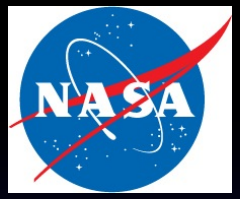
Progress on developments from MISR to MSPI

David J. Diner[1], Michael J. Garay[2], and Russell A. Chipman[3]
[1]*Jet Propulsion Laboratory, California Institute of Technology*
[2]*Raytheon Company*
[3]*College of Optical Sciences, University of Arizona*



Observations and modeling of aerosol and clouds properties for climate studies
September 12-14, 2011 Paris, France

Evolution from MISR to MSPI

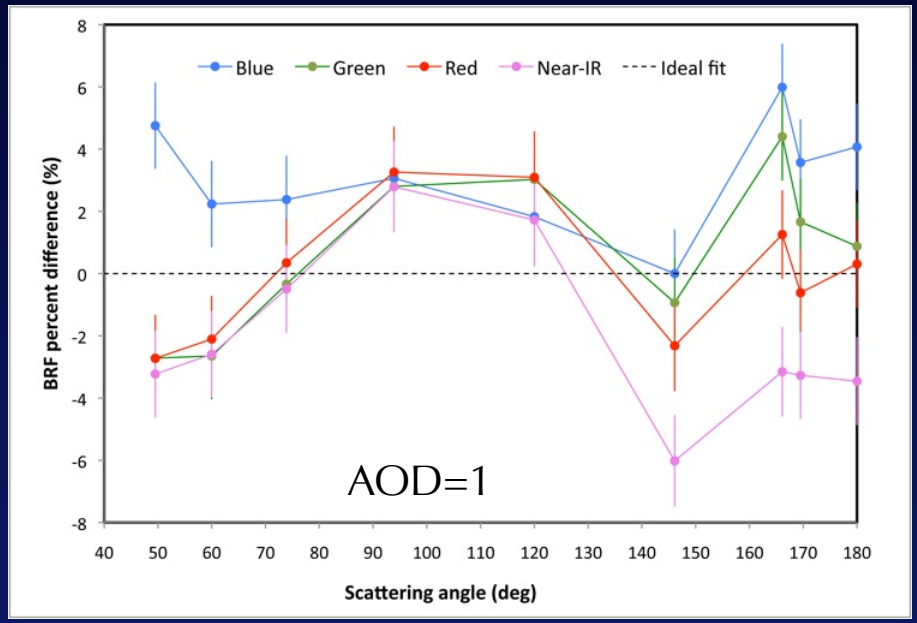
Capability	Multi-angle Imaging SpectroRadiometer (MISR)	Multiangle SpectroPolarimetric Imager (MSPI) strawman concept
UV bands	Not included	365, 385 nm
VNIR bands	446, 558, 672, 866 nm	445*, 540, 645*, 762.5, 865* nm
SWIR bands	Not included	1617*, 1875, 2185* nm *polarimetric bands
Multiangle views	0º-70º views, 9 angles	0º-70º views, 7 angles + gimbaled camera
Polarimetry	Not included	0.5% DOLP uncertainty
Spatial resolution	275 m – 1.1 km	125 m – 2.2 km
Global coverage	9 days	4 days (off nadir); 2 days (nadir)

MSPI requirements derived from Aerosol Science Working Group for the Aerosol-Cloud-Ecosystem (ACE) mission

Aerosol retrievability

MISR operational retrievals	▪ Based on lookup table (LUT) of precalculated aerosol mixture models
MSPI	▪ LUT likely too limiting ▪ Optimization of aerosol and surface parametric models presents an alternative (Govaerts et al., 2009; Waquet et al., 2009; Dubovik et al., 2010)

