SpexOne for the NASA PACE Mission

Otto Hasekamp, Jeroen Rietjens, Antonio di Noia, Guangliang Fu, Lianghai Wu, Jochen Landgraf, Martijn Smit, Aaldert van Amerongen

SRON

AIRBUS DEFENCE & SPACE

Netherlands Institute for Space Research

Netherlands Organisation for Scientific Research (NWO)

Programmatic Matters

- External funding is not yet secured.
- Discussions with NSO ongoing.
- Final decision needed before June 2018 (spacecraft PDR).
- Funding on initial development (toward PDR) needed earlier. Currently ADS-NL and SRON work on internal funding.

Science goals

Aerosol Direct Radiative Forcing

Aerosol effect on cloud formation

air quality (demonstration)

atmospheric correction (demonstration / verification)

SPEXOne Products (100 km swath)

Aerosols (fine and coarse mode):
Single Scattering Albedo (0.025)
Effective radius (10%)
real refr. index (0.02)
imag. refr. index (1 x 10^{-3} or 15%)
Aerosol Optical Thickness (0.03 or 10%)
Aerosol layer height (500 m)
Aersol number column
Particle shape

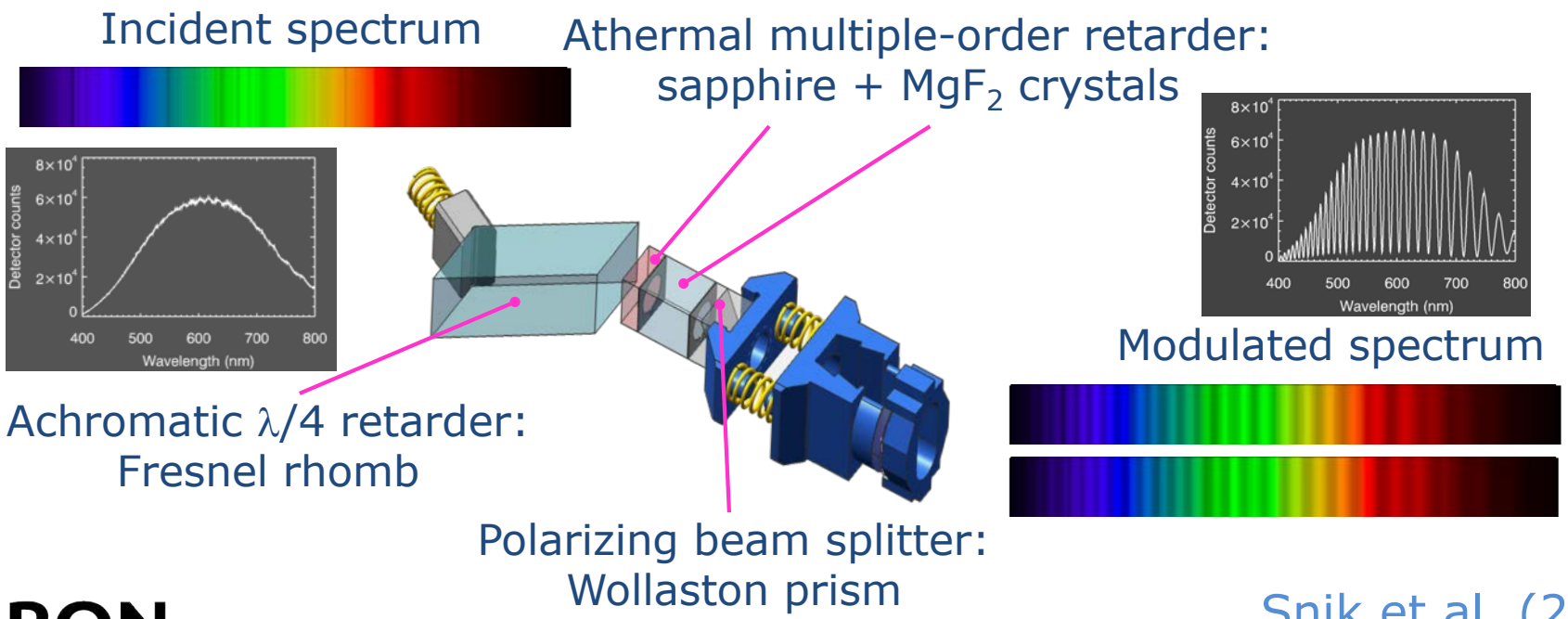
Clouds
Optical thickness (10%)
Effective radius (10%)
Effective variance (50%)
Cloud top height (300 m)
Droplet number column

SRON

Spectral modulation concept

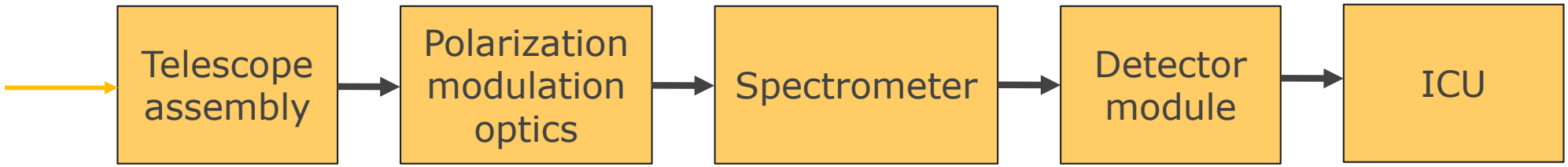
- Goal: high polarimetric accuracy (10^{-3})
- Linear polarization parameters encoded in radiance spectrum by passive optical components

$$I(\lambda) = \frac{I_0(\lambda)}{2}\left[1 \pm P(\lambda)\cos\left(\frac{2\pi\delta(\lambda)}{\lambda} + 2\phi(\lambda)\right)\right]$$



