



# International Ocean Colour Science Meeting 2025

Advancing Global Ocean Colour Observations

## **PACE HARP2**

### **Lessons learned in the calibration of a wide FOV imaging polarimeter**

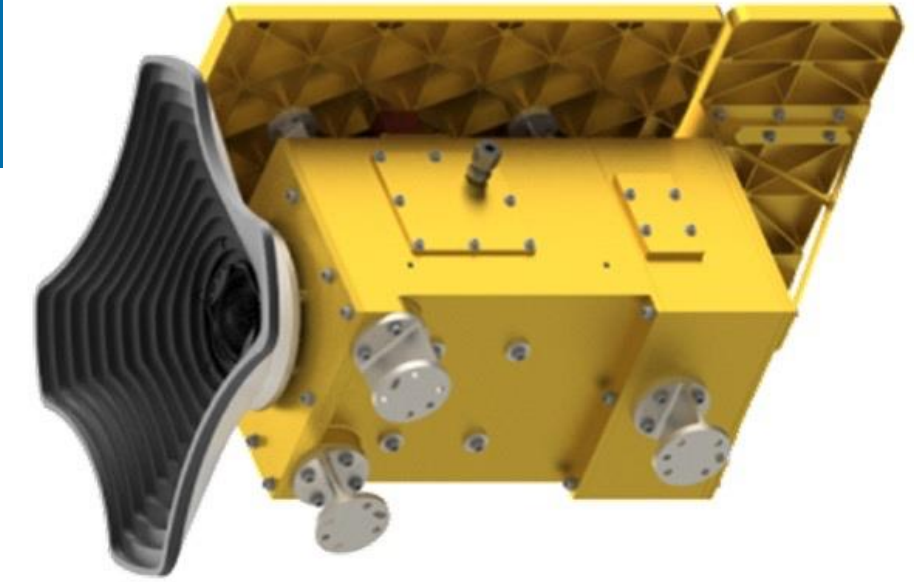
Brent McBride, Noah Sienkiewicz, Xiaoguang Xu,  
Anin Puthukkudy, Roberto Fernandez-Borda,  
Lorraine Remer, and J. Vanderlei Martins

Earth and Space Institute/UMBC  
1 December 2025



# PACE HARP2: Instrument and Specs

HARP2 is a wide FOV, multi-angle imaging polarimeter.