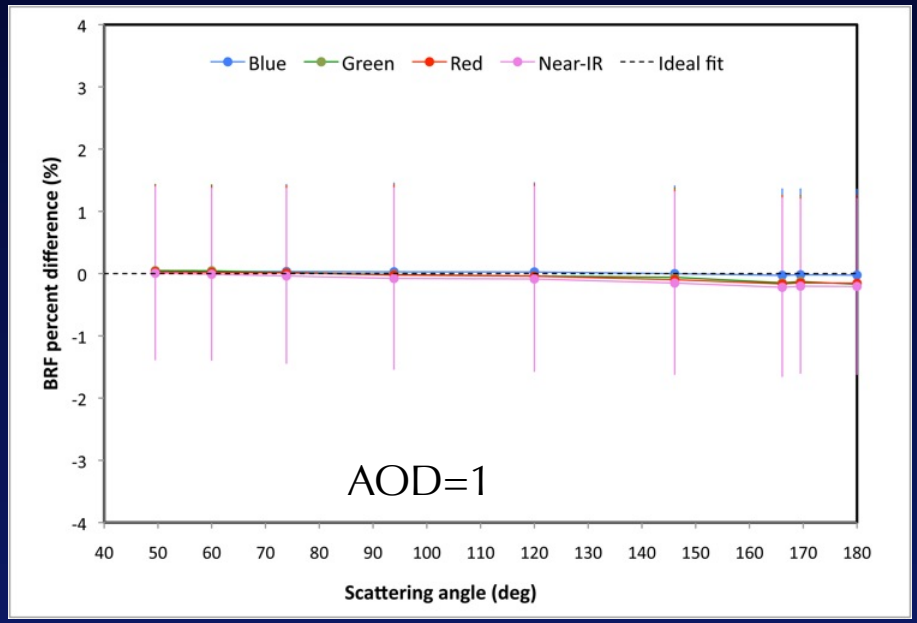
- Kokhanovsky et al. (2010) "blind" retrieval experiment
  - MISR simulation: Radiances only, 9 angles, 4 bands
  - Aerosol models in extended MISR LUT did not accurately reproduce the radiance data
  - AODs biased low by 14%



Aerosol retrievability

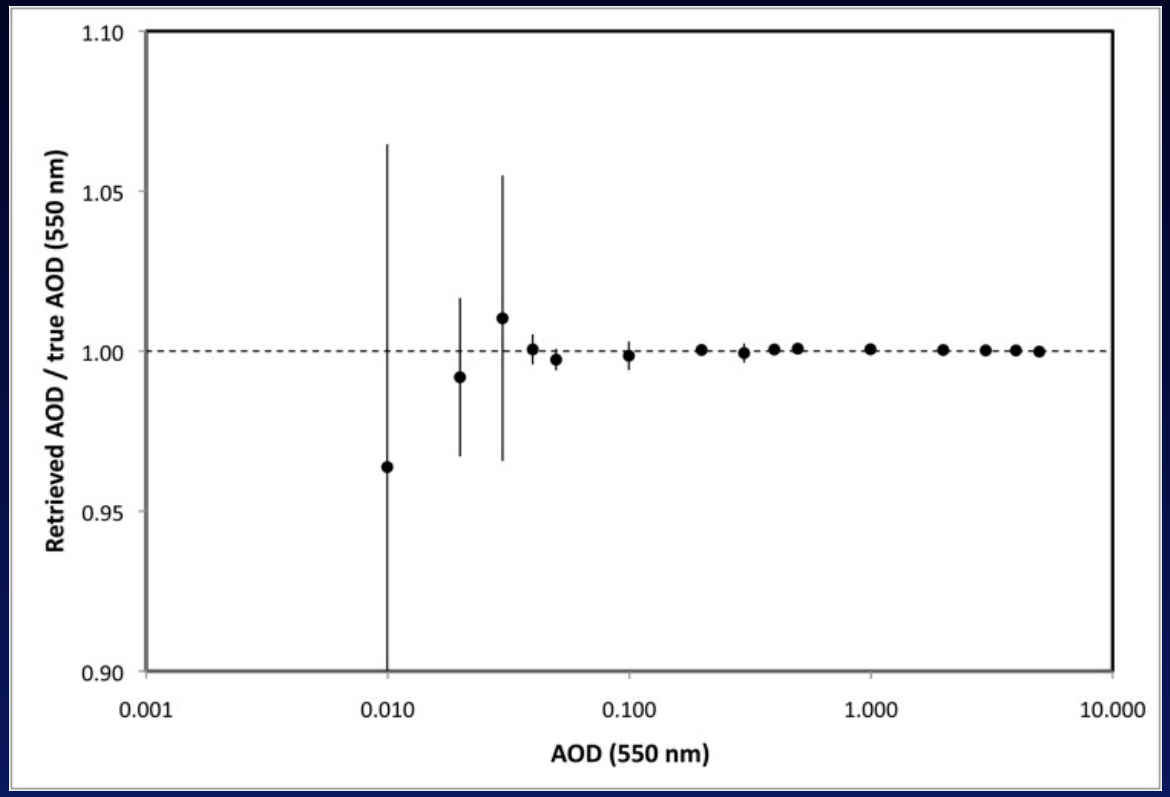
MISR operational retrievals	▪ Based on lookup table (LUT) of precalculated aerosol mixture models. Discretizes aerosol parameters
MSPI	▪ LUT less practical ▪ Optimization of aerosol and surface parametric models presents an alternative (Govaerts et al., 2009; Waquet et al., 2009; Dubovik et al., 2010)

