The SPEXone polarimeter for the NASA PACE mission

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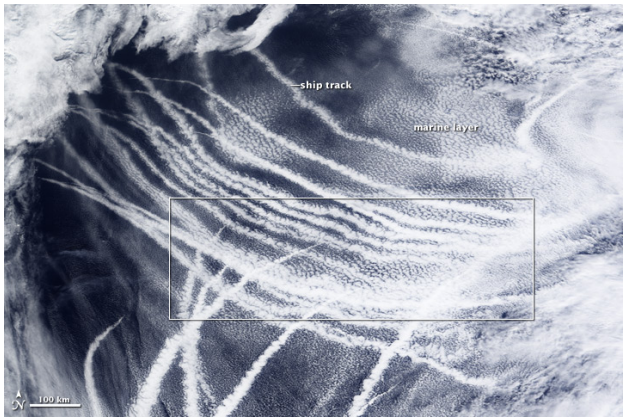
SRON

Netherlands Institute for Space Research

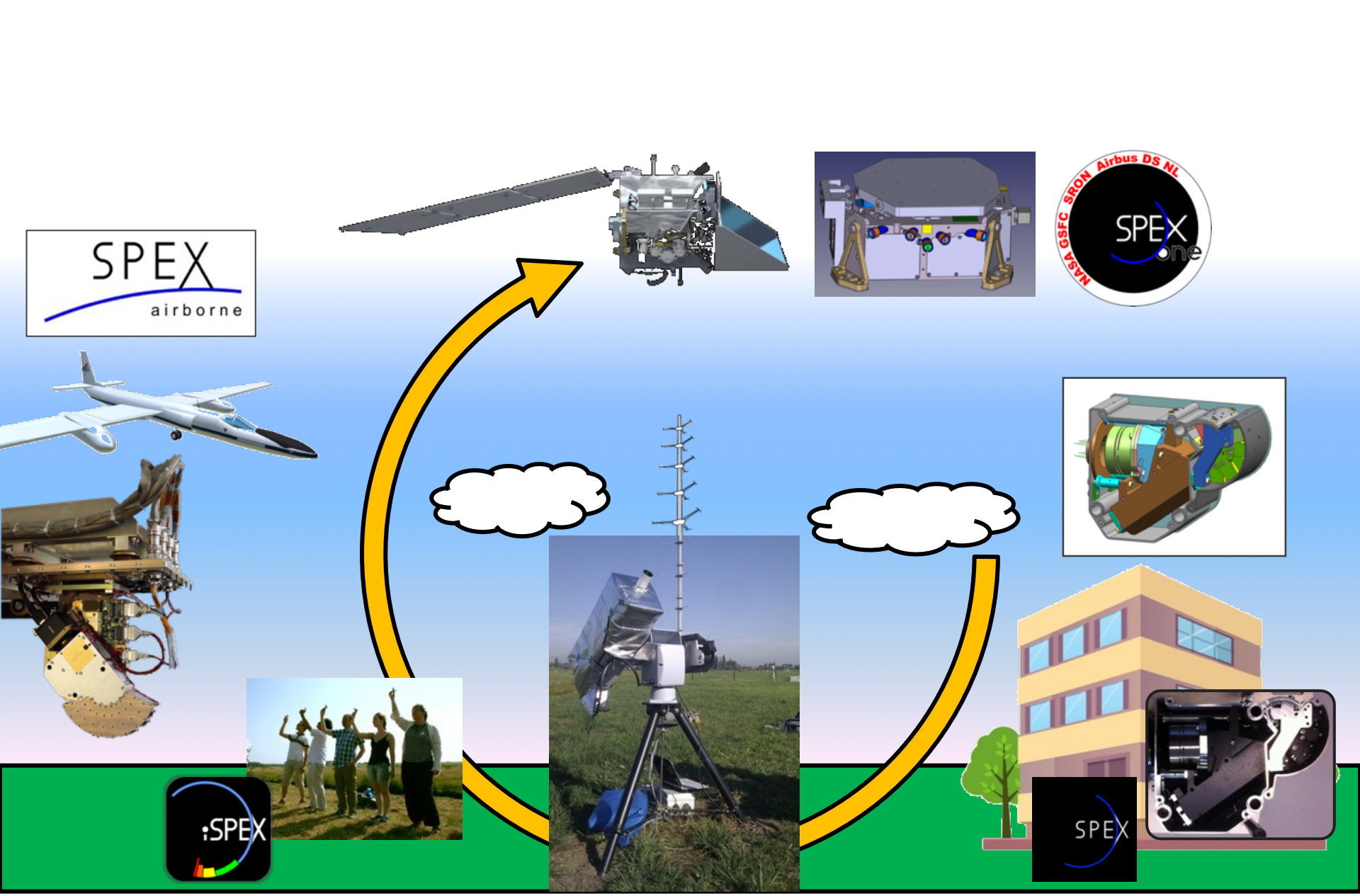
Netherlands Organisation for Scientific Research (NWO)

Goal: Provide measurements of aerosol properties needed to advance quantification of aerosol radiative forcing



Needed (globally):

- ✓ **Direct effect**:
  AOD, SSA, phase function, aerosol above clouds
- ✓ **Indirect effect**:
  Aerosol: Number, size, shape, height, RRI
  Cloud: Size, CDNC, phase, height
- ✓ **Source determination**:
  Complex refractive index, size



