ALTIUS O_3 retrieval algorithms and expected in-flight performance

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ALTIUS instrument

UV channel

	bright limb	solar/lunar occultations	stellar/planetary occultations
Field of view	2° x 2°	2° x 2°	0.2° x 0.2°
Vertical sampling	600 m	600 m	60 m
Spectral filter technology	stack of 4 Fabry-Pérot interferometers		
Spectral domain	250-355 nm		
Spectral resolution	2-3 nm		
Target species	O_3, T°	O_3, BrO, OClO, T°	O_3

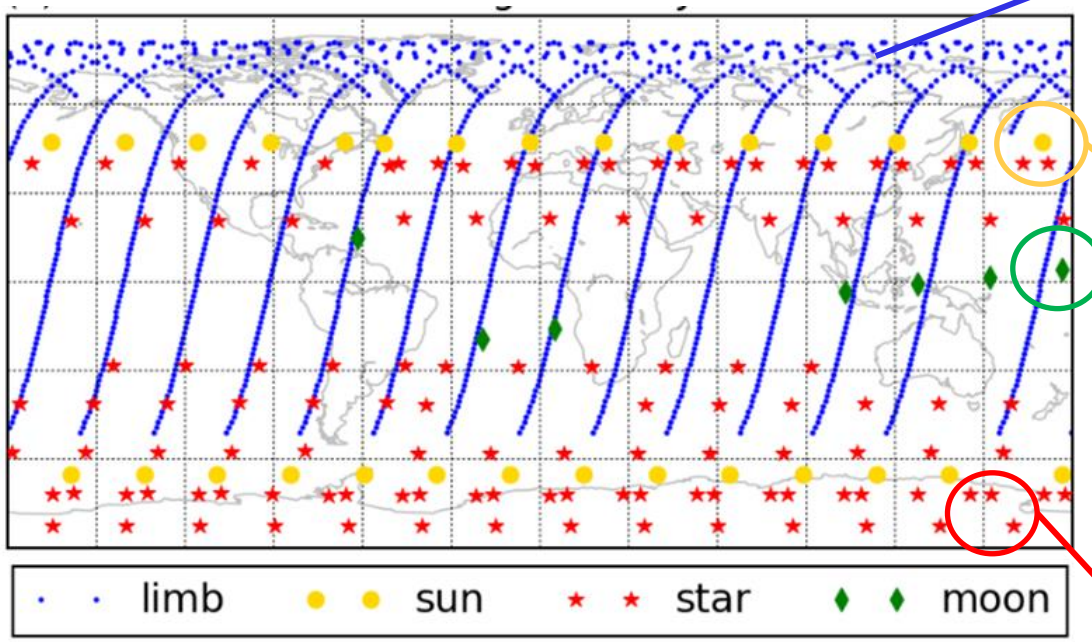
VIS channel

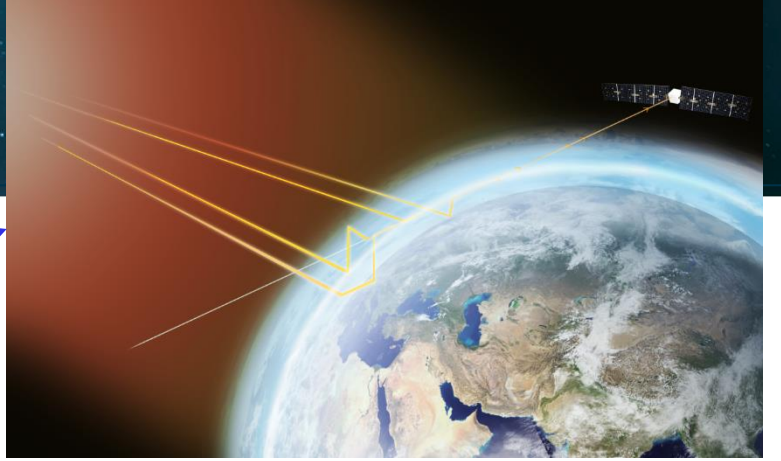
	bright limb	solar/lunar occultations	stellar/planetary occultations
Field of view	2° x 2°		
Vertical sampling	200 m		
Spectral filter technology	acousto-optical tunable filter (AOTF)		
Spectral domain	440-675 nm		
Spectral resolution	2-10 nm		
Target species	O_3, NO_2, aerosols	O_3, NO_2, aerosols, NO_3,	O_3, aerosols

NIR channel

	bright limb	solar/lunar occultations	stellar/planetary occultations
Field of view	2° x 2°		
Vertical sampling	400 m		
Spectral filter technology	acousto-optical tunable filter (AOTF)		
Spectral domain	600-1020 nm		
Spectral resolution	2-10 nm		
Target species	aerosols	aerosols, H_2O	aerosols

ALTIUS observation modes





Limb-scattering

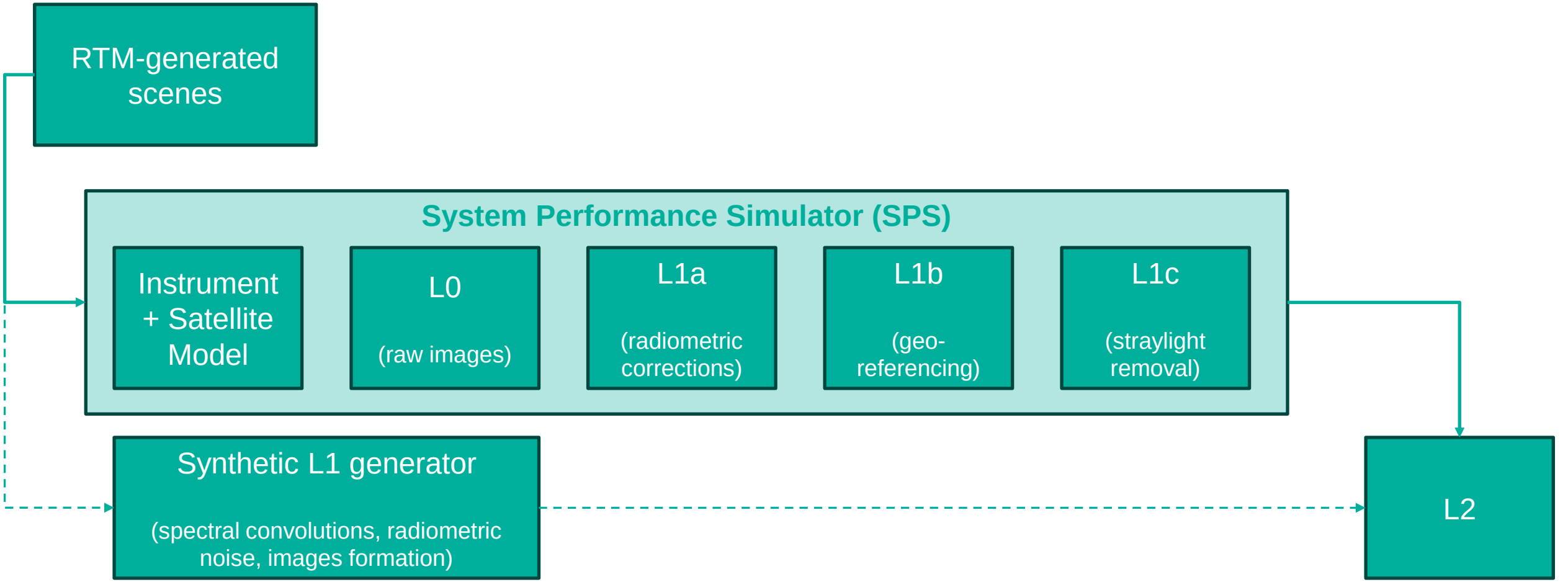
Solar/Lunar occultations

Stellar/Planetary occultations

On the capability of the ALTIUS data to constrain modelled stratospheric O_3
→ Errera et al., AMT 14, 2021