- Kokhanovsky et al. (2010) "blind" retrieval experiment
  - We revisited the problem using an optimization approach (no LUT)
  - Excellent fits, but are the solutions accurate?



MISR optimized retrieval simulation - 1

- Levenberg-Marquardt optimization of a lognormal aerosol distribution parameterized by AOD, complex refractive index, and particle effective radius and size distribution width



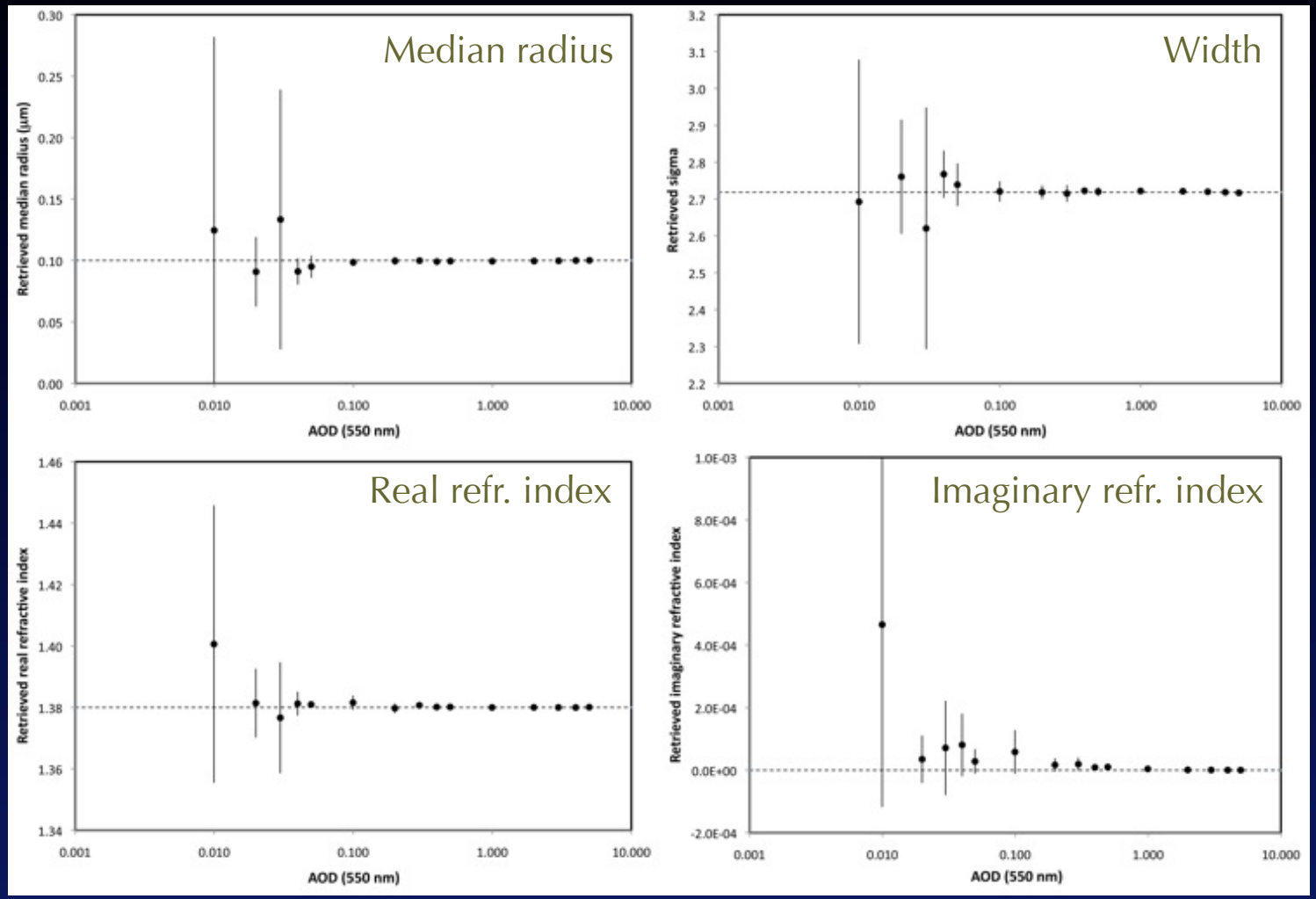
Synthetic radiances in
9 angles, 4 bands
SZA = 60°
Principal plane

