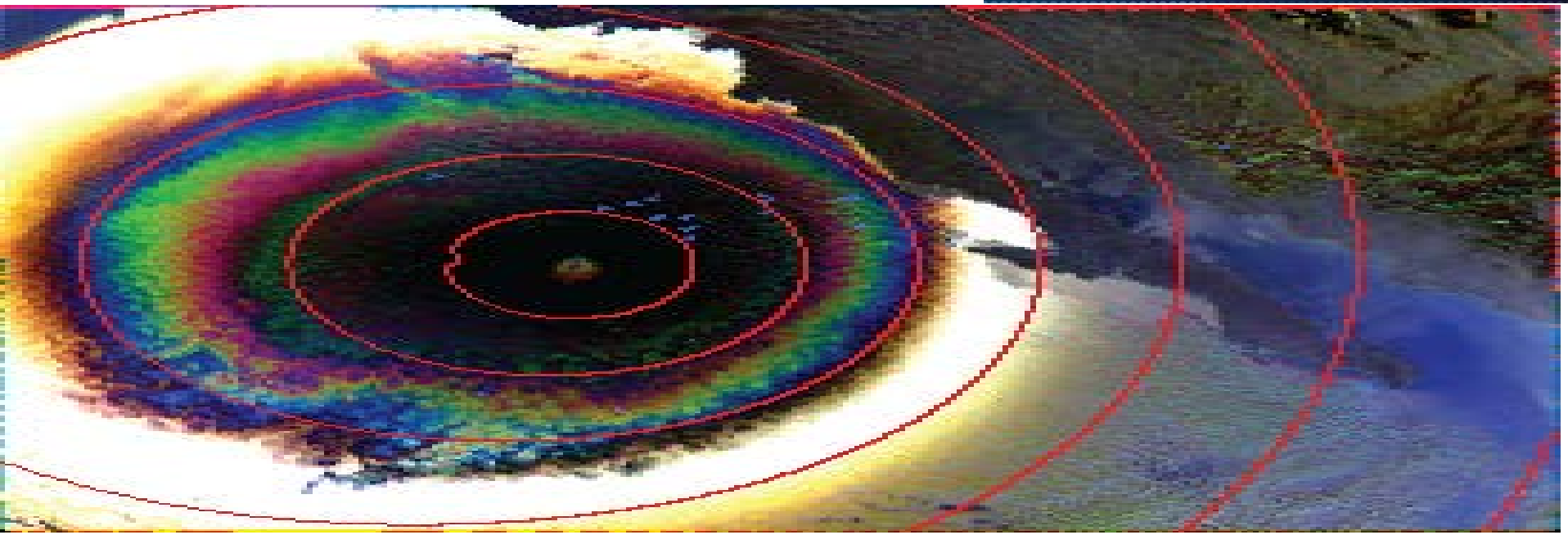
HARP



Polarimetric remote sensing with the Hyper-Angular Rainbow Polarimeter, 3U CubeSat

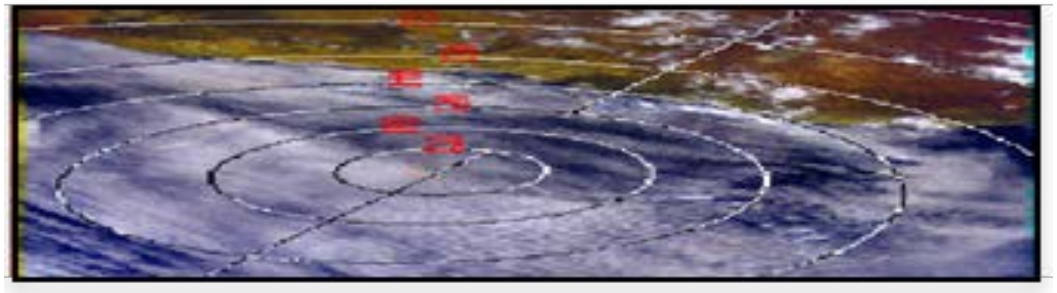
Brent McBride (LACO/UMBC)

9/17/2015

NASA NOAA SCIENCE & TECHNOLOGY CORP. UMBC JCET NASA-GSFC Space Dynamics LABORATORY Utah State University Research Foundation

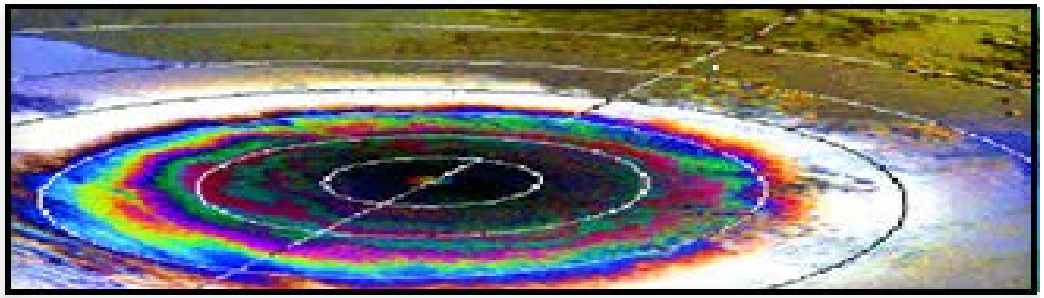
What is a polarimeter?

Traditional radiometers (MODIS/VIIRS) measure radiation over a range of wavelengths → data product: aerosol, cloud droplet, Earth surface properties



Polarimeters (POLDER/AirMSPI) identify the orientation of the electric field of incident radiation → data product: aerosol, cloud droplet characteristics (type, size distribution)

Polarization of backscatter is sensitive to a given surface!



Both methods work to understand the extent of aerosol impact on clouds, radiation budget of Earth, and precipitation.

