HARP: Hyper-Angular Rainbow Polarimeter CubeSat

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Payload Design Leads: Roberto Fernandez-Borda[1], Dominik Cieslak[1]

Spacecraft team: Tim Neilsen[3], Ryan Martineau[3], Cameron Weston[3]

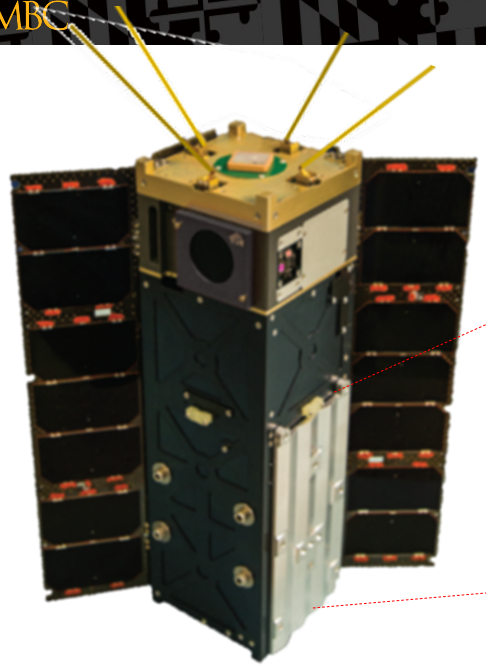
1- UMBC Earth and Space Institute and JCET-UMBC/NASA GSFC
2- University of Sao Paulo
3- Space Dynamics Lab (SDL)

June 3rd, 2021

InVEST-12

HARP CubeSat Technologies

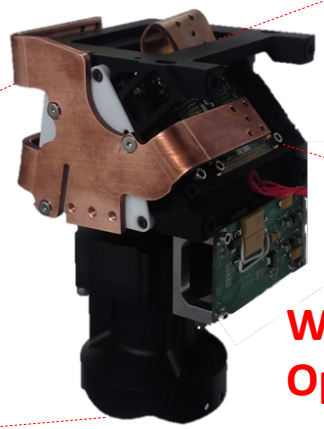
NASA-ESTO InVEST Program



SDL Spacecraft

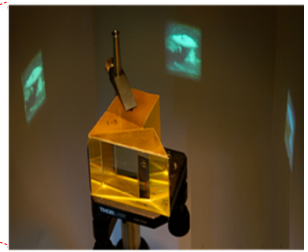
Launched: Nov 2nd, 2019
ISS Deployment: Feb 19th, 2020
First light: April 15th, 2020

UMBC Sensor



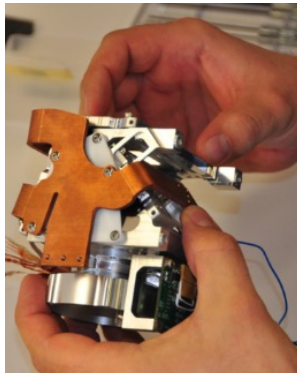
Wide FOV Optics

HARP Prism

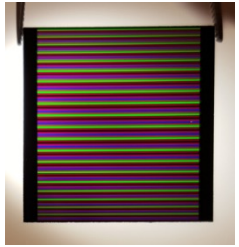


I, Q, U

HARP VNIR Telescope



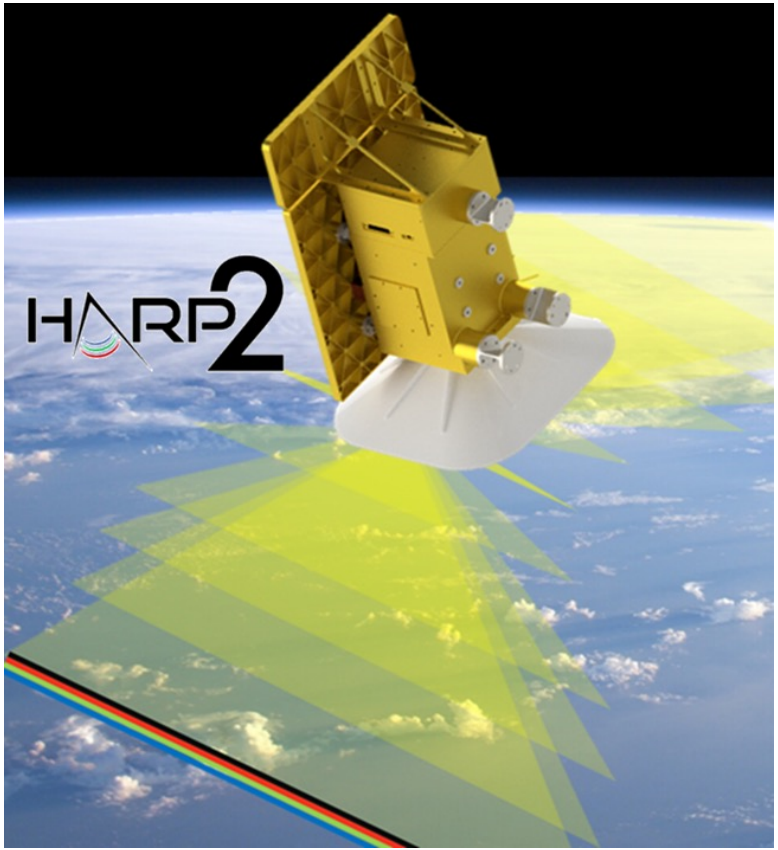
3U size

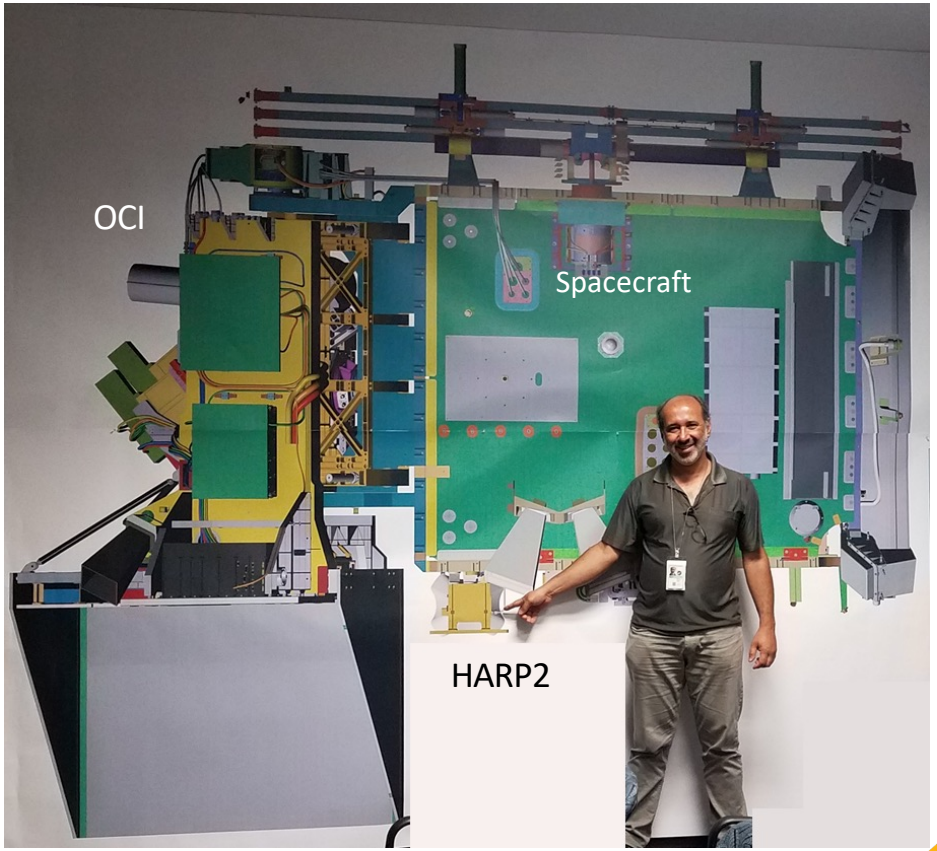


HARP Stripe Filter

Camera and FPGA Electronics

HARP2 – being built for PACE Spacecraft

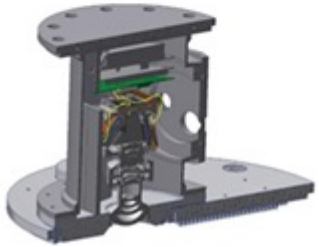




The HARP Polarimeter Family

Concepts Under Development

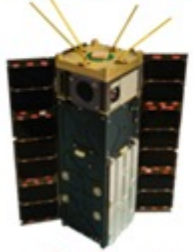
a) Air HARP



Airborne System

- Frequent Ground calibration
- ~40m resolution
- Potential for HARP2 Cal/Val
- Has flown two successful flight campaigns

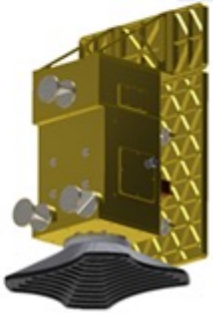
b) HARP CubeSat



Launched to ISS
Nov 2nd, 2019
Deployment
Feb 19th, 2020
First light
April 15th, 2020

- 4 km resolution
- Limited data set: 1 snapshot/day
- No calibrator onboard/only vicarious

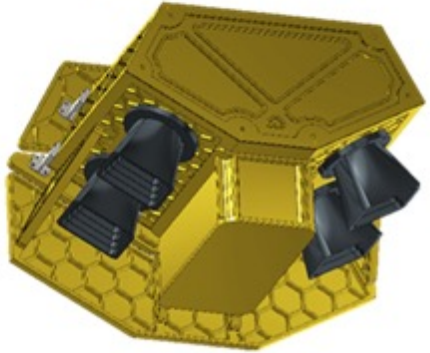
c) HARP2 PACE



Launch: 2022-23

- Improved SNR
- Better calibration features
- ~3 km resolution
- Global coverage in 2 days