## Instrument details:

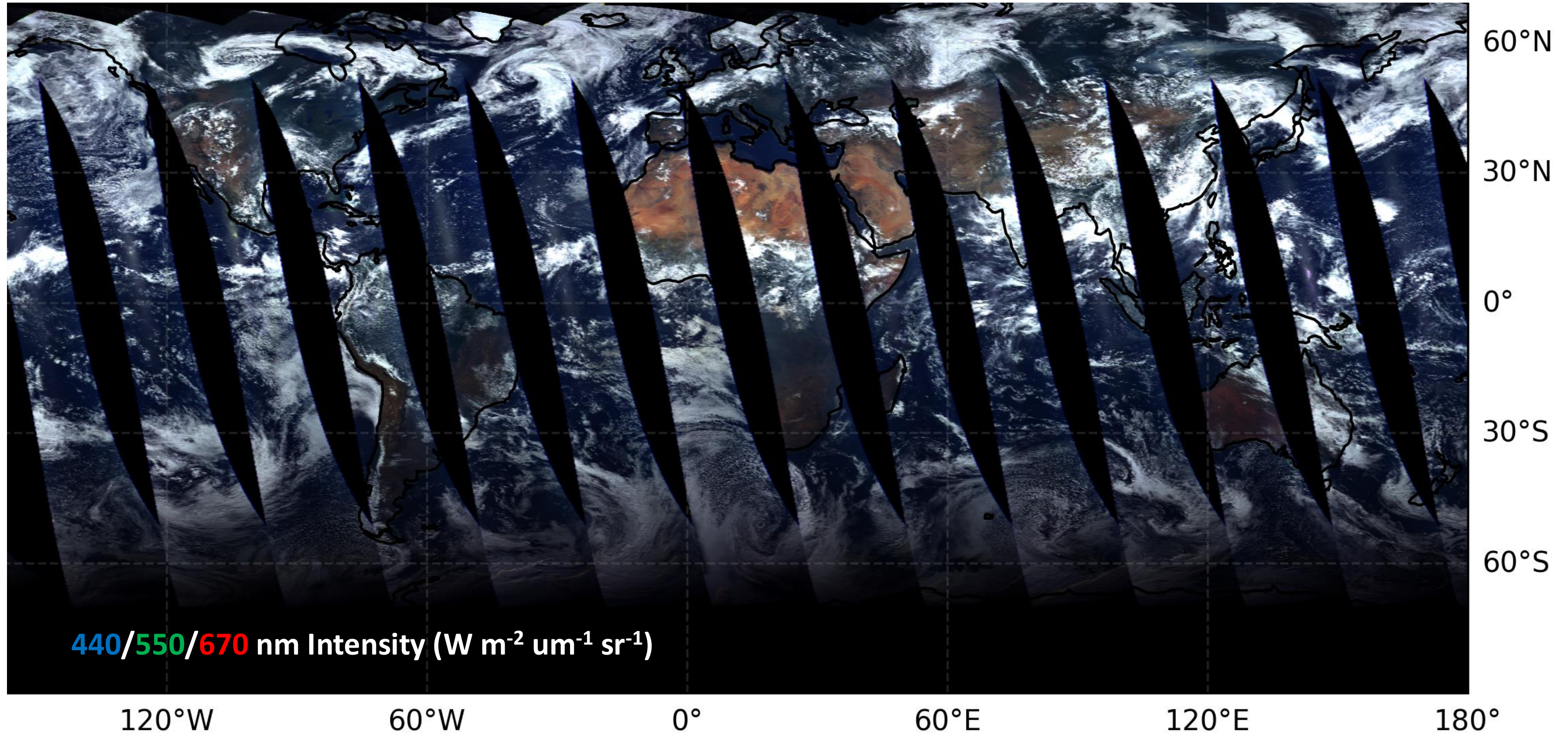
- 3 4MP CCD sensors (12 million science viable pixels!)
- 4 visible wavelengths (440/550/670/870 nm) across 90 cross-track FPA regions
- Angular coverage  $\pm 56^\circ$  ( $47^\circ$ ) along (cross) track, 1550 km swath
- Single px IFOV  $0.055^\circ$  (700 m nadir GSD, 2.5 km L1B, 5.2 km L1C)
- 3 unique polarization states (0, 45,  $90^\circ$ )