Snik et al. (2009)

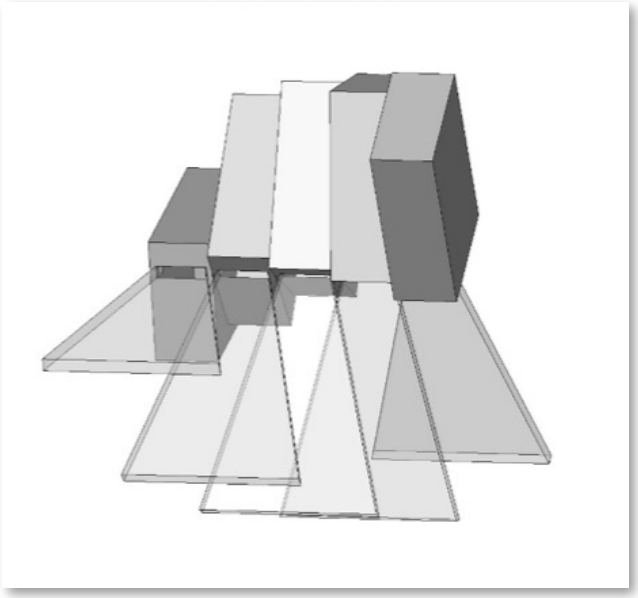
SPEX instrument concept



- Scattered sunlight channeled by telescope assembly
- Polarization modulation optics
- VIS spectrometer
- CMOS detector module
- ICU for instrument control, thermal control, data handling, housekeeping

SpexOne Instrument Specification

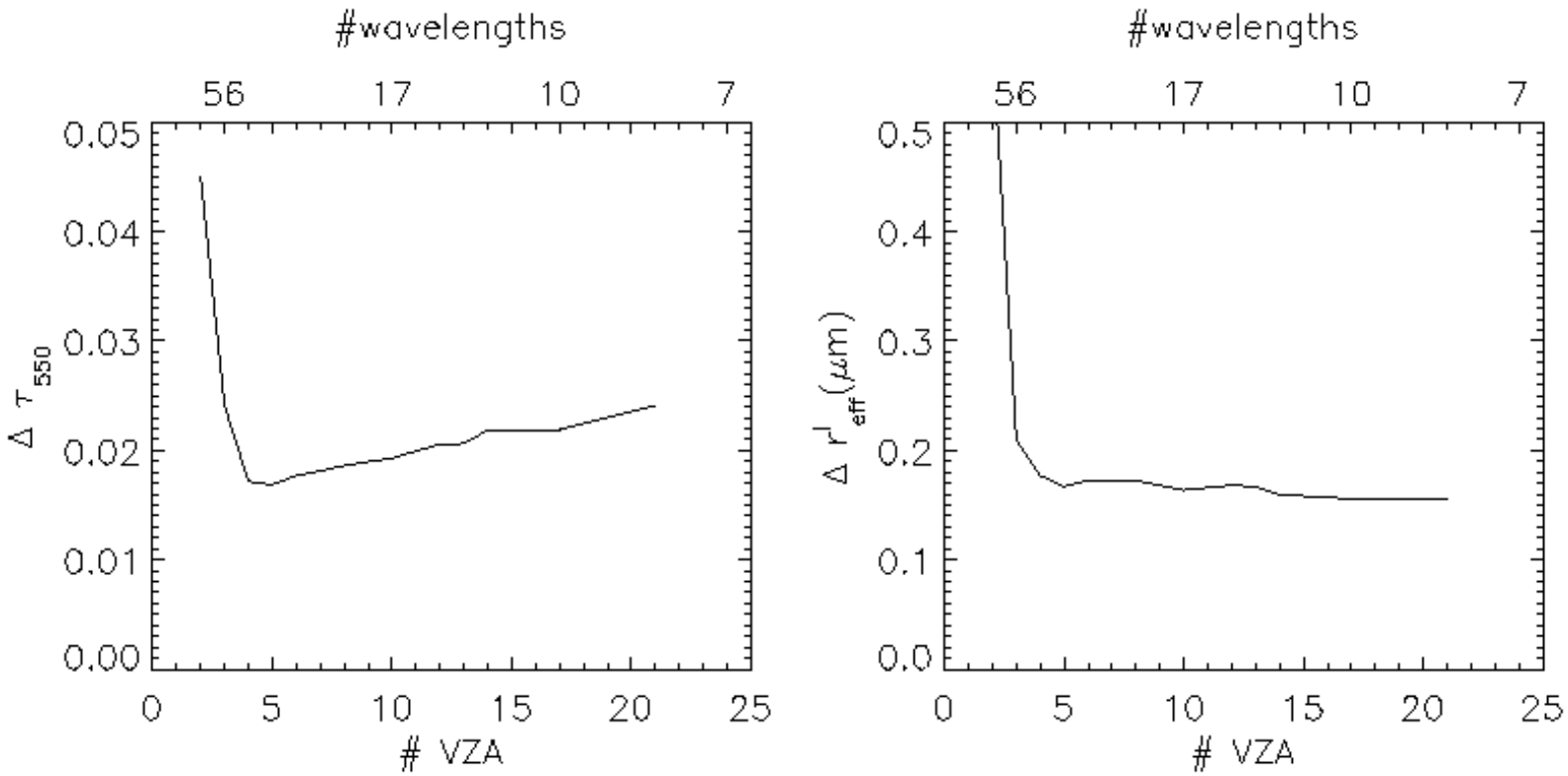
Parameter	Specification
swath	100 km
angular range (at spacecraft)	±50°
# viewing angles	5
spectral range	385–770 nm
spectral resolution intensity	5 nm
spectral resolution DoLP	15 nm @ 385 nm 45 nm @ 770 nm
spatial resolution (for all angles)	5 x 5 km^2
spatial sampling	2.5 x 2.5km^2
polarimetric accuracy	0.003
radiometric accuracy	2%
Signal to Noise Ratio (SNR) at DoLP resolution, for LER=0.03 @770 nm, SZA = 70°	300



