ALTIUS Ozone Retrieval Algorithm in Stellar Occultation Mode Validated using GOMOS Observations.

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ALTIUS website

ALTIUS Stellar Occultation Video Game

ALTIUS (Atmospheric Limb Tracker for the Investigation of the Upcoming Stratosphere) is an ESA Earth-Watch satellite proposed by BISA. It is planned for launch in 2026 and its primary goal is measuring **O_3 high resolution concentration profiles** in the stratosphere. Other species retrievals are also being investigated.

Key points:

- 3 independent 2D spectral imagers: **UV** (250-355 nm), **VIS** (440-675 nm), **NIR** (600-1040 nm)
- Acousto-optic tunable filters in **VIS** and **NIR** channels & Fabry-Perot spectrometer in **UV** channel

In **stellar occultations**, the instrument takes snapshots of a star (or a planet) visible through the atmosphere. The measured signal is compared with the out-of-atmosphere signal to obtain the transmittance along the light path.

However, the air density in the atmosphere contains irregularities caused by turbulences and gravity waves. The light coming from a star and passing through the atmosphere therefore fluctuates along with the air density on its optical path. This phenomenon is called ***scintillation***. It can strongly perturb stellar occultation observations, especially at low tangent altitudes.

3 methods are tested to remove scintillation:

- Tikhonov regularization to minimize the 2nd profile derivative (1)
- Use of synchronized doublets in the measurement vector (2)
- Using a PCA-filter on the transmittance profile (3)

These methods are tested on a typical Canopus occultation using GOMOS L1 and comparing with its L2 product.

Covariance matrix, State vector, Tikhonov regularization

$$\min_{x}\left\|S_y^{-1/2}\left(y_{obs}-F(x)\right)\right\|+\gamma\|R(x-x_a)\|$$

Measurement vector, Forward model

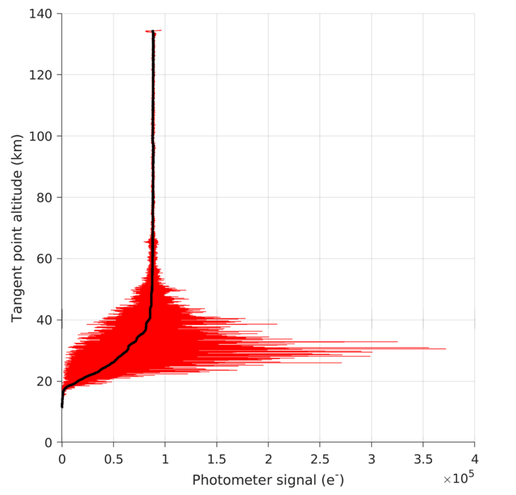
$$R=L_2=\begin{bmatrix}1 & -2 & 1 & 0 & \dots & 0\\ 0 & 1 & -2 & 1 & \ddots & \vdots\\ \vdots & \ddots & \ddots & \ddots & \ddots & 0\\ 0 & \dots & 0 & 1 & -2 & 1\end{bmatrix}$$

Transmittances:

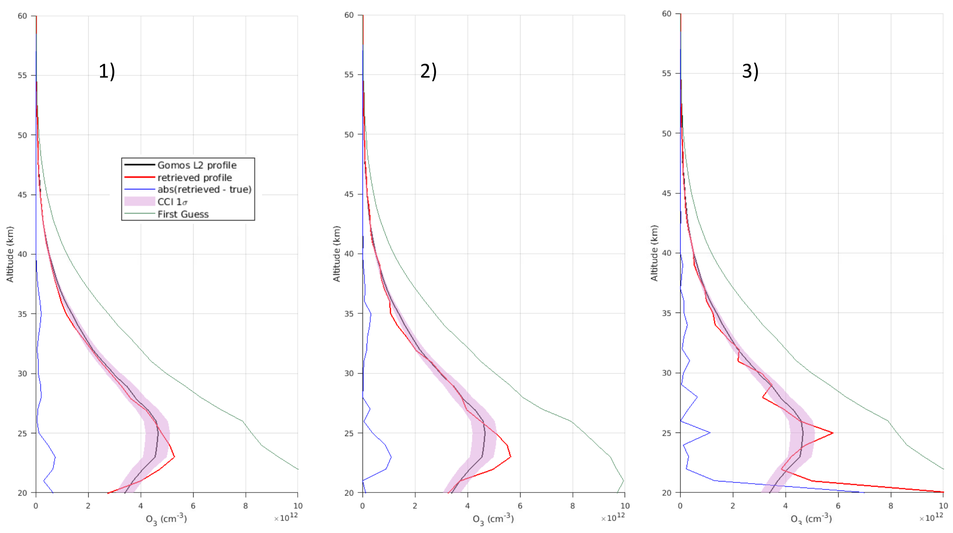
- [T_{300} T_{310} T_{320} T_{550} T_{600} T_{650}]

