Decadal Survey Tier 2 Mission Study
Summative Progress Report

ACE Polarimeter Development

David J. Diner (Jet Propulsion Laboratory, California Institute of Technology)
Brian Cairns (Goddard Institute for Space Studies)
J. Vanderlei Martins (University of Maryland Baltimore County)

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Polarimeter Requirements Summary

Radiometric uncert.	Radiom. stability	Degree of linear polariz. uncert.
±3%	±0.1% over 1 orbit ±0.7% over 5 yrs.	±0.005 to provide required sensitivity to particle size and complex refractive index

Spectral bands	Angular range and sampling	Resolution	Swath	Comment
320-410 nm	±50º along-track (at instrument) with at least 7-20 angles	500 m - 6 km, depending on channel	400 km at all along-track angles; 2-day coverage at nadir orientation	Combination of intensity and/or polarization
440-870 nm	“	Same, plus ~125 m or less at nadir in center of swath	“	≥3 polarimetric channels. 125 m cloud channels are unpolarized
1600 nm	“	500 m 1 - 6 km	“	Intensity only Polarimetric
1380 or 1880 nm	“	1 - 6 km	“	Sensitive to cirrus
2130 or 2250 nm	“	“	“	Polarimetric, or demonstrate not needed

Instrument Measurement Concepts

- Multiple pathways exist and are being actively pursued to meet the ACE polarimeter measurement requirements

Concept	Brief description	Satellite heritage
APS + 3MI	Heritage scanner providing very high accuracy multispectral polarimetry at swath center plus POLDER successor	Glory APS ADEOS-1,2 POLDER PARASOL
MSPI	Multiple pushbroom cameras providing high accuracy polarimetric imagery without any moving parts using photoelastic modulators (PEMs)	MISR for multiangle architecture
PACS	Suite of three wide angle cameras with modified 3-way Phillips beamsplitter to provide high angular density using compact design and no moving parts plus a high resolution cloud imager	POLDER for wide-angle lens

APS = Aerosol Polarimetry Sensor
3MI = Multi-polarization, Multi-directional, Multi-spectral Instrument
MSPI = Multiangle SpectroPolarimetric Imager
PACS = Passive Aerosol and Cloud Suite

Instrument Notional Details

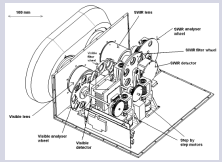
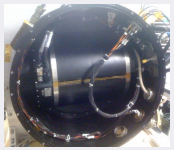
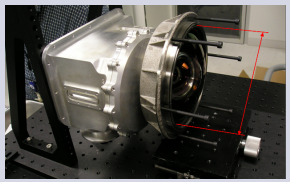
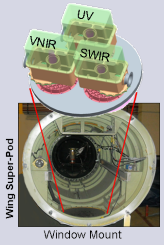
Concept	Bands (nm)	No. of angles	Swath*	Spatial resolution*	Polarization uncertainty
APS + 3MI	APS: 410, 555, 673, 865, 1378, 1600, 2250 3MI: 340-2200 (12 bands) including 5 polarimetric bands	APS: >60 3MI: 15	APS: 4 km 3MI:. ~1500 km	2-7 km at nadir	APS: ±0.001 3MI: ±0.020
MSPI	355, 380, 445, 470, 555, 660, 865, 1595, 1875, 2120	7 Option for high angular density in one band	1800 km (nadir) 680 km (off-nadir)	150 m (nadir) 275 m (stereo) 1.1 - 2.2 km (else)	±0.005
PACS	Polarimeter: 360, 380, 410, 440, 550, 670, 870, 910,1640, 1880, 2100, 2250 Cloud Camera: 670, 870, 2100, 2250	22 multi-spectral 66 in one band 3 pointable	1500 km 400 km	Polarimeter ~1 km at nadir 200 m pointable	±0.005