SPEX's passive spectral modulation technology guarantees **very high polarimetric performance**: Instantaneous measurement of degree of linear polarization and total flux as a continuous function of wavelength in a single shot. High reliability with the **absence of moving parts**

Angular versus Spectral Information

(Keeping total number of measurements constant)

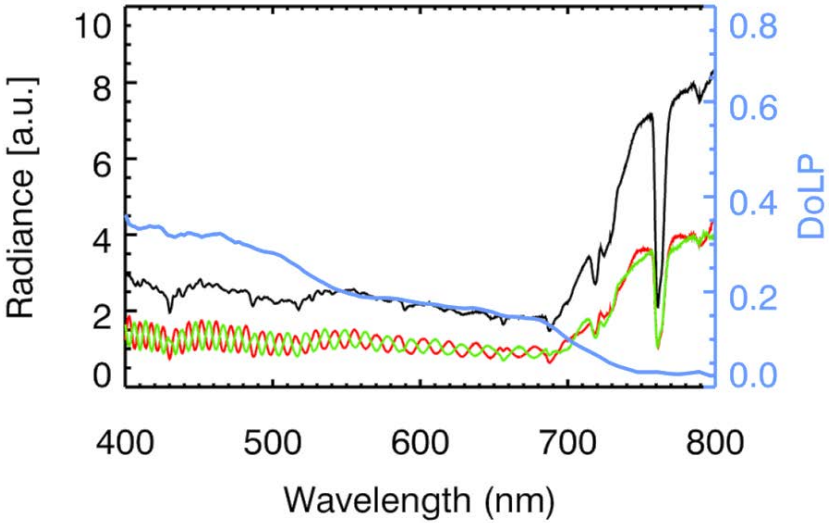


Hasekamp and Landgraf, AO, 2007

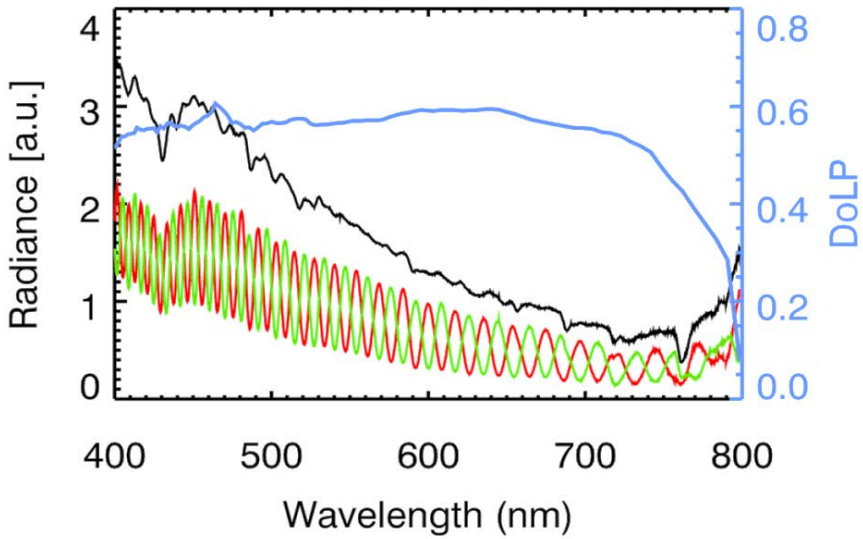
- 5 viewing angles needed (+- 55°)
- After that point adding wavelengths helps more than adding angles.
- Results confirmed by later studies (Wu et al., 2015; Xu et al., 2017)