Images from POLDER (Parasol/CNES). Adapted from Breon et al. 2005

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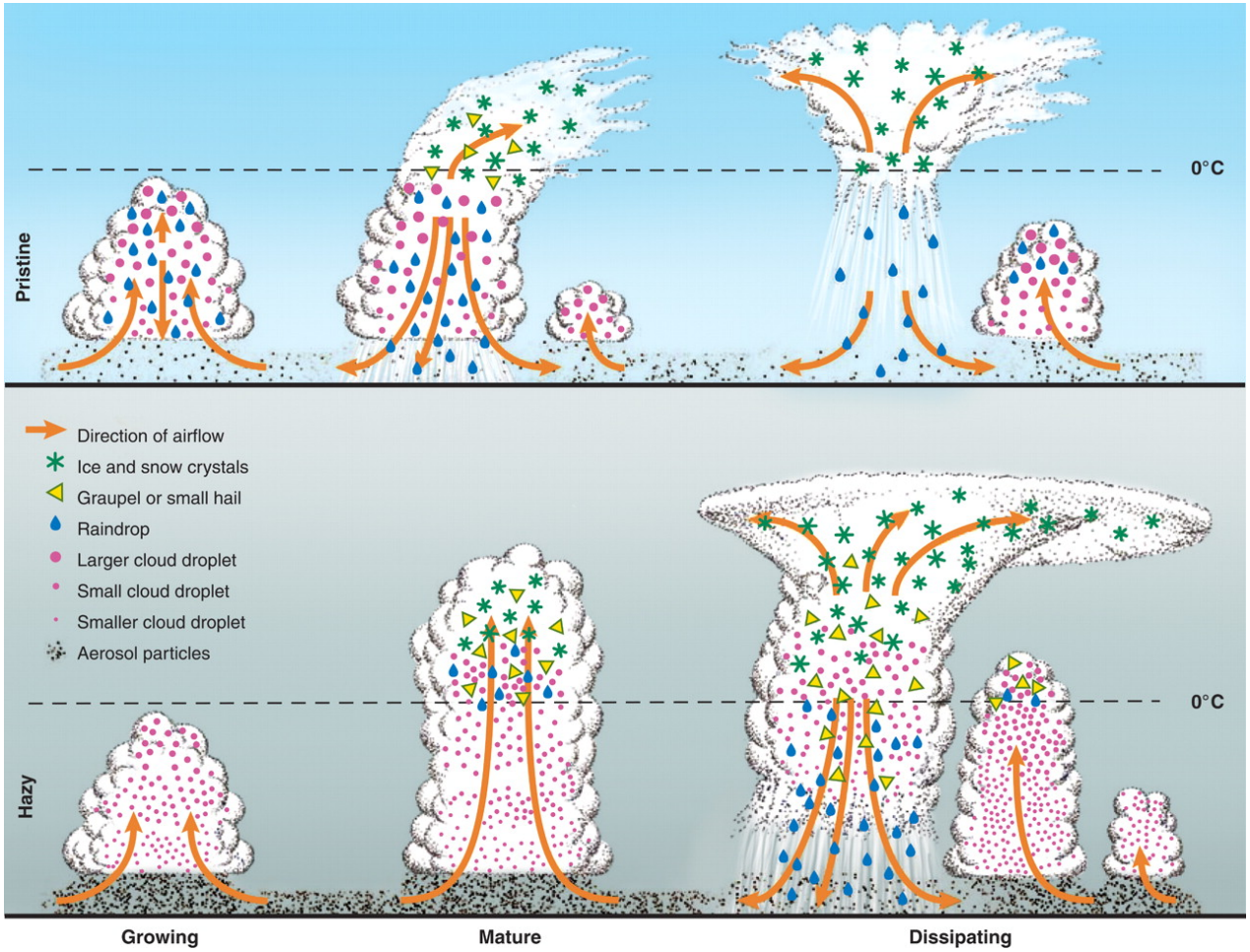
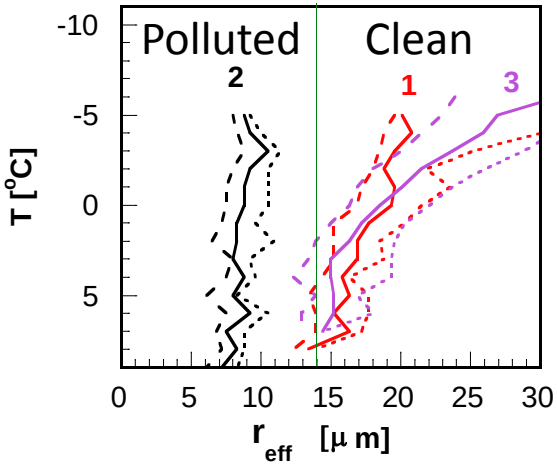
How can polarimeters complement radiometric data?



Clean clouds have larger droplets and start earlier precipitation



Polluted clouds have smaller droplets and grow deeper without precipitating

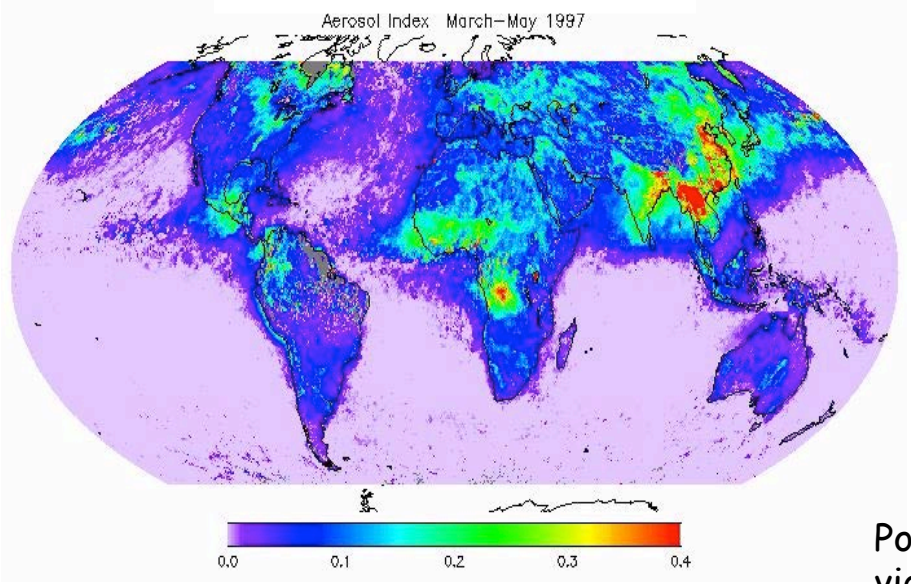
Polarimeters give <u>variance</u> to a size distribution, allowing for understanding of specific aerosol composition, not just eff. radius.