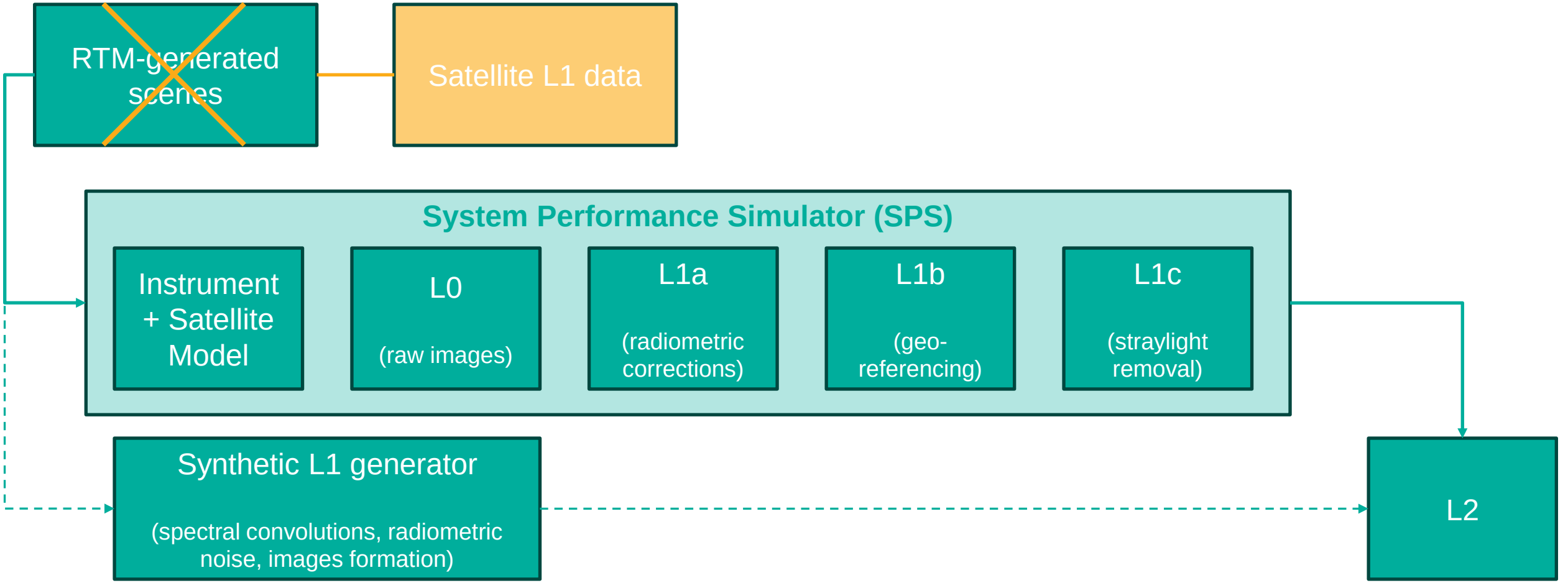
ALTIUS mission performance verification approaches

1. Based on synthetic data



ALTIUS mission performance verification approaches

1. Based on synthetic data
2. Based on existing satellite data



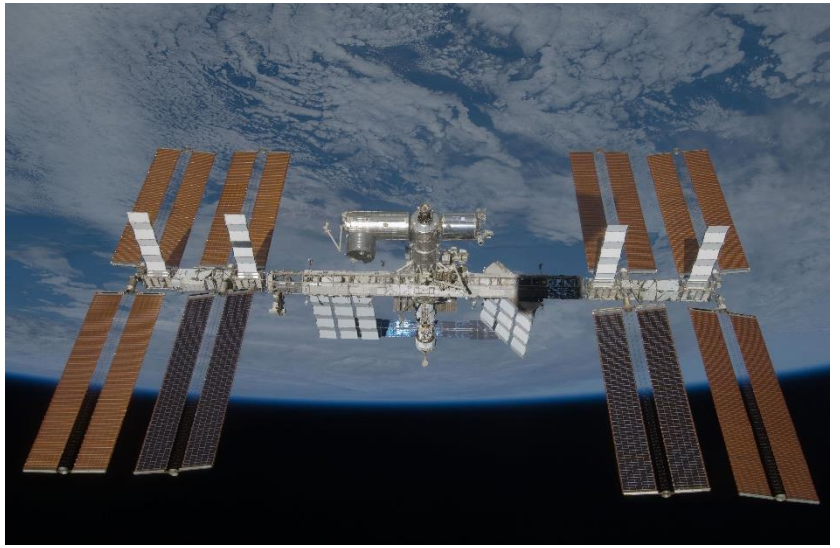
ALTIUS mission performance verification approaches

Bright limb

OMPS-LP

Solar occultations

SAGE-III



Stellar occultations

GOMOS

ALTIUS mission performance verification approaches

Satellite instrument L1 file

OMPS-LP: -limb radiance spectra
-solar angles
-satellite position/velocity
GOMOS: -atmospheric transmittance spectra
-1kHz scintillation term
-star ID and TOA spectrum
SAGE-III: -atmospheric transmittance spectra

Satellite instrument L2 file

-O3 profile
-Aerosol extinction coef. profile (at TBD wavelength)
-Temperature
-Pressure
-Albedo

ALTIUS "stimulification"

-Creation of a pseudo stimuli
-Replacement of atmospheric parameters (T°, P, O3, etc)
-Update the light source settings (solar angles or star ID)
-Interpolation/extrapolation of the (ir)radiance spectra on the ALTIUS altitude and wavelength grid

ALTIUS SPS

-Simulation of the spectral images at the requested wavelengths (according to an acquisition plan)
-Estimation of measurement errors
-Georeferencing

L2

(O_3 profile)

Satellite instrument L2 validation report

-Latitude and altitude-dependent O3 profile random and systematic differences
Source: Ozone CCI+ PVIR v4.0

Performance Evaluation Module (PEM)

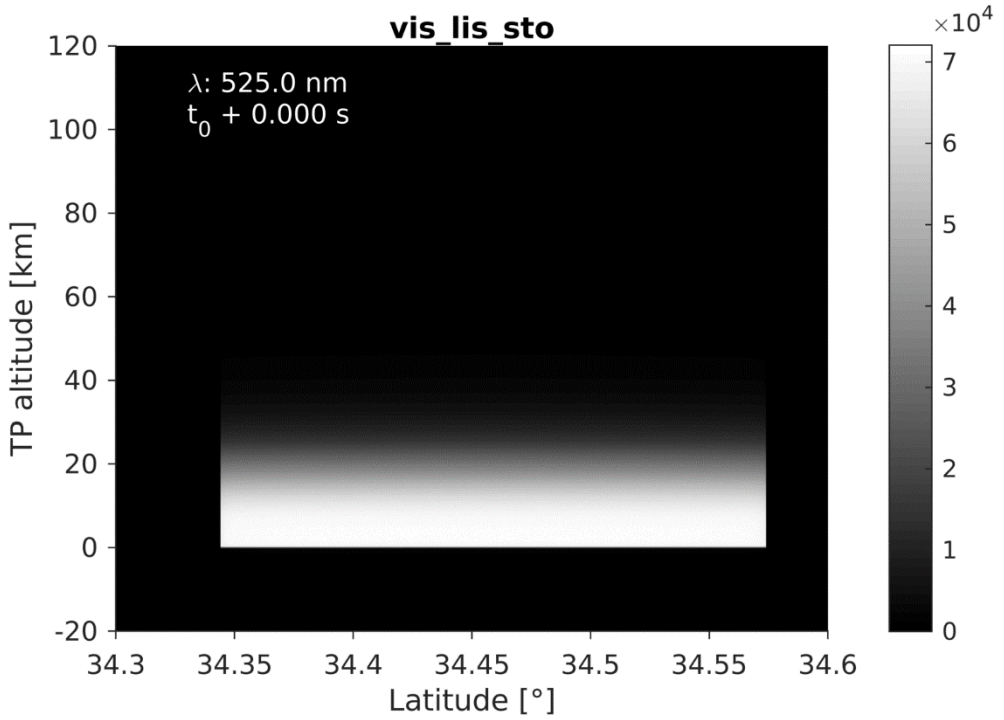
-Comparison of the 2 retrieved O3 profiles
-Assessment of significance with respect to the satellite product validation report