r_m = 0.1 μm
σ = 2.718
n = 1.38 – 0i

Black surface

Diner, D.J., R.A. Hodos, A.B. Davis, M.J. Garay, J.V. Martonchik, S.V. Sanghavi, P. von Allmen, A.A. Kokhanovsky, P. Zhai (2011). Atmos. Res., in press.

MISR optimized retrieval simulation - 2



Diner, D.J., R.A. Hodos, A.B. Davis, M.J. Garay, J.V. Martonchik, S.V. Sanghavi, P. von Allmen, A.A. Kokhanovsky, P. Zhai (2011). Atmos. Res., in press.

Observational capability developments

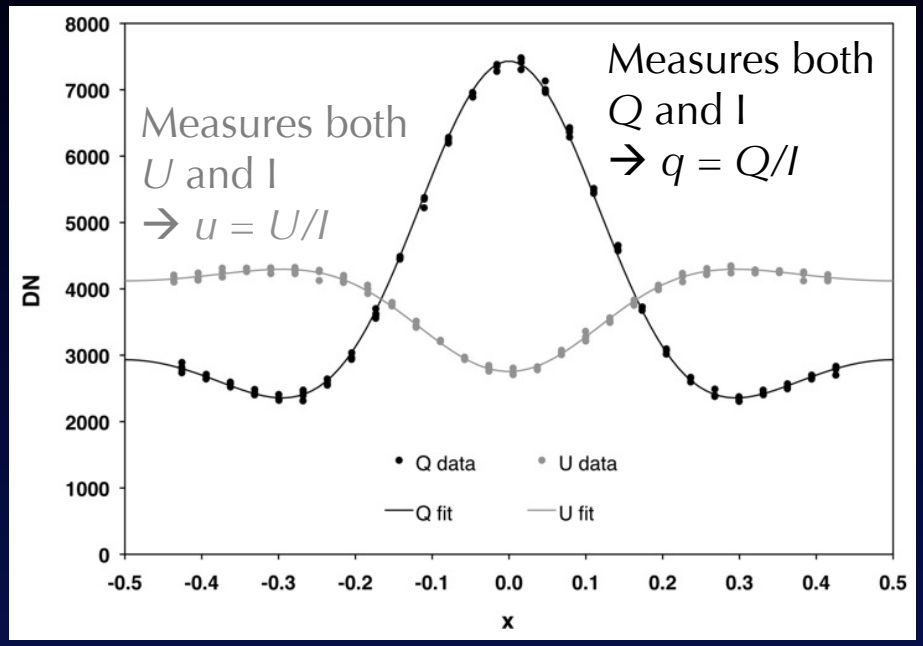
- GroundMSPI is operating in the field

Spectral bands

355, 380, 445, 470*, 555, 660*, 865*, 935 nm (*polarimetric)