## Geophysical measurement:

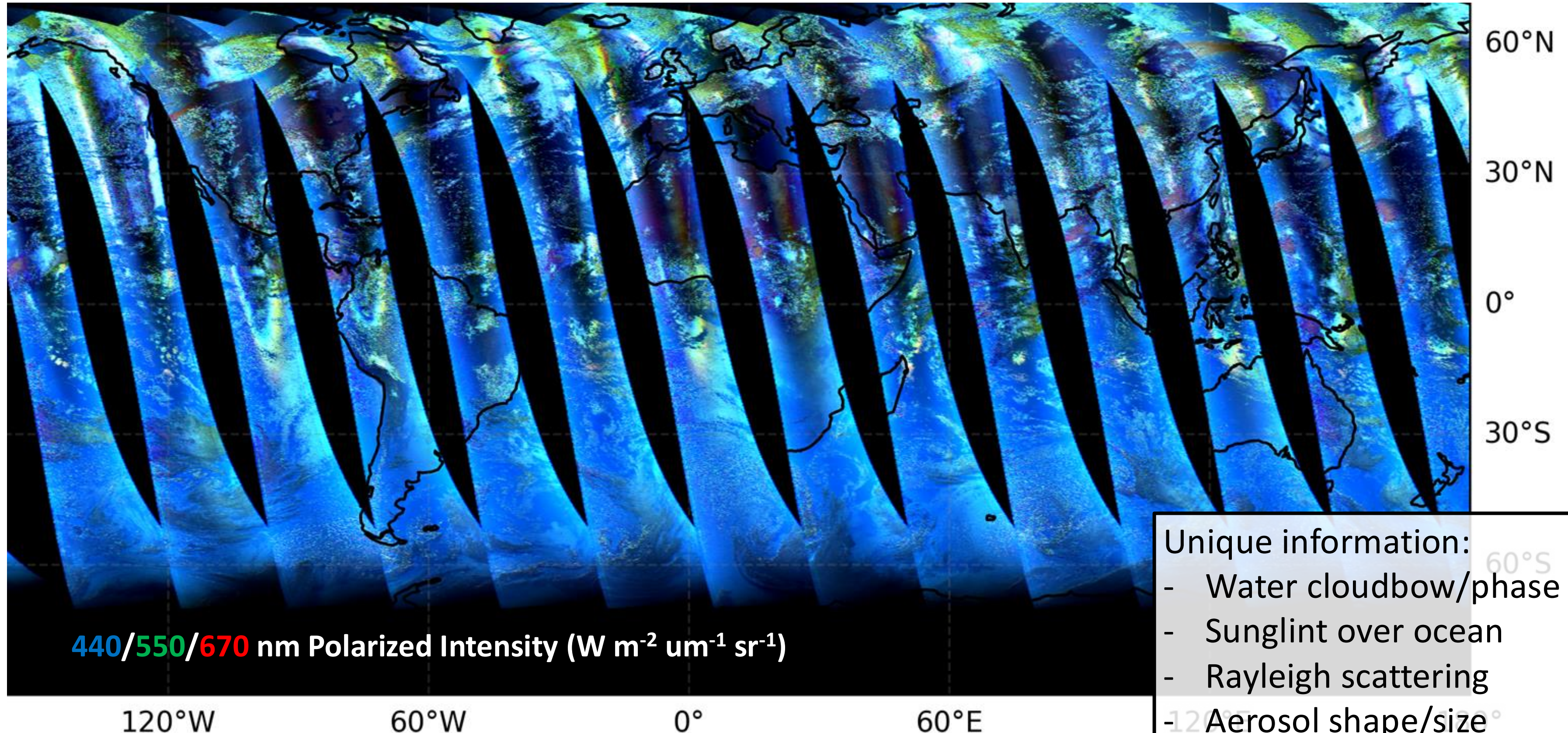
Pixel-level data product is heritage radiance (I), but *also* radiance encoded in the angle of the scattered electric field:

- excess of 0 over  $90^\circ$  (Q)
- excess of 45 over  $135^\circ$  (U)
- and derived: degree and angle of linear polarization (DOLP/AOLP)

# PACE HARP2: Global Data, Radiance RGB Composite (Nadir)



# PACE HARP2: Global Data, Polarized RGB Composite (Nadir)



- Unique information:
- Water cloudbow/phase
  - Sunlint over ocean
  - Rayleigh scattering
  - Aerosol shape/size
  - Ocean color?

## Pre-launch quantitative (\*in conjunction with GSFC)

- Detector level: noise floor, dark current, non-linearity, flatfield, co-alignment
- Optical level: ellipsometric modeling (Zemax), sub-component testing
- System level: geometric, polarization sensitivity, SRF\*, absolute radiance
- Characterization\*: thermal vac, EMI/EMC, vibration, boresight
- C&DH @ Observatory-level\*: data compression/rates, data volume/duty cycle