Intercomparison report

Limb scattering mode

Main differences between ALTIUS and OMPS-LP :

- ALTIUS takes spectral images at selected wavelengths, while OMPS-LP records spectra



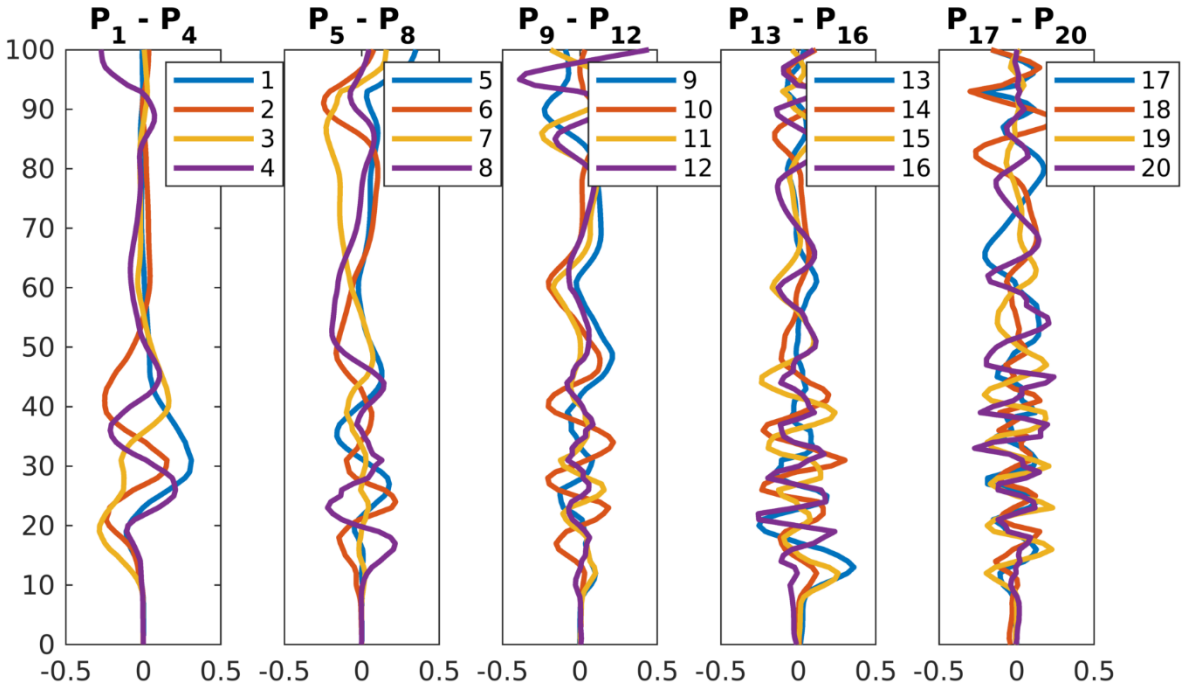
ALTIUS O_3 wavelengths:
UV: 300, 315, 351 nm
VIS: 525, 600, 675 nm

OMPS-LP O_3 wavelengths (v2.6):
UV: 295, 302, 306, 312, 317, 322, 353 nm
VIS: 510, 606, 675 nm

Limb scattering mode

Main differences between ALTIUS and OMPS-LP :

- ALTIUS takes spectral images at selected wavelengths, while OMPS-LP records spectra
- L2P forward model and state vector



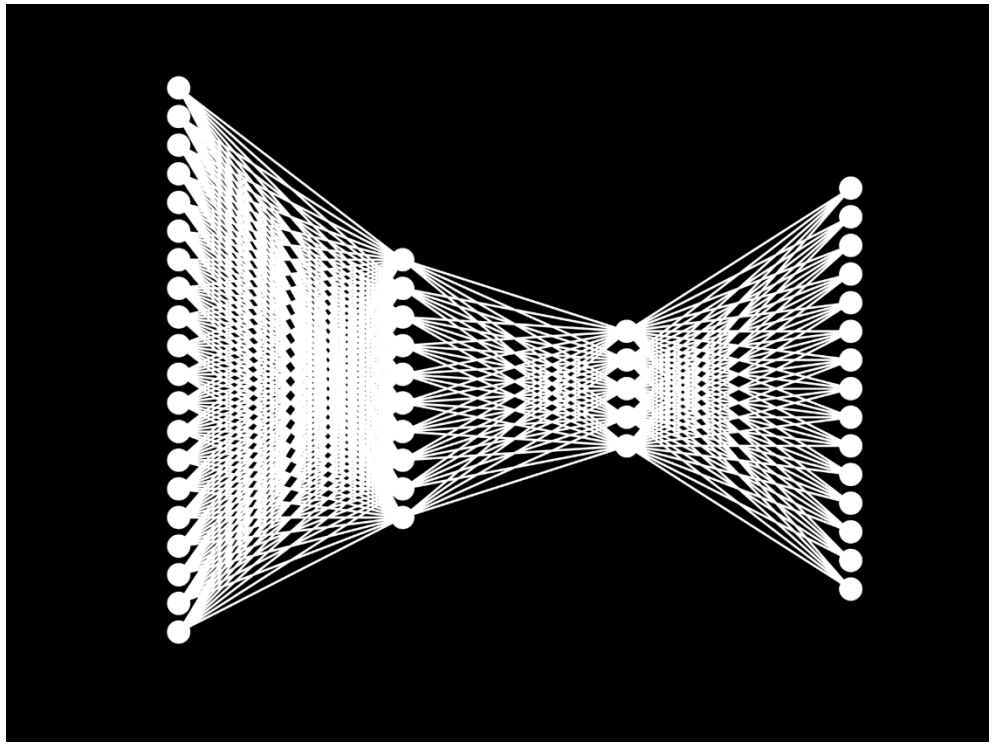
State vector:

O_3 profiles are described by the principal components of a climatology.