Adapted from Jiang et al. 2008

Types of polarimetric data product

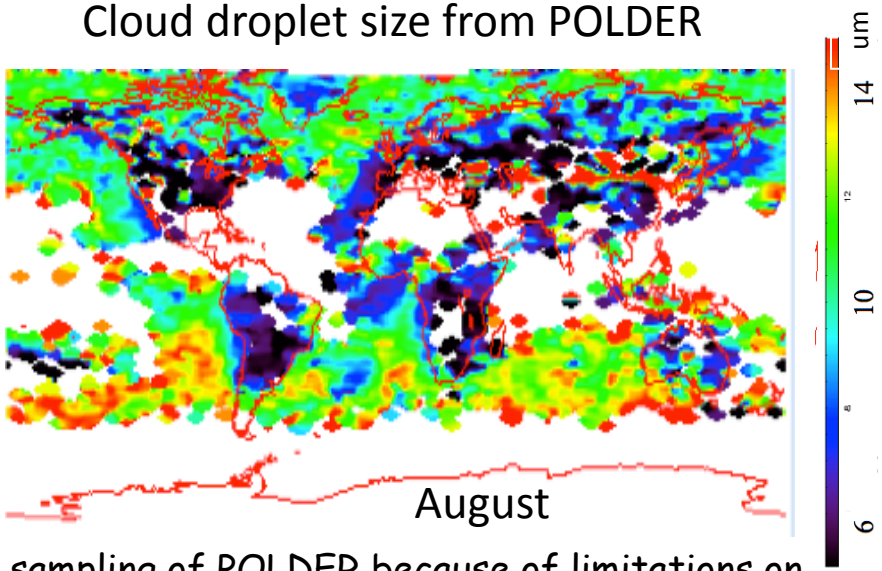
Polarization provides new information on aerosol and cloud properties and their interaction. HARP design is an advance over POLDER's filter wheel system.

Aerosol loading



Aerosol retrievals are possible with wavelengths proposed in HARP's Goal Mission

Cloud droplet size from POLDER



Poor sampling of POLDER because of limitations on viewing geometry and filter wheel design is resolved in HARP.

Hints at smaller droplets over continents, and in particular polluted areas.

Bréon FM et al, Science, 2002

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HARP Objectives

- Advance Hyperangular, Imaging Polarimetric concepts for the NASA/ACE (Aerosol, Cloud and Ecosystems) Mission
- Prove that CubeSat technology can provide science-quality multi angle imaging data paving the way for lower cost aerosol-cloud instrument developments.
- Student training.

HARP Science Goal

- Demonstrate the ability to characterize the **micro physical properties** of **aerosols and clouds** at the scale of individual moderate-sized clouds for the ultimate purpose of narrowing uncertainties in climate change.

Flight Instrument: January 2016
Full Spacecraft flight-ready: March 2016

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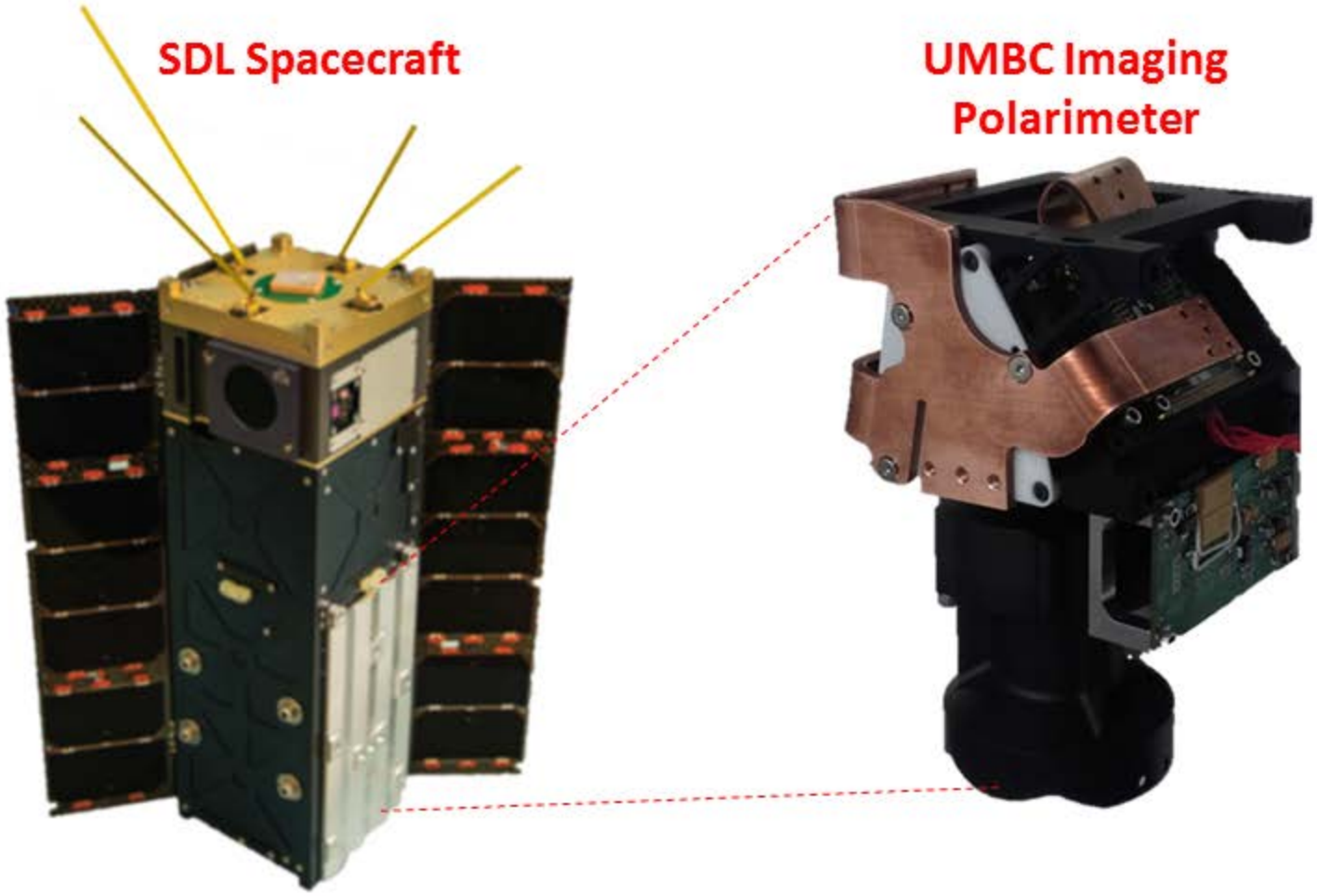
HARP

Photos of Actual Instrument & Spacecraft

SDL Spacecraft

UMBC Imaging Polarimeter



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Utah State University Research Foundation