SPEX Hyperspectral Radiance and Polarization Measurements

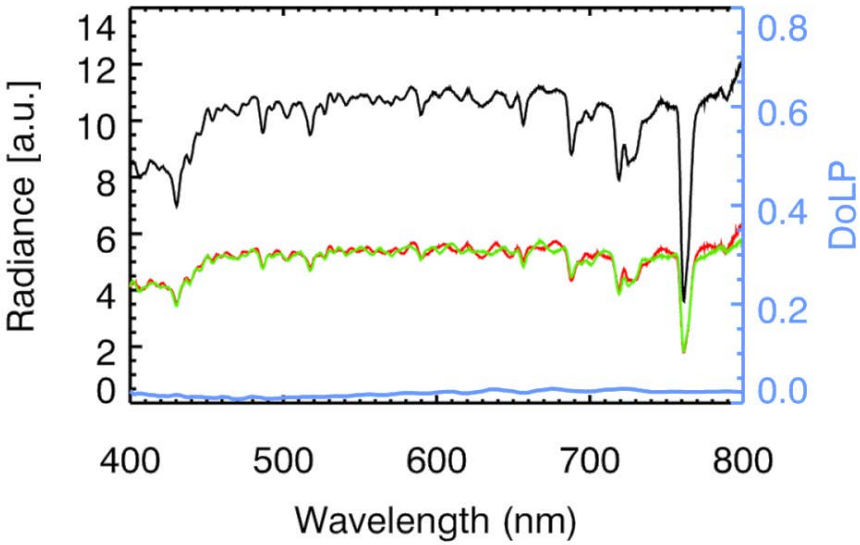
VEGETATION



OCEAN

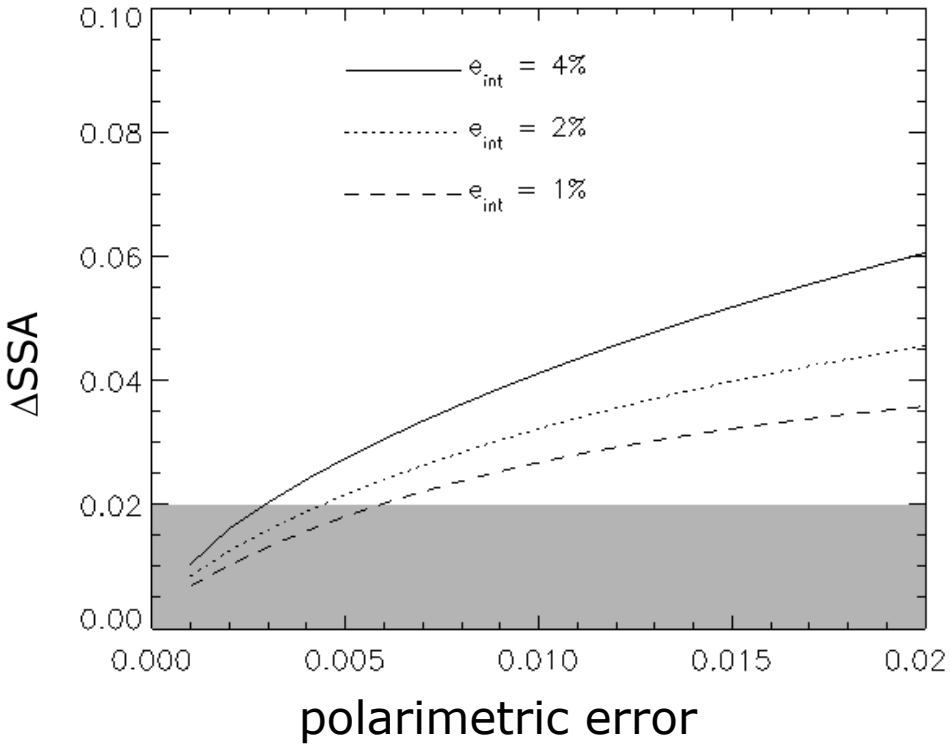


CLOUDS

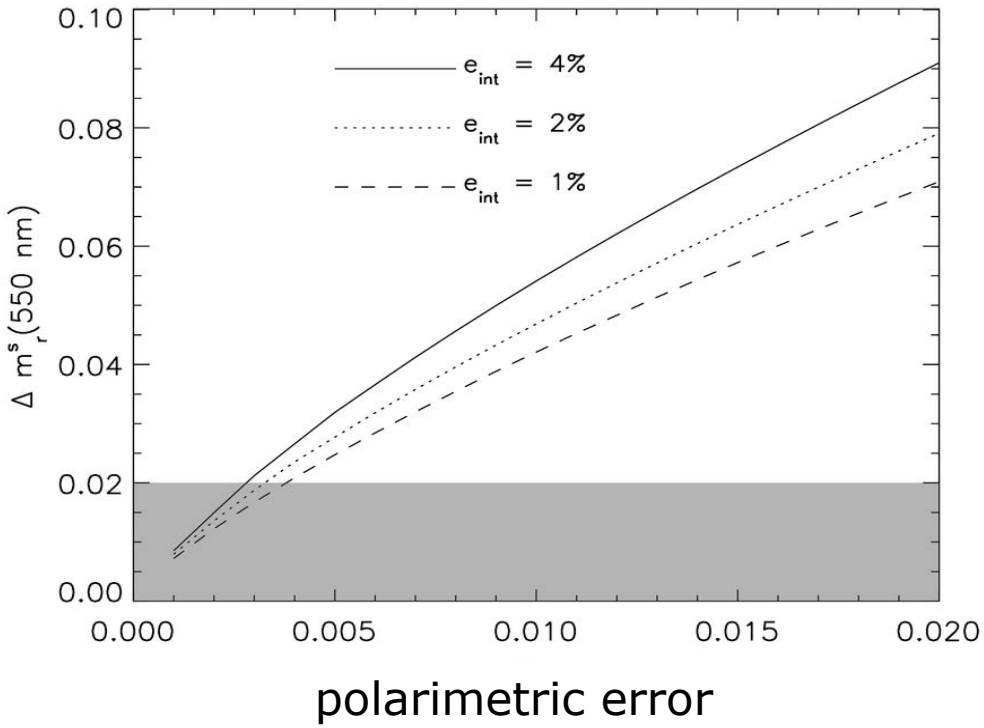


Focus on Polarimetric Accuracy

Single Scattering Albedo



Real Refractive Index



Hasekamp and Landgraf, AO, 2007
