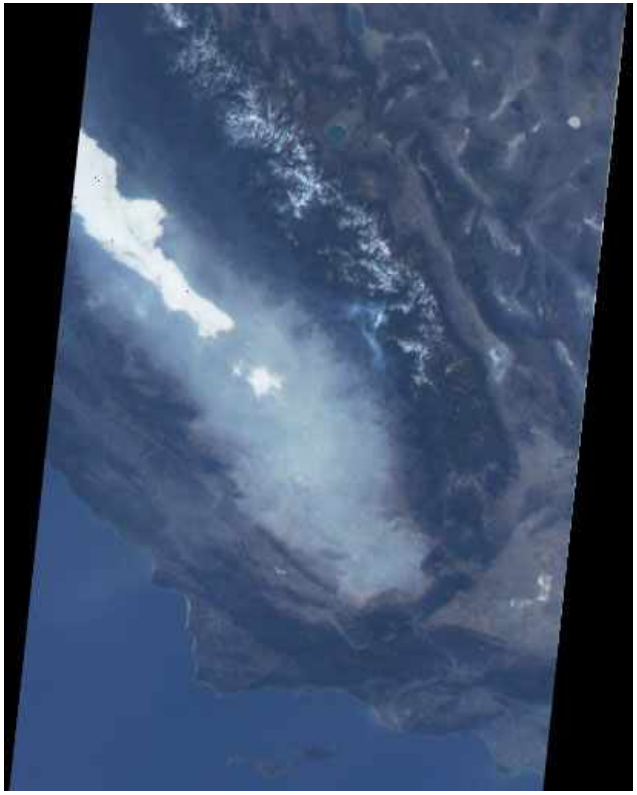
400-km swath

Multiangle observations on microscales (0.1 μm – 100 μm)

- particle size and shape



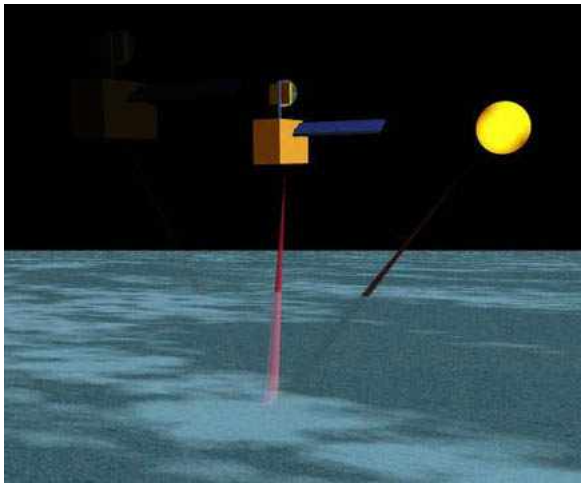
"Radiometric" approach



70º view

Multiangle observations on microscales (0.1 μm – 100 μm)

- particle size and shape



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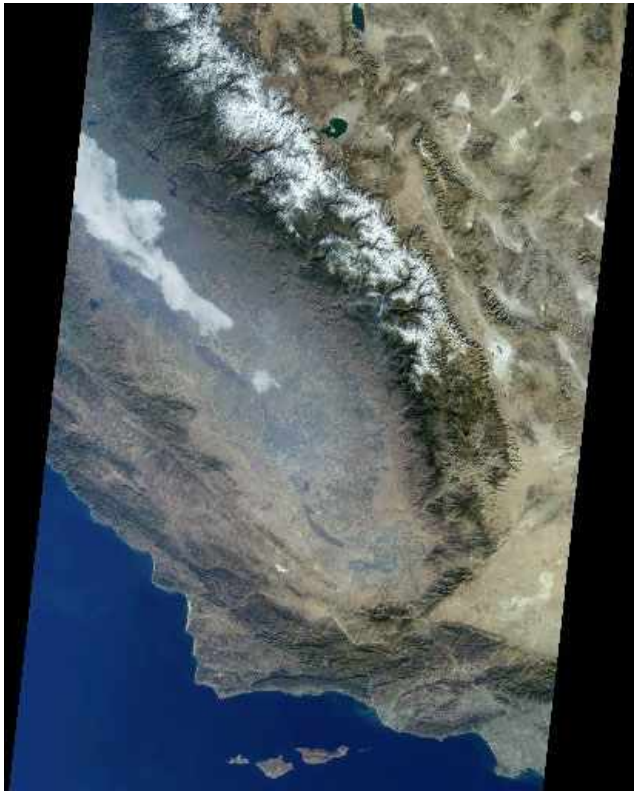
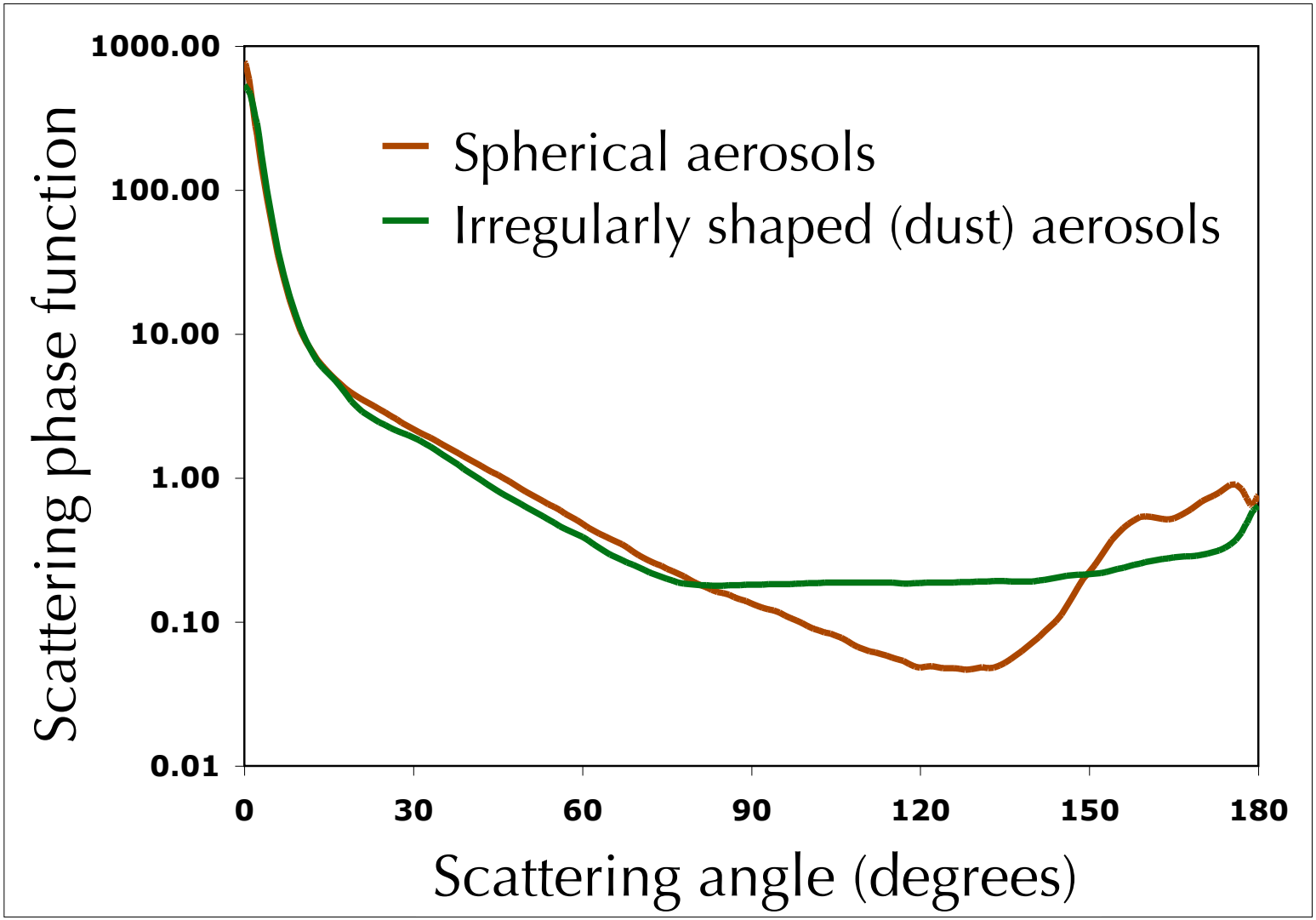