*Assumes 470 km altitude orbit

Intensity-only bands Polarimetric bands

Instrument Prototypes

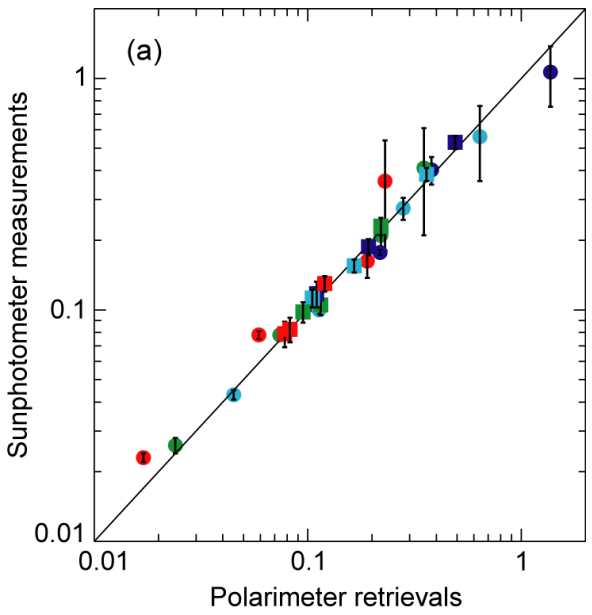
- Aircraft prototypes for the candidate ACE instruments exist
  - *The different sensors have unique designs and complementary capabilities, providing excellent opportunities to crystallize ACE strategies and perform cutting-edge aerosol and cloud science*

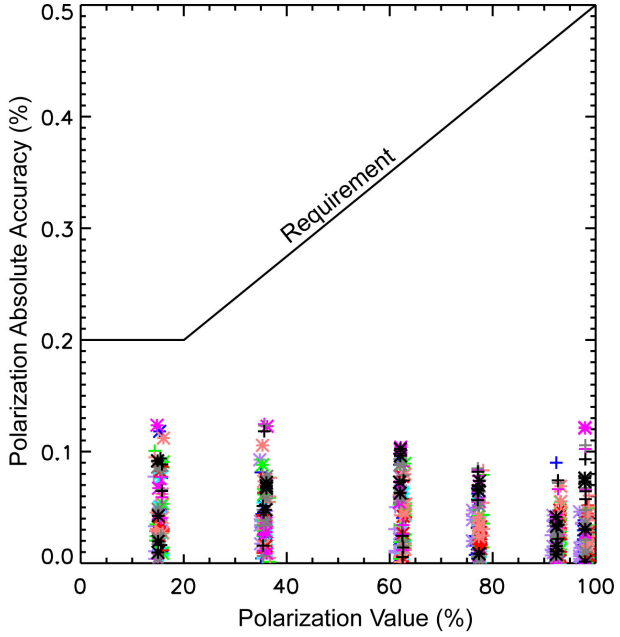
Concept	Aircraft prototype	Prototype status
APS + 3MI	RSP + OSIRIS  	Two RSPs have flown on various platforms with 100% success acquiring >1000 hours of data from 50 m to 17 km altitude in eleven major field deployments. RSP-1 is on the LaRC B200 with HSRL. RSP-2 test flight on the NASA ER-2 in January 2011. OSIRIS first field campaign took place May 2008.
MSPI	AirMSPI  	Engineering checkout flights occurred on ER-2 in October 2010 (acquires UV/VNIR imagery). SWIR in development, with IIP-10 decision pending.
PACS	APACS  	PACS-VNIR is currently being tested in the lab. To be integrated onto ER-2 Spring 2011. Design for PACS-UV and SWIR is completed. IIP-10 decision pending for prototype development.

Technology Assessments

Concept	Technology support	Technology item	TRL
APS + 3MI	AITT (integration of RSP-1 on WFF P-3) Glory Project CNES	APS 3MI VNIR 3MI SWIR	8 (9 after Glory launch) 9 6
MSPI	IIP-04 (dual PEM technology); AITT (AirMSPI fabrication) AIST IIP-07 (SWIR optical extension) IIP-10 proposal (SWIR focal plane)	UV/VNIR technology Onboard processing SWIR optics High speed, low noise SWIR focal plane	6 4 (8 after U. Mich. Cubesat) 4-5 3
PACS	NASA HQ, GSFC, UMBC, IIP-10 proposal	Polarimetry system Readout electronics, detectors	4 (6 after ER-2 deployment) 8