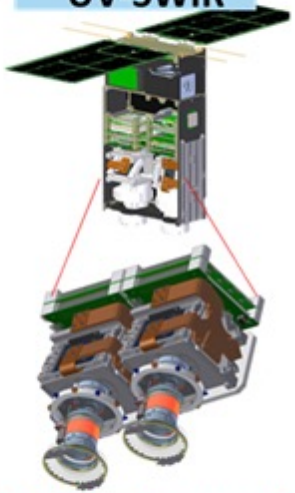
d) Mega-HARP UV-SWIR



New Concept

- Extended Wavelength range (UV to SWIR wavelengths)
- Improved SNR
- Full calibration features
- ~0.5km resolution

e) ASTEC 6U UV-SWIR



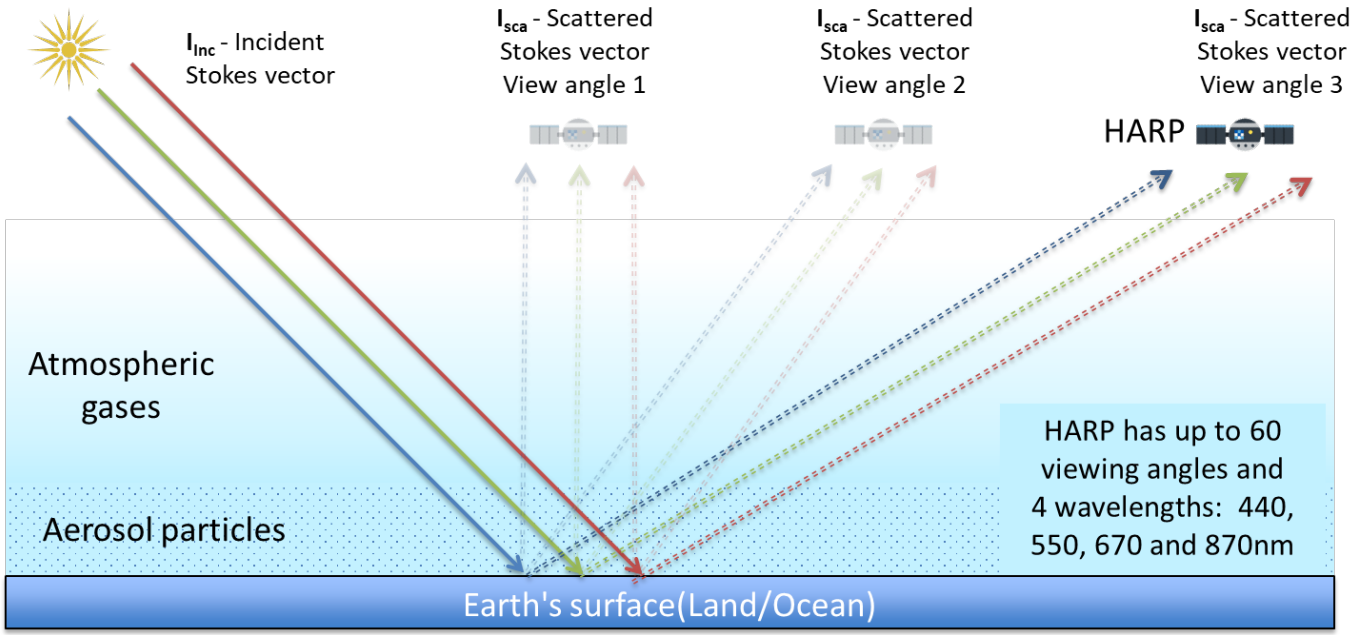
ASTEC Polarimeter concept for SmallSat constellation

- UV-SWIR polarimeter
- Wide FOV/Global coverage

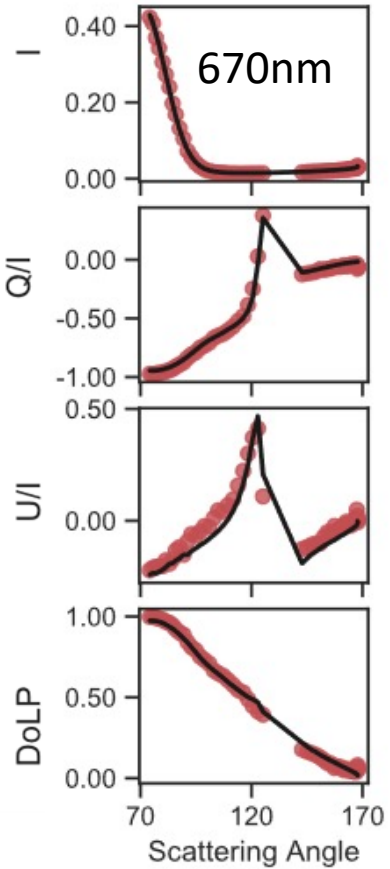
Current Projects

HARP observations

HARP measures $(I, Q, U)_{scatt}$ for every wavelength and every pixel in up to 60 different viewing angles



Observation and model

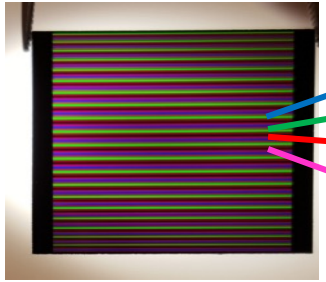


HARP Unique sampling strategy

Push-broom measurements

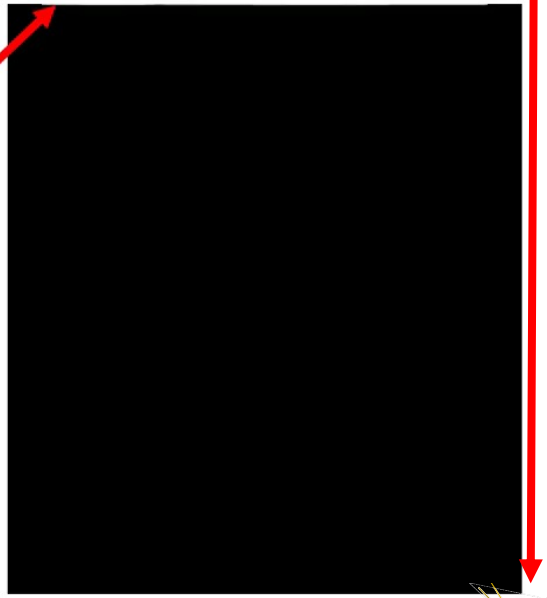
HARP

HARP Spectral "Stripe Filter"



Backward viewing angle

Red nadir pushbroom

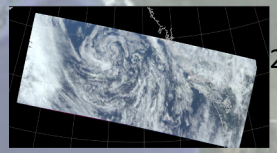


HARP Spectral Channels:

- $440\ nm$
- $550\ nm$
- $670\ nm$
- $870\ nm$

Similar sampling can be done at different wavelengths or different lines in the detector (viewing angles)

HARP CubeSat Captures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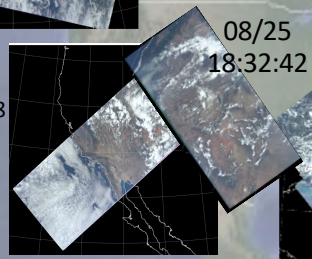
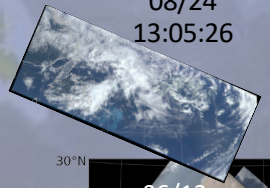
23:28:55


07/27
23:12:48

08/25
18:32:42

07/28
20:52:52

06/23
18:42:22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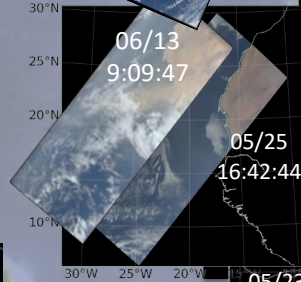
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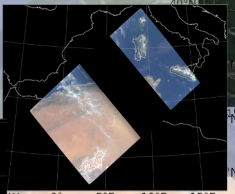
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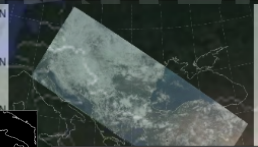
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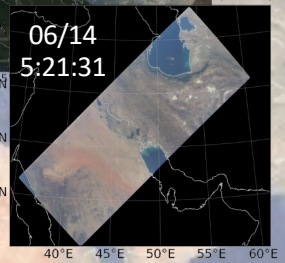
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05/25
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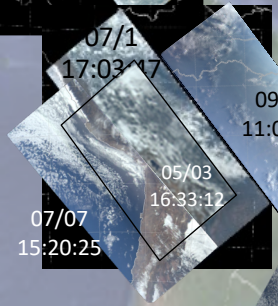
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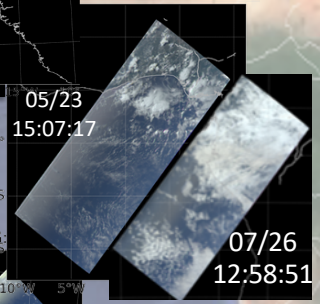
09/13
11:01:31

05/03
16:33:12

07/07
15:20:25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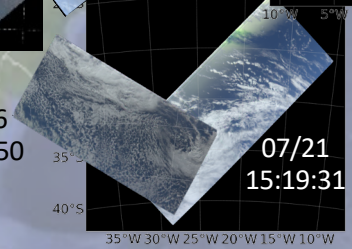
15:07:17