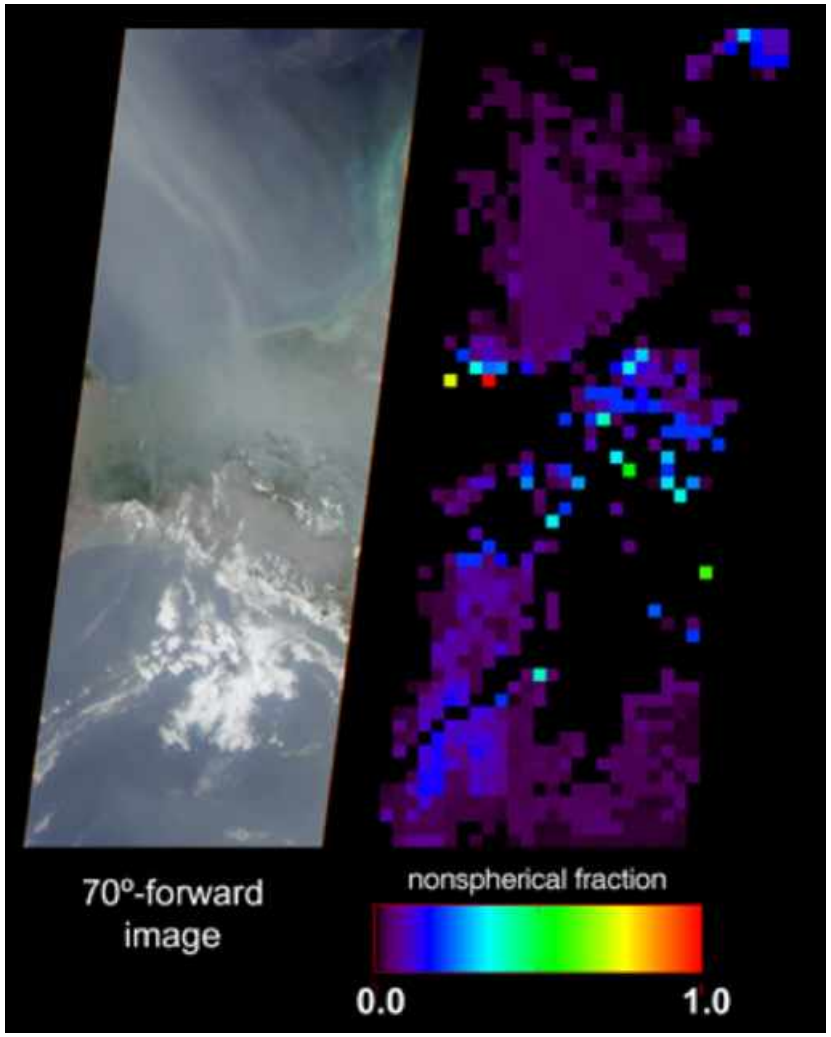
nadir view

Differentiating particle type by angular scattering

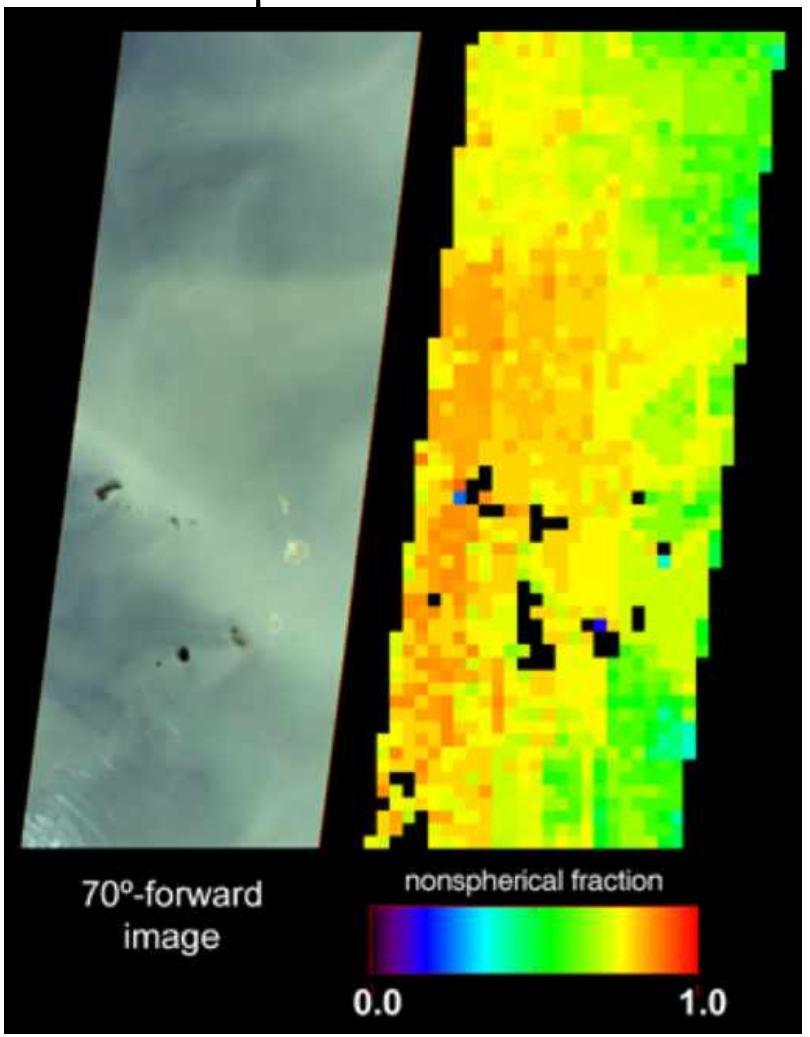


MISR sensitivity to aerosol particle shape

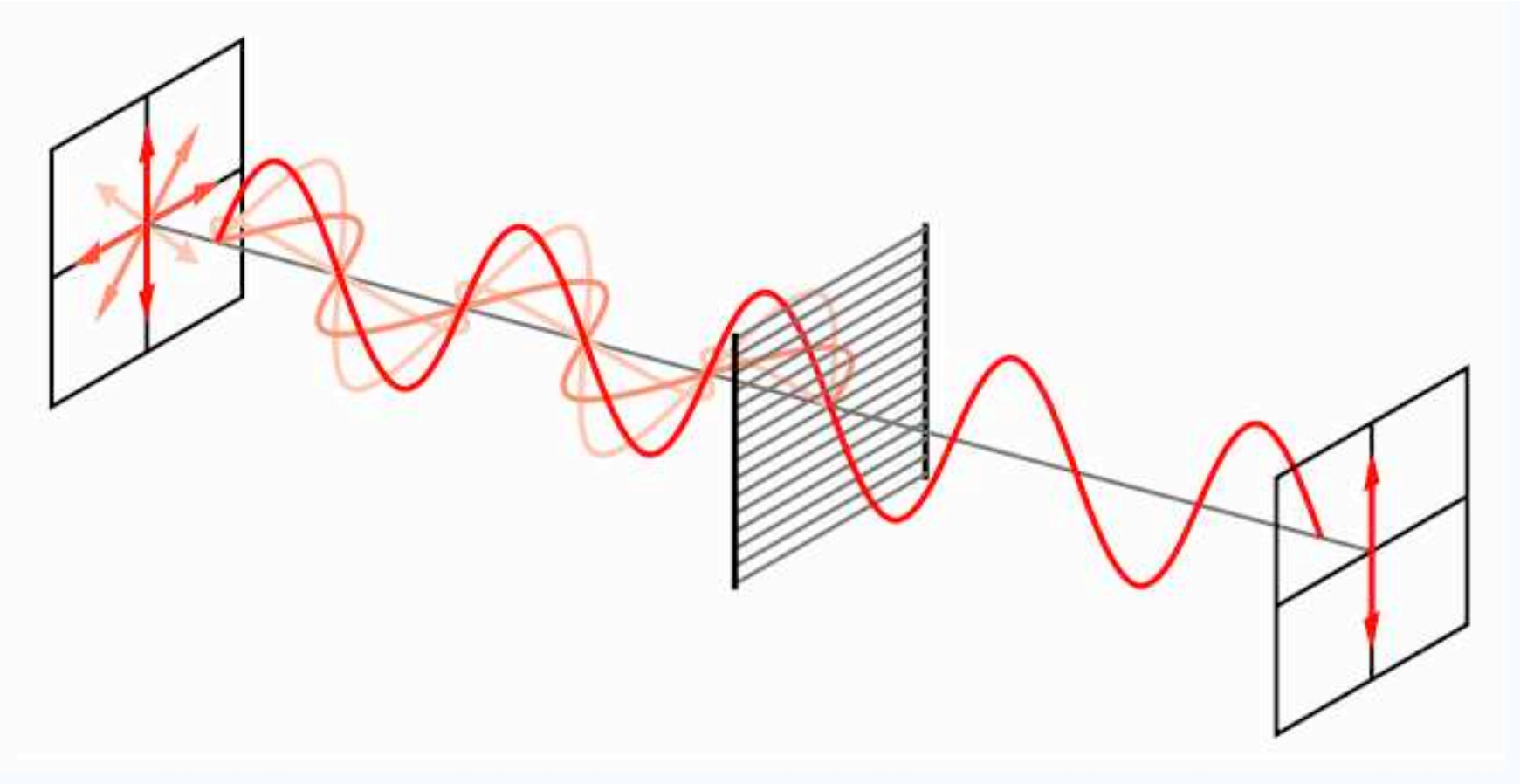
Smoke over the Yucatan Peninsula