Example Results - RSP

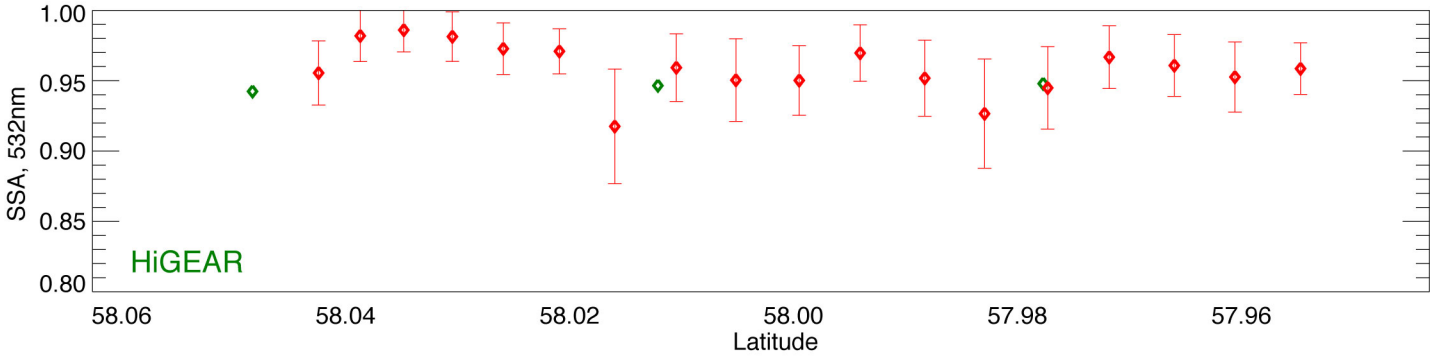




The Glory APS uses the same functional architecture as RSP with dark reference and polarimetric calibration every 1.5-sec scan to ensure polarimetric accuracy < 0.1%.

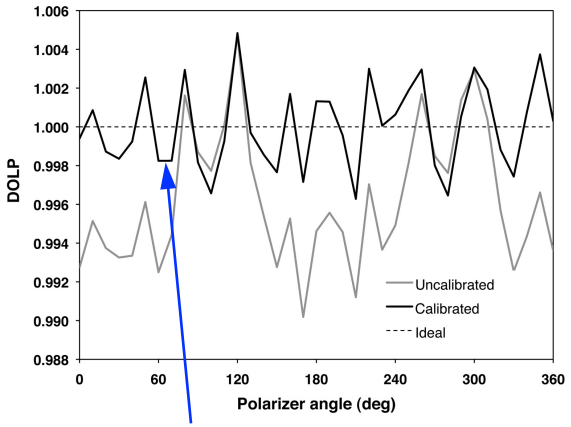
Spectral optical depths retrieved from RSP show excellent agreement with ground-based sunphotometer data.

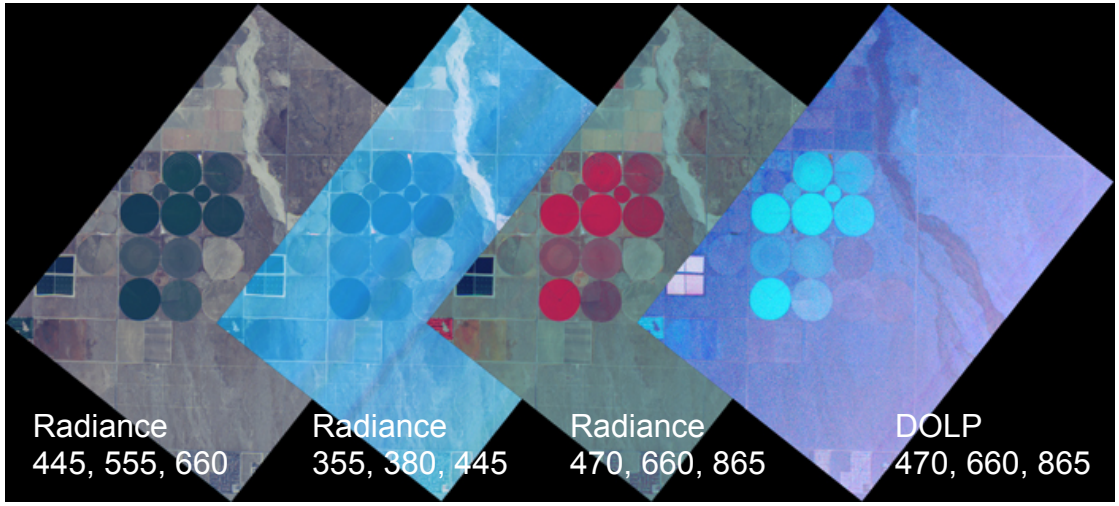
Polarimetric retrievals initialized and constrained by HSRL provide single scattering albedo over land and water. This example compares RSP retrievals with HiGEAR in situ data.