07/26
12:58:51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07/21
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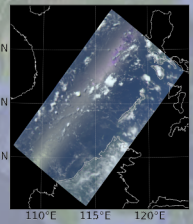
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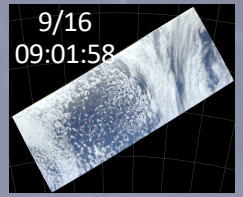
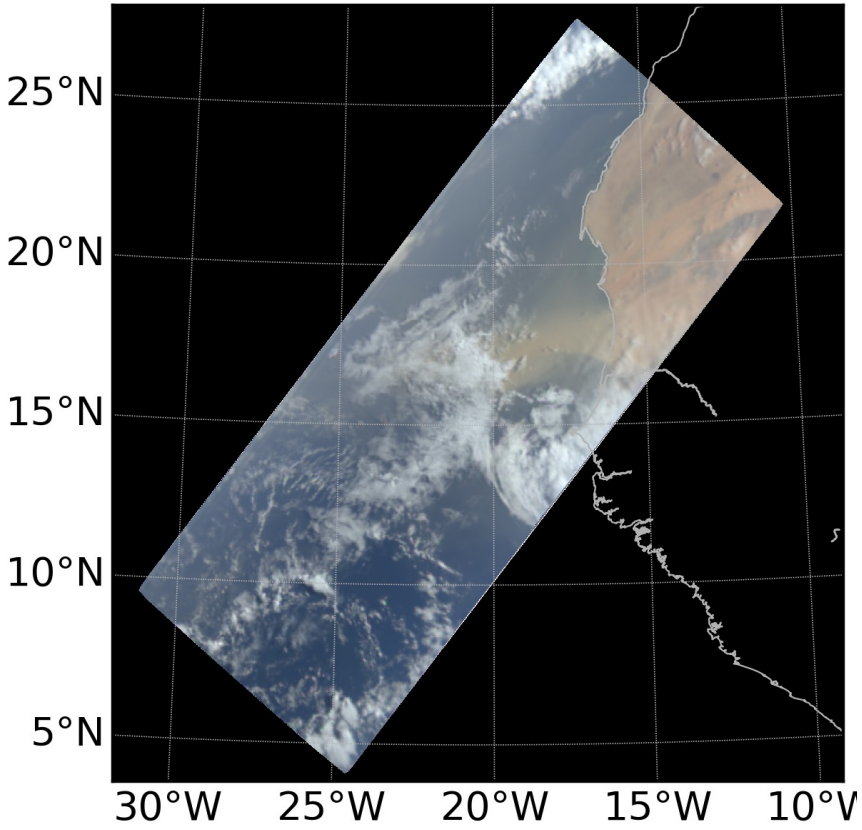
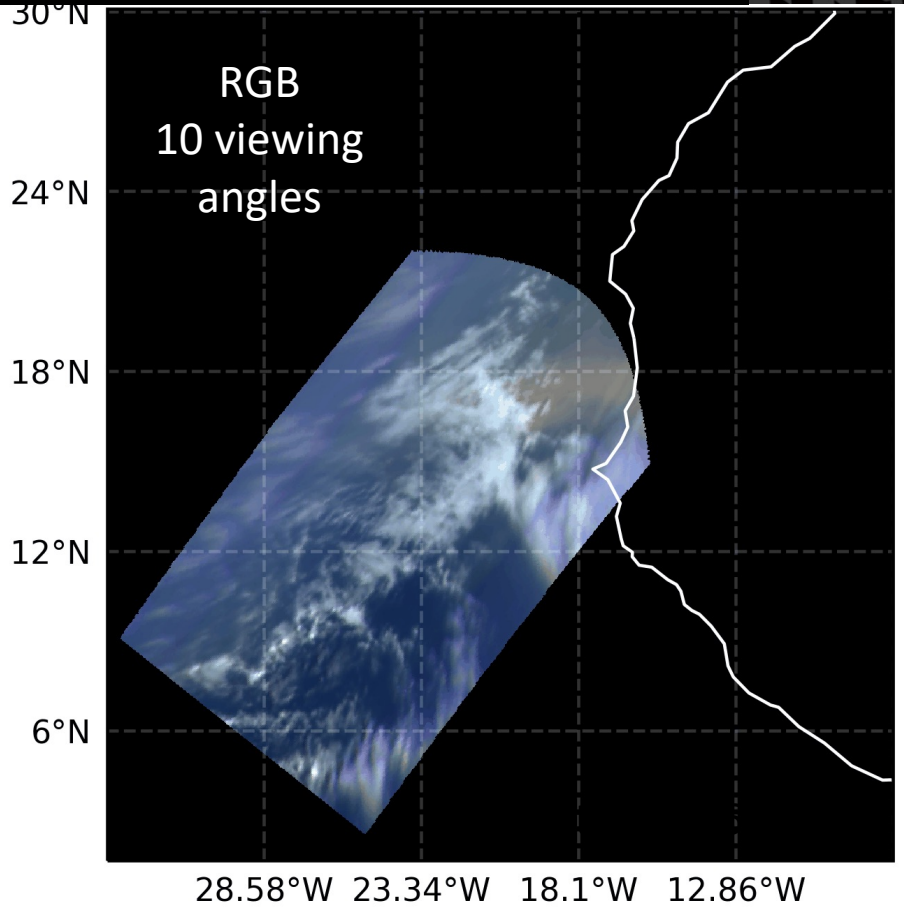

9/16
09:01:58

Not all HARP images are included here.

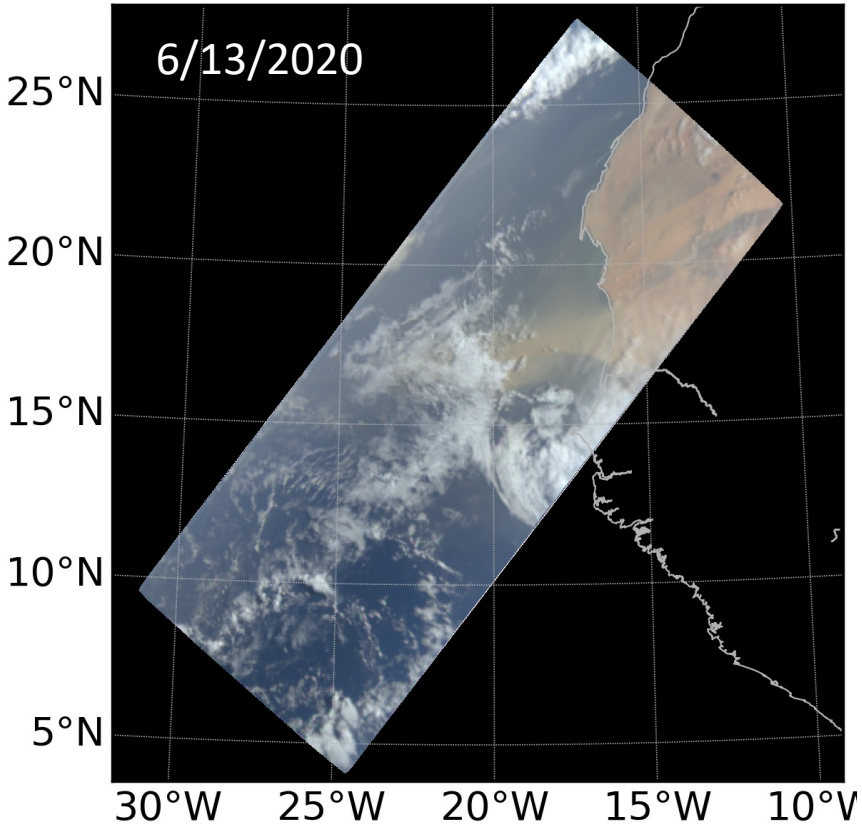
Wallops ground station has been down since late September 2020. We are anticipating more captures once it resumes.