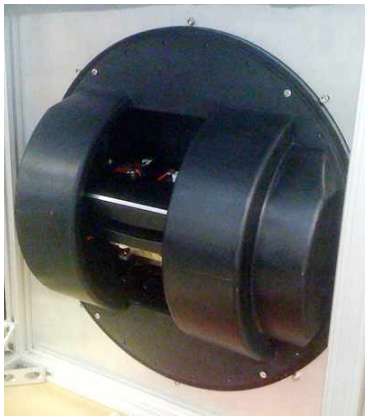
Airborne Saharan dust over the Cape Verde Islands



Adding polarization



AirMSPI on ER-2 aircraft



MSPI
Multiangle SpectroPolarimetric Imager

Operational since 2010

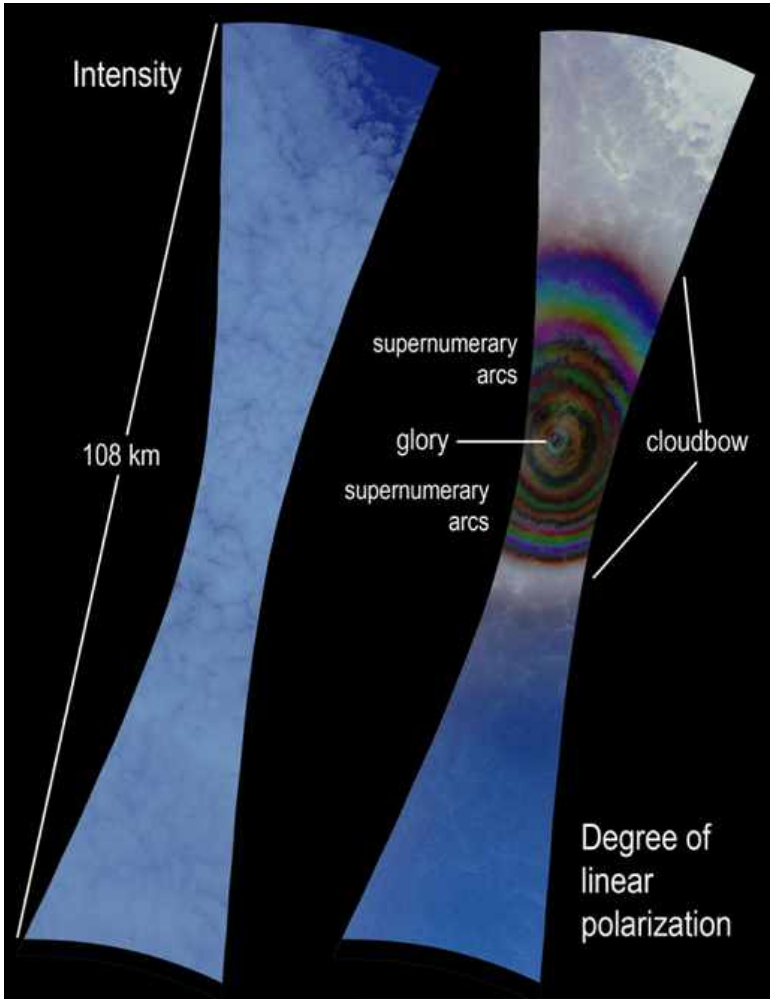
Selectable view angles: 67° forward to 67° backward