- AirMSPI has flown on the NASA ER-2 Oct. 2010, Aug./Sep. 2011

MSPI polarization modulation approach



1 frame ~ 40 msec

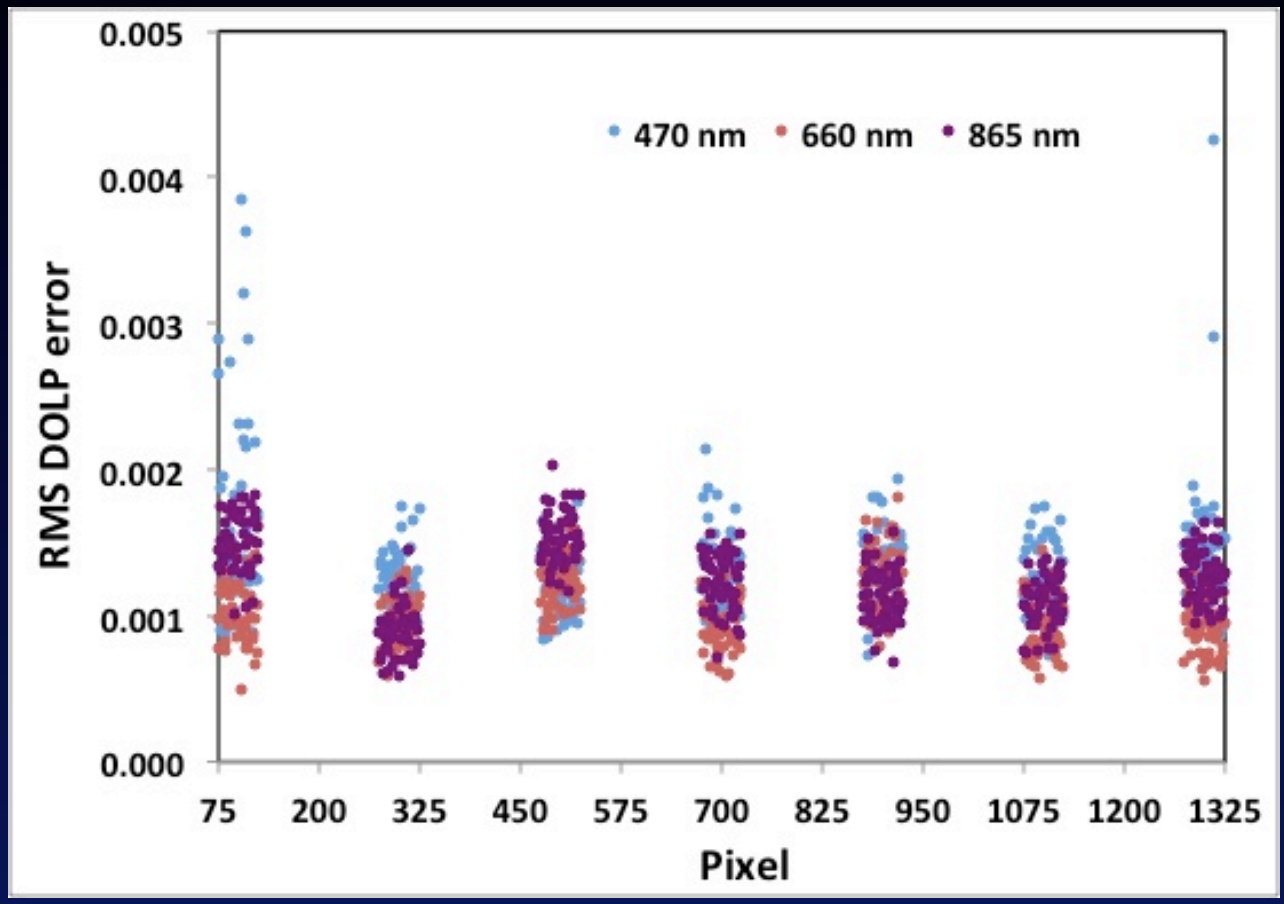
Photo-elastic modulators (PEMs) time-modulate the Stokes components Q and U. Intensity I is unmodulated.

$$DOLP = \sqrt{q^2 + u^2}$$

$$AOLP = \frac{1}{2}\arctan\frac{u}{q}$$

Diner, D.J., A. Davis, B. Hancock, S. Geier, B. Rheingans, V. Jovanovic, M. Bull, D.M. Rider, R.A. Chipman, A. Mahler, and S.C. McClain (2010). *Appl. Opt.* 49, 2929-2946.

GroundMSPI calibrated DOLP error



RMS DOLP error = 1σ deviation in DOLP of fully polarized target rotated through 360º of orientation