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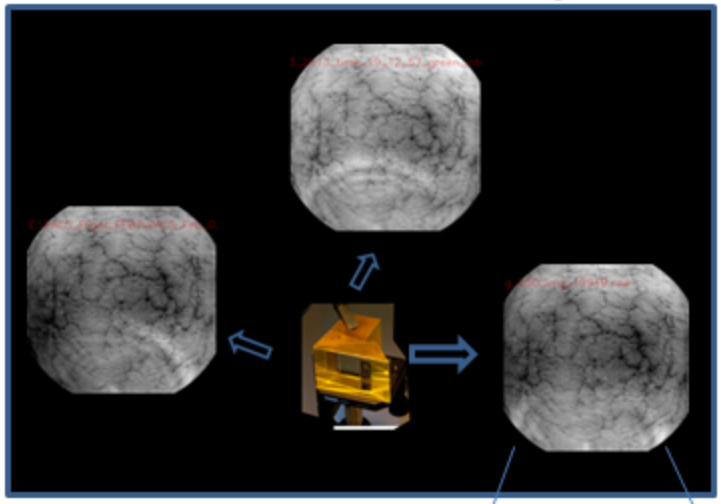
The HARP payload is a small imaging polarimeter with multiple viewing angles, four wavelengths and three polarization angles

Prism/Polarization Separation



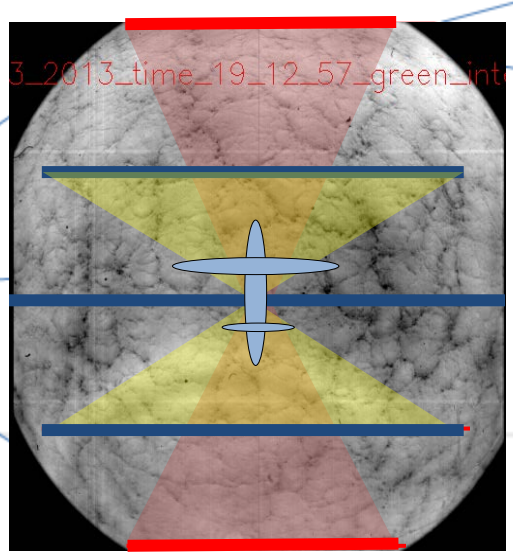
HARP Specs

- Up to 60 viewing angles at 670nm
- Up to 20 viewing angles at 440, 550, 670, 870nm
- 2.5km resolution
- 94 deg FOV X-track
- 110 deg FOV along track

Multi/Hyper Angle with multiple pushbrooms

Multi Wavelength

Stripe Filters: Angular and Wavelength Separation



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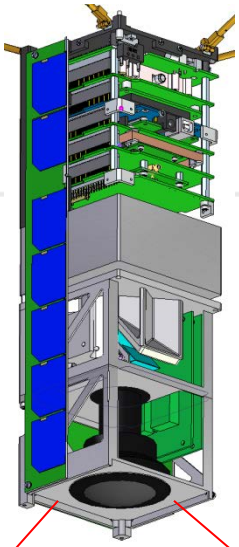
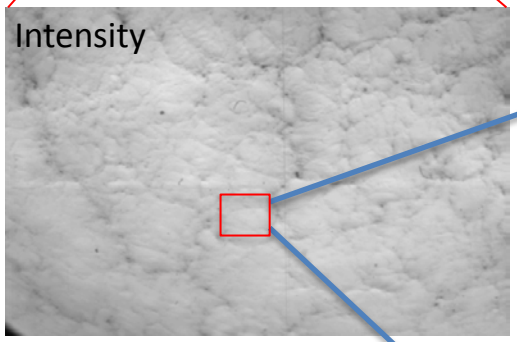
Retrieving aerosol/cld drop properties

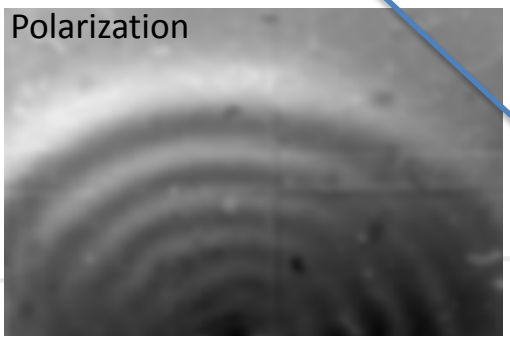


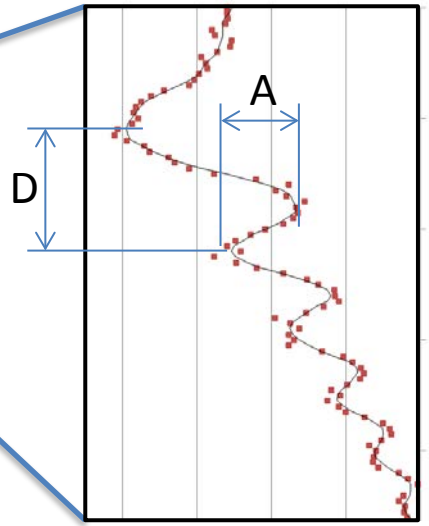
Up to 60 viewing angles of the same target from space

Example of sunglint over the East Coast of the US

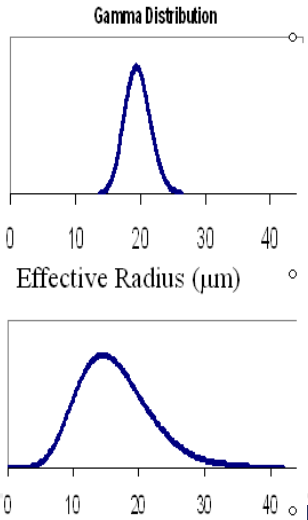
Hyper-angular capability will provide full cloudbow retrievals from small area (~4x4km)







D, A parameters allow for measurements of cloud droplet effective radius and variance