Eight spectral bands 355, 380, 445, 470*, 555, 660*, 865*, 935 nm *polarimetric (photoelastic modulators)

10 m sampling

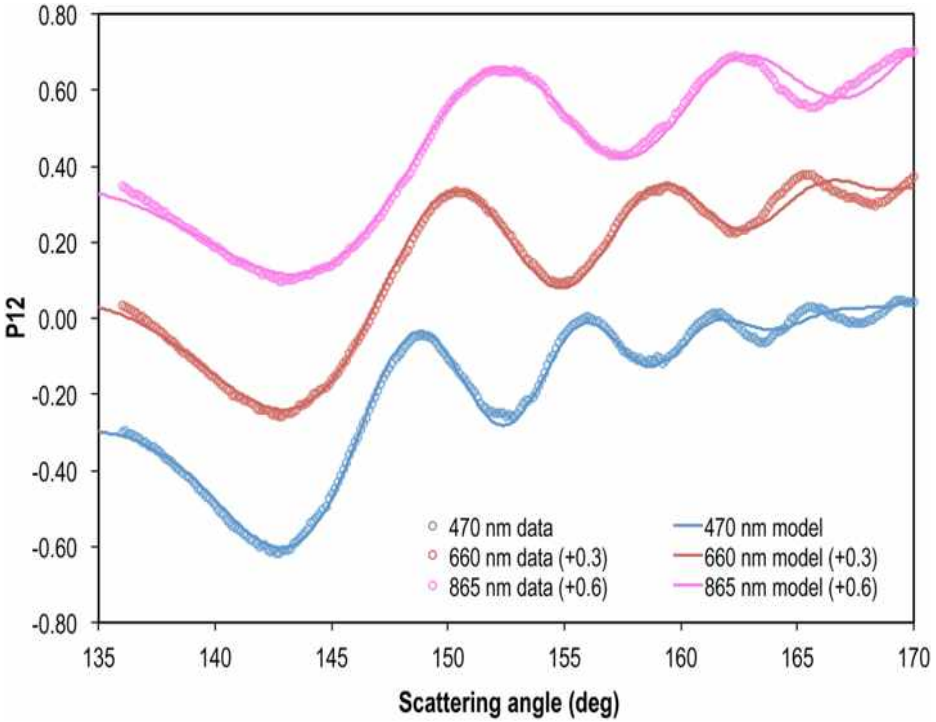
11-km swath

Polarimetry and cloud microphysics



Stratocumulus clouds off the California coast

The glory, supernumerary bows, and cloudbow tell us the particles are spherical.

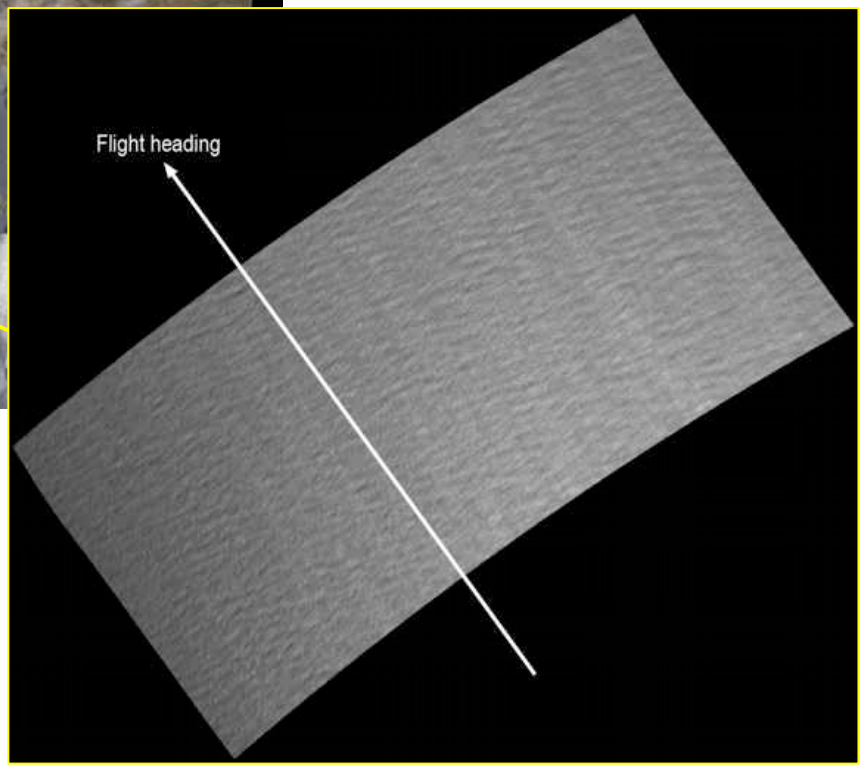


Following Bréon and Goloub (1998), the fringes correspond to mode radius = 7.5 μm.