## On-orbit cal/val

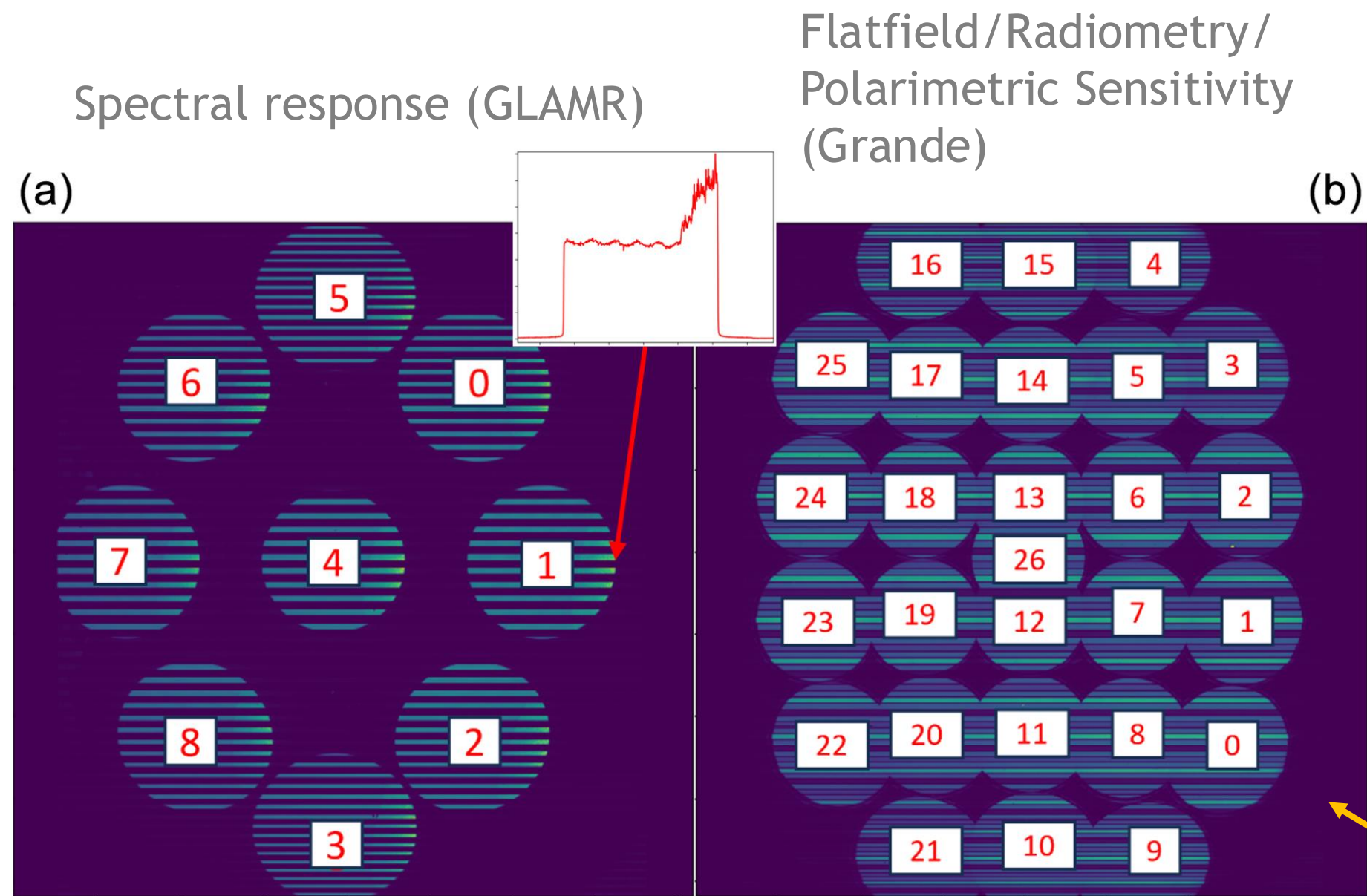
- CONOPS for DITL, special cals (alignment, Earth-view flatfield, limb)
- Darks (full/sci mode, 1/orbit ea.)
- Solar calibration (1/week)
- Lunar calibration (3/month)
- Global PICS: North Africa crowd, Dome C, Salar de Unuyi, Lake Titicaca, +
- Intercomparisons: PACE OCI/SPEXone, PACE-PAX+, MODIS, etc.
- Geometric cal/val: vs. Landsat chips

+ daily automated, internal trending and monitoring across all performance metrics

# Lesson 1: Pre-launch full FOV cal is necessary.

Sienkiewicz et al. (2024)