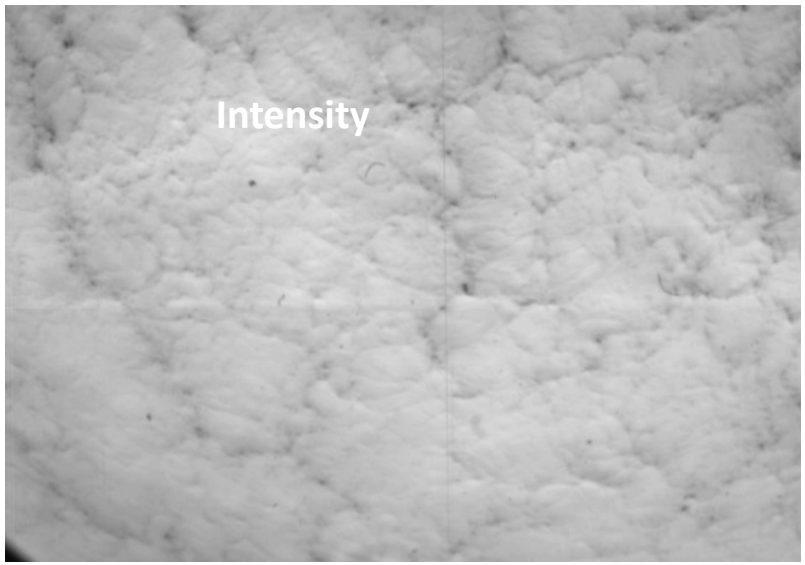
Reff = 10μm
Veff = 0.01

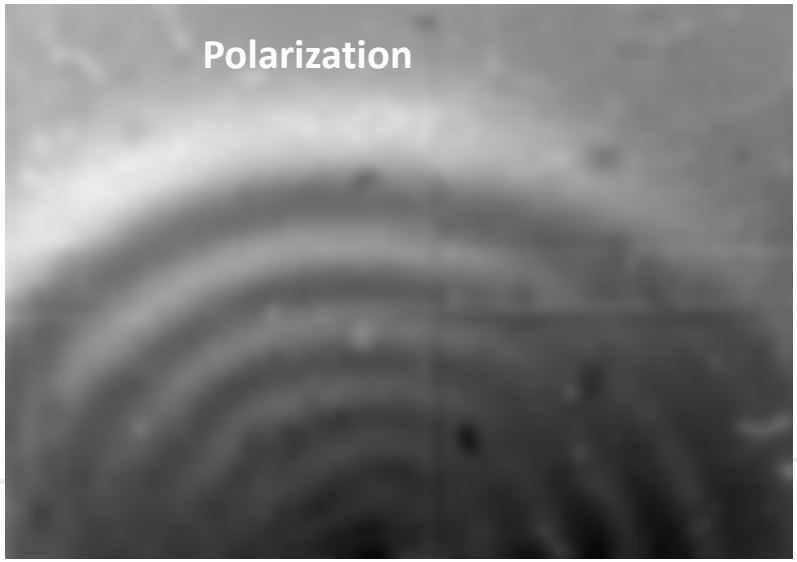
These two cases are undistinguishable from Intensity meausrements only (MODIS,VIIRS)

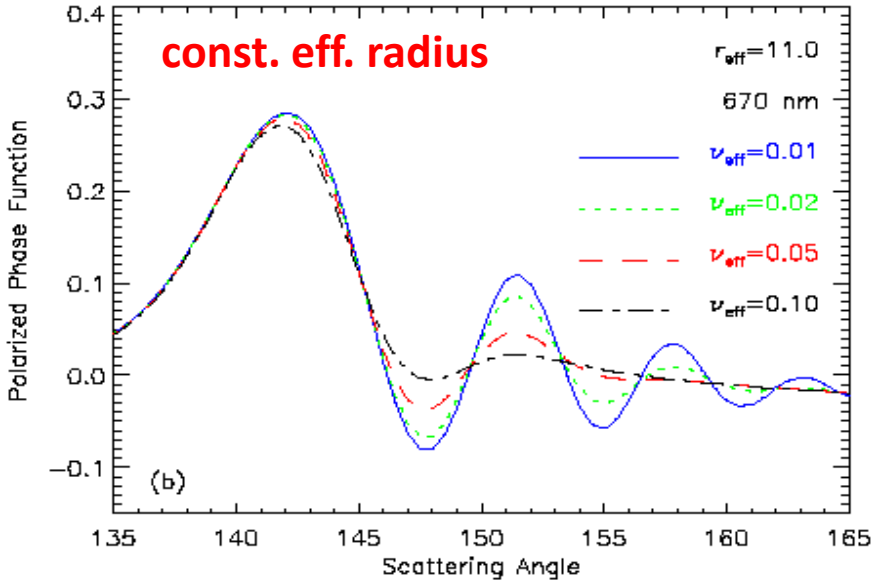
Reff = 20μm
Veff = 0.09

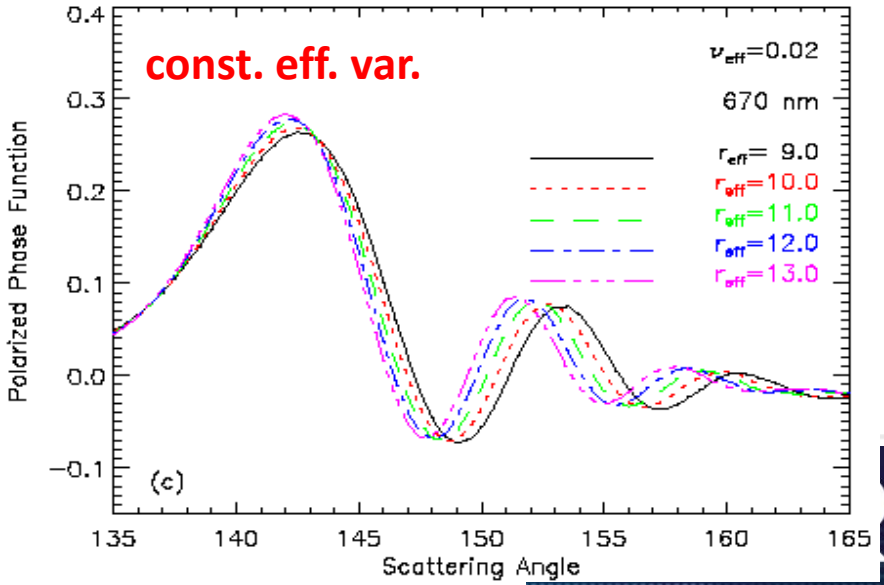
How are size distribution variances dependent on scattering angle?

Model data shown for cloud droplets (UMBC PACS VNIR – PODEX 2013)









Summary

- HARP CubeSat technology with potential for economical science-quality aerosol/cloud droplet data, student involvement
- Multi-angle capability allows for “cloudbow” polarization signature, structure parameters allow for retrieval of eff. radius/var.
- Space-borne polarimetry provides variance to size distributions, can distinguish between two scenes with same eff. radius, provide support to estimates made by MODIS/VIIRS (radiometers)
- Polarimetric remote sensing narrows uncertainty of aerosol impact on climate change