MISR and AirMSPI

MISR overpass on 19 July 2012

AirMSPI data acquired
~30 min later



AirMSPI 865 nm nadir intensity

Polarimetric sensitivity to aerosol size

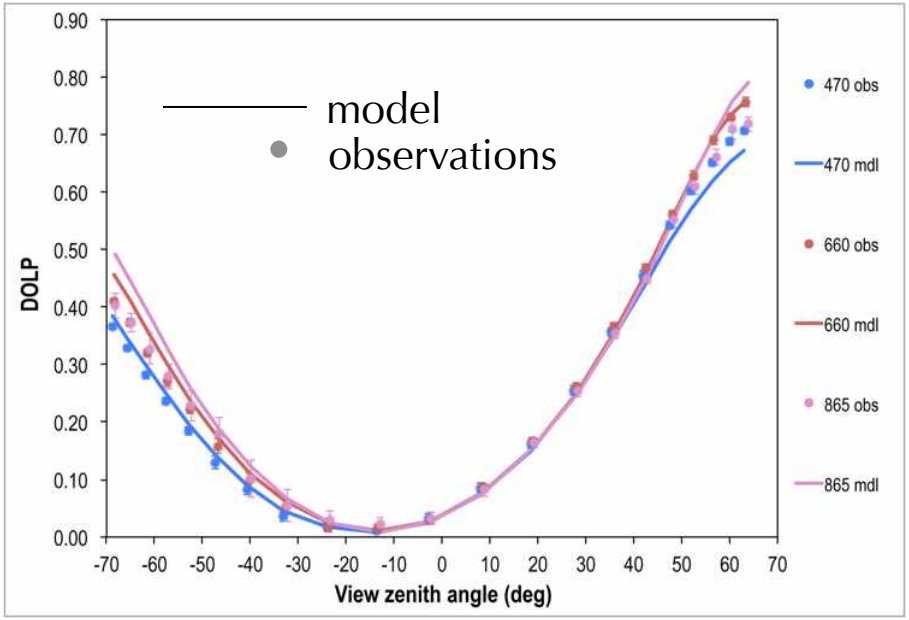
Monomodal aerosol model

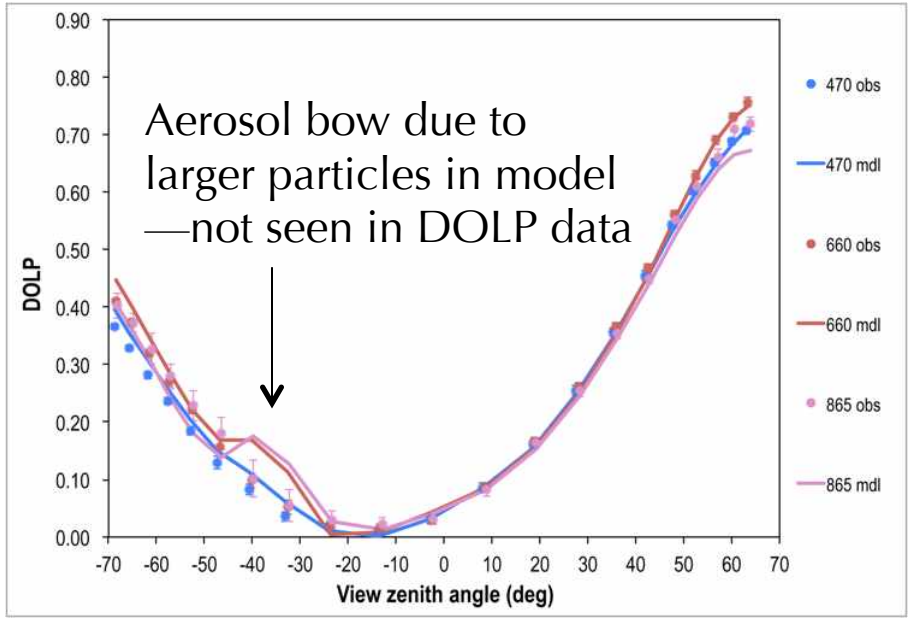
Median particle radius 0.06 μm

Bimodal aerosol model

40% fine mode, median particle radius = 0.03 μm

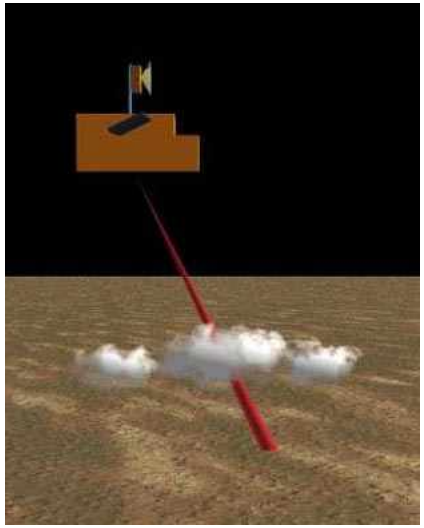
60% coarse mode, median particle radius = 1.00 μm



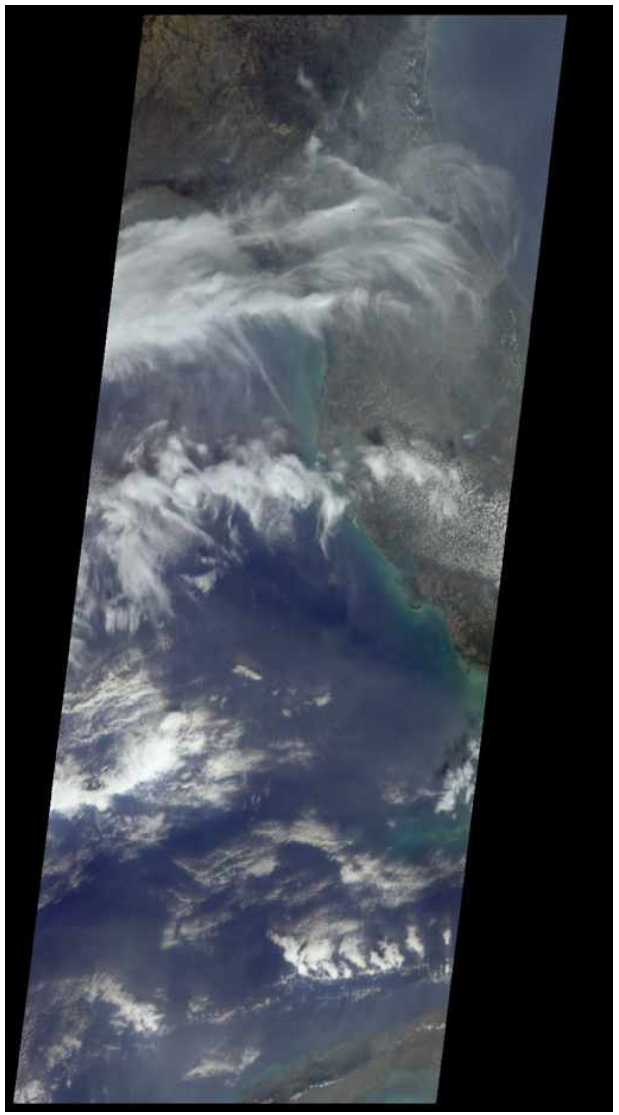


Multiangle observations on mesoscales (km's - hundreds of km)

- cloud fields
- aerosol plumes



"Geometric" approach



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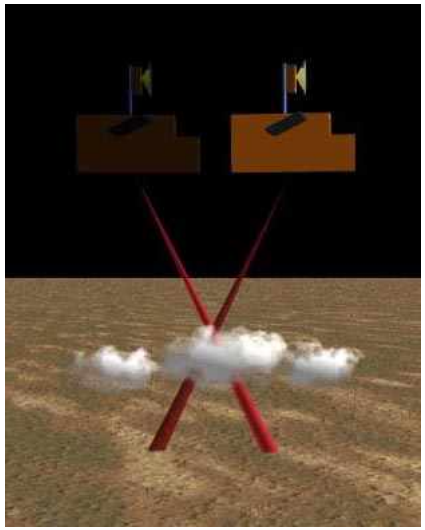