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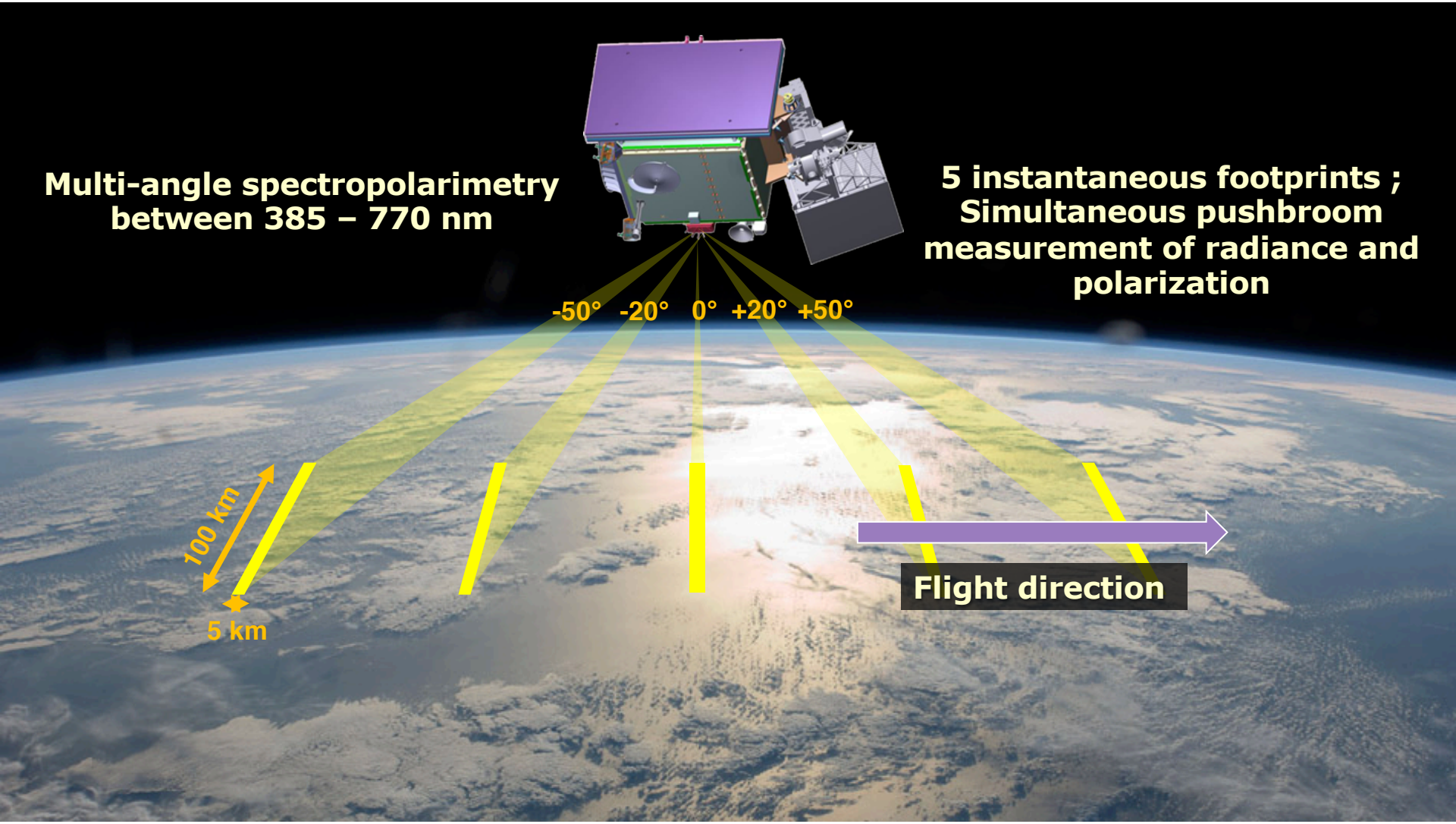
Multi-angle spectropolarimetry between 385 – 770 nm
5 instantaneous footprints ; Simultaneous pushbroom measurement of radiance and polarization
-50° -20° 0° +20° +50°
100 km
5 km
Flight direction

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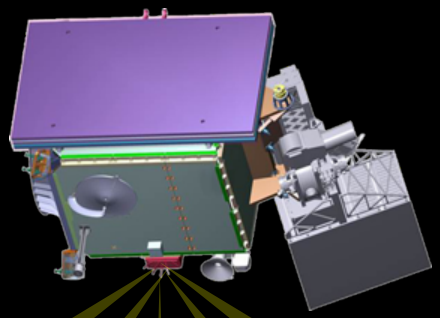
Multi-angle spectropolarimetry between 385 – 770 nm



5 instantaneous footprints ; Simultaneous pushbroom measurement of radiance and polarization

-50° -20° 0° +20° +50°

100 km

5 km

Parameter	Specification
Spatial resolution (sampling)	5X5 km^2 (2.5X2.5 km^2)
Spectral resolution radiance	~2-4 nm
Spectral resolution polarization	10 nm @ 385 nm 45 nm @ 770 nm
Radiometric uncertainty	< 2%
Polarimetric uncertainty	< 0.003

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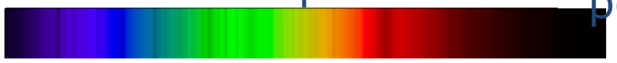
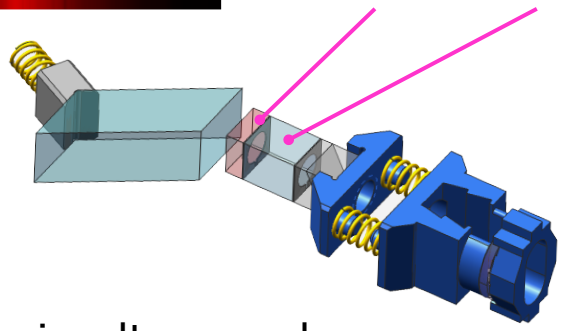
Spectral modulation: Polarization encoded in radiance spectrum

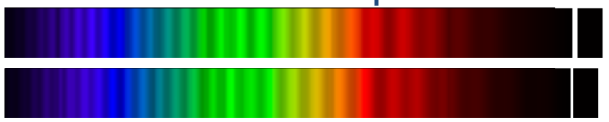
Incident spectrum



polarization modulation optics



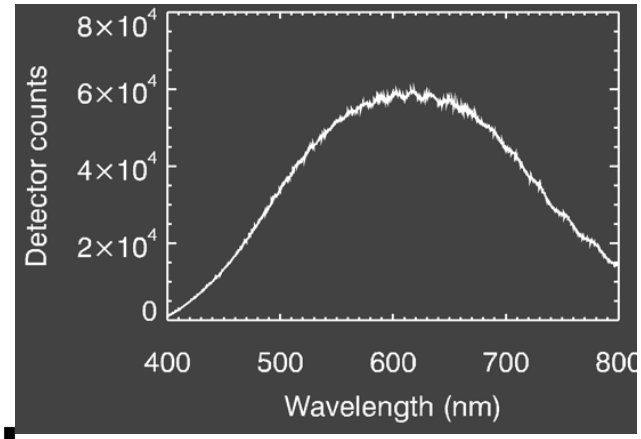
Modulated spectrum

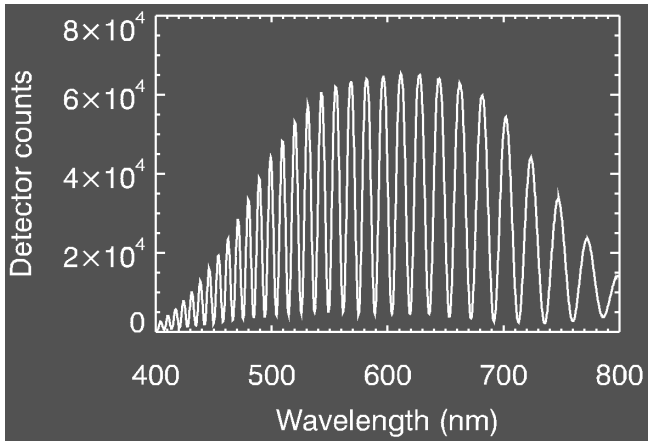


Advantages

- No moving parts
- Radiance and DoLP simultaneously
- Highly accurate and robust