Limb scattering mode

Main differences between ALTIUS and OMPS-LP :

- ALTIUS takes spectral images at selected wavelengths, while OMPS-LP records spectra
- L2P forward model and state vector



L2P Forward model:

ANN trained on pairs
state vector – radiance profile

Inputs:
O_3, air, aerosol density, aerosol PSD (r, σ), albedo, SZA, SRAA

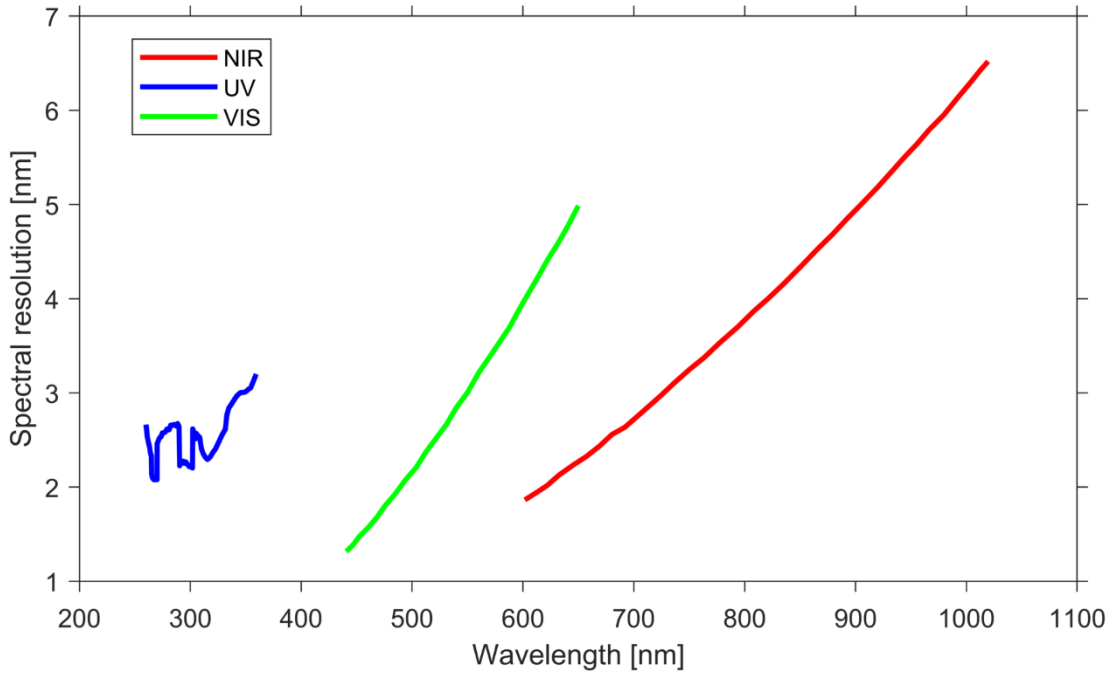
Outputs:
$I(z,\lambda), Q(z,\lambda), U(z,\lambda)$

Radiative transfer model:
SMART-G (Monte Carlo)

Limb scattering mode

Main differences between ALTIUS and OMPS-LP :

- ALTIUS takes spectral images at selected wavelengths, while OMPS-LP records spectra
- L2P forward model and state vector
- Spectral resolution



ALTIUS spectral resolution:

UV: 2 - 3 nm
VIS: 1.5 – 5 nm
NIR: 2 – 7 nm

OMPS-LP spectral resolution:
1 – 40 nm

Limb scattering mode

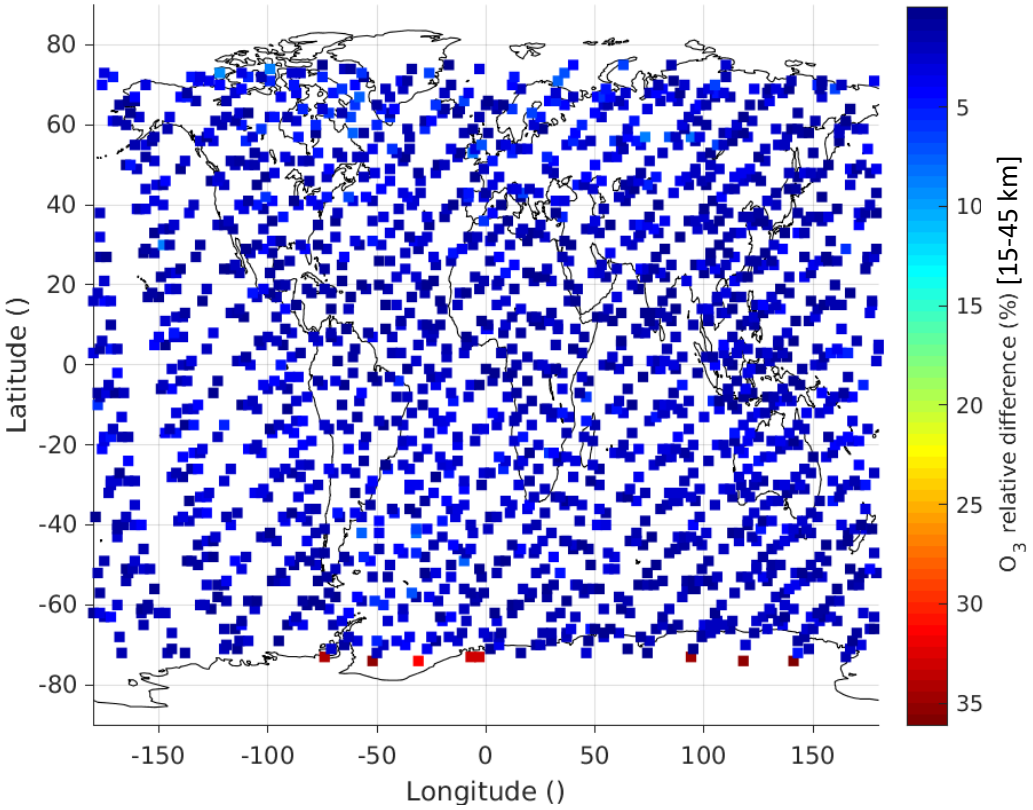
Main differences between ALTIUS and OMPS-LP :

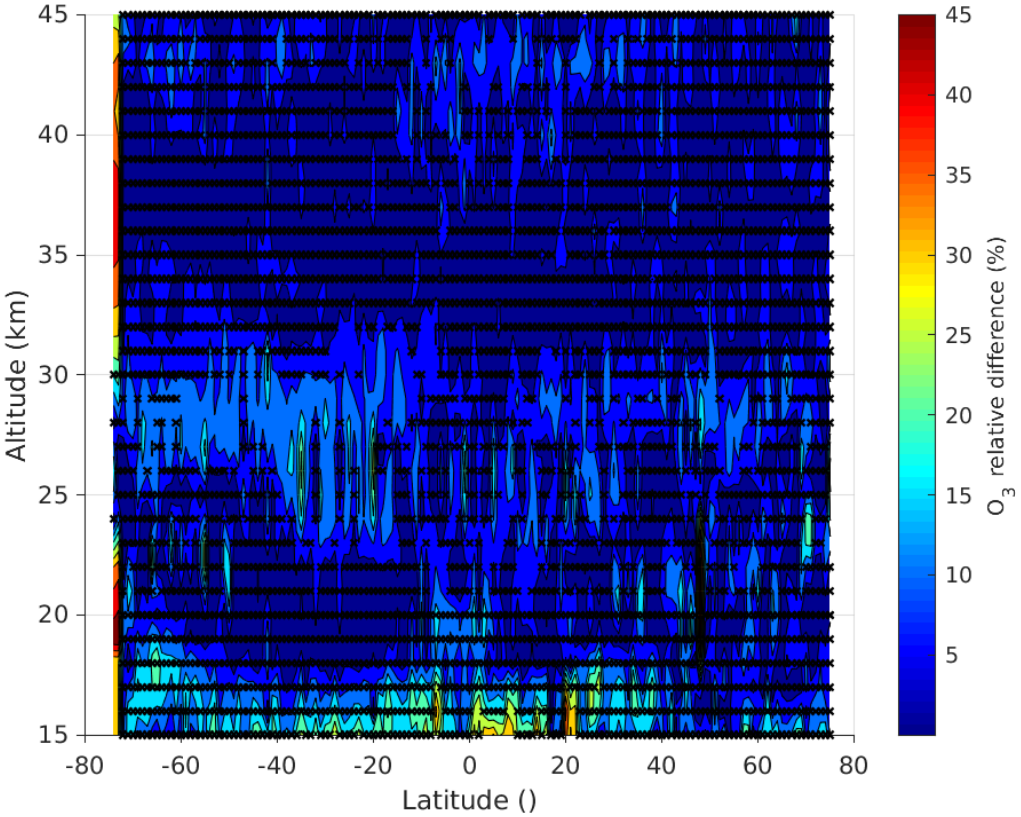
- ALTIUS takes spectral images at selected wavelengths, while OMPS-LP records spectra
- L2P forward model and state vector
- Spectral resolution
- Orbit inclination, local time, vertical/horizontal sampling, etc.