HARP

HARP

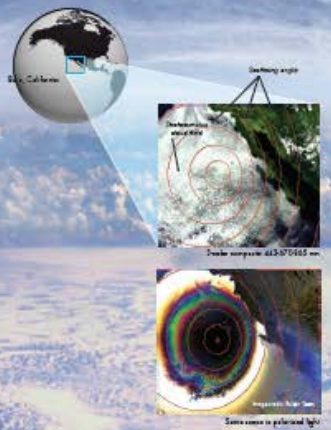
Hyper-Angular Rainbow Polarimeter

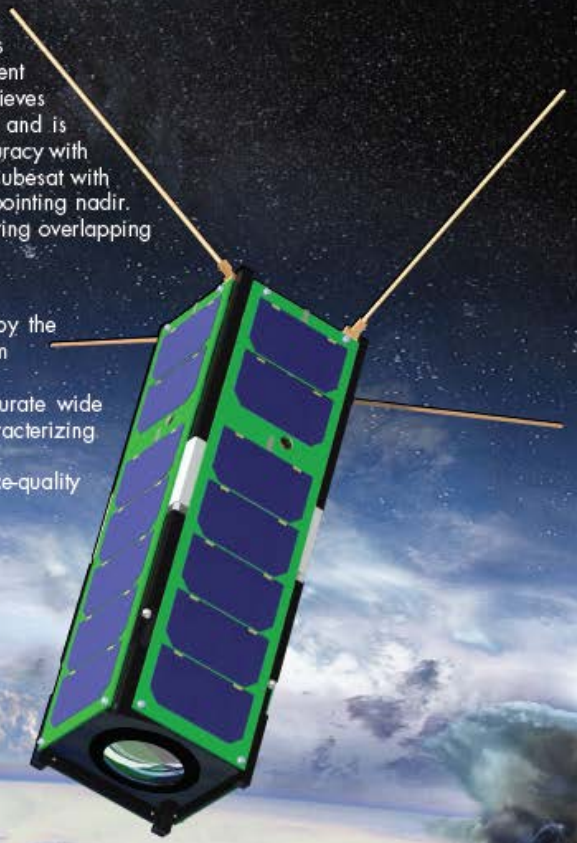
In-Space Validation of Earth Science Technologies (InVEST)

The HARP payload is a wide FOV imager that splits three spatially identical images into three independent polarizers and detector arrays. This technique achieves simultaneous imagery of three polarization states and is the key innovation to achieve high polarimetric accuracy with no moving parts. The spacecraft consists of a 3U Cubesat with 3-axis stabilization designed to keep the imager pointing nadir. The hyper-angular capability is achieved by acquiring overlapping images at very fast speeds.

OBJECTIVES:

- Space validation of new technology required by the NASA Decadal Survey Aerosol-Cloud-Ecosystem (ACE) mission
- Prove the on-flight capabilities of a highly accurate wide FOV hyper-angle imaging polarimeter for characterizing aerosol and cloud properties
- Prove that cubesat technology can provide science-quality Earth Sciences data





Thank you!!!

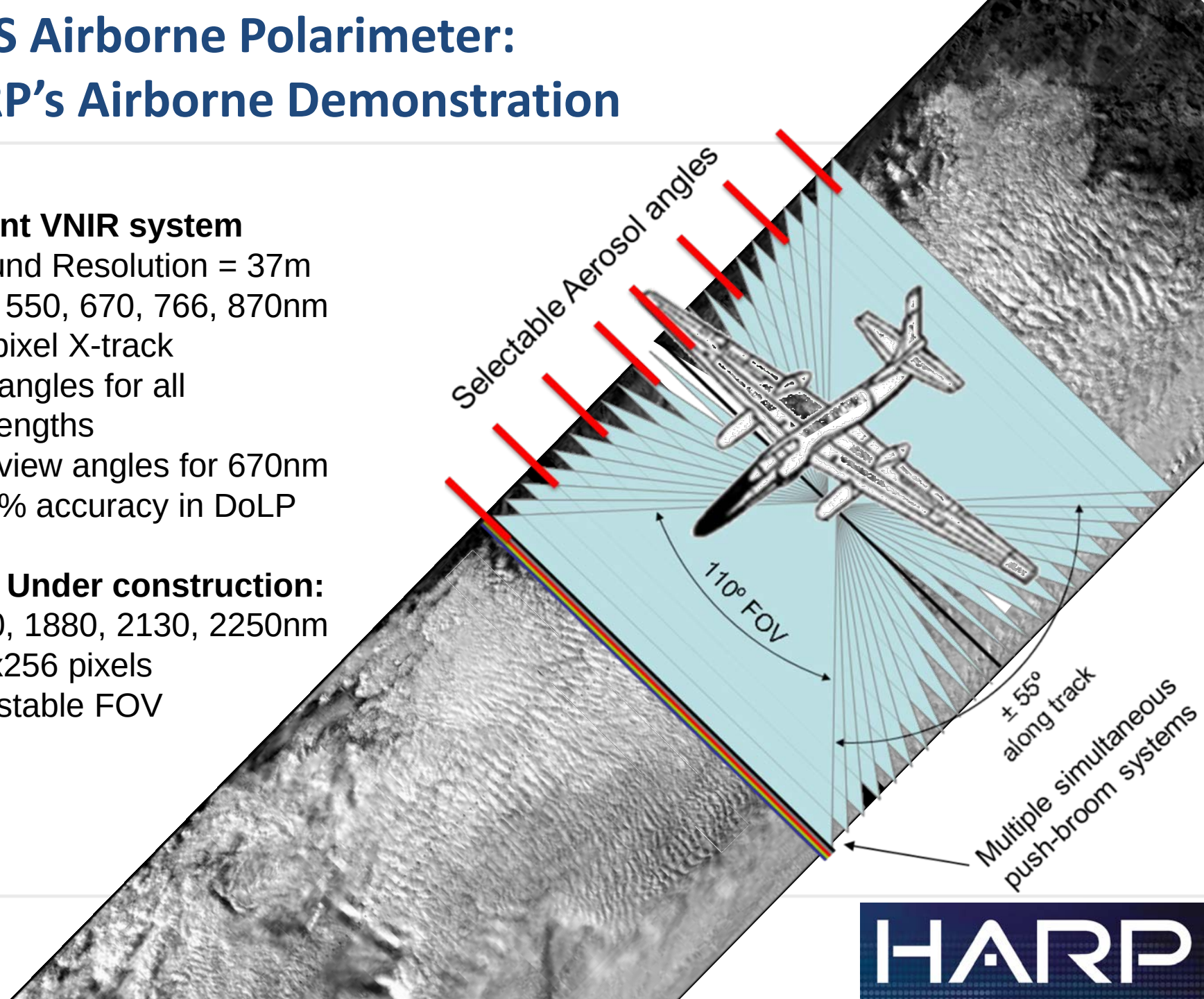
UMBC NASA STC JCET NOAA Space Dynamics Laboratory

Backup Slides

PACS Airborne Polarimeter: HARP's Airborne Demonstration

Current VNIR system
- Ground Resolution = 37m
- 470, 550, 670, 766, 870nm
- 1 K pixel X-track
- 65+ angles for all wavelengths
- 130 view angles for 670nm
- ~0.3% accuracy in DoLP

SWIR Under construction:
- 1650, 1880, 2130, 2250nm
- 320x256 pixels
- Adjustable FOV