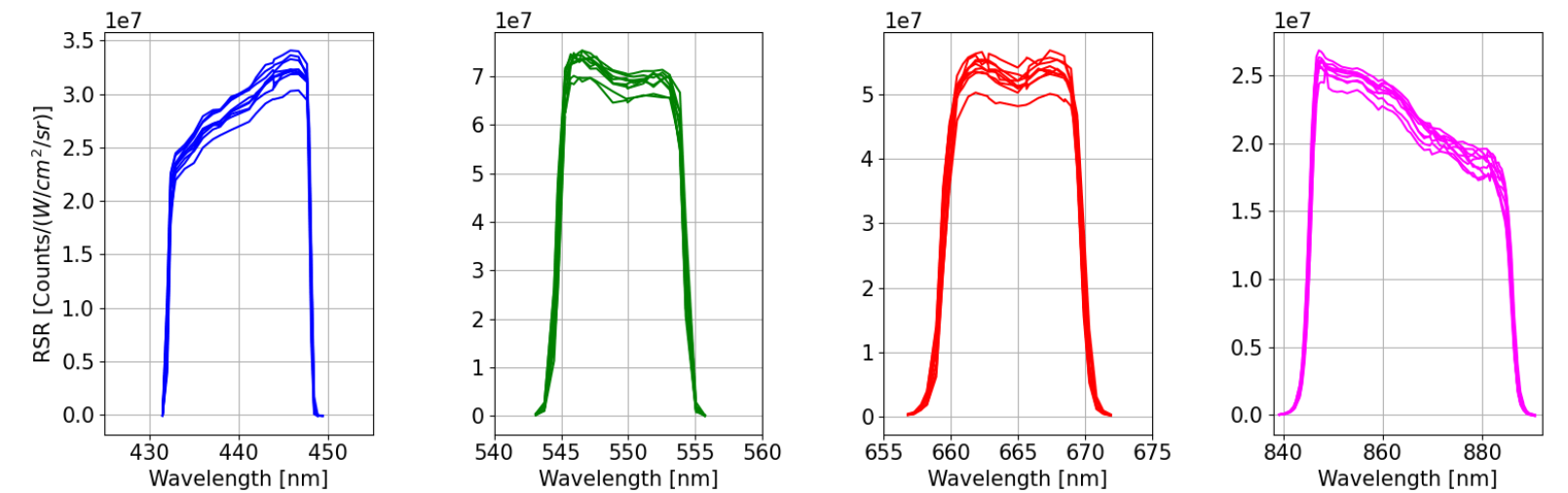
Instruments like HARP2 may degrade non-uniformly at different AOI. A full spectral and polarimetric baseline is a good defense.



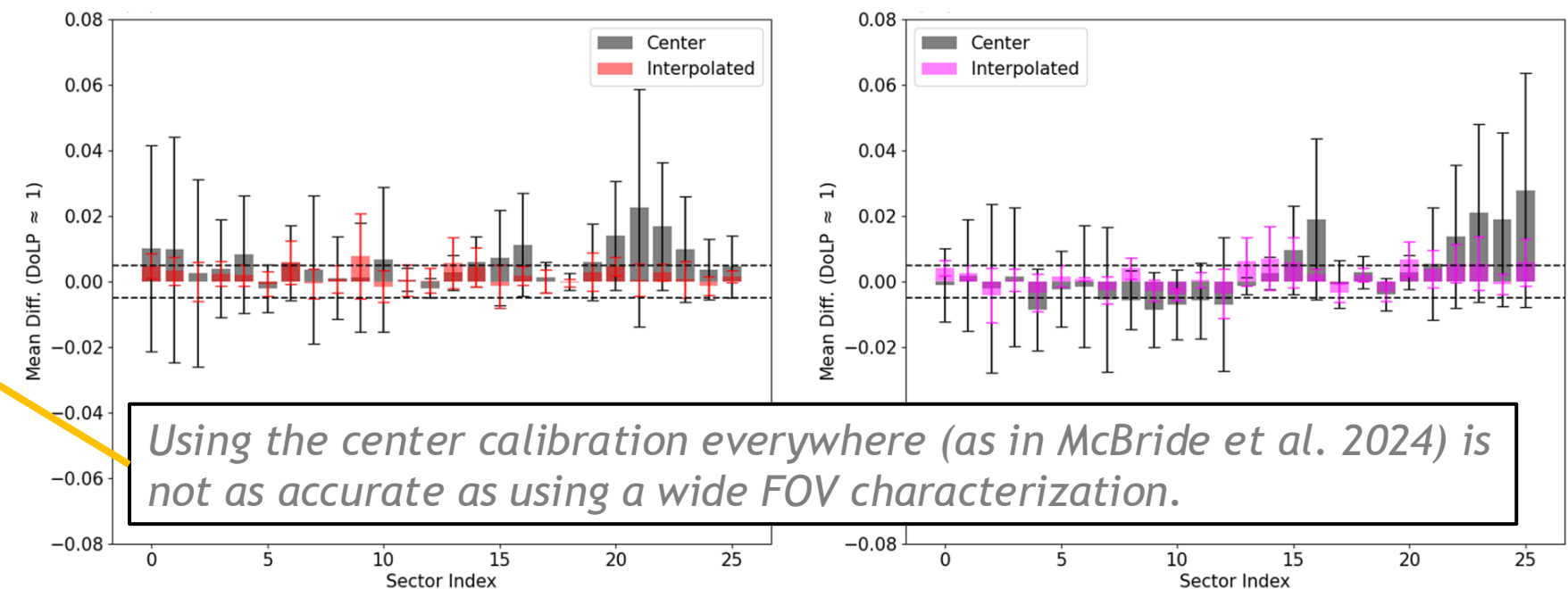
HARP2 CCD image (2048x2048)  
Numbers are FOV sectors.