Example GroundMSPI imagery

470, 660, 865 nm Intensity

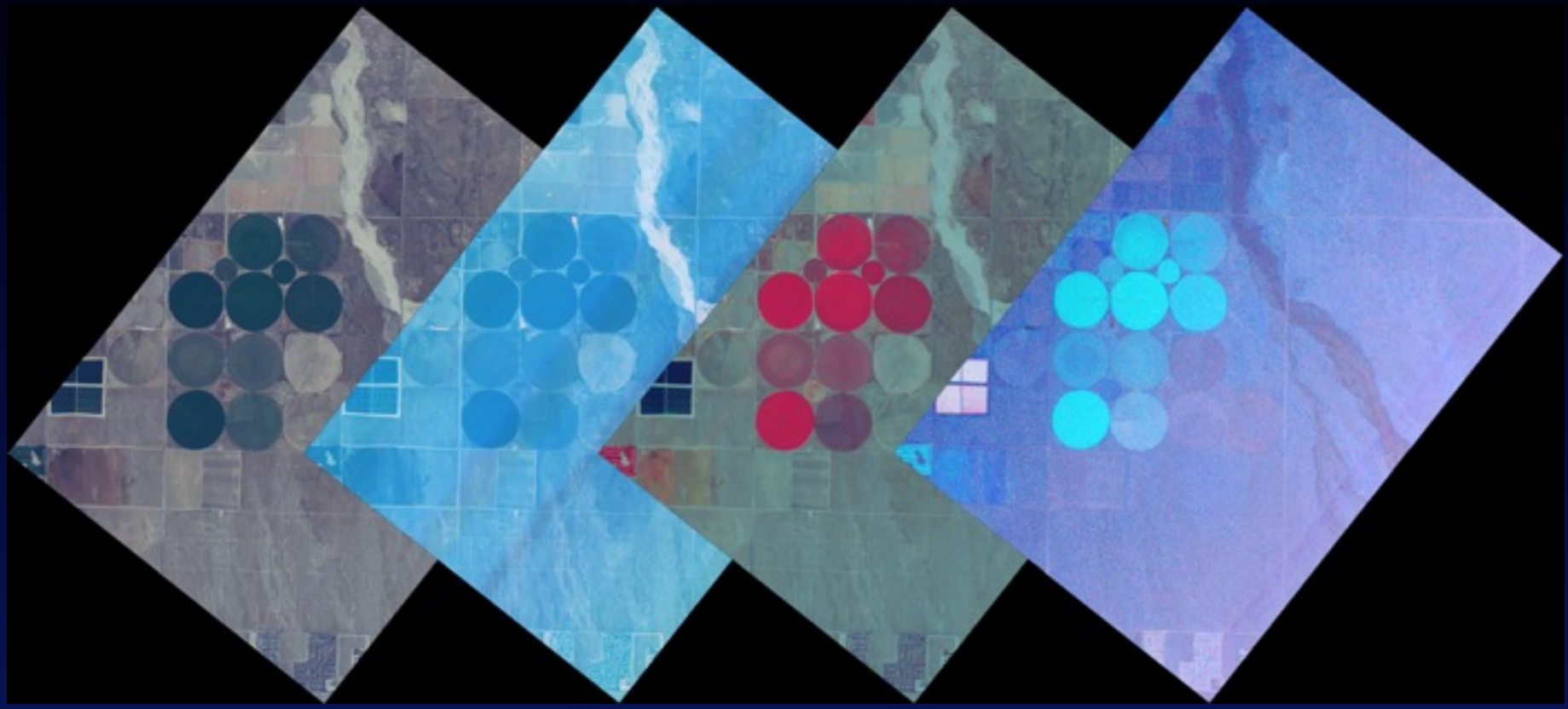
470, 660, 865 nm DOLP

470, 660, 865 nm AOLP

GroundMSPI polarization quiver plot

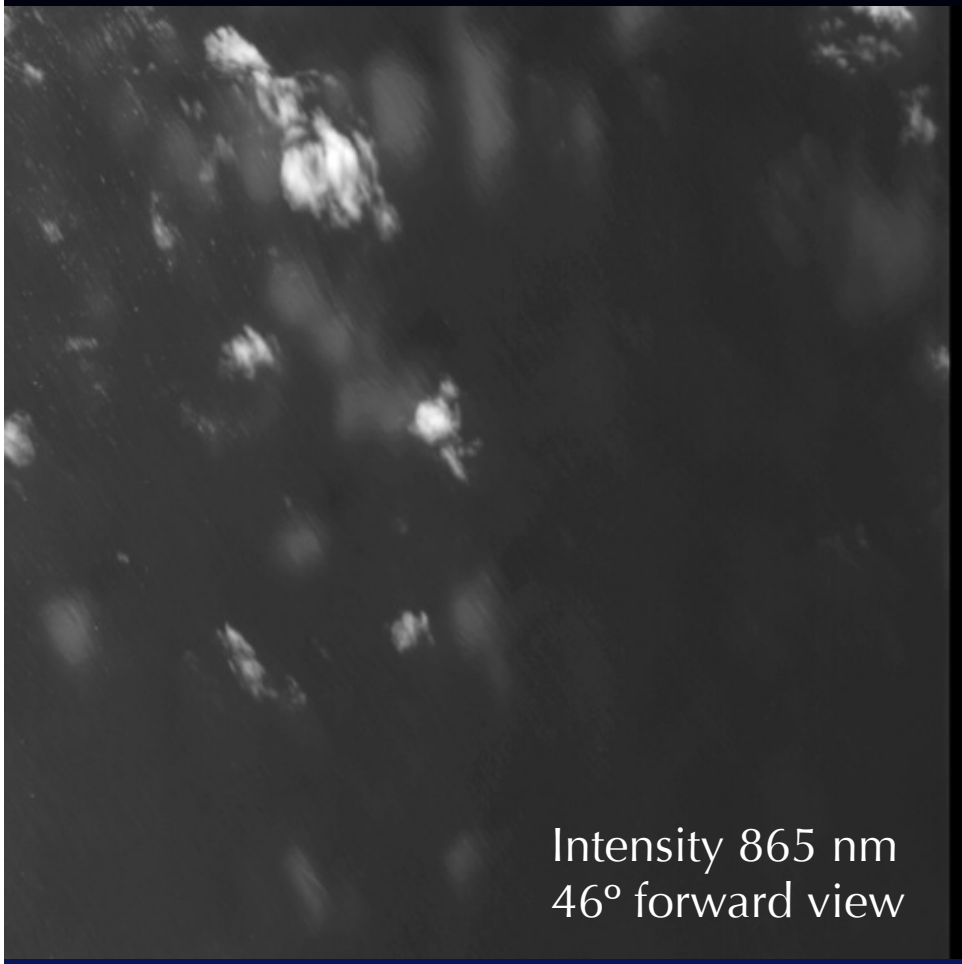
- GroundMSPI time lapse imagery at Kitt Peak, 18 March 2011