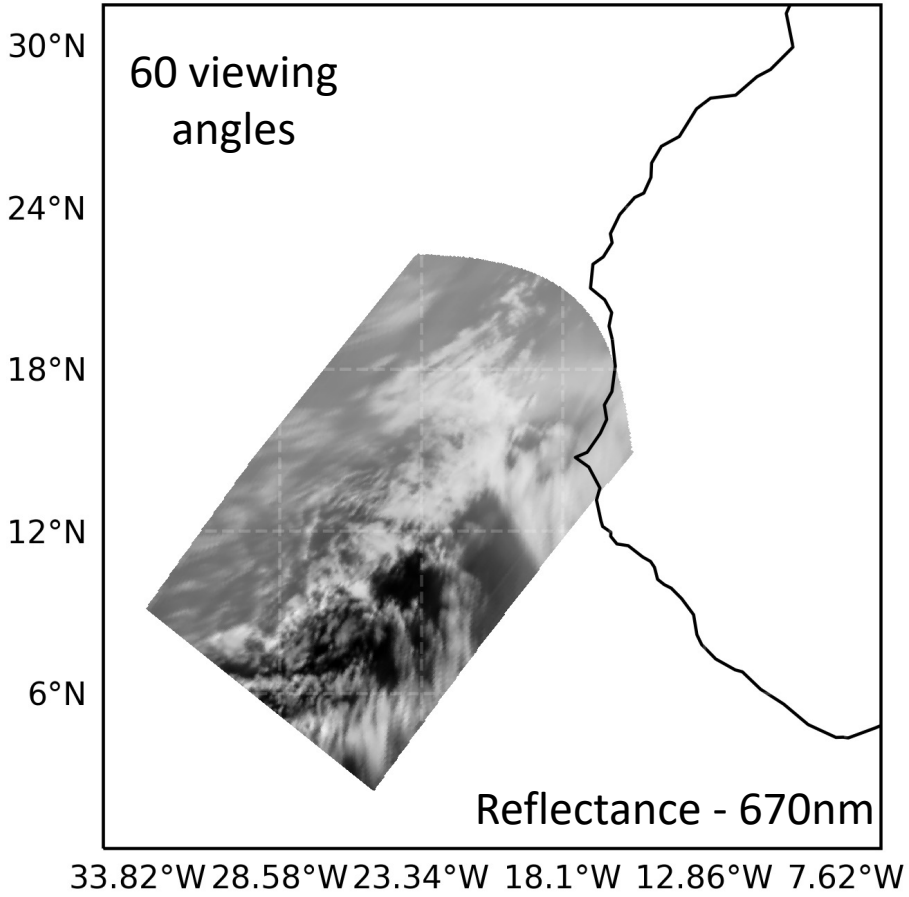
Multi-Angle Intensity of Saharan Dust





Multi-Angle Intensity of Saharan Dust



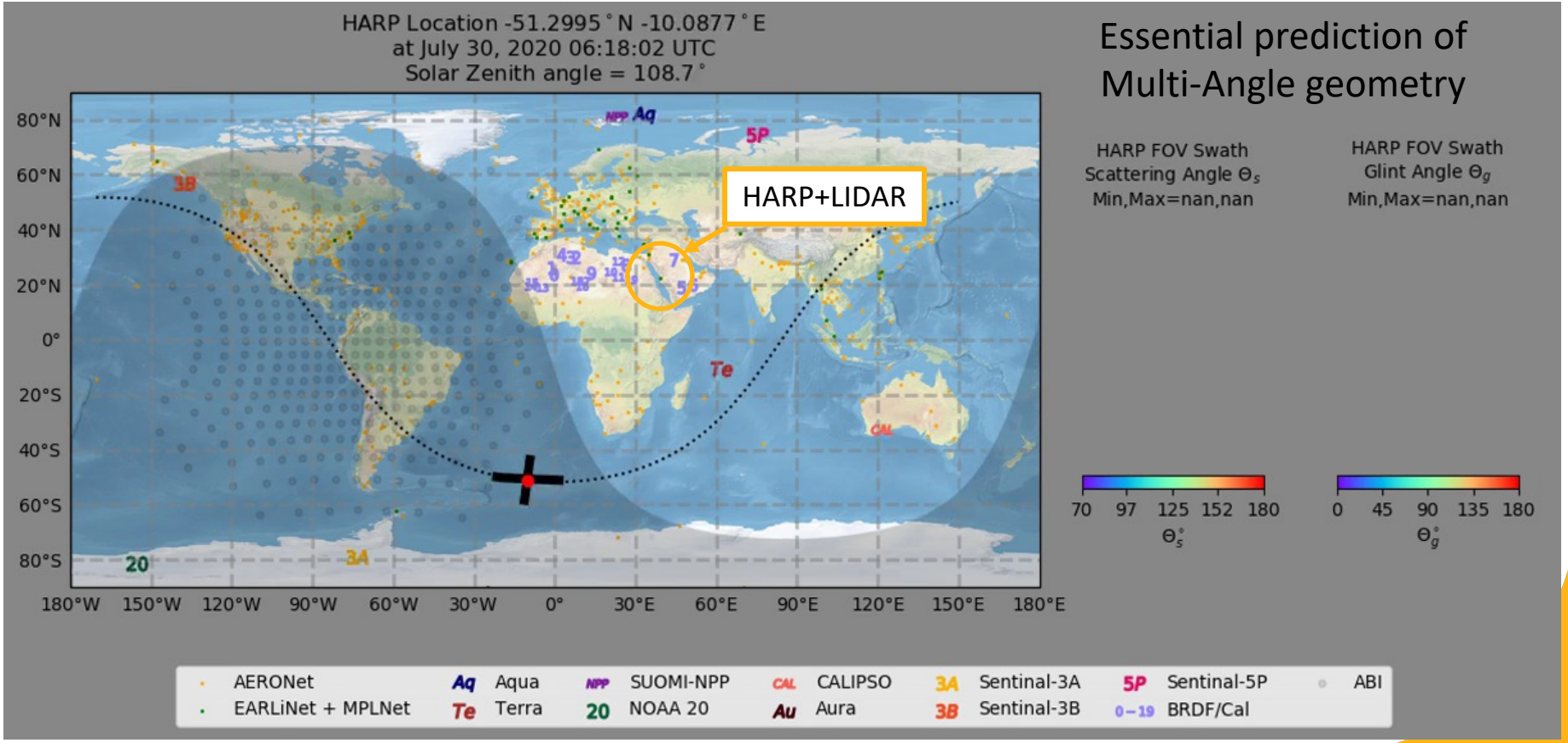


Calibration/Validation with other satellites

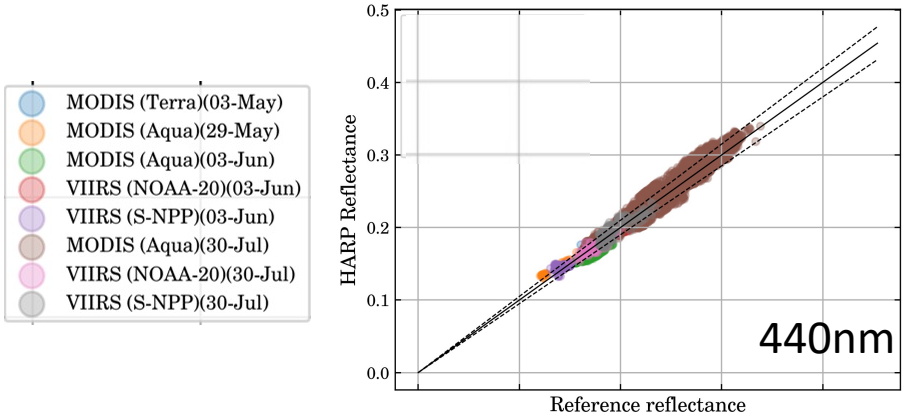
Anin Puthukkudy*, Noah Sienkiewicz*

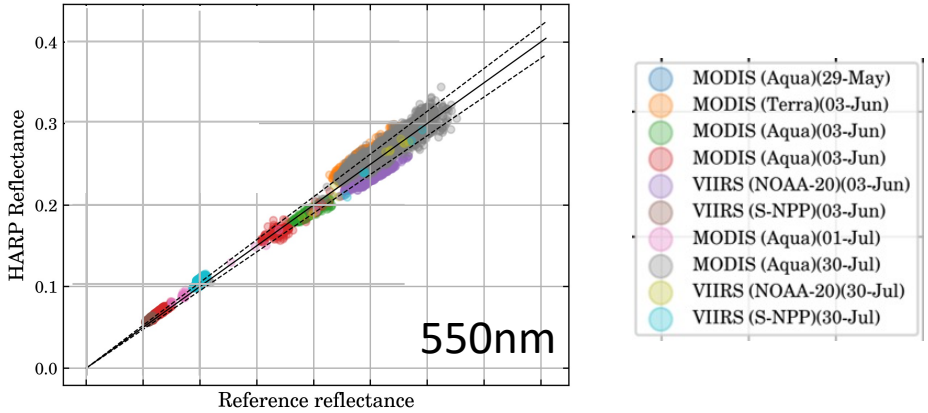
(*) Graduate students

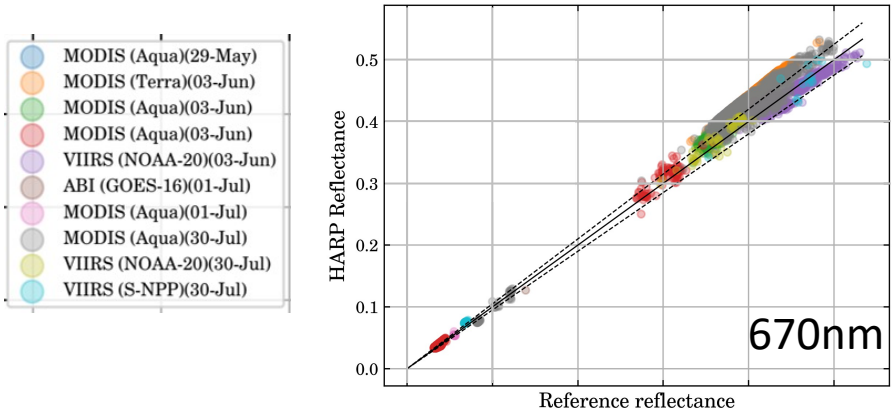
HARP predictive tools x other satellites - Operational

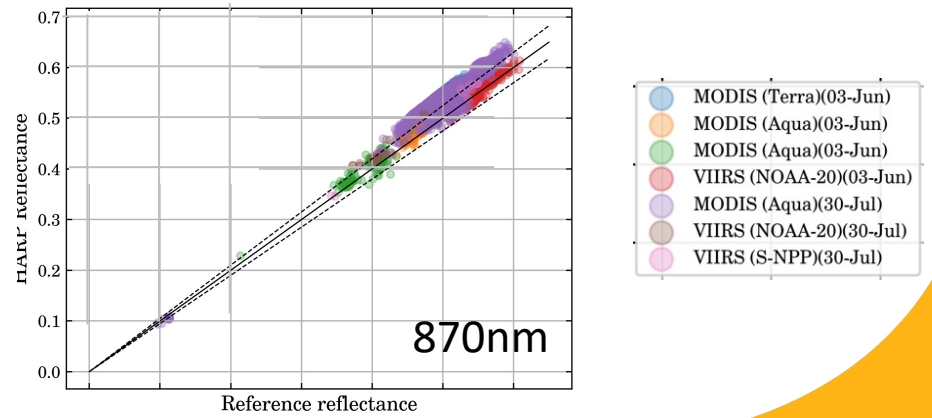


HARP Intercomparisons with other Satellites



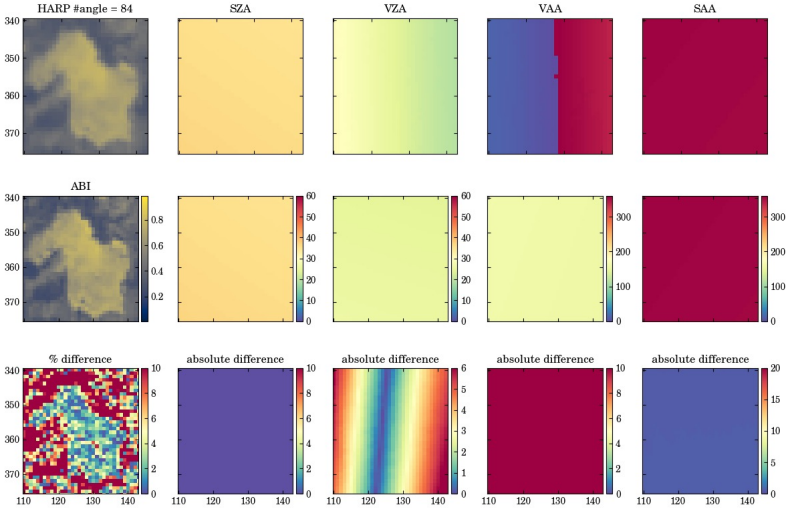




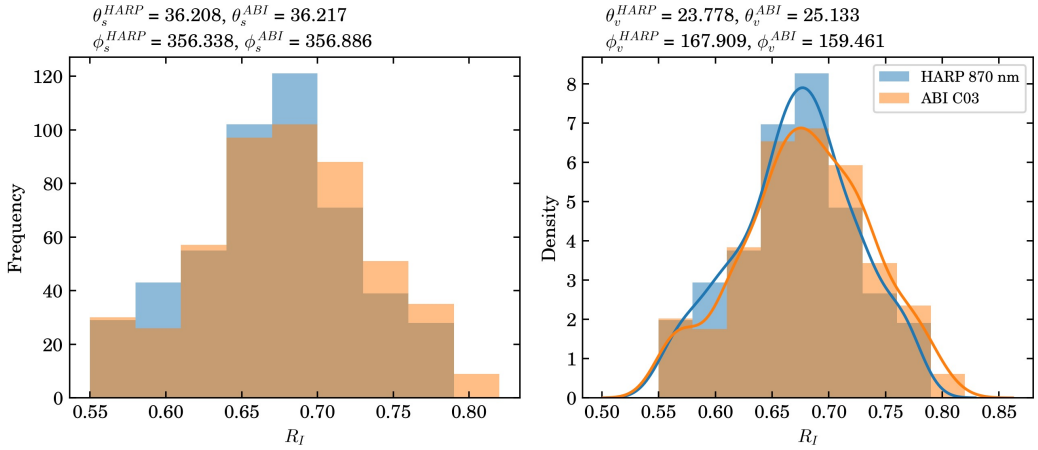


03-May-2020 HARP X Geostationary ABI

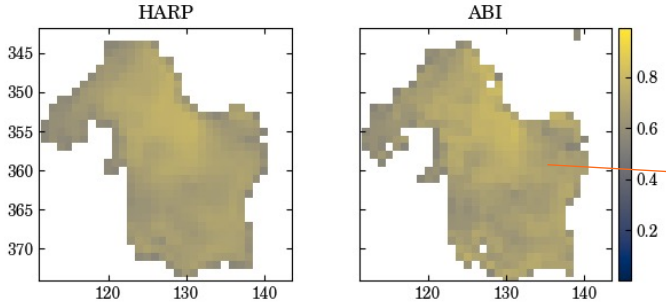
Geometry is never perfect!!!