Example Results - AirMSPI

AirMSPI imagery over Palmdale, CA – 7 Oct 2010

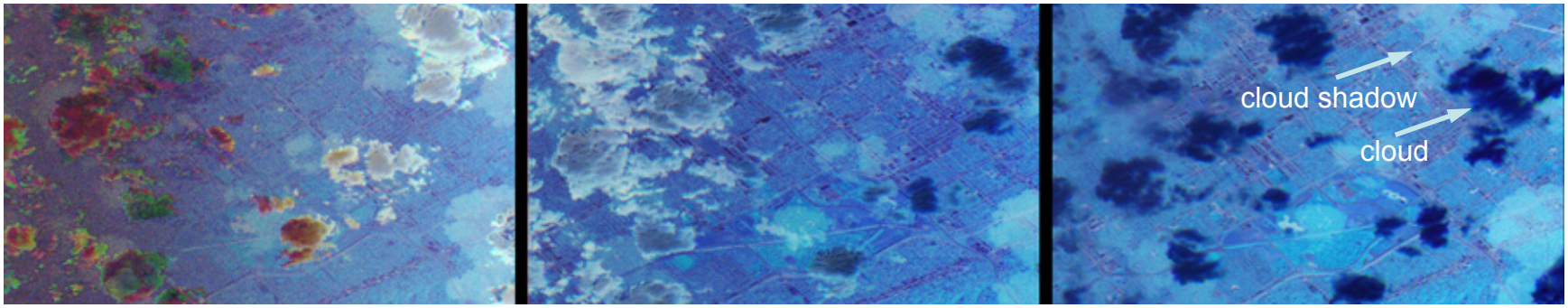




Calibrated DOLP = 1.000 ± 0.002
(data from GroundMSPI, similar to AirMSPI)

AirMSPI polarization imagery over Van Nuys, CA – 7 Oct 2010 – DOLP 470, 660, 865 nm