  - Dome is coated in titanium dioxide, a depolarizer
- Superimposed by "quiver plot" at 470, 660, 865 nm
  - Length of lines proportional to DOLP
  - Orientation shows AOLP in meridian plane

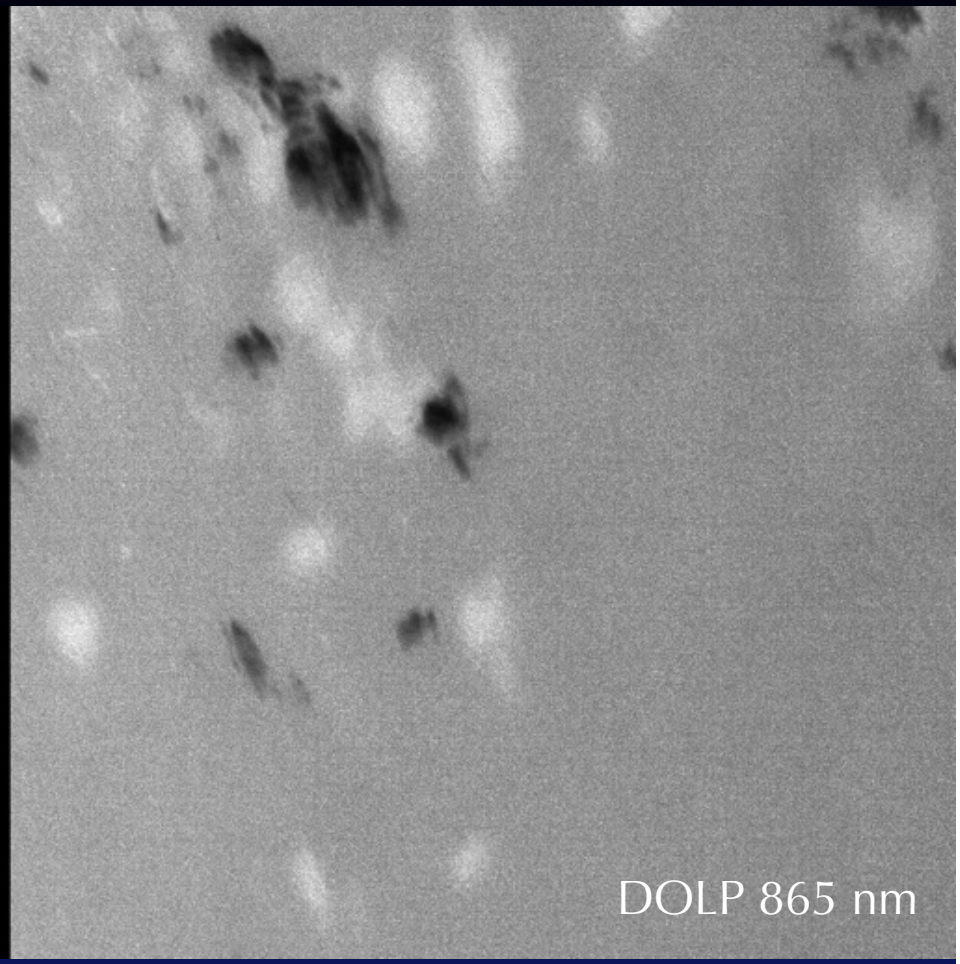
AirMSPI first flight imagery, 7 October 2010