Snik et al. (2009)





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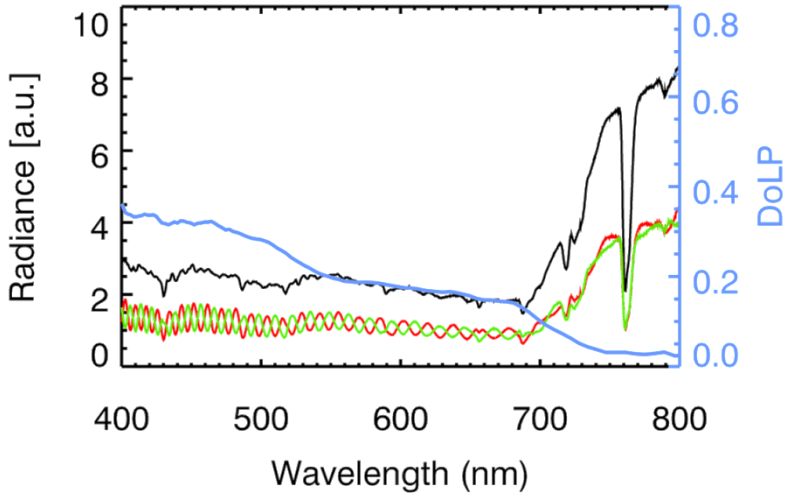
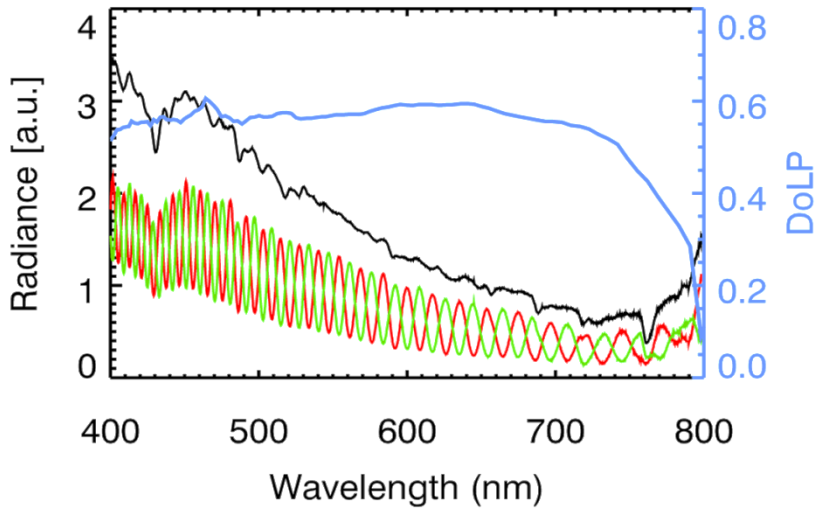
SPEX Hyperspectral Radiance and Polarization Measurements

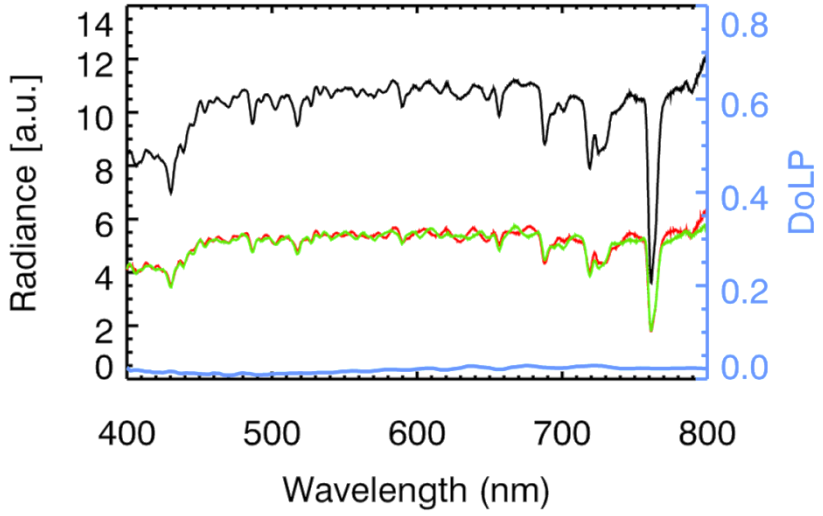
VEGETATION



OCEAN



CLOUDS



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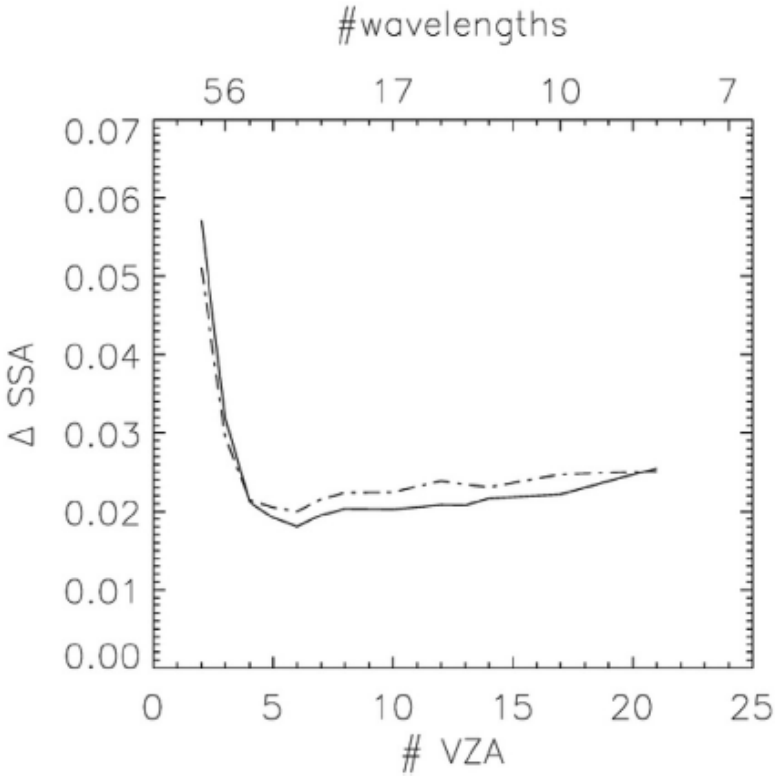
Angular versus Spectral Information