Limb scattering mode

Results of >2000 OMPS-LP observations processed (March 2016).

- ! SPS not yet able to digest OMPS-LP missing values → Results are to be seen as a validation of the L2P only !
- Good overall agreement (within the significance of the CCI+ validation exercise)



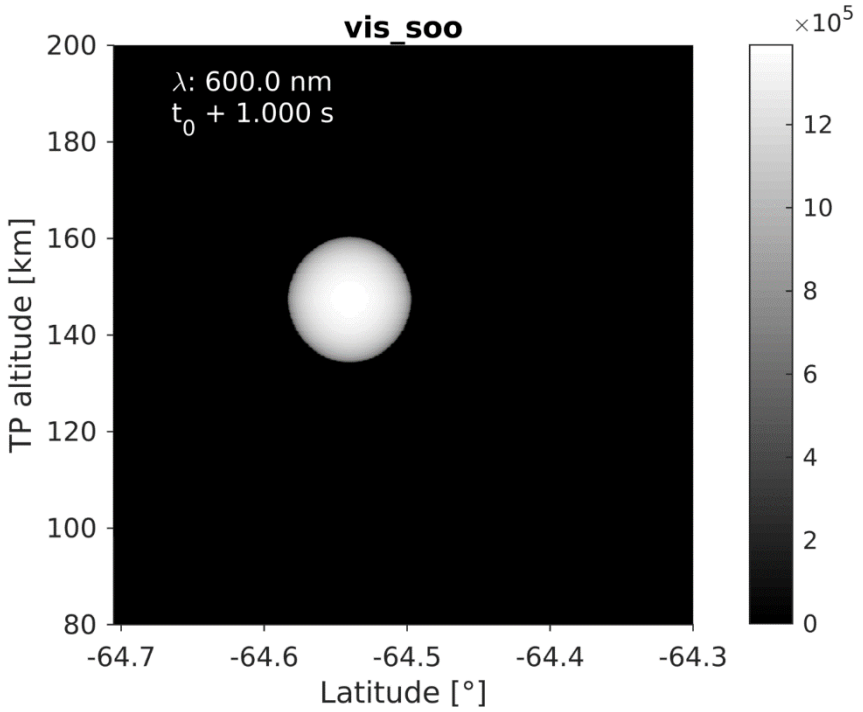


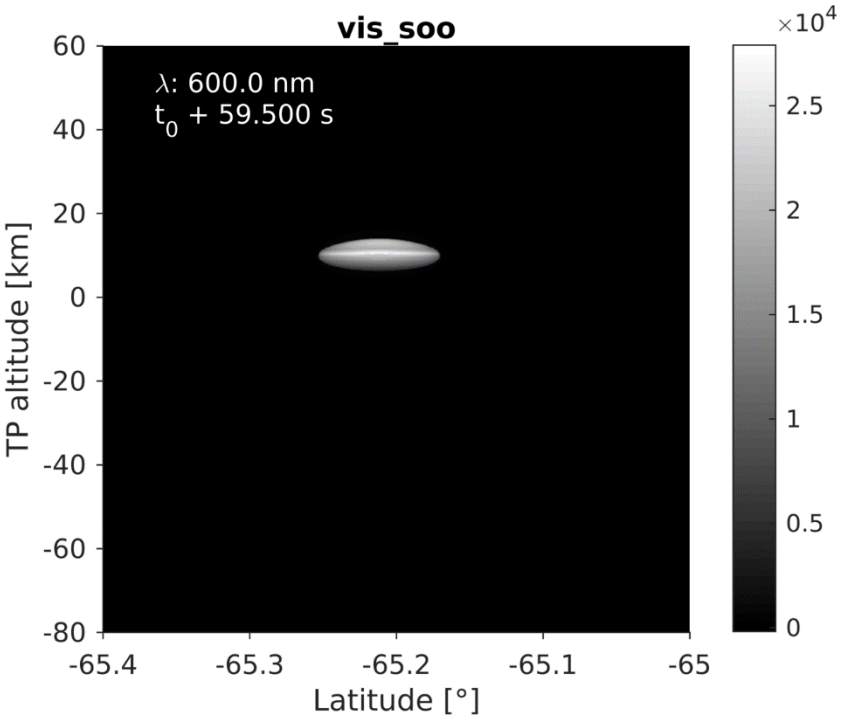
See Poster P5.6 by Sotiris Sotiriadis

Solar occultation mode

Main differences between ALTIUS and SAGE-III ISS :