supernumerary bows cloudbow ← increasing backscatter



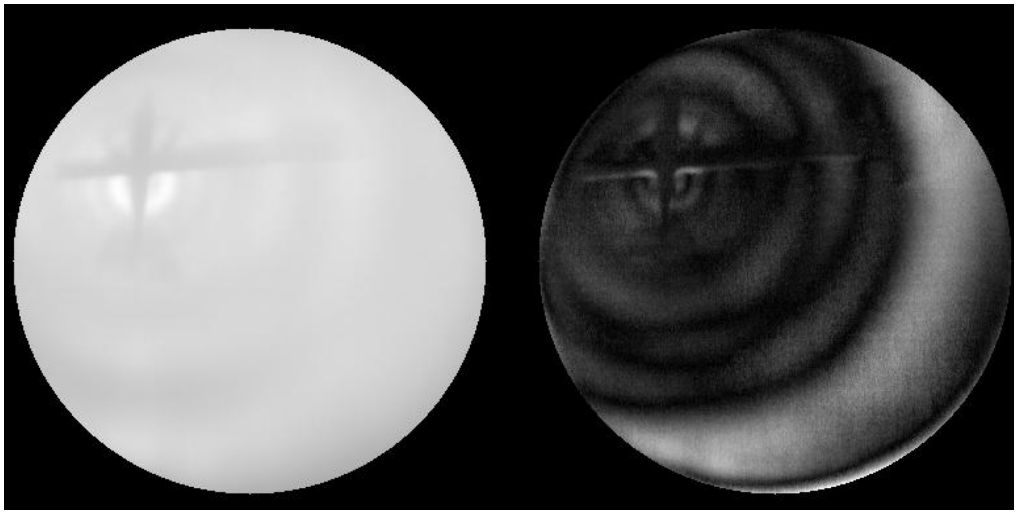
+26° view Nadir view -26° view

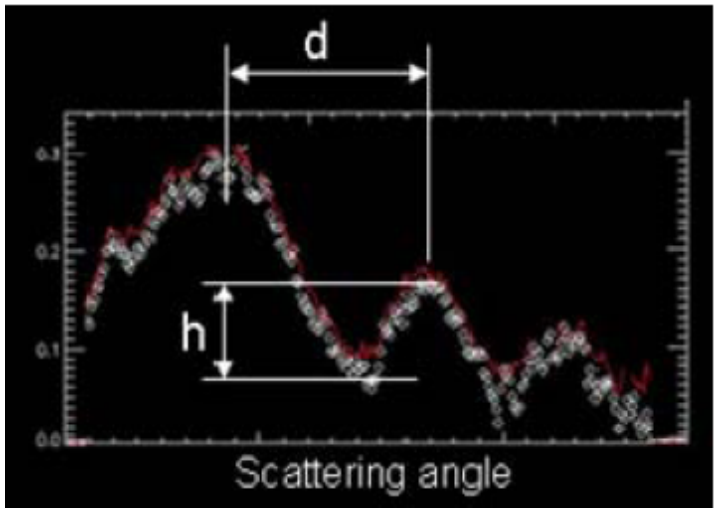
Example Results - APACS

PACS early prototype measurements during VOCALS 2008 aboard the CIRPAS Twin Otter aircraft

Unpolarized cloud image

Polarized cloud bow





First wide FOV lens test showing small polarization artifacts to be corrected

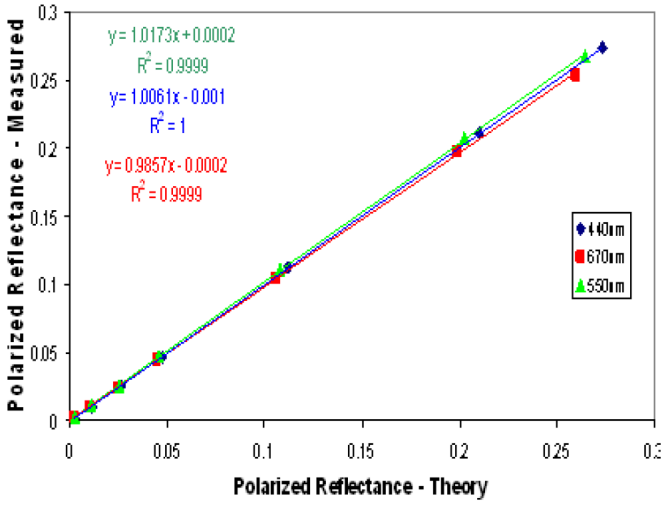
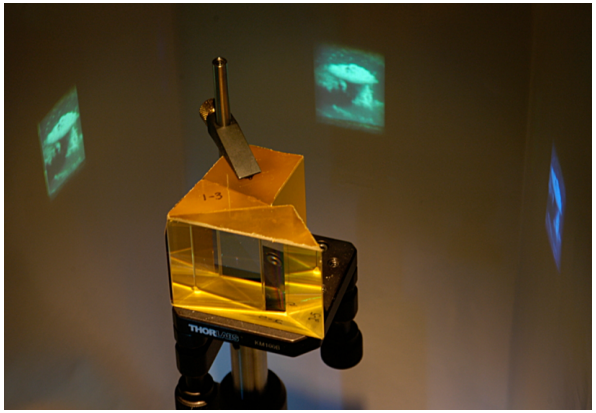


Image splitting with the PACS prism



Polarimeter Path Forward

- Sustaining NASA's current investments in ACE polarimeter technology (optical components, detectors, calibration) would support an ACE launch in ~2018
  - *Will provide essential continuity to Terra/A-Train observations along with unprecedented process-oriented measurements*
  - *Technology development benefits from flight heritage as well as significant new technology investments from ESTO and others*
- As hardware technology readiness matures, it is now vital to invest in using the aircraft polarimeter suite to refine instrument requirements, explore measurement synergies and trade-offs, and advance algorithm and data processing approaches
  - *A Polarimeter Definition Experiment (PODEX) with RSP, AirMSPI, APACS, and possibly OSIRIS integrated on the ER-2 is proposed for 2011 as a first step*
  - *Additional algorithm development, cal/val, and science campaigns will facilitate mission readiness*
  - *Co-flight with the LaRC HSRL-2, an airborne radar, and the NASA P-3 will provide a powerful ACE simulator as well as the needed suborbital complements to the satellite measurements*