(Keeping total number of measurements constant)



Hasekamp and Landgraf, AO, 2007

- 5 viewing angles needed.
- After that point adding wavelengths helps slightly more than adding angles.
- Results confirmed by later studies (Wu et al., 2015; Xu et al., 2017)

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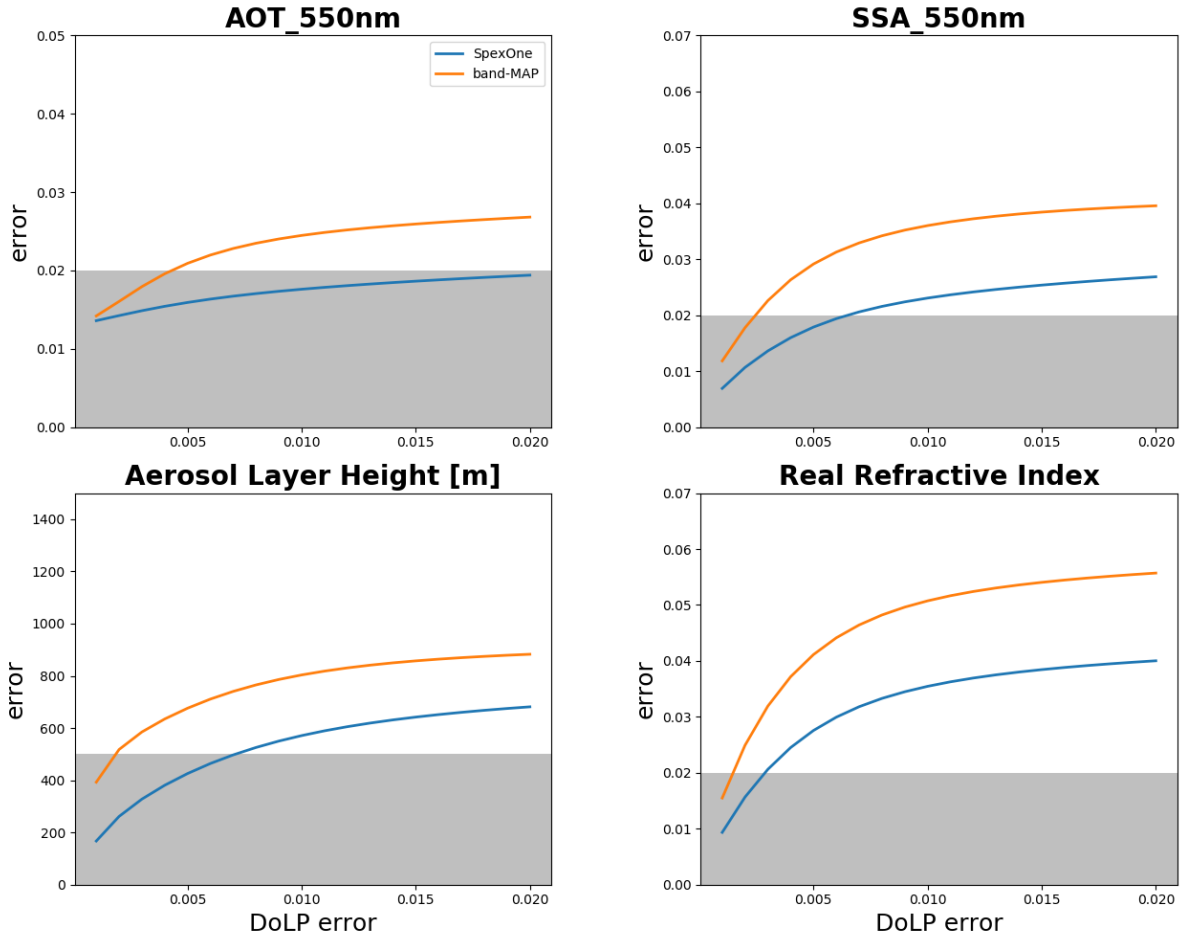
Focus on Polarimetric Accuracy

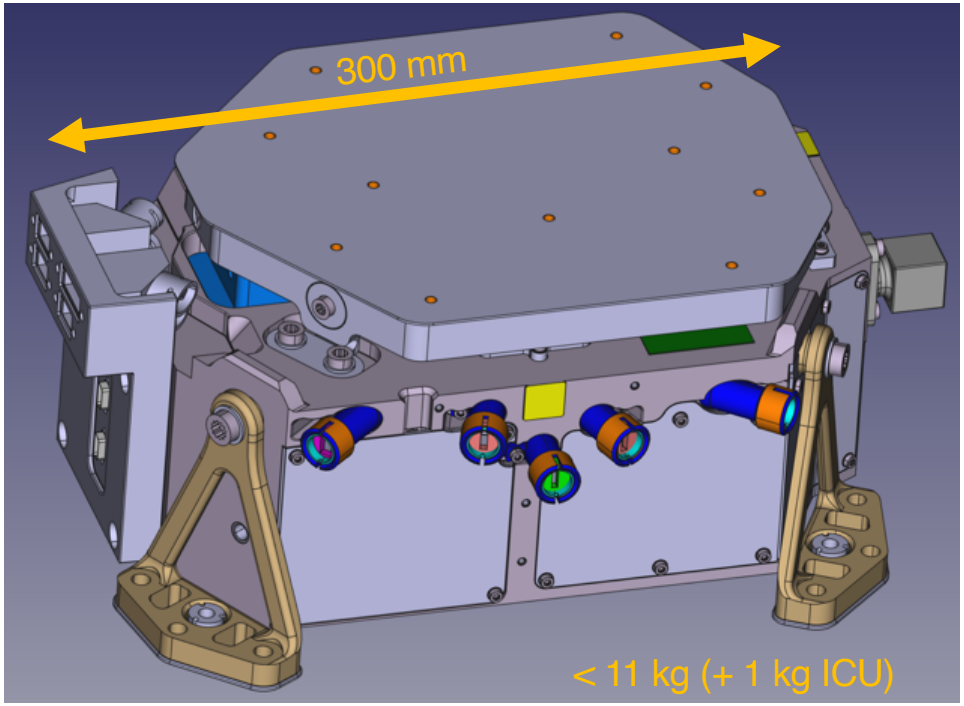


Fine (BB) particles

band-MAP:
Generic instrument with
13 angles, 3MI spectral bands
(for comparison)

Hasekamp et al., JQSRT, 2019


Telescope assembly
Polarization modulation optics
Spectrometer
Detector module
ICU