- ALTIUS takes spectral images of the Sun at selected wavelengths

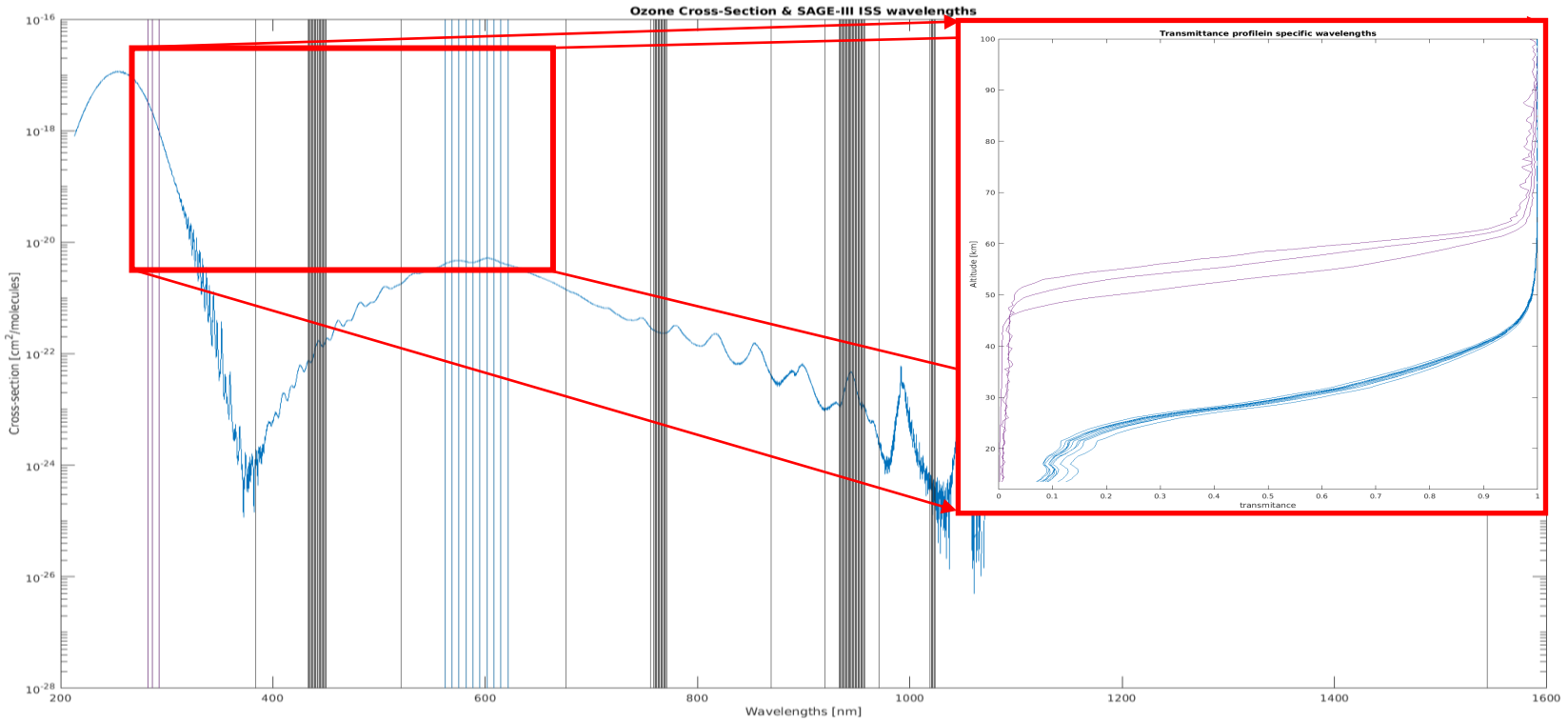




Solar occultation mode

Main differences between ALTIUS and SAGE-III ISS :

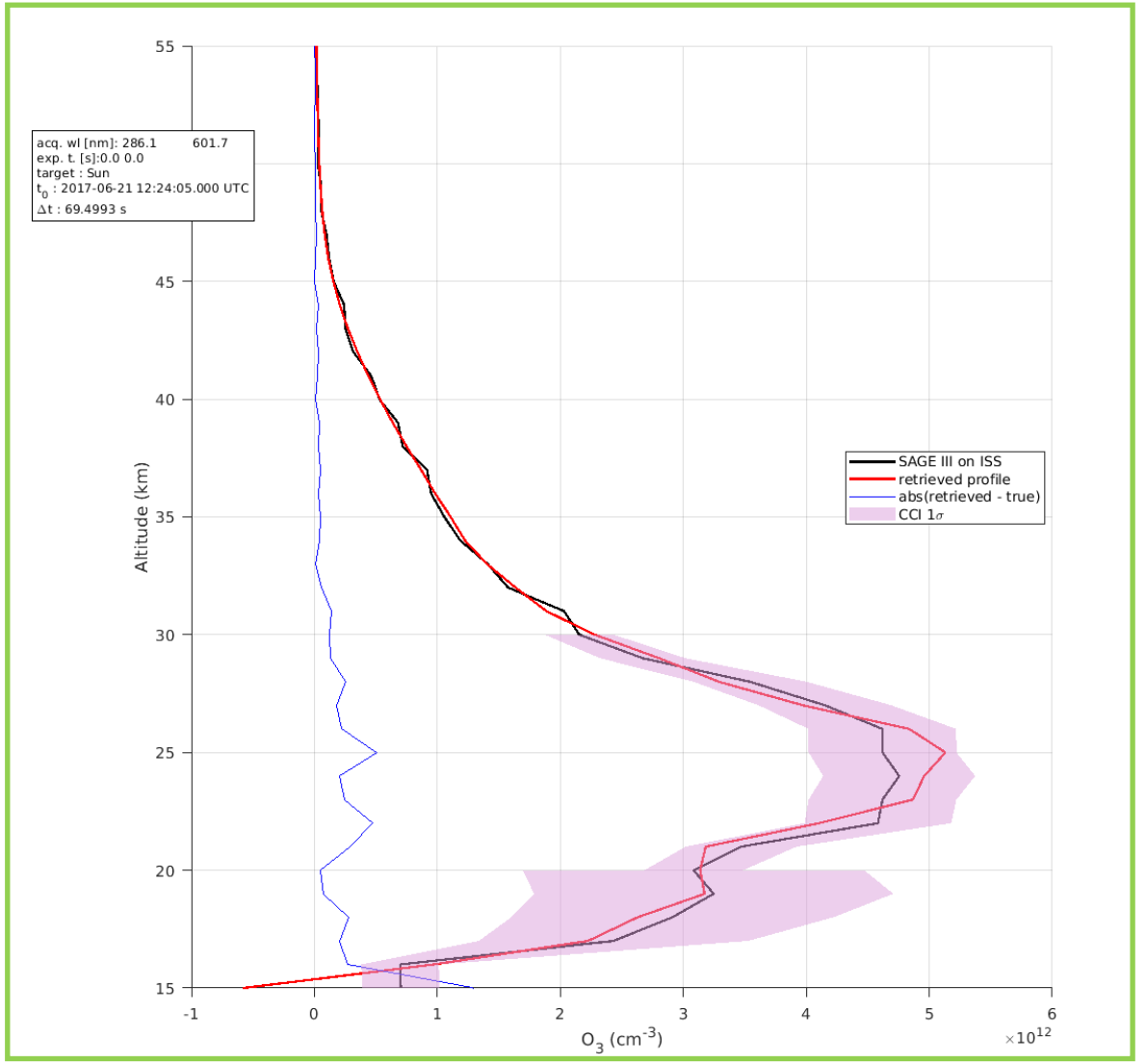
- ALTIUS takes spectral images of the Sun at selected wavelengths
- SAGE-III L1 files contain a limited number of wavelengths → Spectral convolution by SPS tricky!



Solar occultation mode

Full end-to-end processing of one SAGE-III occultation:

- ! The SPS takes ages to fabricate the >1000 spectral images acquired by ALTIUS during the occultation !
- Differences are within the CCI+ PVIR 68% quantile
- If confirmed with more SAGE-III occultations, then the ALTIUS performance in solar occultation is adequate (instrument + algorithms).