Hasekamp, AMT, 2010

Descopes

Availability of external funds made 2 descopes necessary

- 2015: SPEX + ASPIM

VNIR + SWIR (hyperangular), swath 900 km

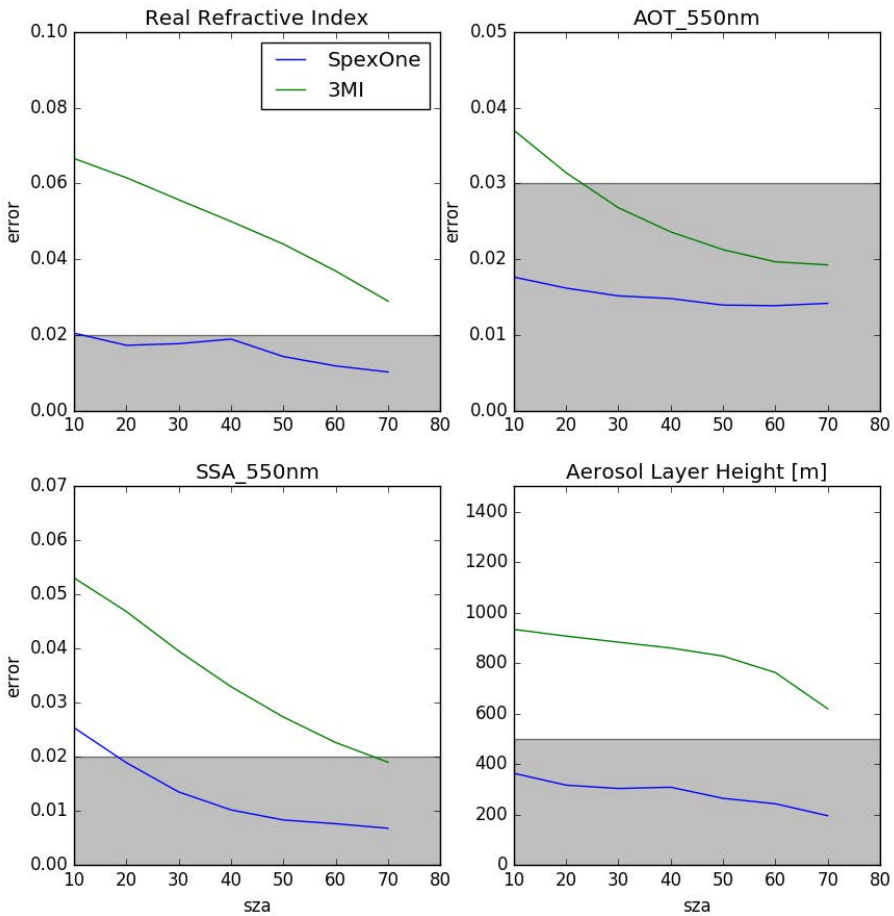
- 2016: SpexLite

VNIR, swath 900 km

- 2017: SpexOne

VNIR, swath 100 km

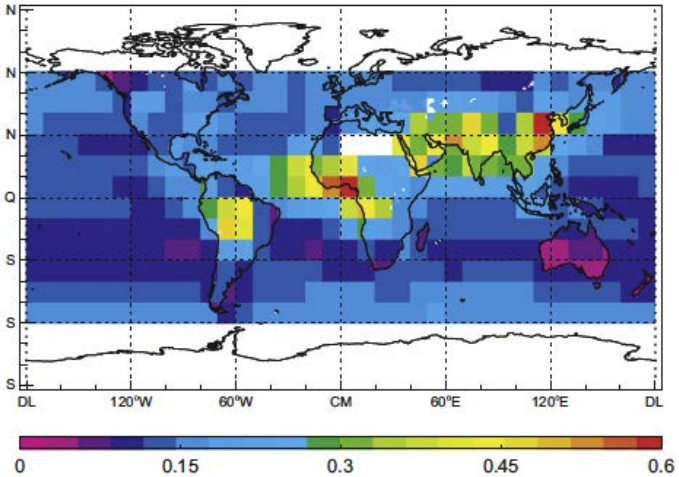
Descope – 1: Can we do without SWIR?