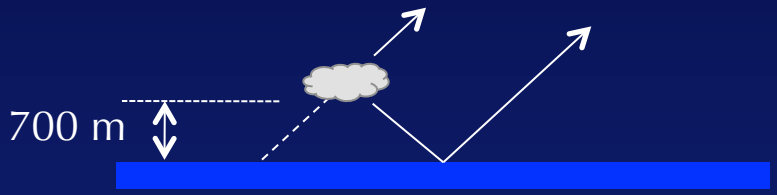


Radiance	Radiance	Radiance	DOLP
445, 555, 660	355, 380, 445	470, 660, 865	470, 660, 865

Clouds and cloud reflections over ocean







Clouds: 3% - 30%
Water background: 35 - 65%
Cloud reflections in water: 60 - 80%

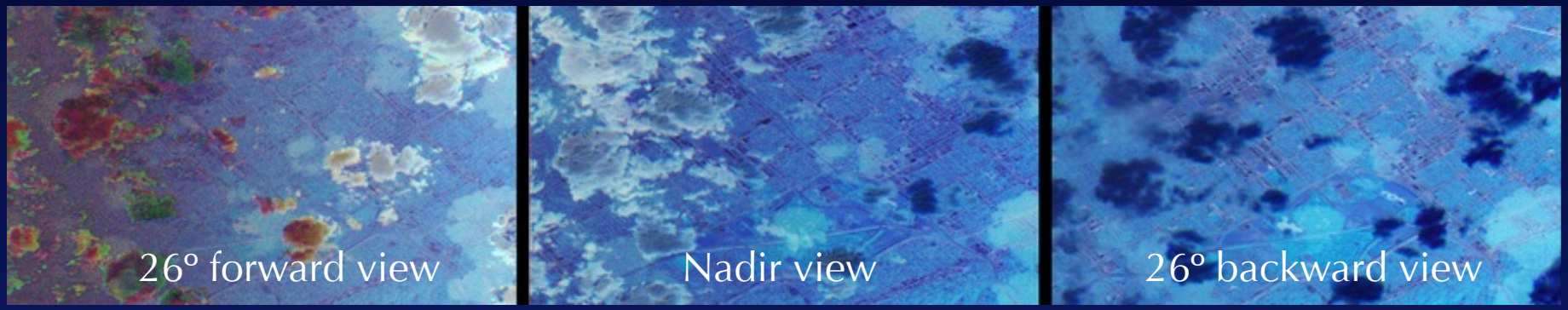
Clouds in polarized light

AirMSPI imagery over
Van Nuys, CA

DOLP, 470, 660, 865 nm

supernumerary bows

cloudbow



170° 145° increasing backscatter 110°

Concluding remarks

- The MSPI concept is derived from MISR heritage
- MSPI is a UV-SWIR multiangle imager with high polarimetric accuracy using photoelastic modulation
- New retrieval paradigms are needed to handle the advance in information content
- UV-VNIR GroundMSPI and AirMSPI prototypes are currently in operation
- UV-SWIR AirMSPI-2 is under development
  - New channels planned include O_2 A-band, a cirrus channel at 1875 nm, and polarimetry at 1617 and 2185 nm