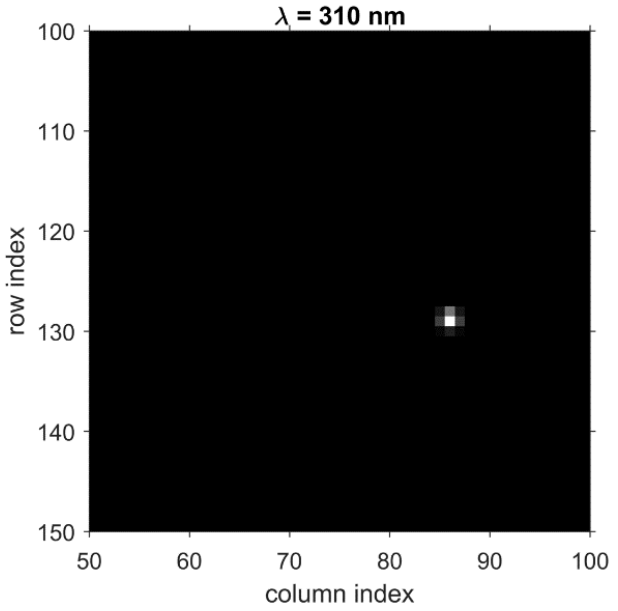
See Poster P5.2 by Kristof Rose

Stellar occultation mode

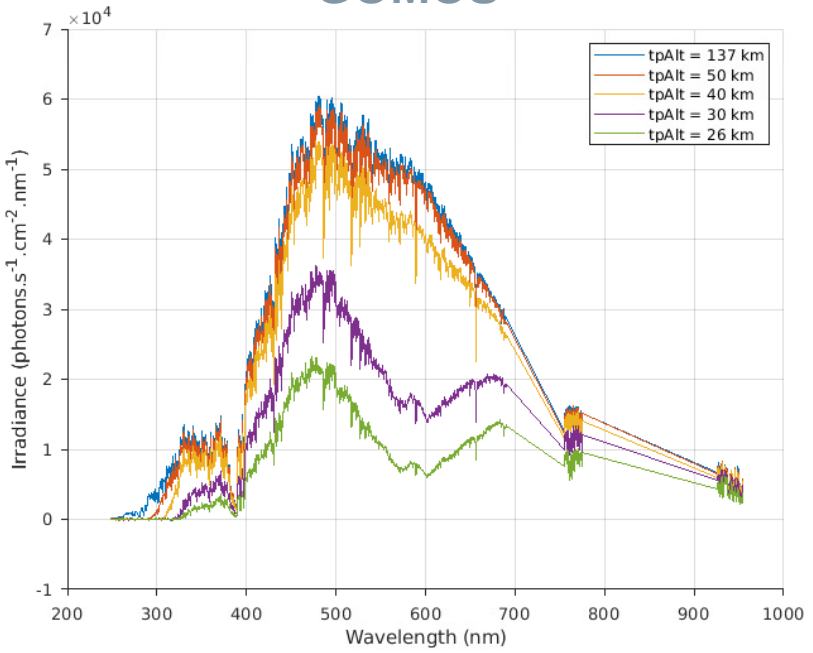
Main differences between ALTIUS and GOMOS :

- ALTIUS takes spectral images of the stars at selected wavelengths, while GOMOS acquires spectra.

ALTIUS



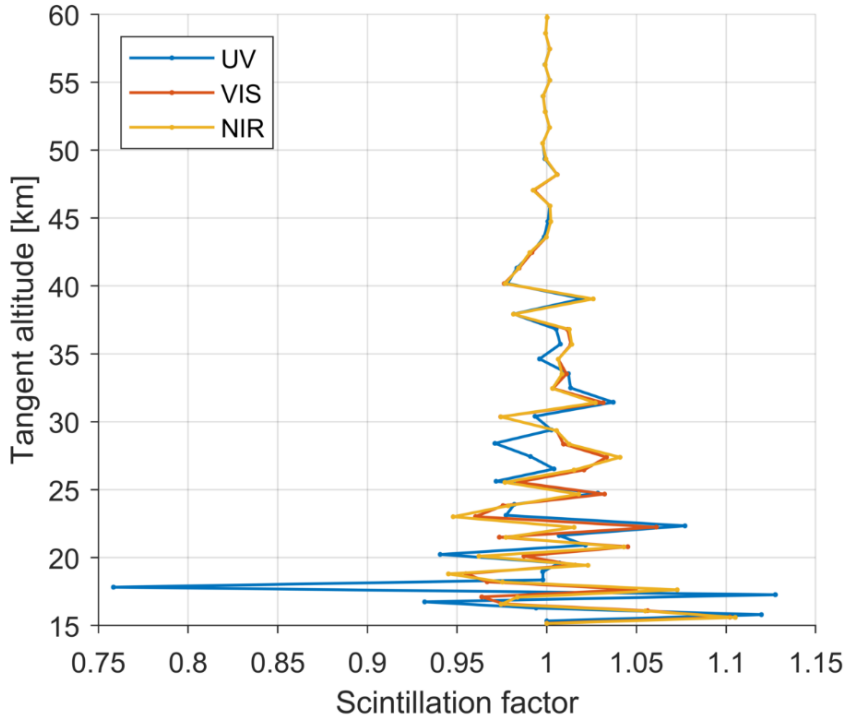
GOMOS



Stellar occultation mode

Main differences between ALTIUS and GOMOS :

- ALTIUS takes spectral images of the stars at selected wavelengths, while GOMOS acquires spectra.
- GOMOS had 2 fast photometers to assess star scintillation, ALTIUS has not.



Typical amplitude of the scintillation factor for 1 second snapshots (typ. ALTIUS).

Two ways are envisaged to mitigate scintillation in ALTIUS data:

- simultaneous acquisitions and normalizations
- stronger regularization (on oscillations)