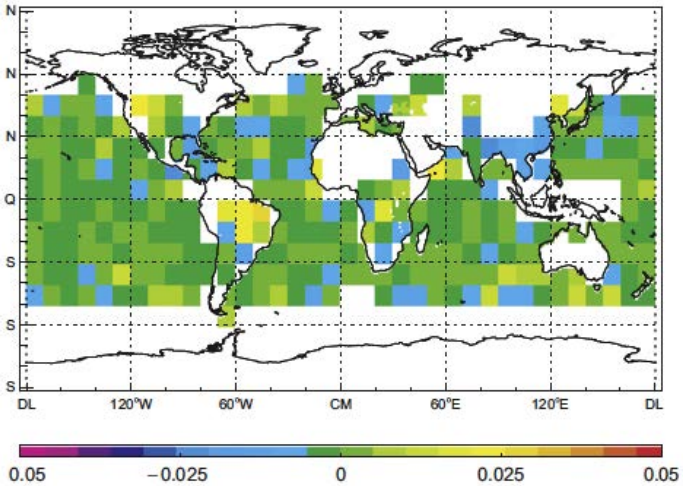
Also without SWIR SpexOne can provide significant improvement over 3MI because of higher polarization accuracy (~1 order improvement)

Descope – 2: Is a 100 km swath still useful?

MODIS
Annual mean AOT - 2007



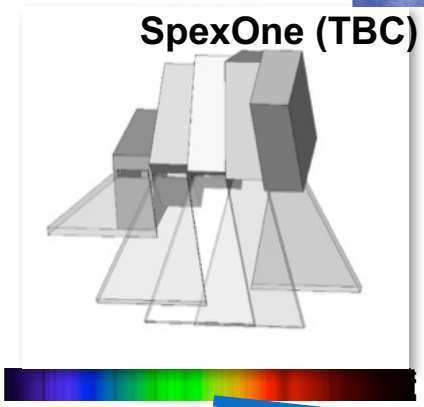
Δ single pixel vs full swath



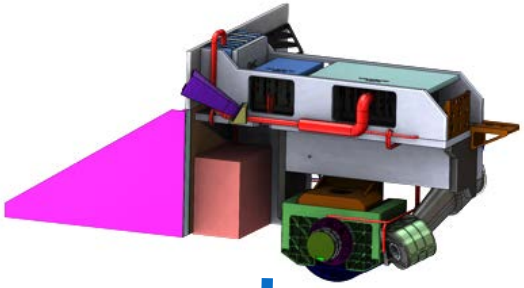
- A single pixel instrument provides the same annual mean AOT for most of the globe.
- SpexOne has 20 times more coverage.
- For climate applications SpexOne provides useful coverage.
- For air quality forecasts the coverage of SpexOne is too limited.
- SpexOne is still valuable for evaluation of air quality models.
- SpexOne can serve as input to retrieval algorithms of HARP and OCI on PACE to extend spatial coverage.
- SpexOne data will be assimilated in GEOS-5 together with HARP and OCI.

SRON Geogdzhayev et al., JQSRT, 2013

SpexOne (TBC)



OCI

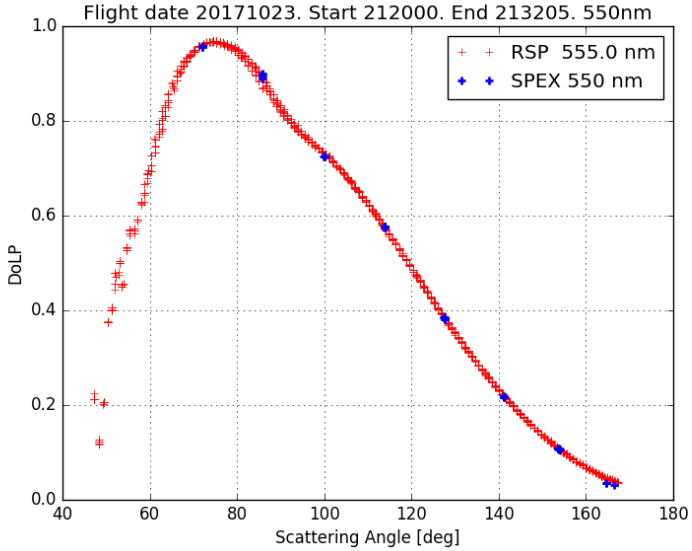


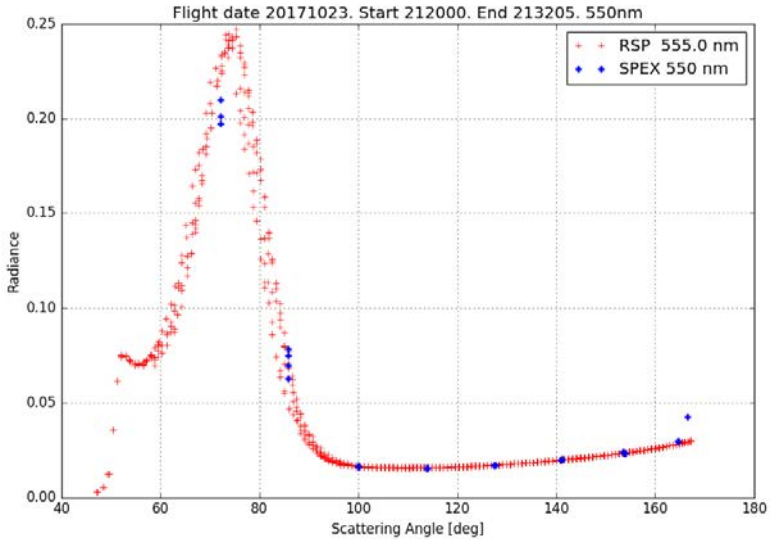
- Hyperspectral, multi (5)-angle, radiance and polarization measurements for 385-770 nm
- Hyper-angular radiance and polarization measurements at 4 spectral bands (440-870 nm)
- Hyperspectral single viewing angle measurements 340-890 nm + 6 SWIR bands