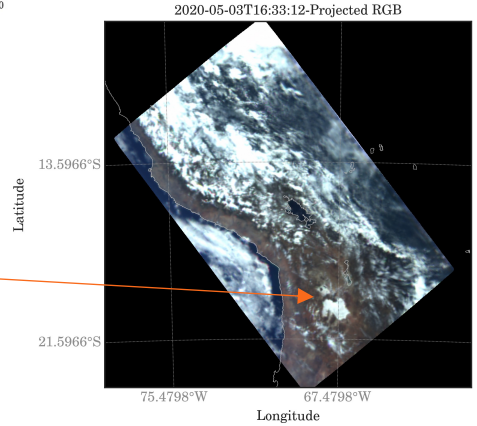


Histogram of the reflectances



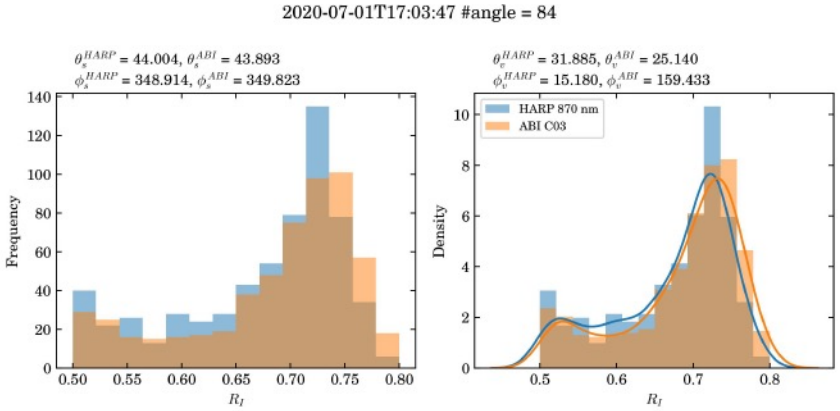
Salar De Uyuni (Bolivia) [ABI data resampled in HARP lat-lon grid]



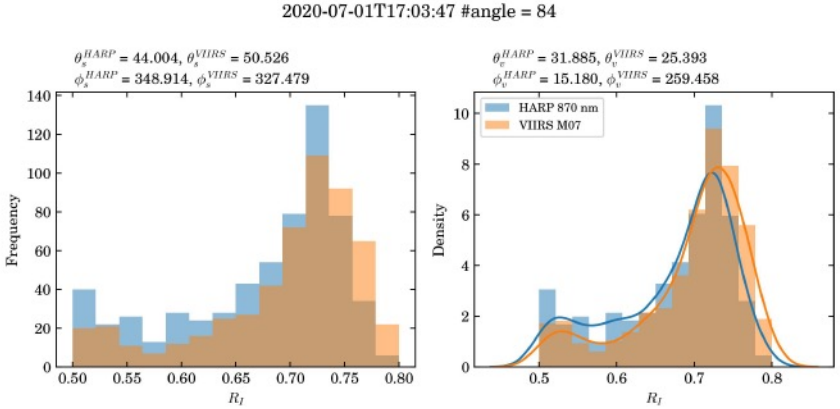


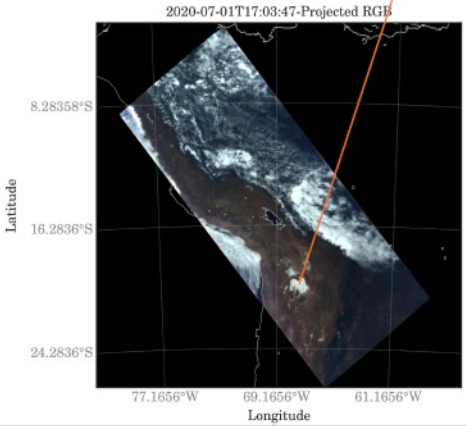
01-Jul-2020

Comparison with ABI over the Salr De Uyuni salt flat



Comparison with VIIRS on S-NPP over the Salr De Uyuni salt flat





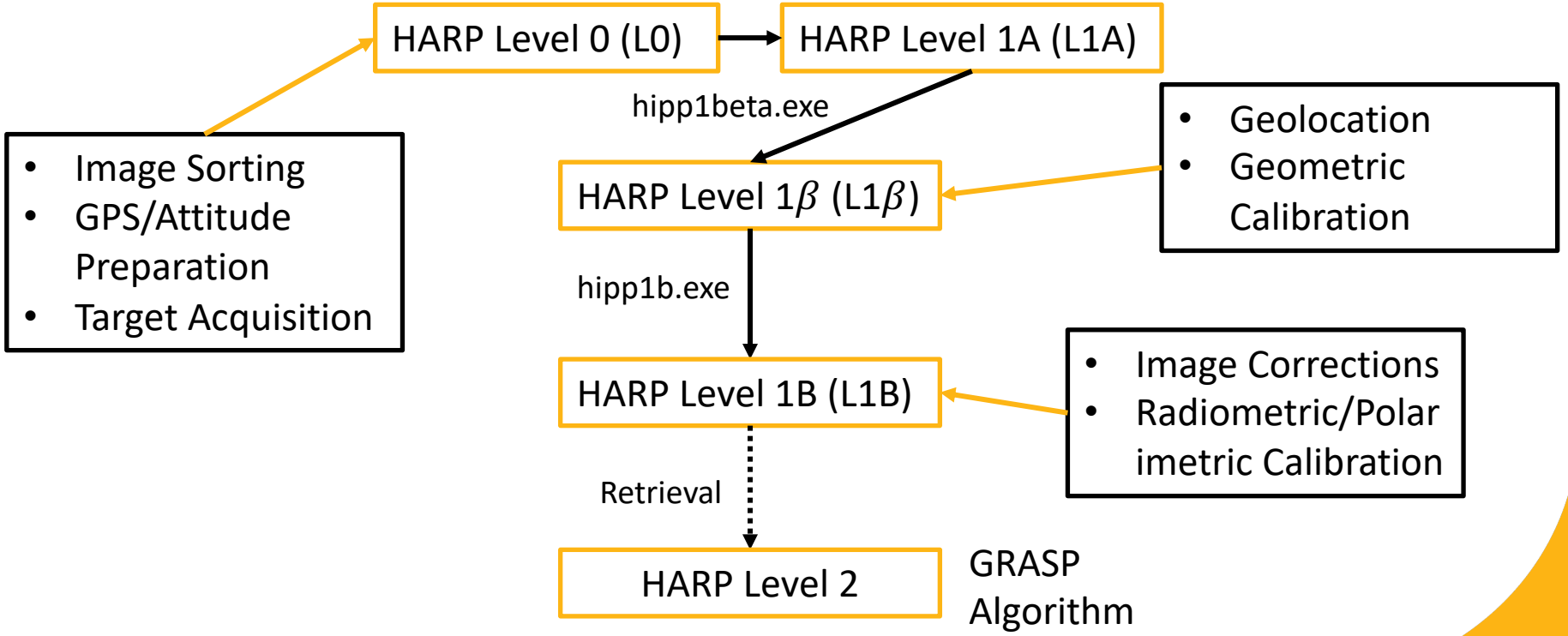
Data Processing algorithms

Richard Xu, Anin Puthukkudy*, Brent McBride*, Noah Sienkiewicz*, Oleg Dubovik

(*) Graduate students

HARP HIPP Algorithm is fully developed and Operational

HIPP is being delivered for HARP2/PACE processing



Lead HIPP Developer: Dr. Xiaoguang (Richard) Xu

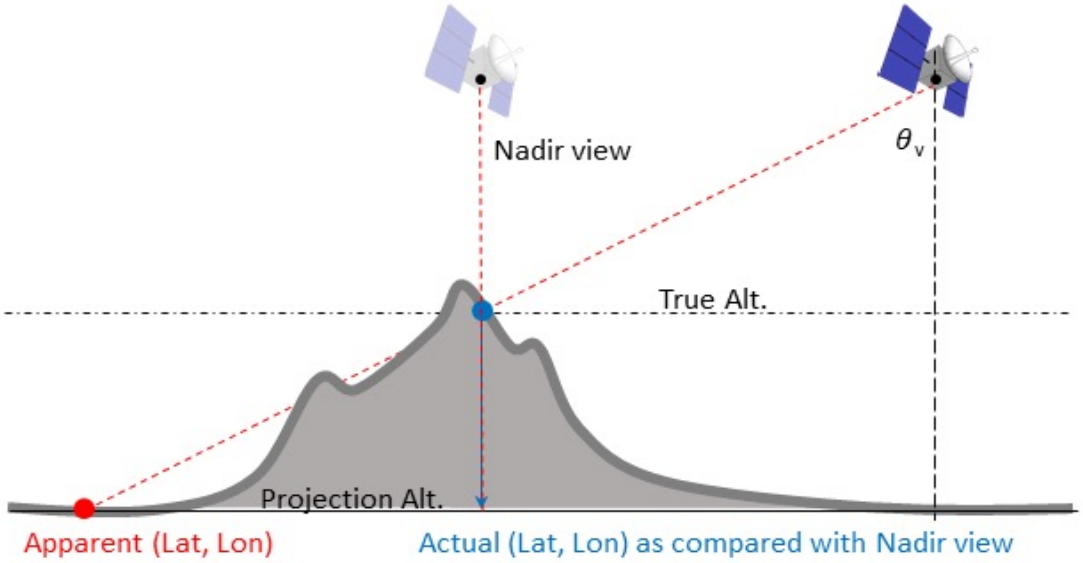
HARP Topography correction – Fully Implemented