300 mm
< 11 kg (+ 1 kg ICU)

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SPEXone Milestones October 2019 launch -38 months

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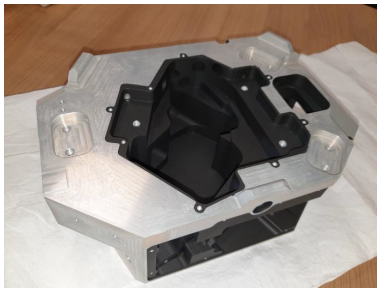
SPEXone instrument status

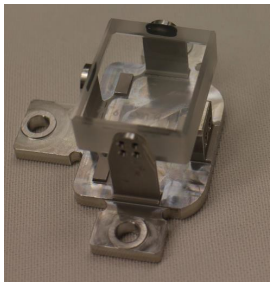
- Parts coming in; System Integration Review held October 21st
- Opto-mechanical integration @SRON
- System integration and test @ADSN
- Calibration @SRON

PMO assembly

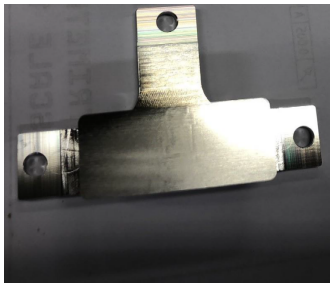


Spectrometer housing
Lucassen

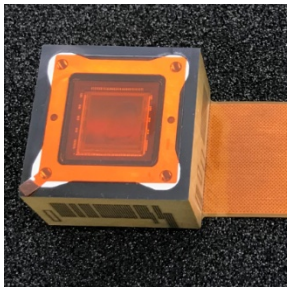
ICU
Hyperion



Grating
assembly



Freeform mirrors
TNO



Detector module
3Dplus

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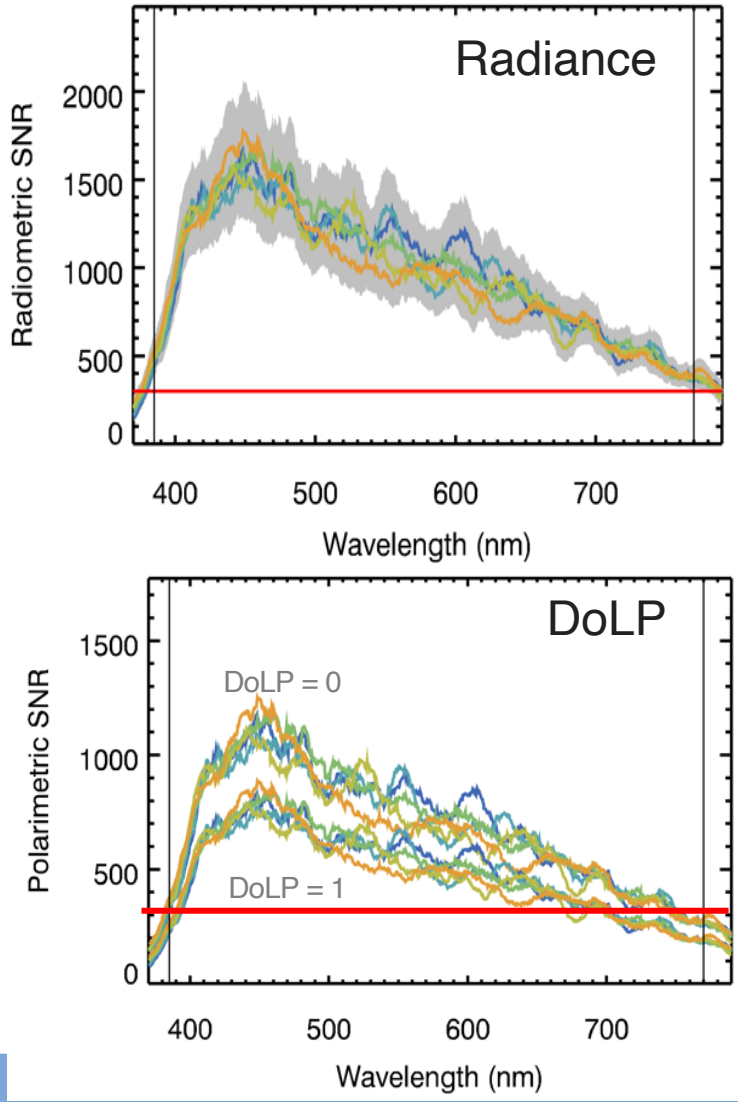
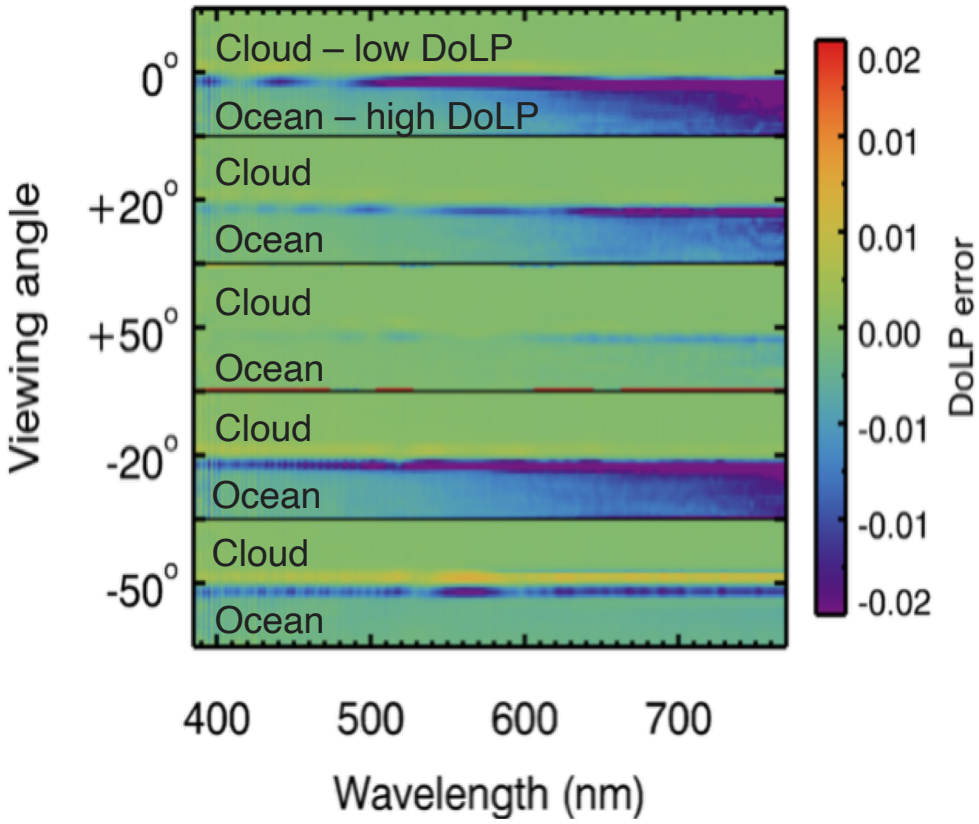
Performance Modeling

SNR for dark ocean at SZA=70°



Stray light for swath with 50% bright cloud and 50% dark ocean at SZA-70°



For most challenging case factor 10 correction is needed. For the vast majority a factor 5 is sufficient.