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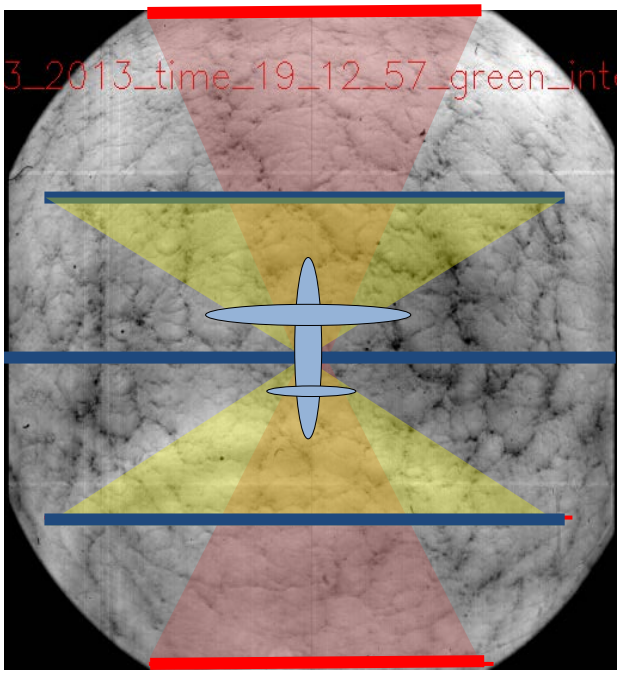
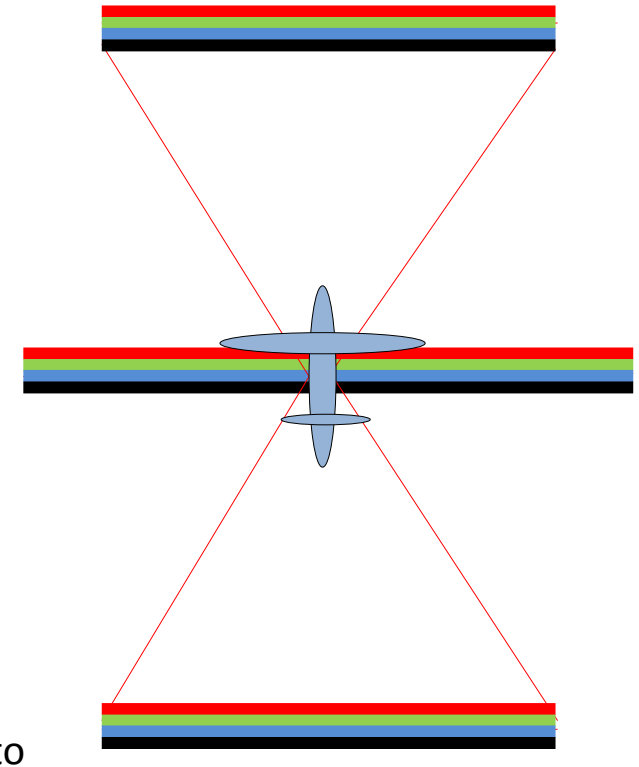
Hyperangular/Multi-wavelength approach

Multiple Push-Brooms can be selected from different row in the detector array



Stripe filters in the focal plane array can provide multiple wavelengths and viewing angles

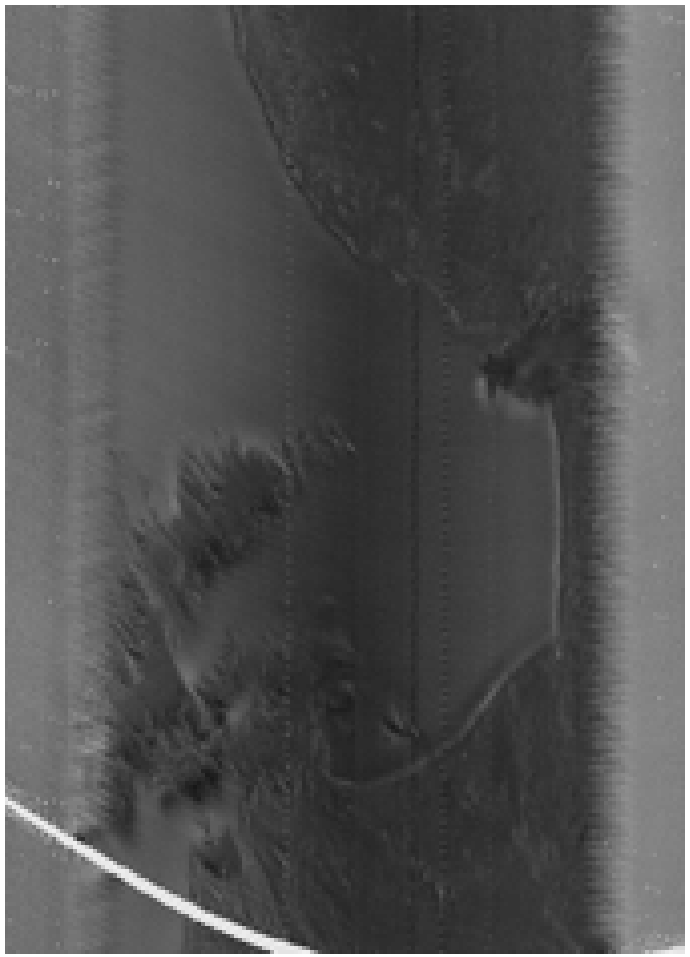


Fwd and Aft push-brooms have smaller cross track swath to compensate for longer distance to ground projection