Correction from latitude (ϕ) and longitude (λ) from Earth surface height

$$\phi_c = \phi_0 + \left(\frac{-2\,\pi/180}{NED_2}\right)(\Delta h)$$

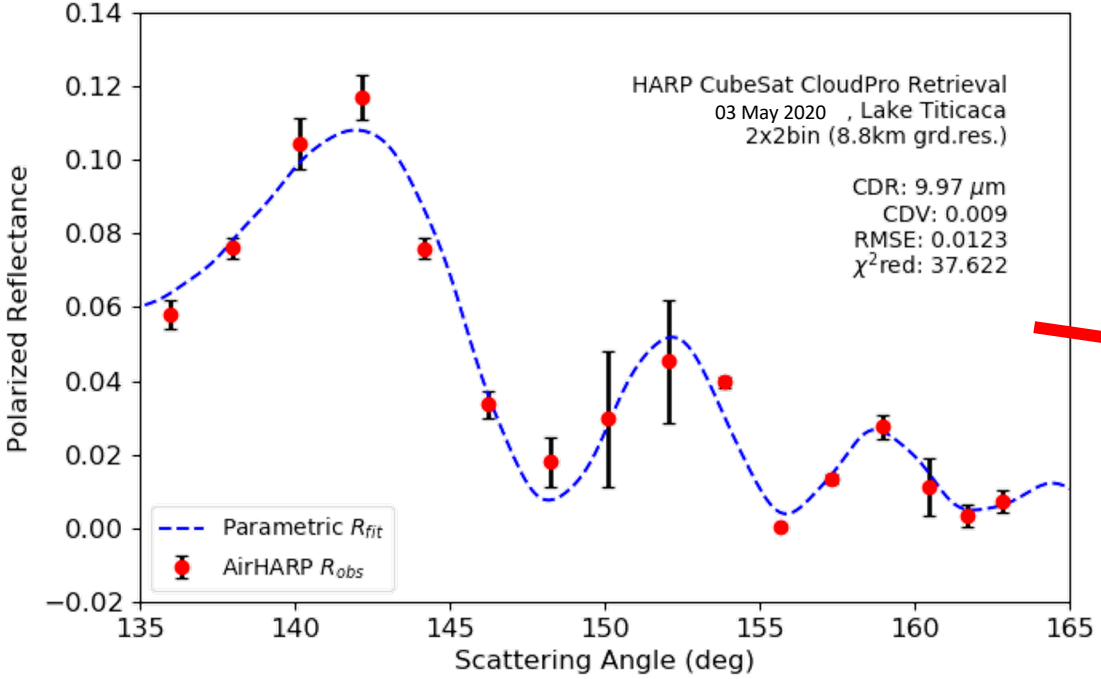
$$\lambda_c = \lambda_0 + \frac{\left(\frac{-2\,\pi/180}{NED_1}\right)(\Delta h)}{cos(\phi_c 2\,\pi/180)}$$

- Applied via an iterative height search against digital elevation map from SRTM
- Optimized to skip nadir pixels/flat regions

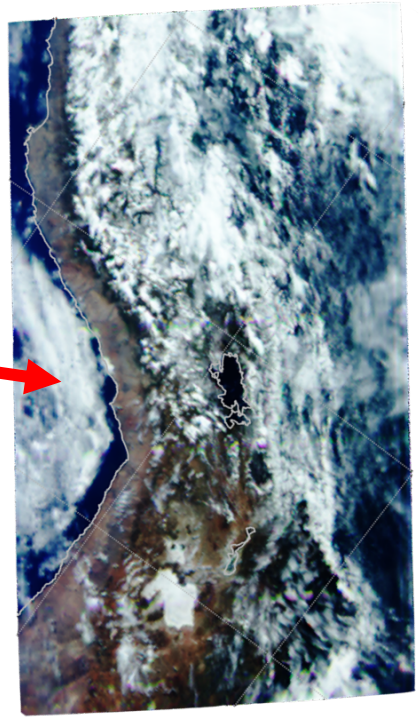


Level-2 Cloud Microphysics Retrieval from Space

HARP CubeSat 670nm (~8.8km^2 resolution)