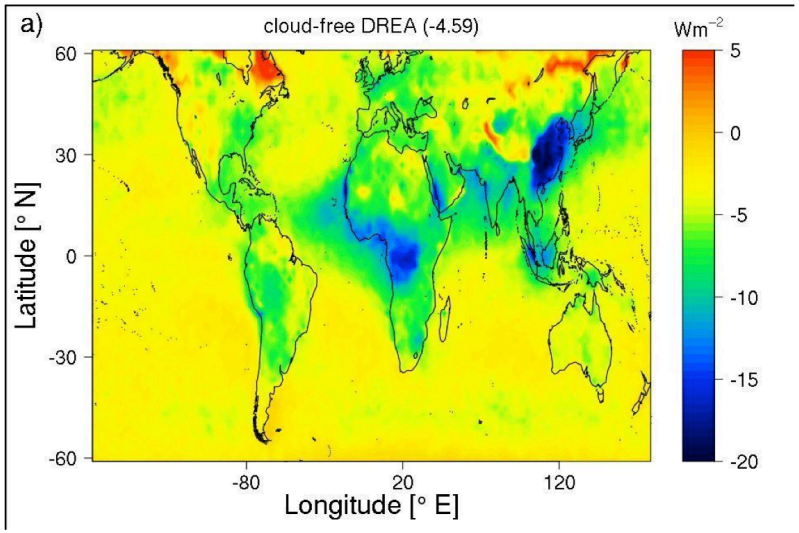
Aerosol retrieval from multi-angle polarimetry

SRON Aerosol Retrieval Algorithm:

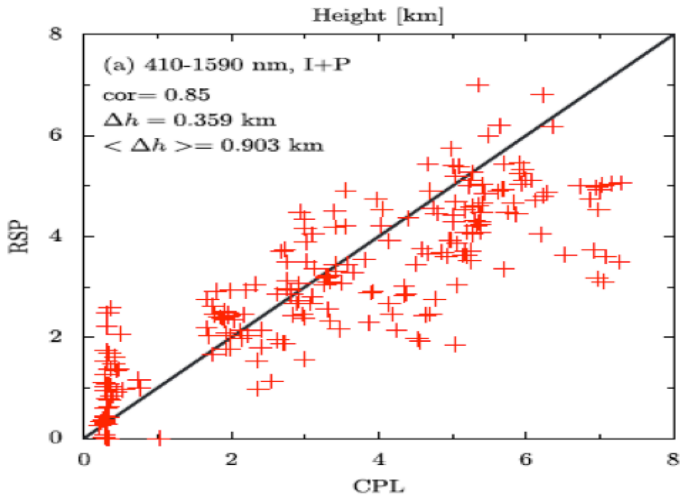
	r_{eff}	v_{eff}	m_r	m_i	N	f_{sph}
fine mode						X
coarse mode						
Other	Aerosol layer height, surface BDRF parameters					
Derived	AOT, SSA, phase function					

References:
Hasekamp et al, JGR, 2011
Stap et al., AMT, 2015
Wu et al., AMT, 2015; GRL, 2016
Lacagnina et al., JGR, 2016;2017
Fu & Hasekamp, AMT, 2018
Schepers et al., JQSRT, 2016

Direct radiative effect from PARASOL



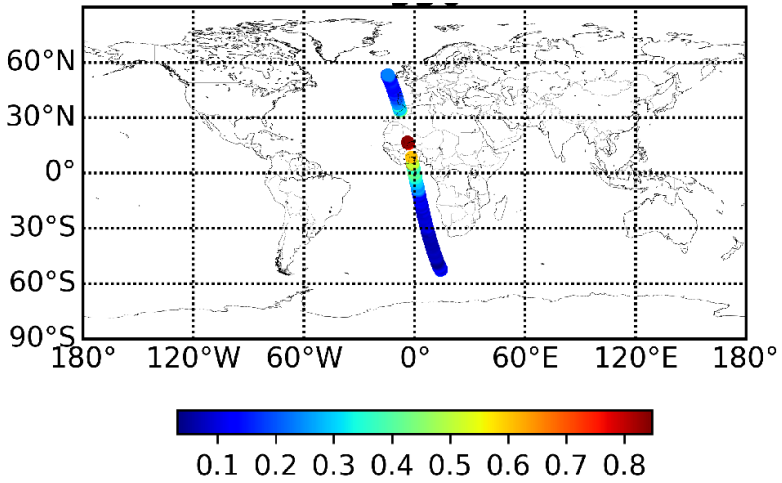
Aerosol height from RSP



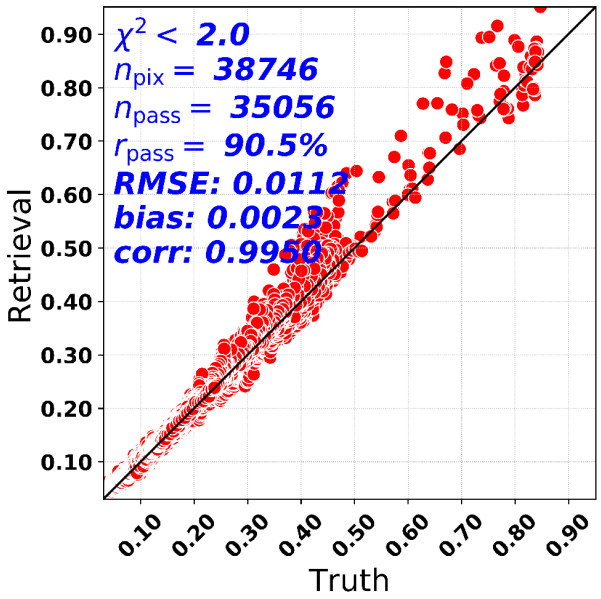
Processing time per pixel: ~2.5 s (SPEXone) / ~0.5 s (POLDER)