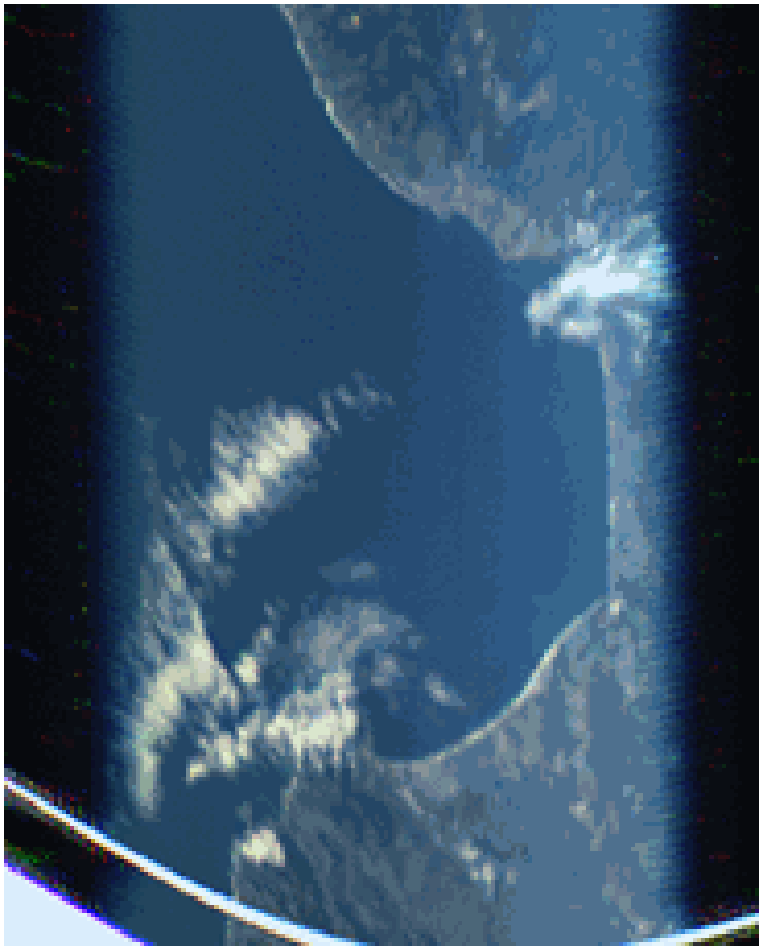
Similar technology as POLDER, MISR, GLORY (failed)

HARP

Example of hyperangular observations of sunglint from PACS-Aircraft



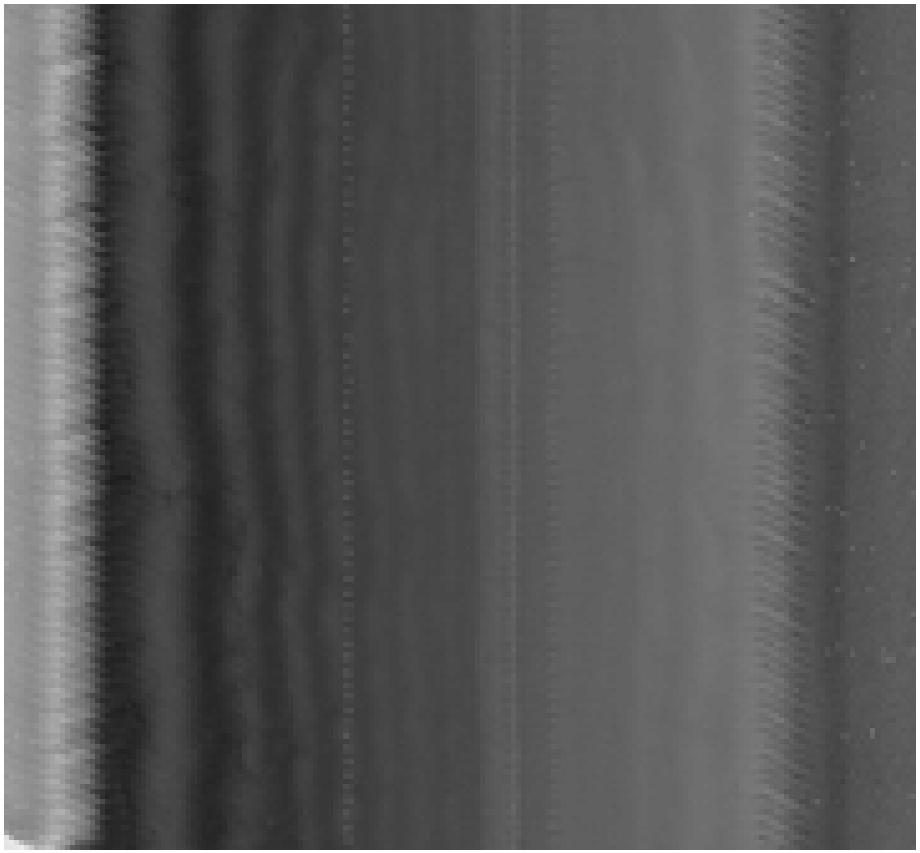
DoLP - Red



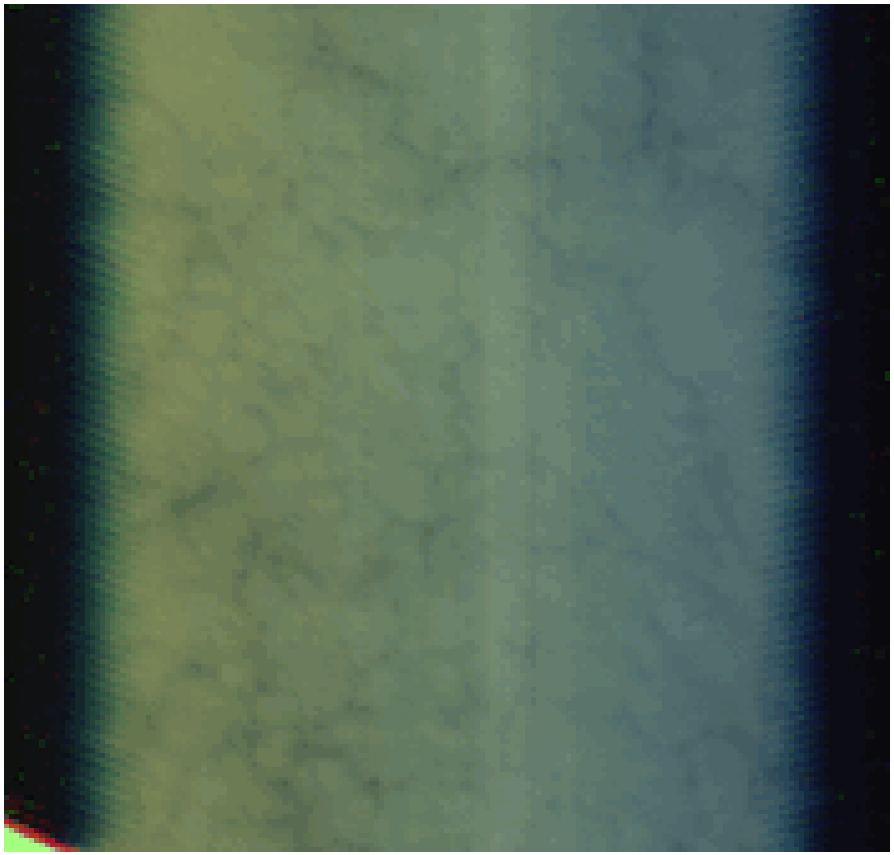
Intensity RGB

HARP

Hyperangular Movie of Cloubow from PACS-Aircraft



DoLP - Green



Intensity RGB

HARP