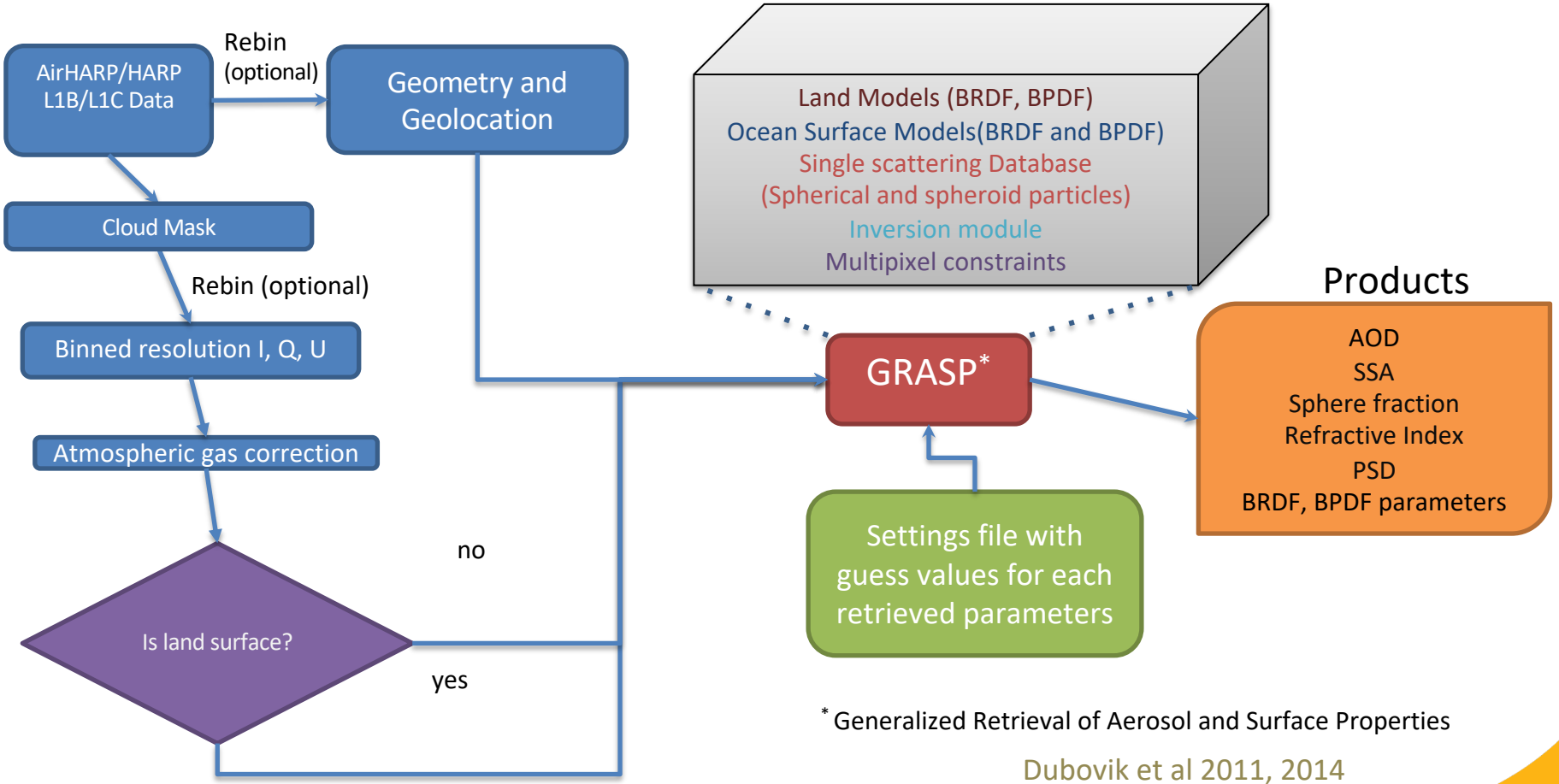


HARP Nadir Pushbroom



First Ever Hyper-Angular Cloudbow Retrieval from Space

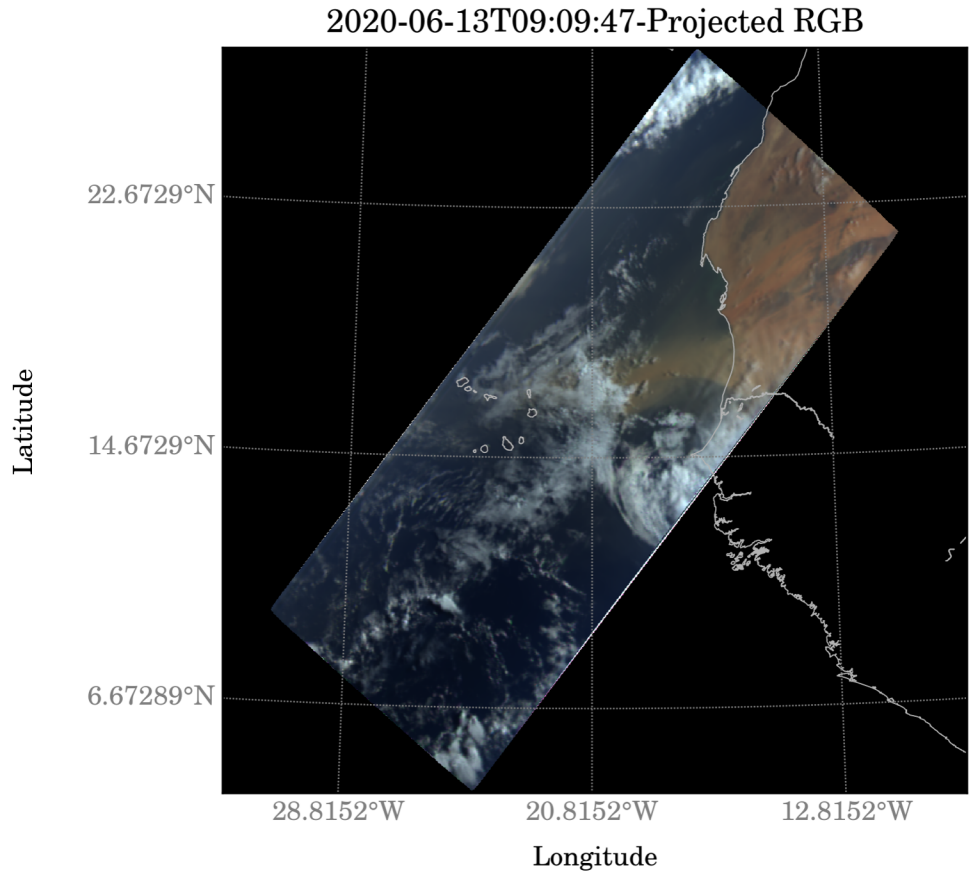
Level 2 aerosol retrieval with GRASP

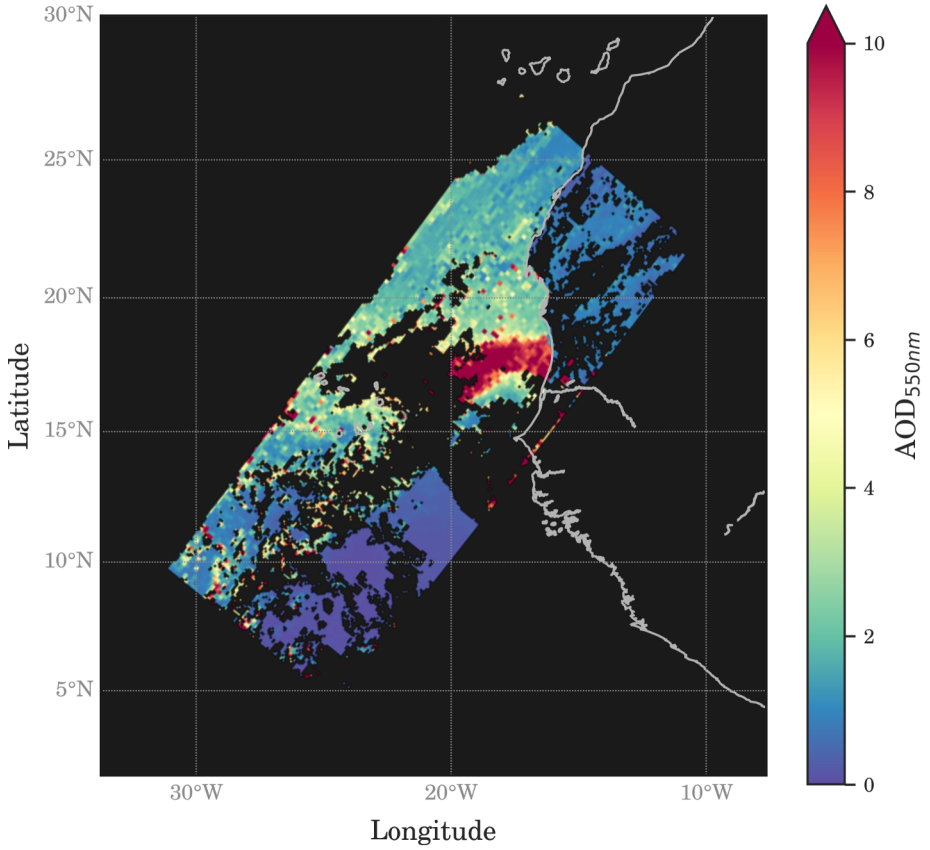


* Generalized Retrieval of Aerosol and Surface Properties

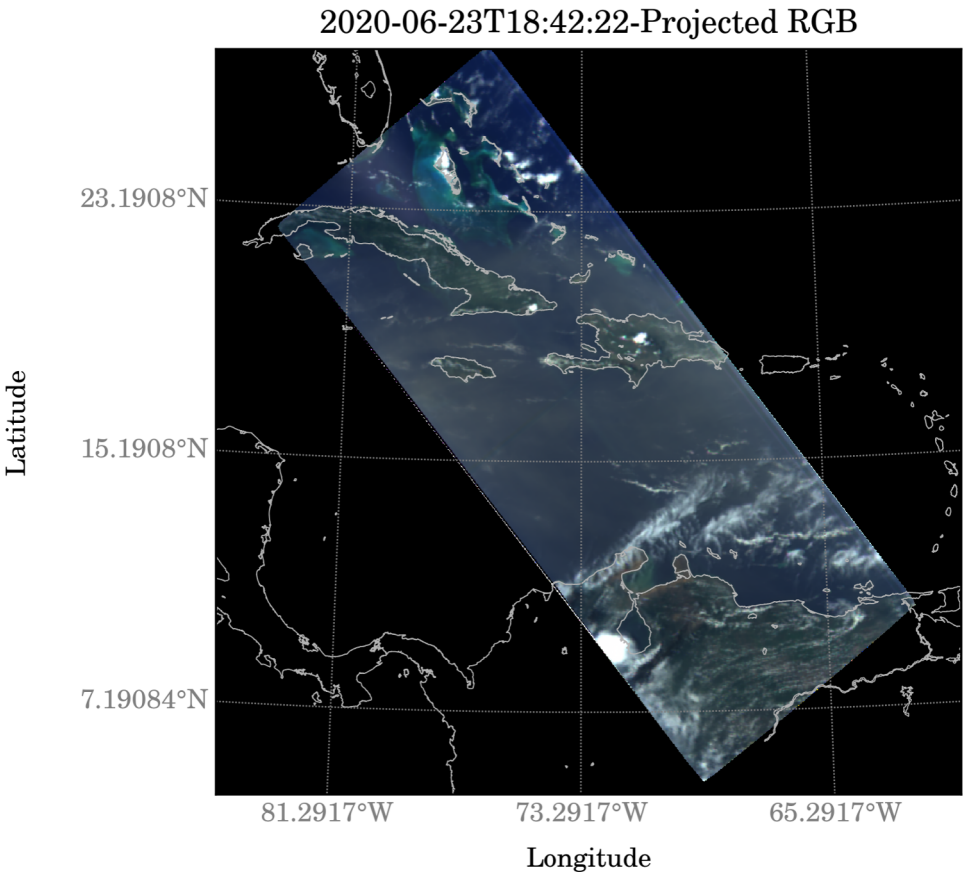
Dubovik et al 2011, 2014

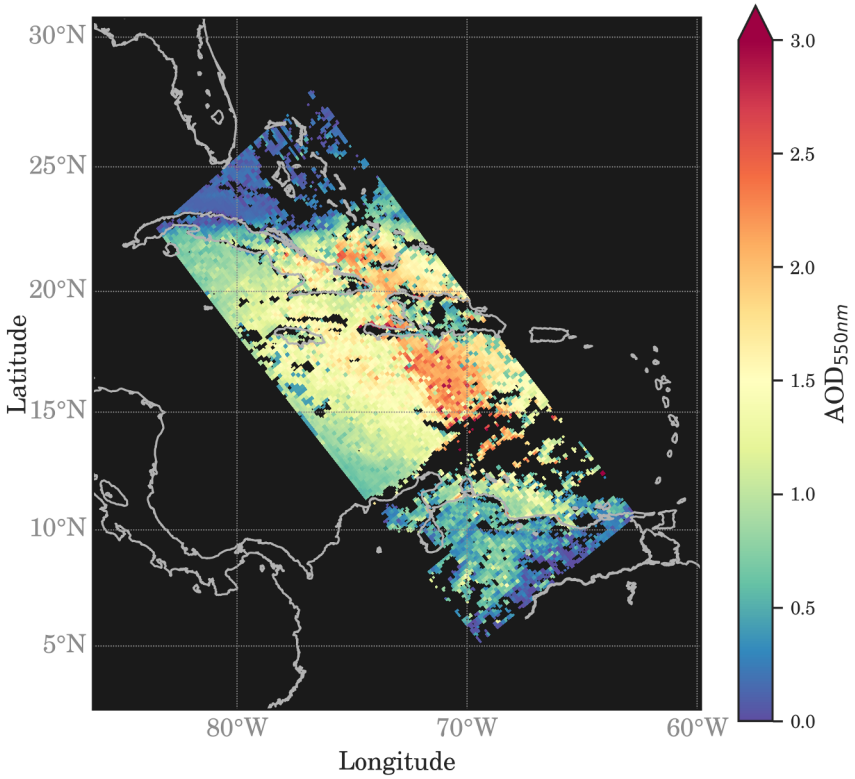
13-June-2020 Saharan Dust Transport



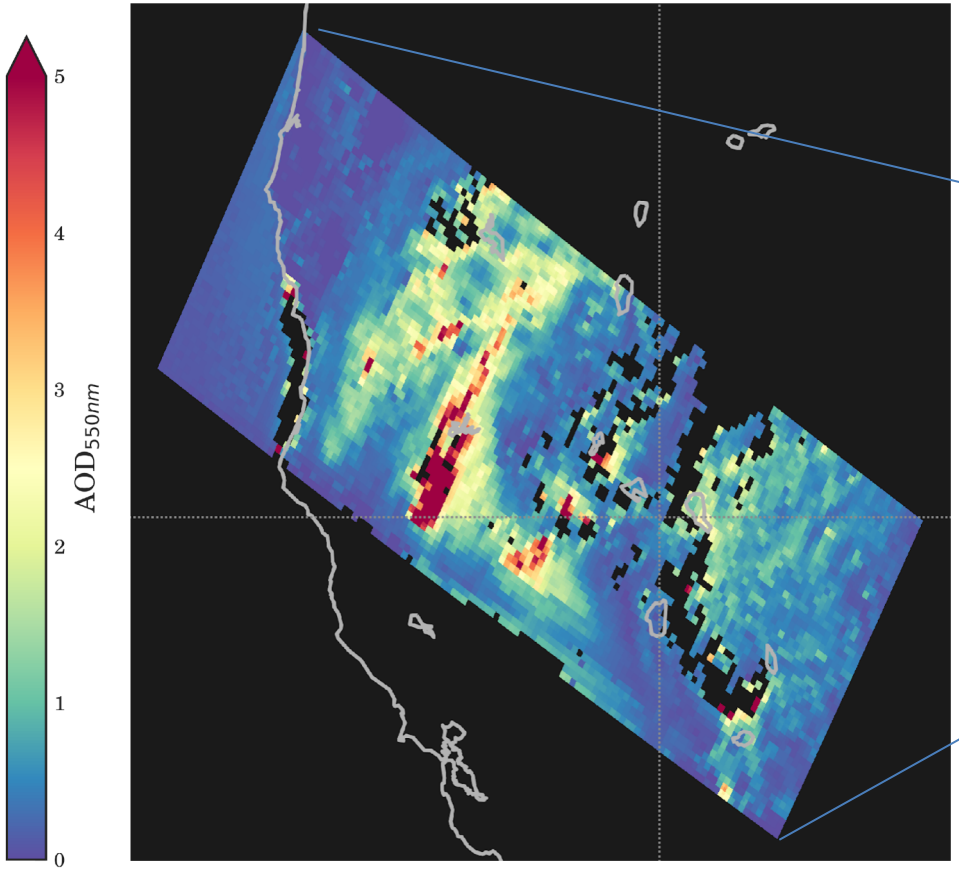