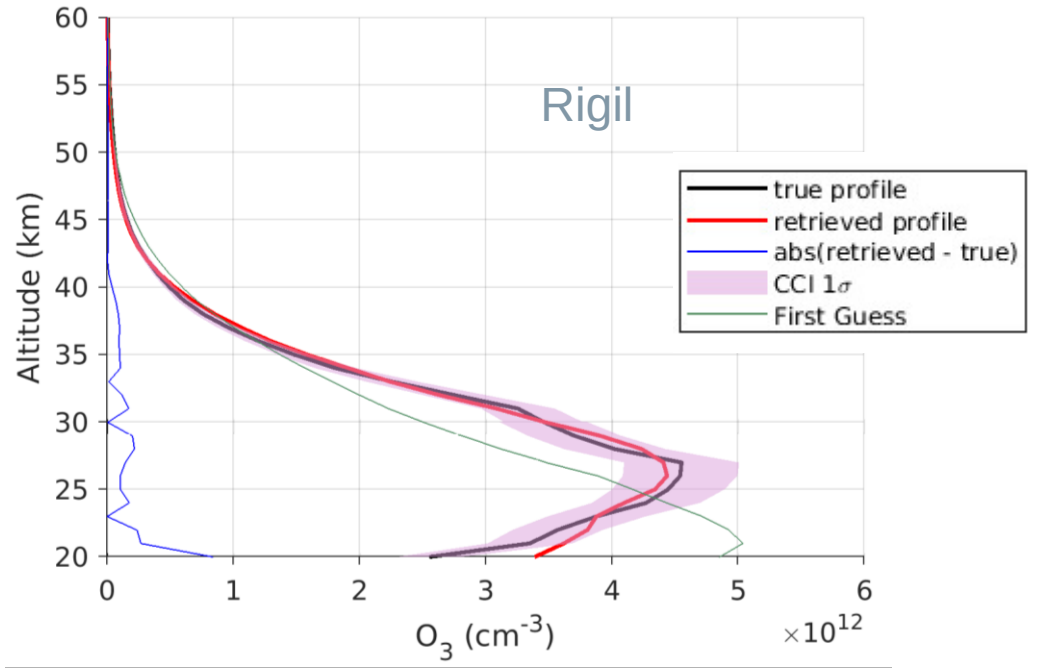
Stellar occultation mode

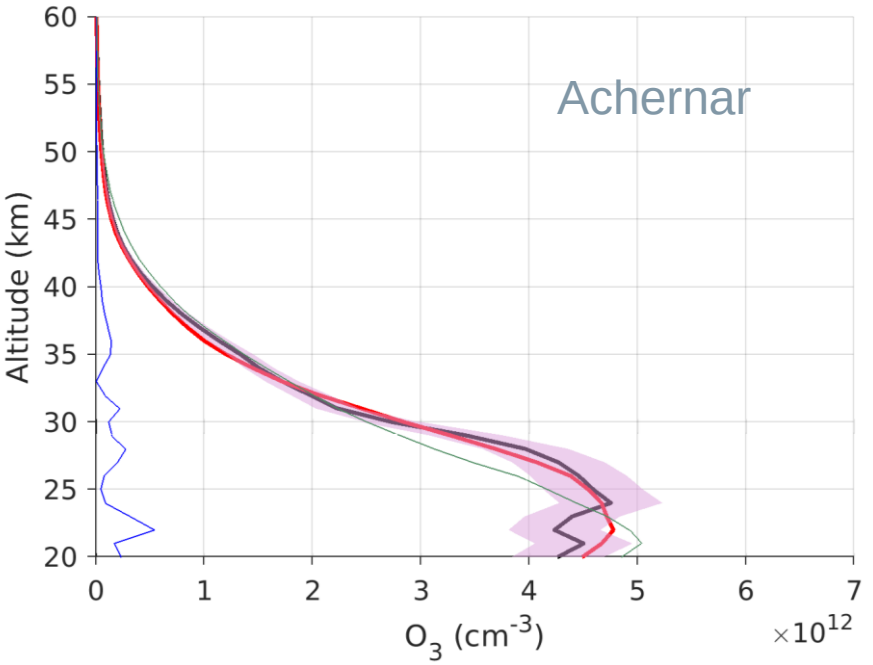
Main differences between ALTIUS and GOMOS :

- ALTIUS takes spectral images of the stars at selected wavelengths, while GOMOS acquires spectra.
- GOMOS had 2 fast photometers to assess star scintillation, ALTIUS has not.
- ALTIUS has a smaller aperture, hence reduced SNR (likely limiting to the 10-15 brightest bodies)

Stellar occultation mode

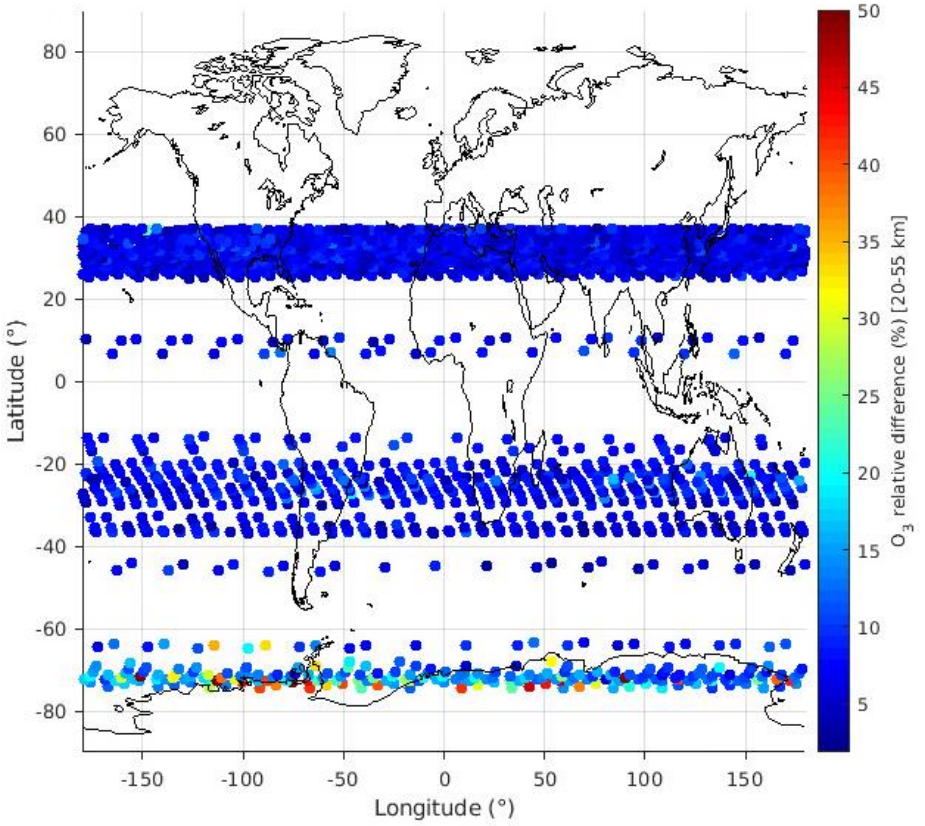
Full end-to-end processing of GOMOS data were achieved with the SPS, and the baseline L2P.

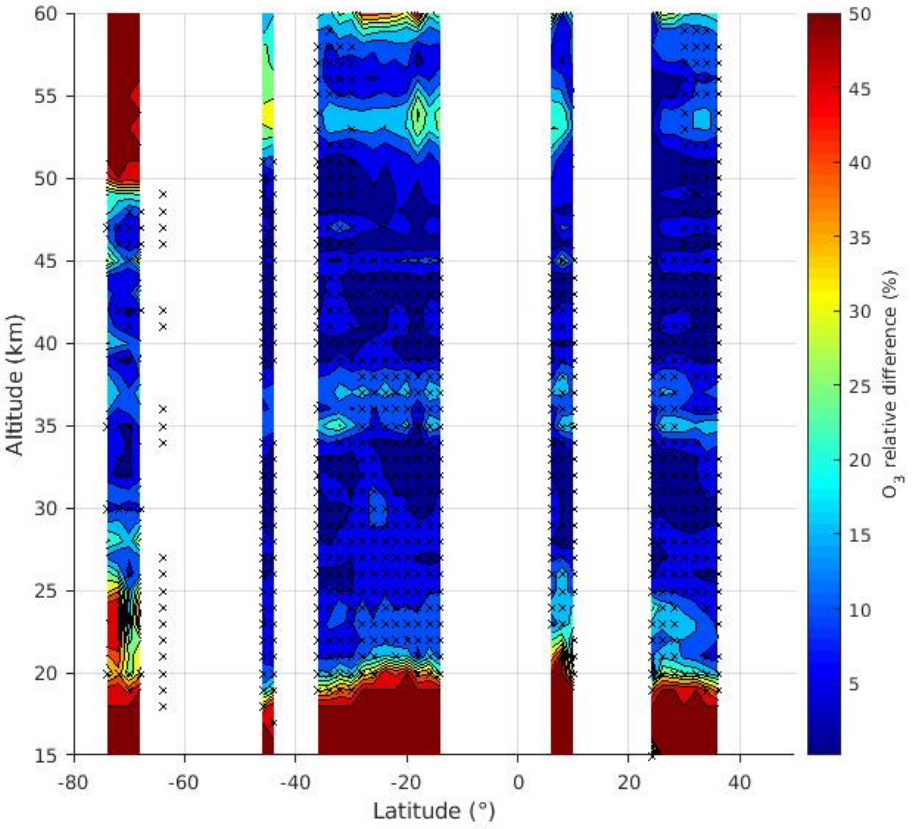




Stellar occultation mode

Full end-to-end processing of GOMOS data were achieved with the SPS, and the baseline L2P.
Many occultations of year 2004 were processed (SPS also very slow). Good agreement is observed down to 20km.





See Poster P5.1 by Antonin Berthelot

Conclusions

ALTIUS will deliver stratospheric O_3 concentration profiles from 3 observation modes:

- daytime: limb scattering
- twilight: solar occultations
- nighttime: stellar/planetary/lunar occultations

Verification of the product performance is ongoing, using full end-to-end simulations

- ✓ instrument performance with the SPS
- ✓ data processing algorithms (L1P, L2P)

One approach for the mission performance assessment is based on heritage satellite datasets:

- limb scattering → OMPS-LP
- solar occultations → SAGE-III ISS
- stellar occultations → GOMOS

First results show a good agreement within CCI+ PVIR products spread.