Synthetic Retrievals

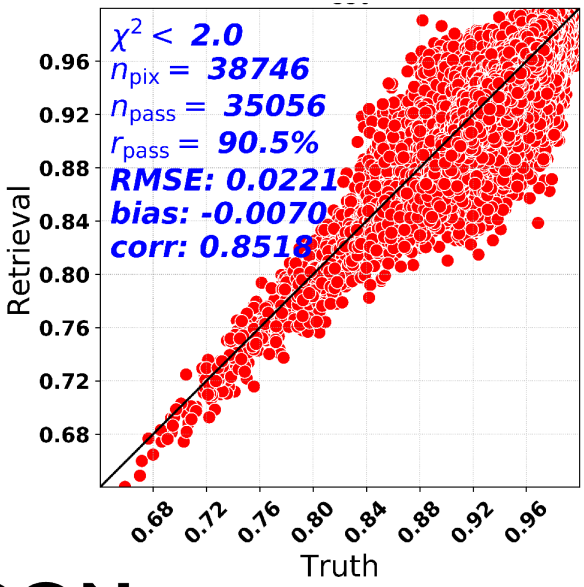
Orbit AOD



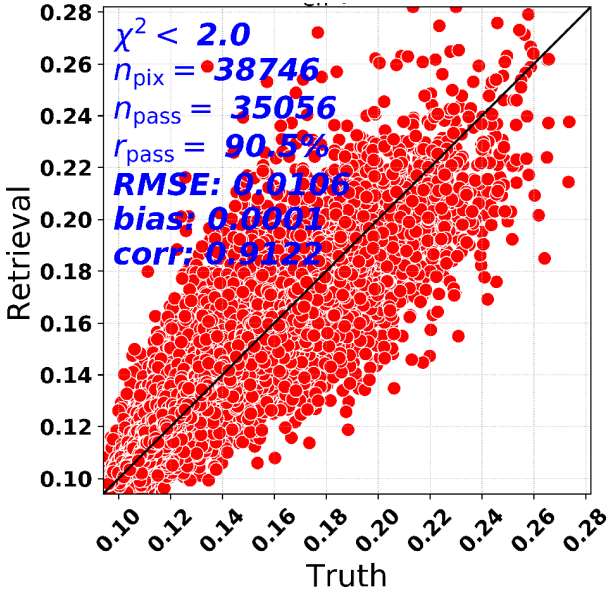
AOD



SSA



$r_{eff}(\mu m)$



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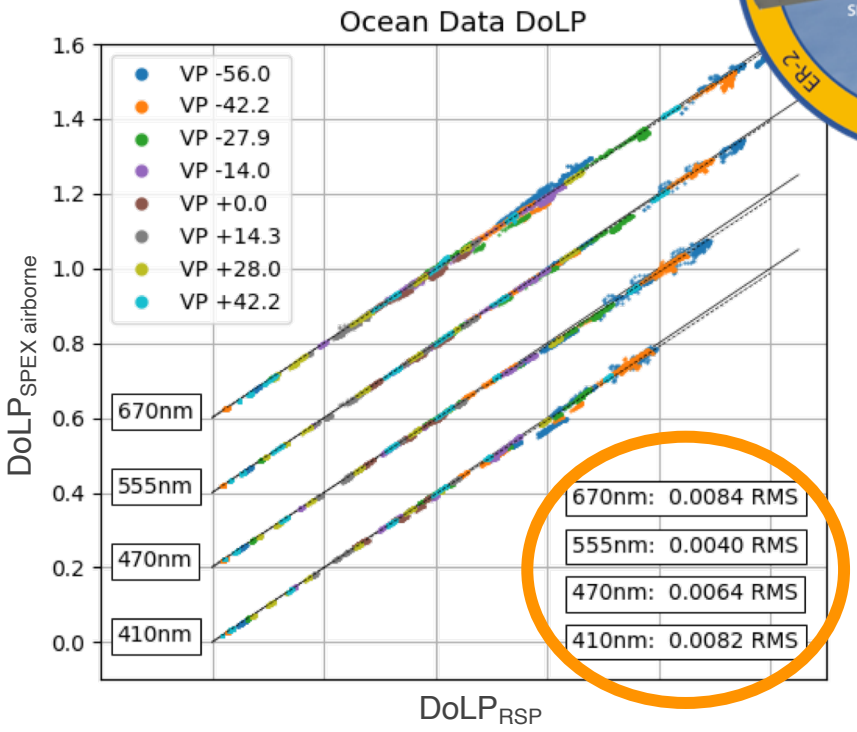
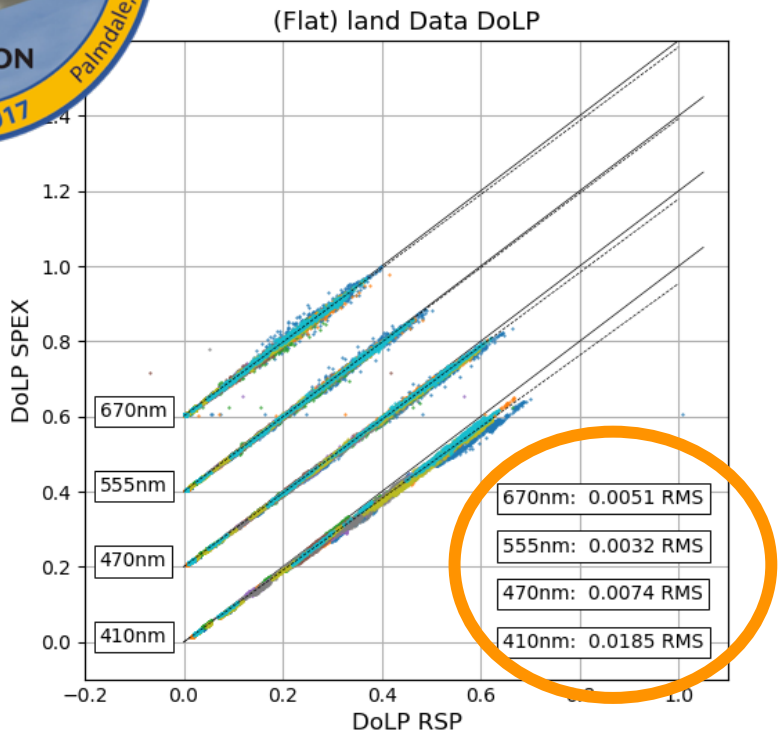
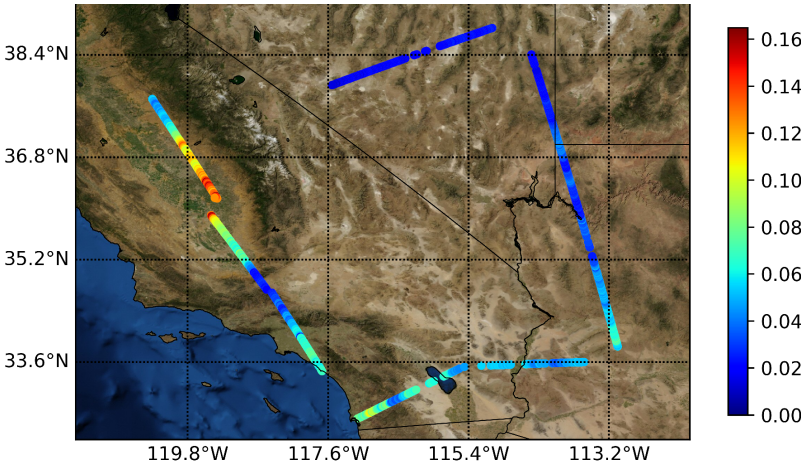
SPEX airborne - in-flight performance