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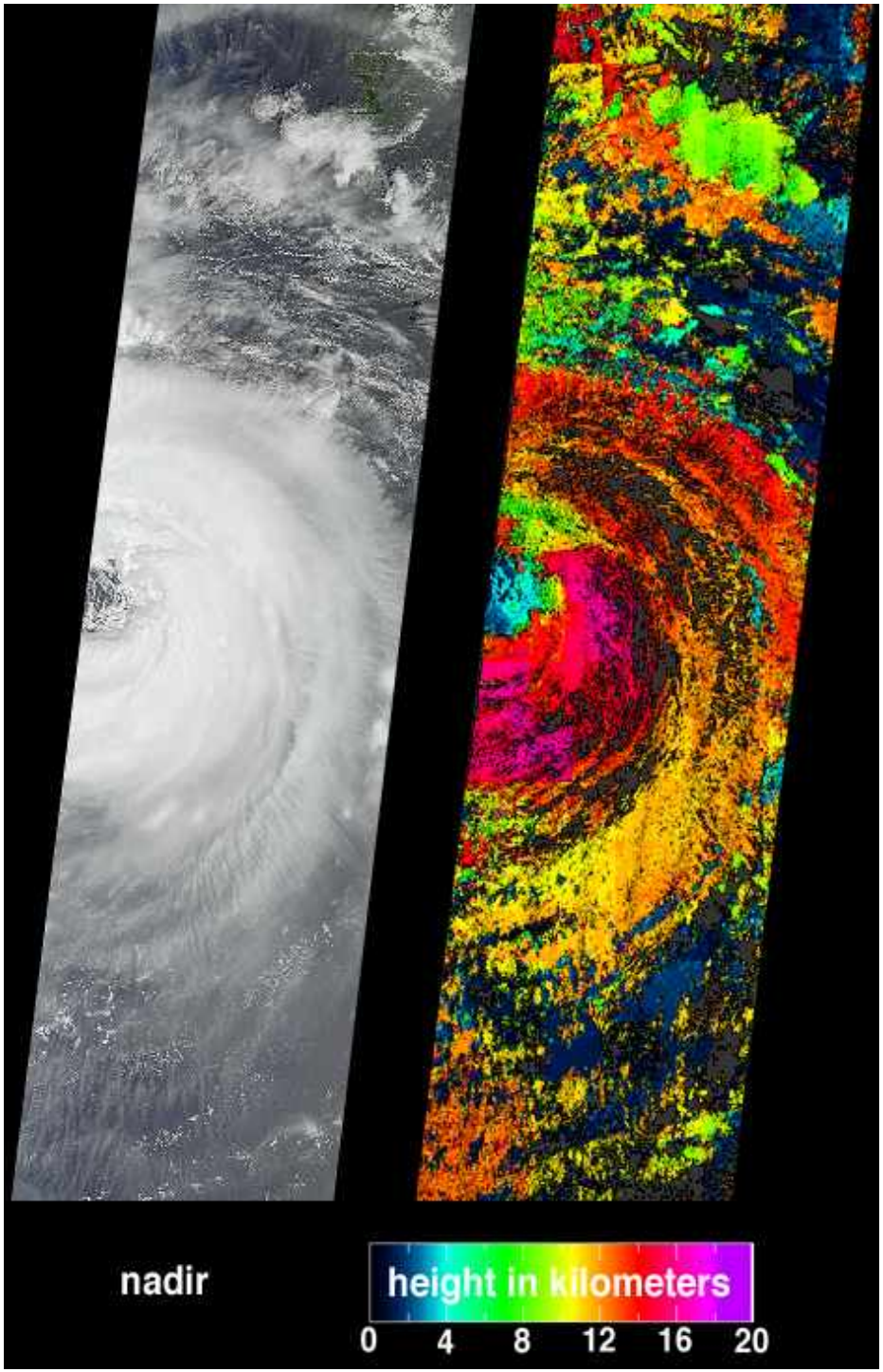
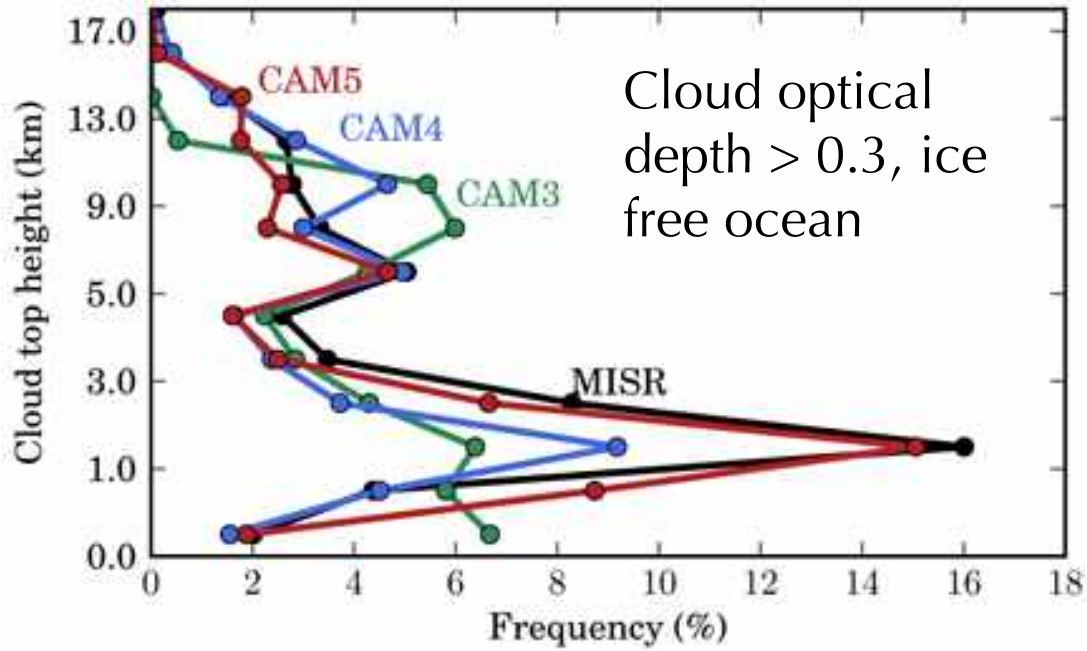


Stereoscopic cloud height retrievals

- purely geometric, using pattern matching
- insensitive to temperature profile or inversions
- insensitive to absolute radiometric calibration drift
- useful for other solar system planets

Typhoon Sinlaku (Sept 2002)

Climate model evaluation



CAM3 (2004)

CAM4 (2010)
Changes to deep convection, cloud parameterizations, default dynamical core

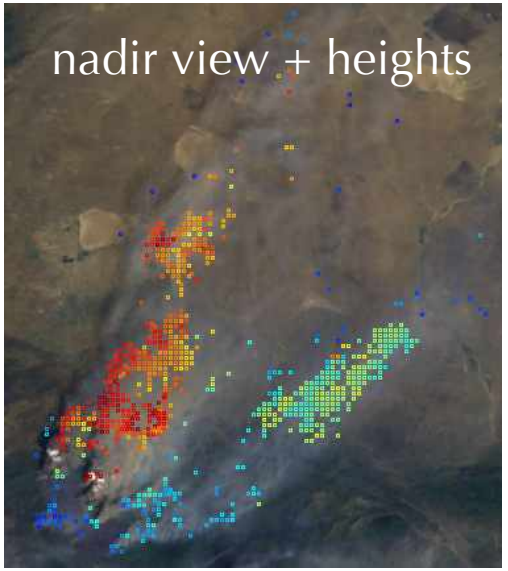
CAM5 (2010)
New treatment of boundary layer, shallow convection, stratiform clouds, radiation

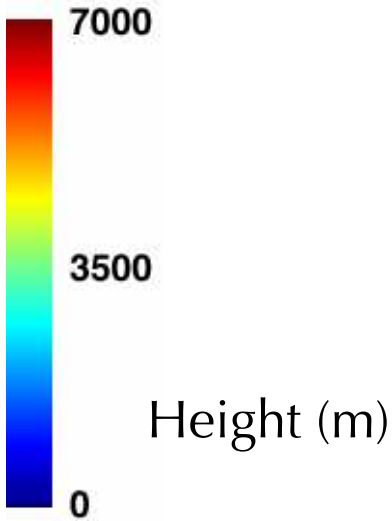
Improved representation of cloud vertical distribution, especially low clouds, is especially important for climate feedbacks.