Pre-launch cal @ NASA GSFC  
2022-2023

We learned that HARP2 SRF has ~no FOV dependence.



Polarization is impacted by barrel distortion!

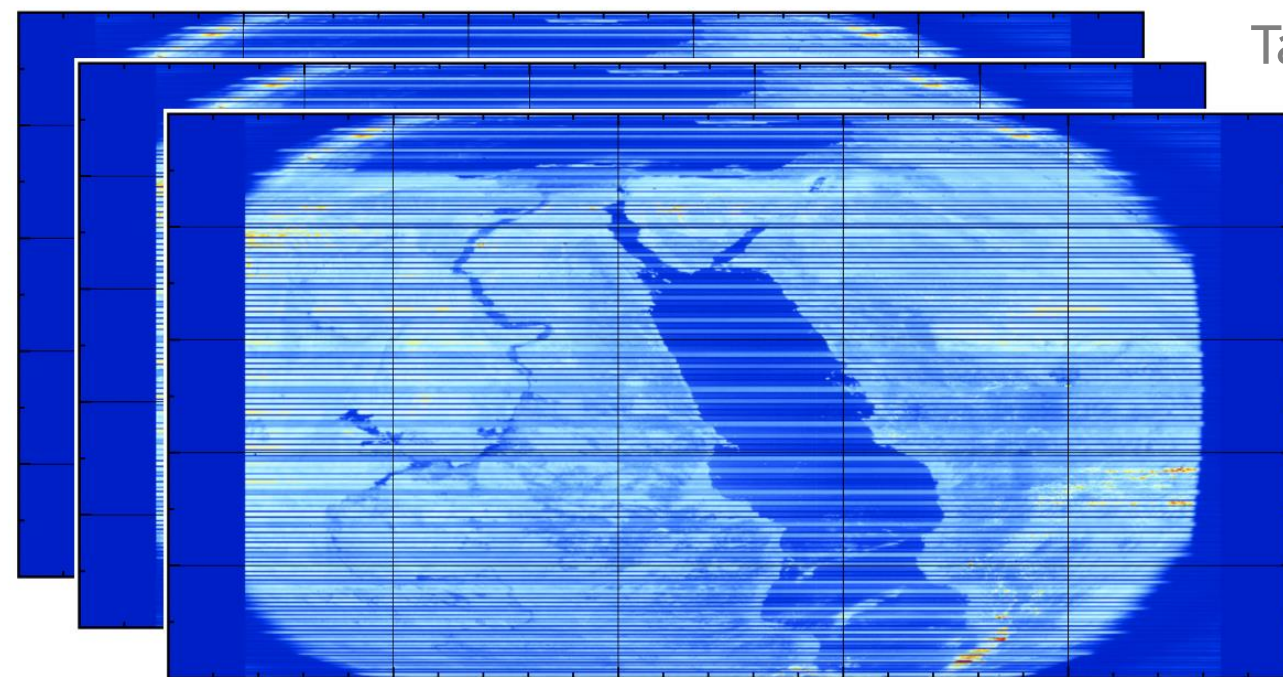


Using the center calibration everywhere (as in McBride et al. 2024) is not as accurate as using a wide FOV characterization.