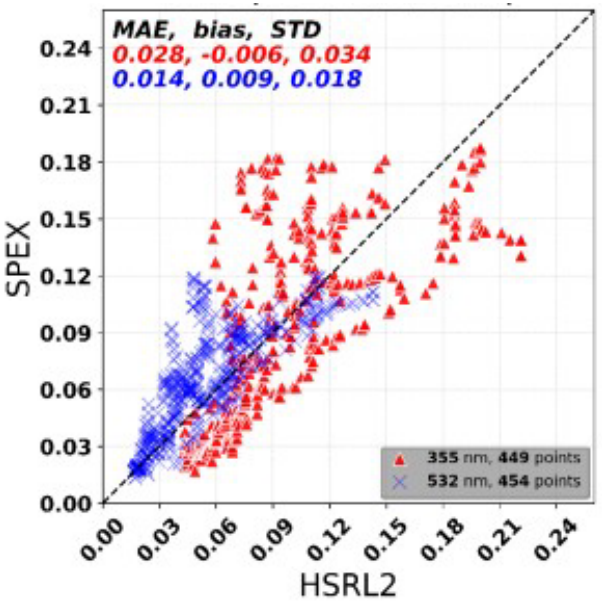




Smit, Rietjens, et al., Applied Optics, 2019

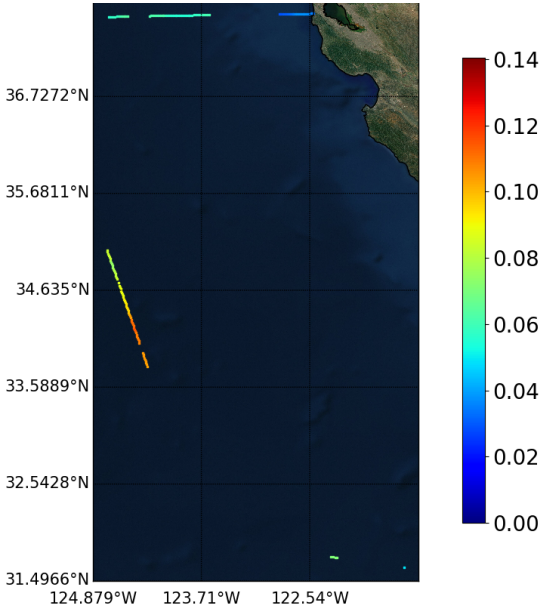
SPEX airborne aerosol retrievals

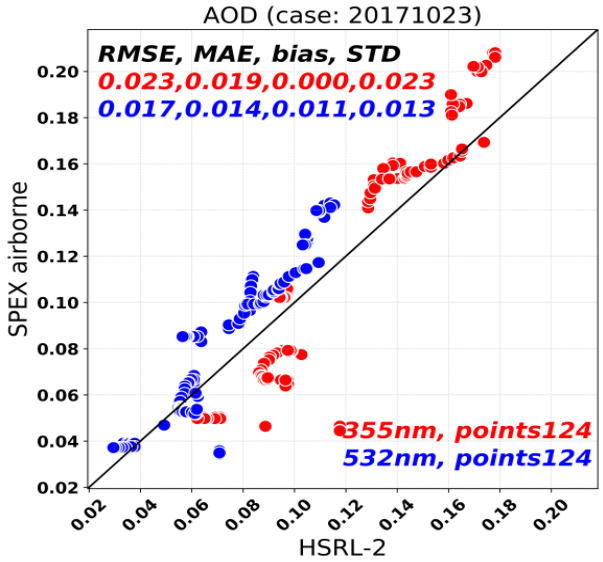




Fu et al., 2019, AMTD

Presentation Wednesday 11.15 by Guangliang Fu





Fan et al., 2019, Remote Sensing, Submitted

Poster nr. 29 by Cheng Fan

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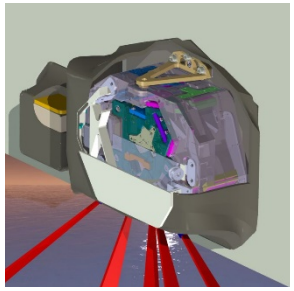
PACE synergetic science

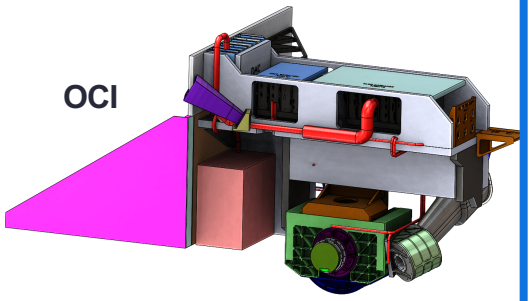
SPEXone



Hyperspectral, multi (5)-angle, radiance and polarization for 385-770 nm

Focus: Aerosol

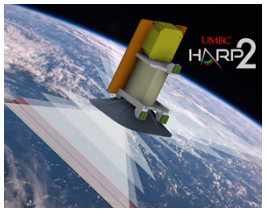
OCI



Hyperspectral 1-angle 340-890 nm + 6 SWIR bands

Focus: Ocean color

HARP2



Hyper-angular radiance and polarization at 4 spectral bands (440-870 nm)

Focus: Clouds

Synergetic retrieval

- Unprecedented information on aerosol absorption.
- Unprecedented information on aerosol type and size.
- Unprecedented capability on aerosol above cloud retrievals.
- Simultaneous aerosol and cloud measurements for indirect effect studies.
- Unprecedented passive remote sensing of aerosol layer height
- Unprecedented capability for atmospheric correction ocean color remote sensing.

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