Kay, J. E., et al. (2012). *J. Climate* **25**, 5190-5207

Wildfire smoke plume injection heights

45° backward view

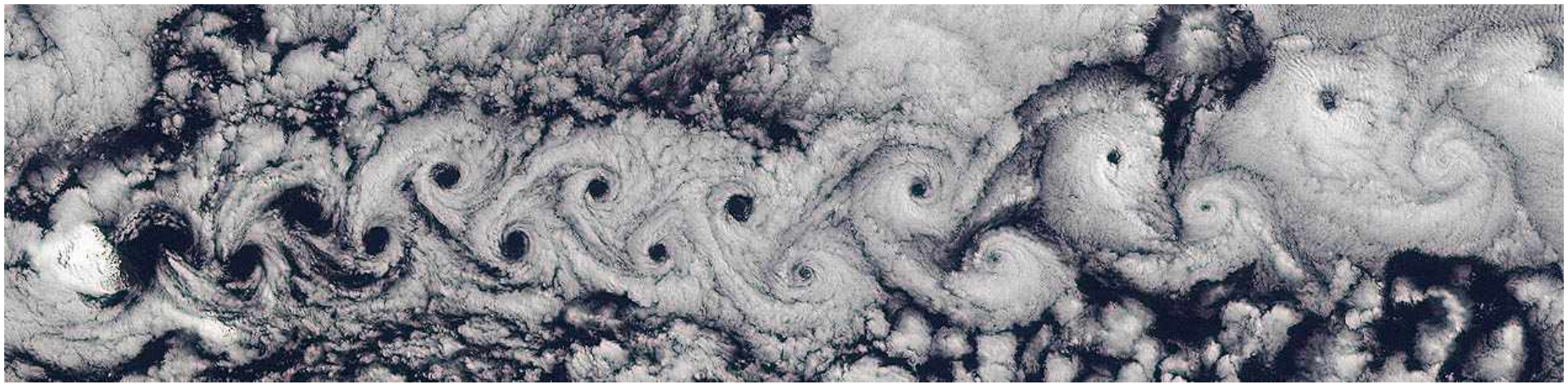




Credit: D. Nelson (Raytheon/JPL)