# Lesson 2: Leverage a variety of Earth view cal.

HARP2 CONOPS team and PACE FOT determined the value and potential need for special cals prior to launch:

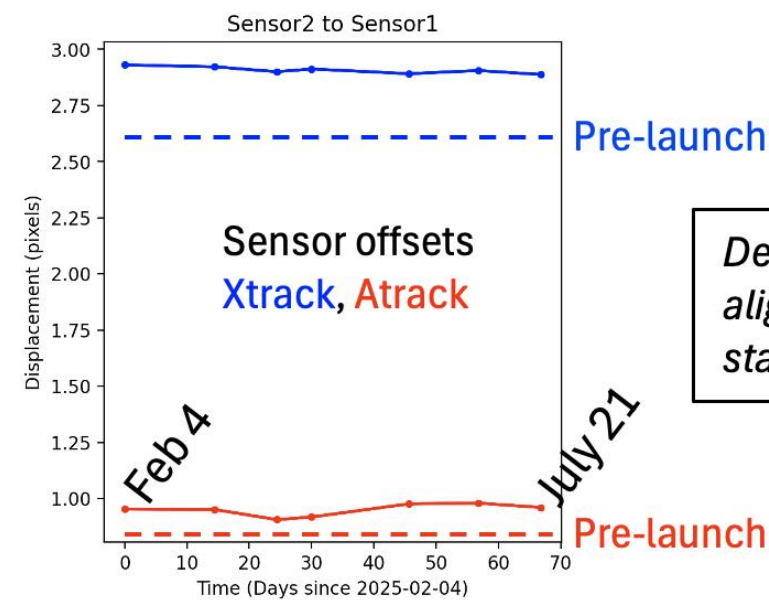
- “Earth-view flatfield”: full FOV P2P relative response without risk of solarization + defect detection
- Detector co-alignment: full-size captures over feature-rich targets
- Limb views: stray light characterization
- Lunar cal: a clear-aperture degradation check + low DOLP val w/ phase