- Unprecedented information on aerosol absorption.
- Unprecedented information on aerosol type
- Unprecedented capability on aerosol above cloud retrievals
- Simultaneous aerosol and cloud measurements for indirect effect studies.
- Bottom-up and top-down estimates for above cloud radiative effect.
- Unprecedented passive remote sensing of aerosol layer height

Spex airborne results

Polarimeter intercomparison
DoLP and radiance vs Scattering angle
SPEX & RSP 550nm

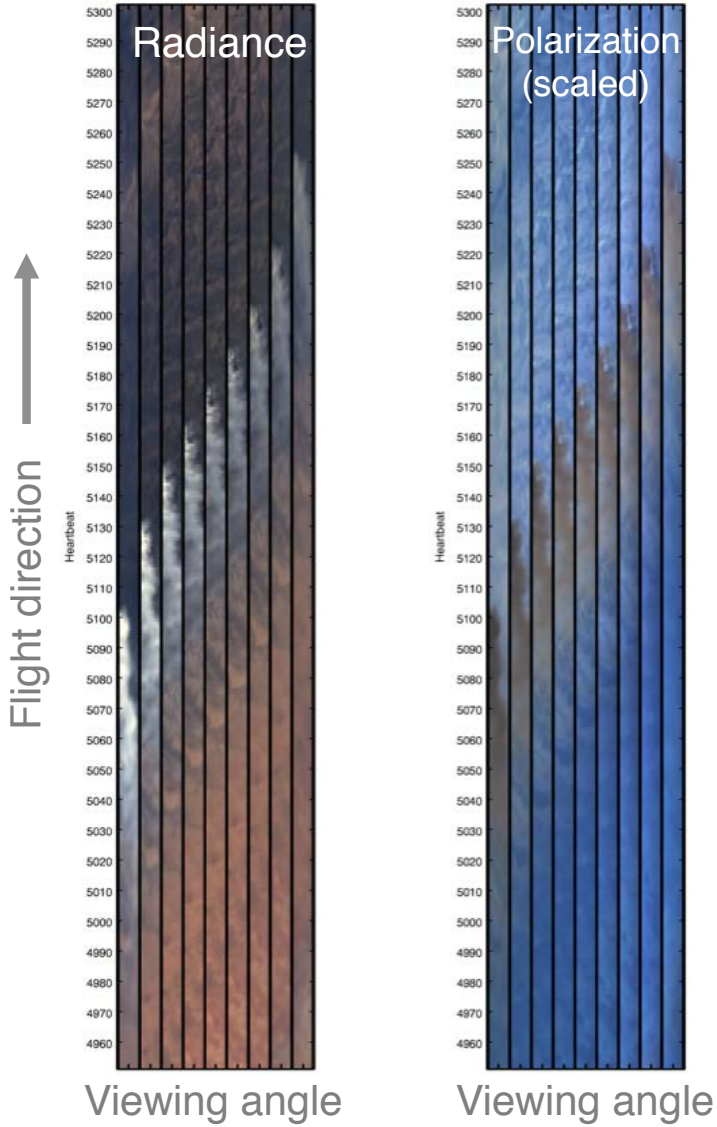