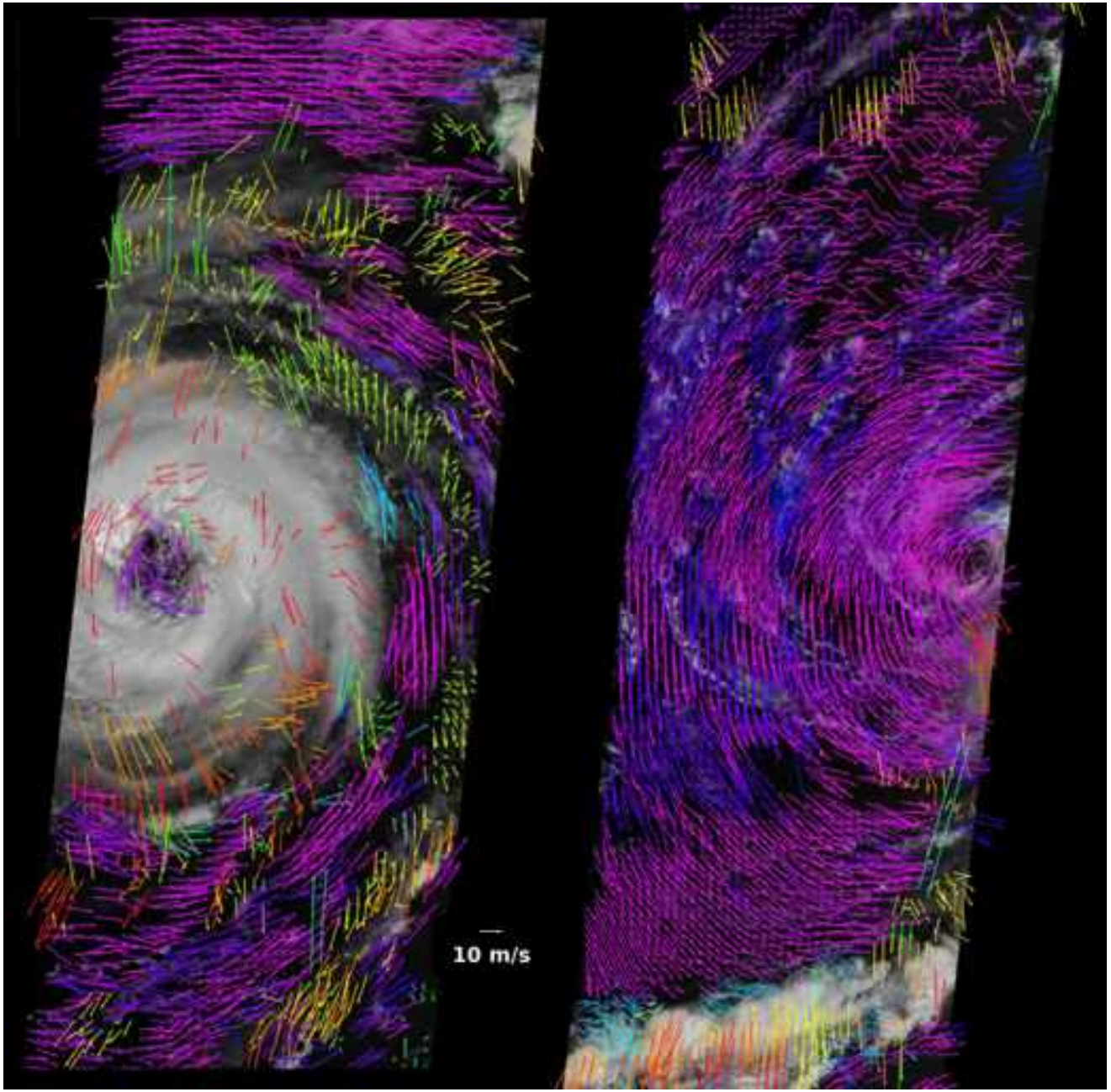
Adding the temporal dimension

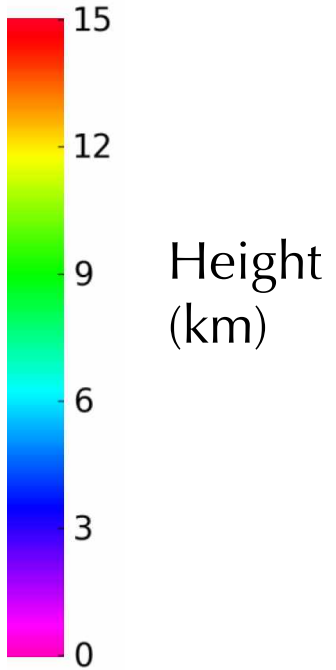
Time-lapse of MISR views



Von Karman vortex street
near Jan Mayen Island

Wind retrievals



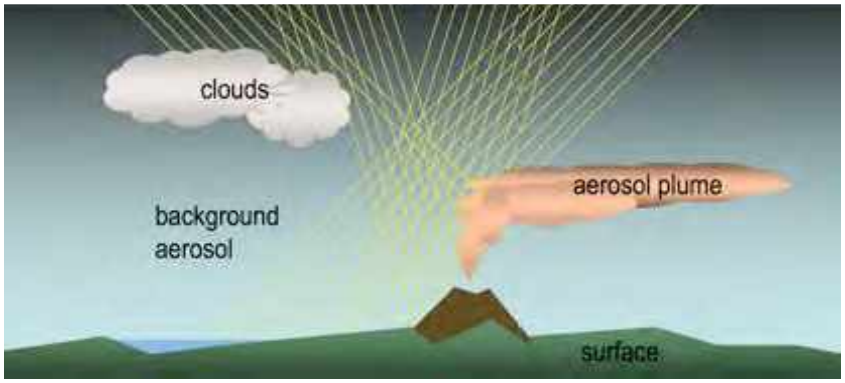


Credit:
K. Mueller (JPL)

Hurricane Alberto (2000) Tropical Storm Franklin (2005)

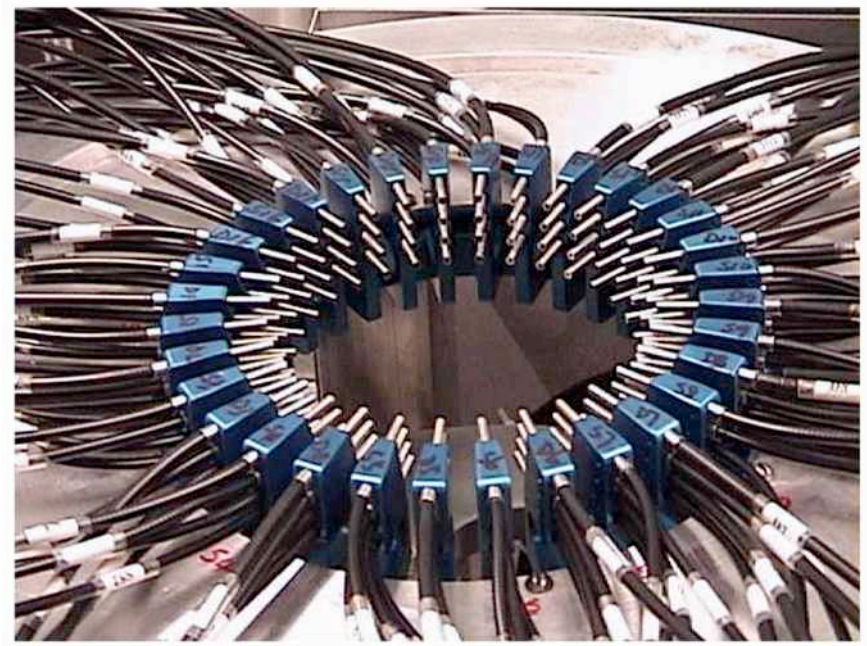
Looking ahead

Future paradigm



- Atmosphere is modeled as a continuum of particle densities (3-D multi-pixel retrievals)

Optical tomography

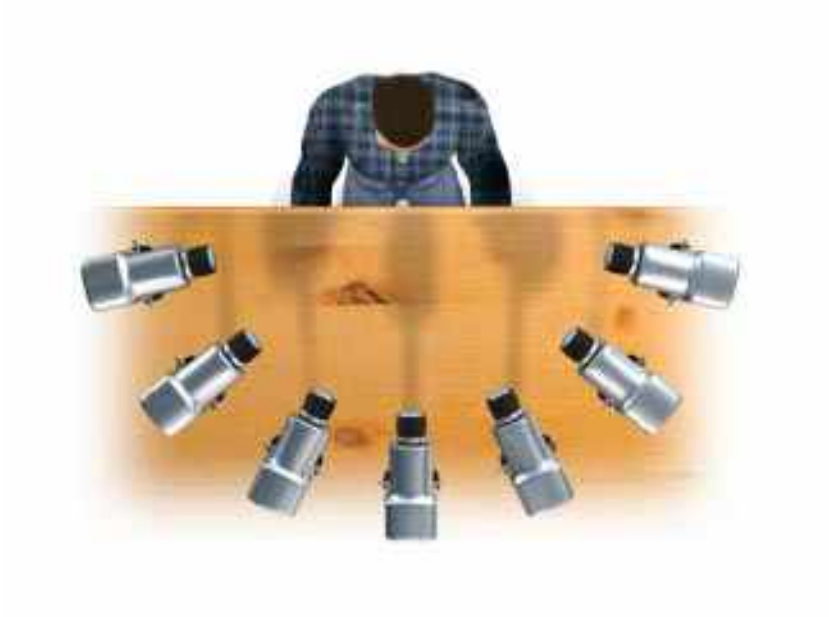


The recovery of the *cross-sectional distribution of optical parameters inside a highly scattering medium from information contained in measurements that are performed on the boundaries of the medium*.

(Klose and Hielscher, 2003, *Inv. Problems* **19**, 387-409

Tele-immersion

"Sea of cameras" approach (UNC Chapel Hill)
(Fuchs et al., 1994, *Proc. First Int. Conf. on Medical Robotics and Computer Assisted Surgery*)



Lanier, J. (2001). "Virtually there." *Sci. Amer.*, April, 66-75.

Conclusions

- Passive multiangle remote sensing captures 3-D spatial structure + dynamics ("4-D")
- Modern technologies enable broad spectral coverage and accurate polarimetric imaging
- Compact versions of the instruments described here have applications to future Earth and planetary observing systems, e.g.,
  - Particle properties and cloud-tracked winds and on Mars, Venus, and Titan
- Fast computational methods are needed for a more realistic representations of particle-laden atmospheres
  - Supplementing stereoscopic pattern matchers and particle property retrievals with tomographic, virtual reality algorithms + 3-D vector radiative transfer codes