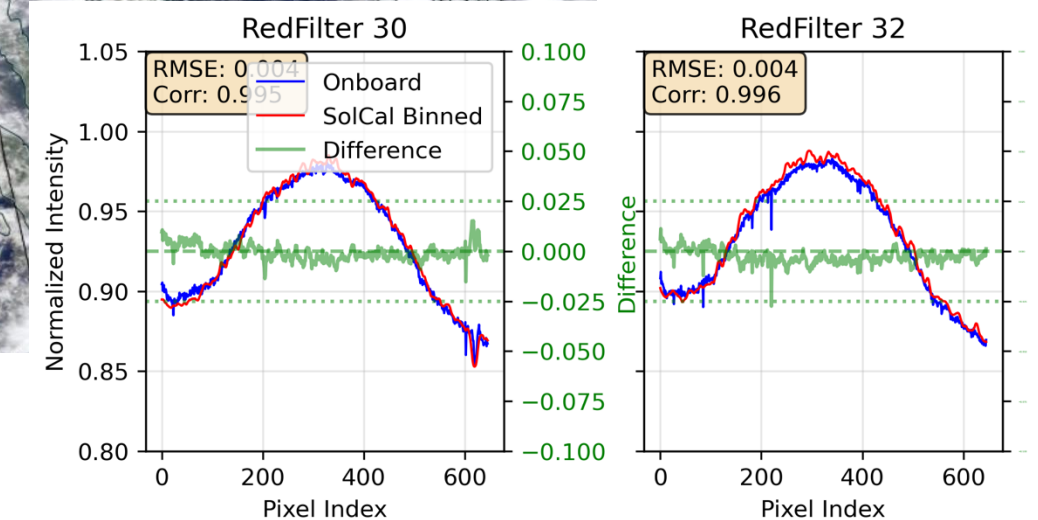
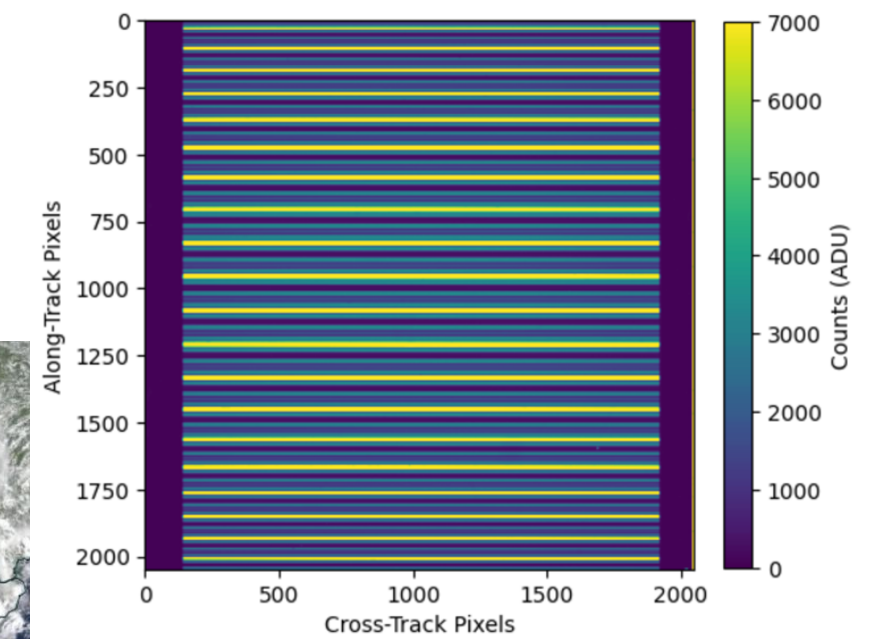
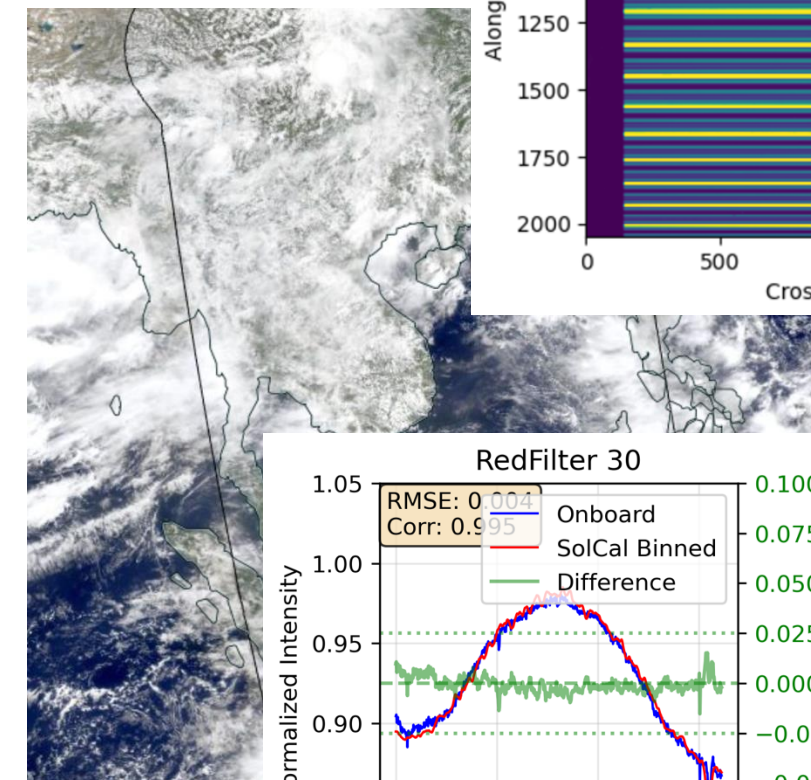
HARP2 CCD imagery (2048x2048)

Stable pixel-level detector co-alignment is critical to prevent false polarization. (1/month)

Target: Red Sea (35N, 20E)



Target: Indonesia (4N, 110E)



Solar cal-like configuration done while in Earth view compares well to solar cal. (1/month)

HARP2 and SPEXone are:

- the first two co-located EO polarimeters in orbit with public data,
- contributed to PACE (“do-no-harm”) with no levied requirements, and
- *expected* to achieve 0.5% DOLP accuracy over the PACE mission to enhance PACE goals.

But neither HARP2 or SPEXone have on-board polarization calibrators, and current vicarious polarimetric calibration knowledge is limited.

Established techniques from POLDER era: Rayleigh scattering over open ocean, sunglint DCC/ice crystal zero point validation, VRT over traditional PICS - **all require significant srf/atm/property assumptions.**

We propose the disk-integrated Moon as the most ideal PICS for polarimeters:

- DOLP with phase is well-known, and LEO instruments are outside the atmosphere
- Inversion angle phase is unpolarized (~23-25 deg) for stable and regular low DOLP val
- Ongoing study with HARP2 to define cadence and viability (McBride et al. 2026, in prep)



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**Thank you!**

Questions and Answers