23-June-2020 Saharan Dust Transport

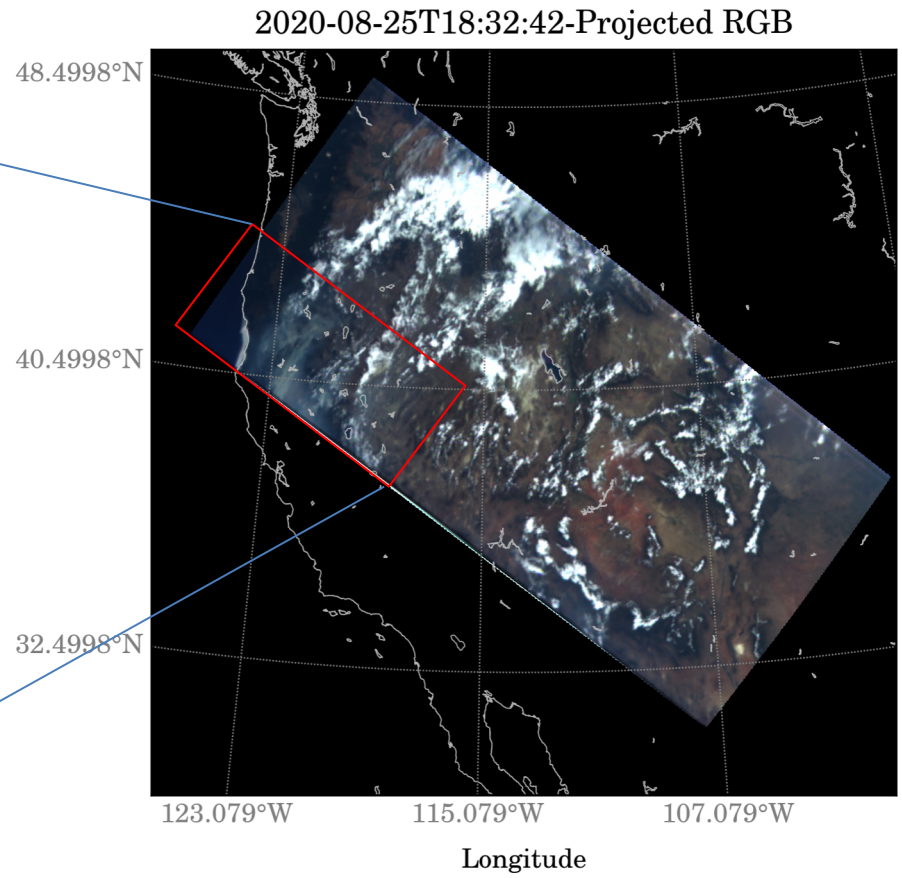




25-August-2020 California-Oregon Fire

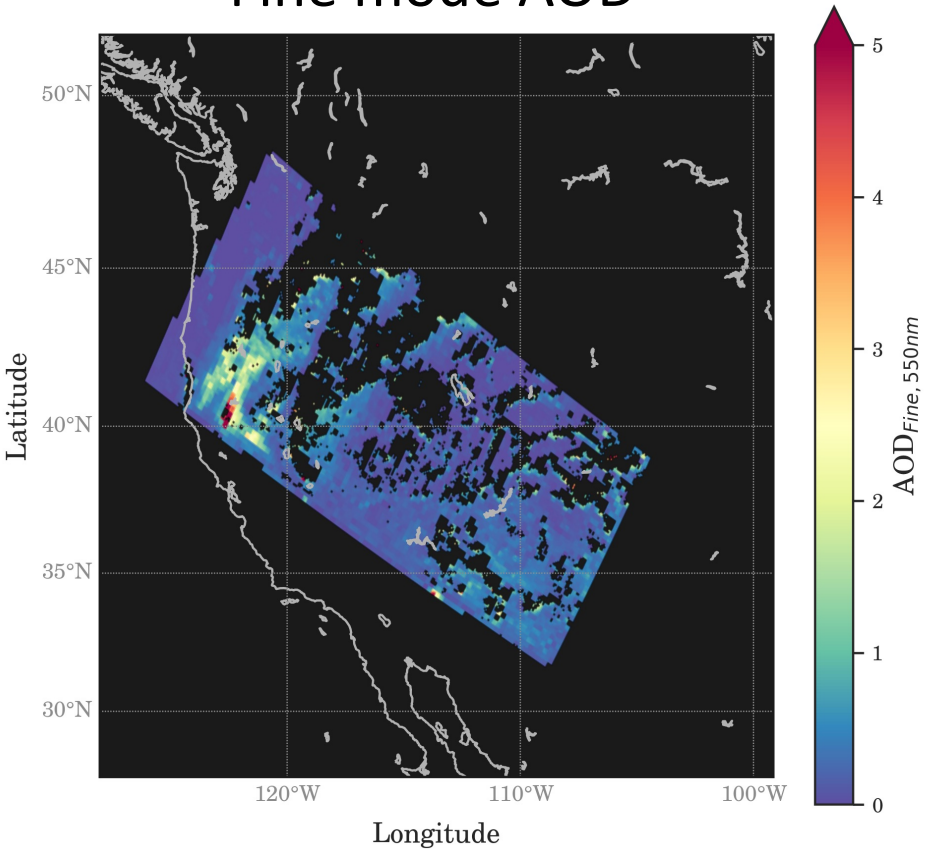


3.3 km resolution AOD retrievals

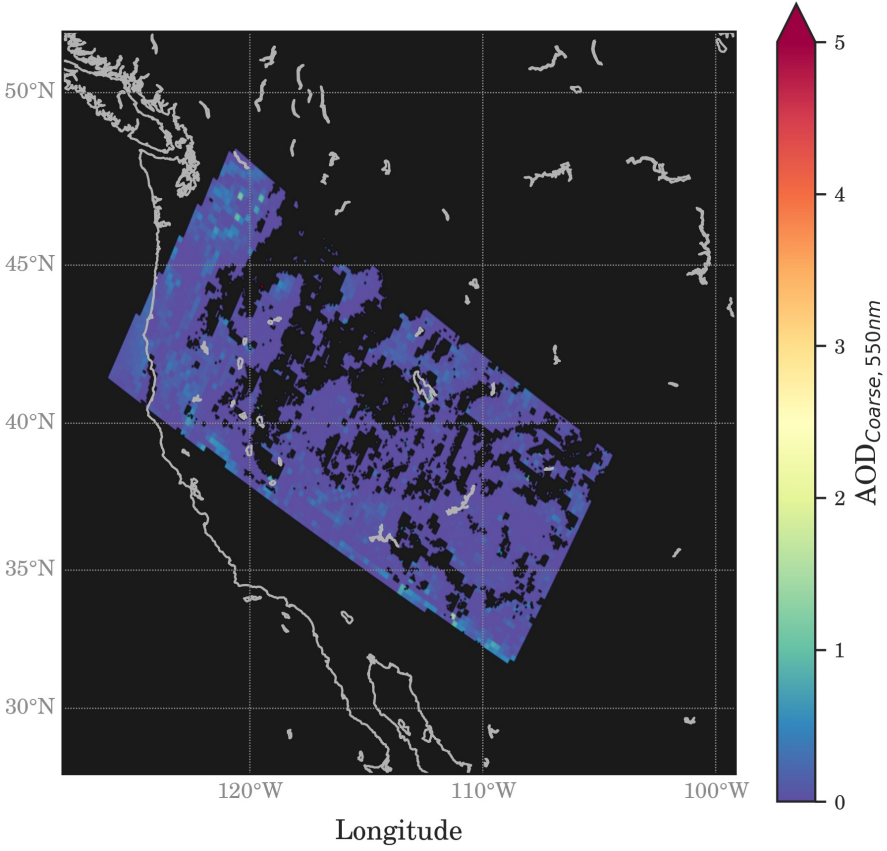


25-August-2020 California-Oregon Fire

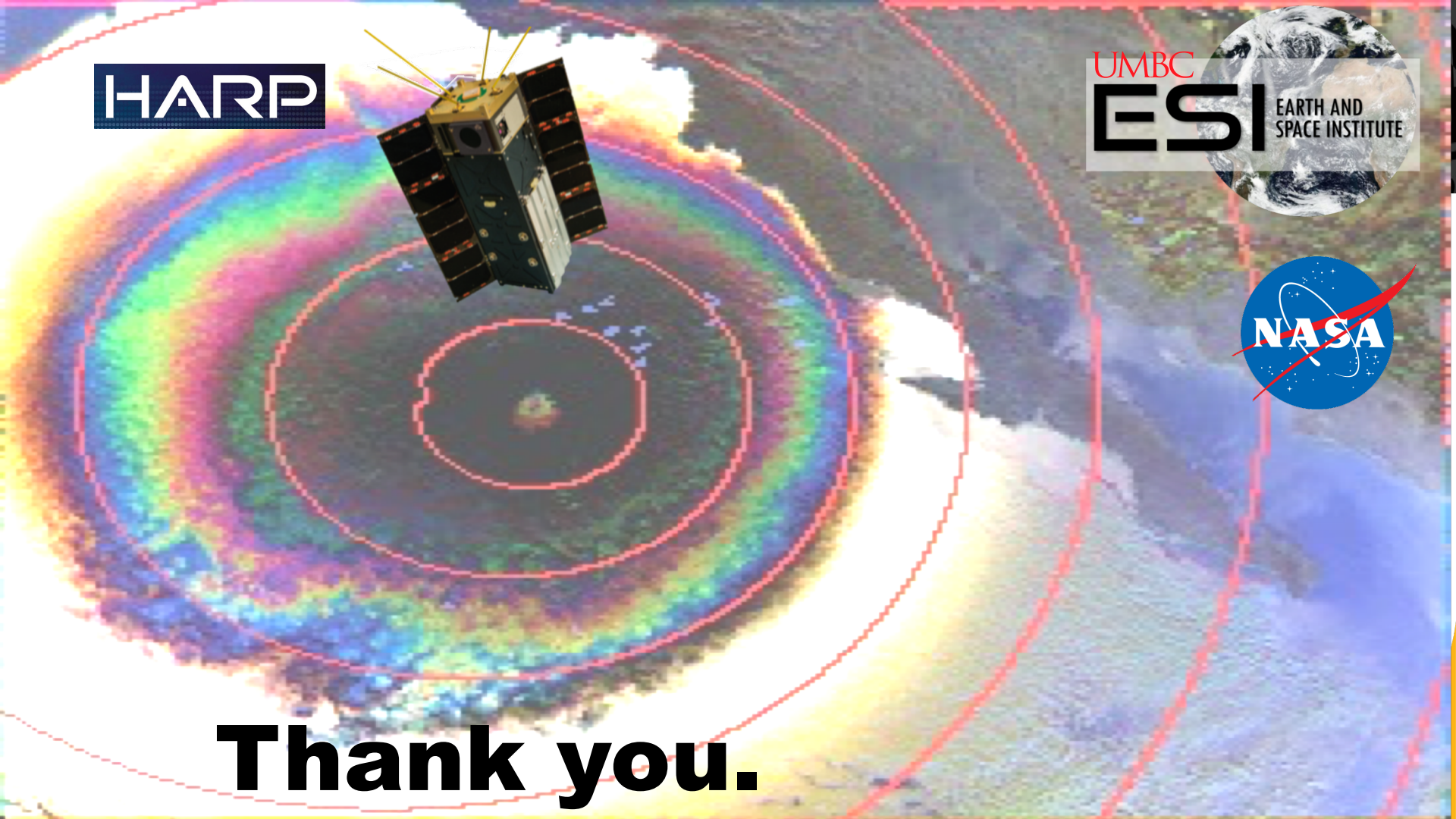
Fine mode AOD



Coarse mode AOD



6.6 km resolution AOD retrievals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Thank you.