Forest fires near Flagstaff

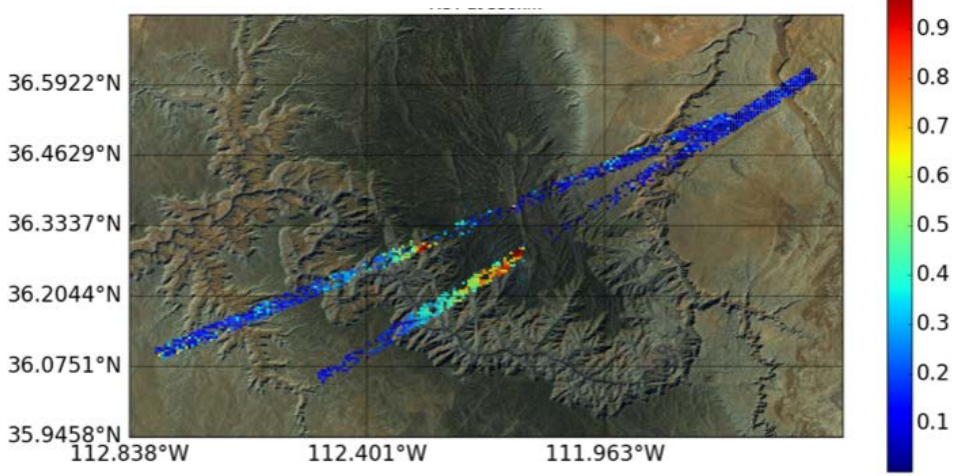
As seen from the ER-2 cockpit

As seen by SPEX airborne

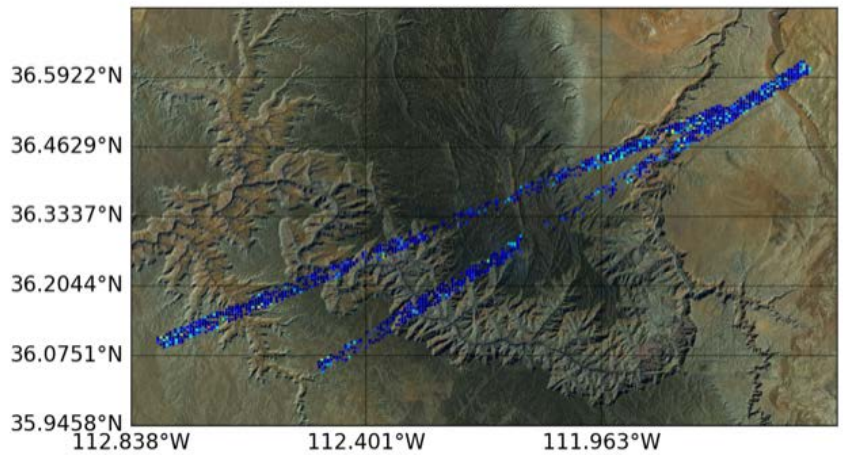


Preliminary SPEX L2 data for Smoke over Grand Canyon on October 27 2017.

Fine mode AOT



Coarse mode AOT

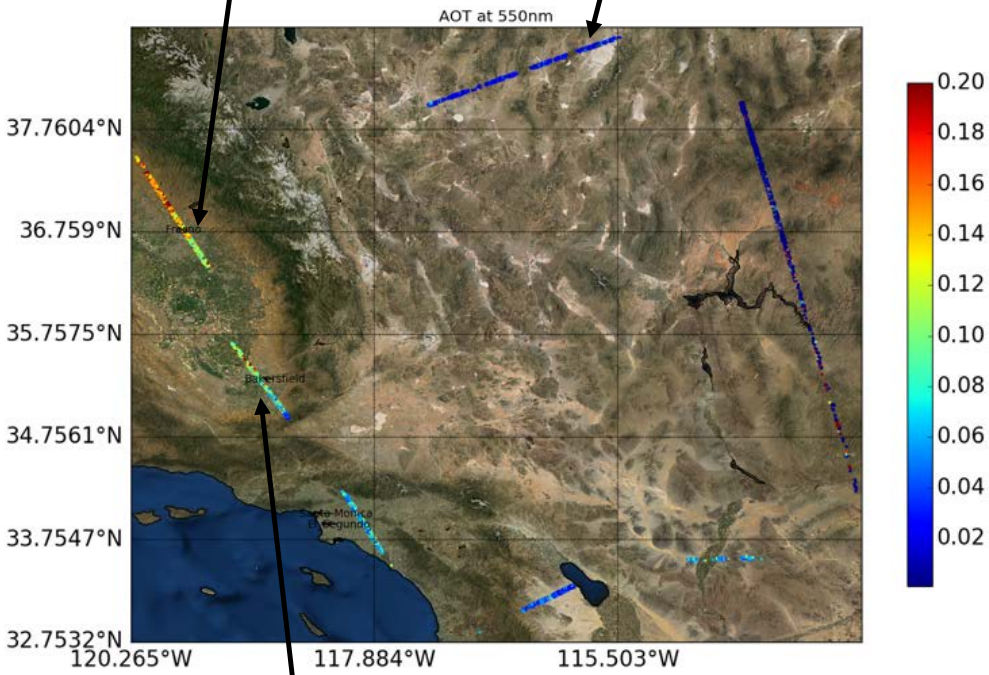


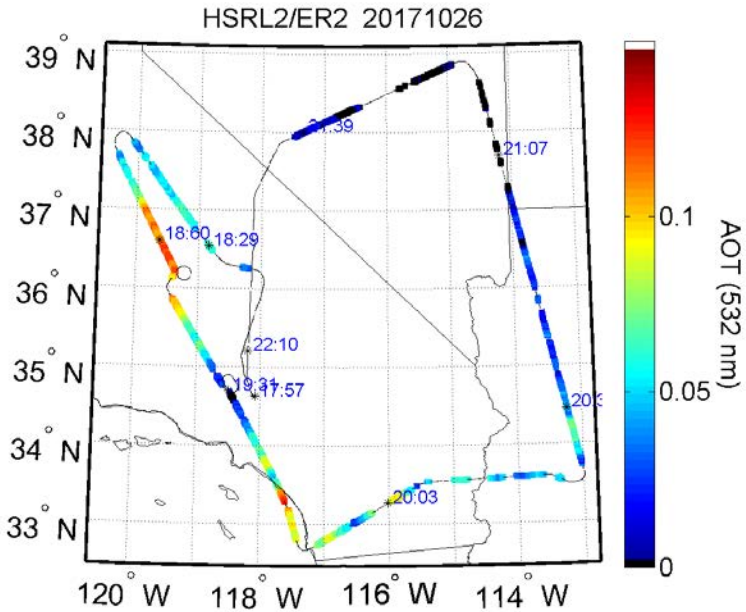
MODIS image

Low AOT over Land

Fresno:
AERONET: 0.15
SPEX: 0.14

Railroad Valley:
AERONET: 0.03
SPEX: 0.04





Bakersfield:
AERONET: 0.08
SPEX: 0.09