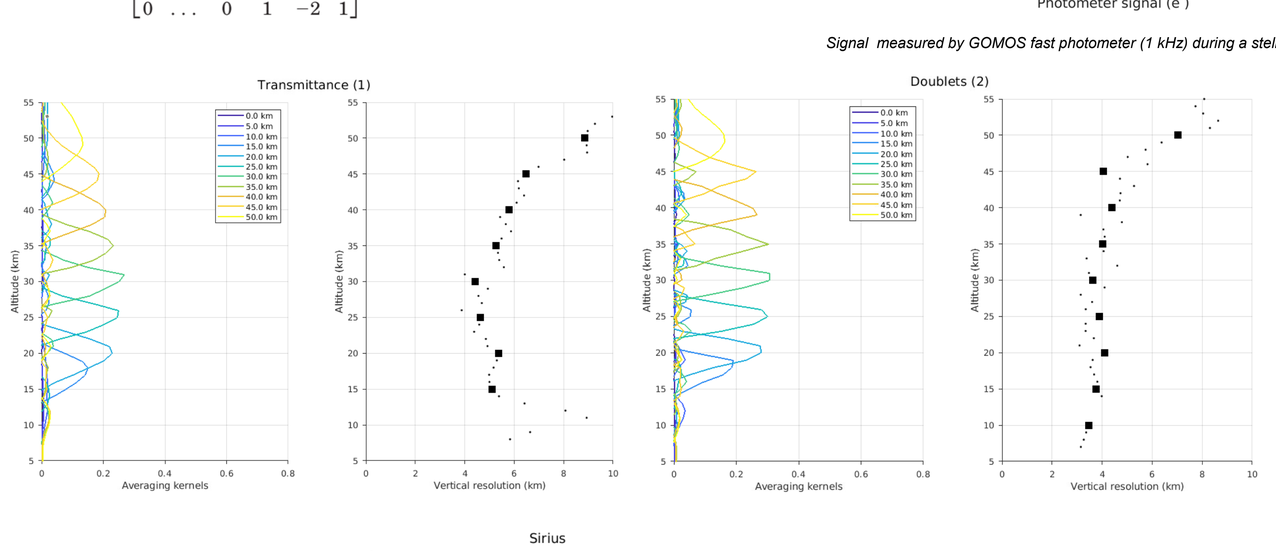
Doublets :

- [T_{310}/T_{442} T_{320}/T_{442} T_{442}/T_{603}]



Signal measured by GOMOS fast photometer (1 kHz) during a stellar occ-

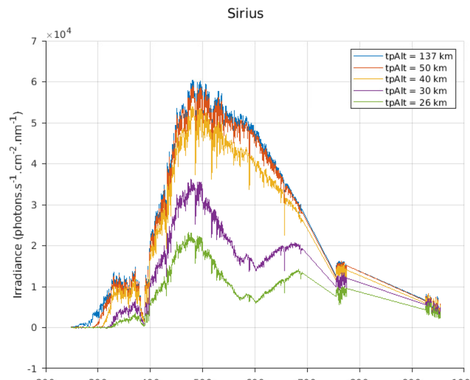




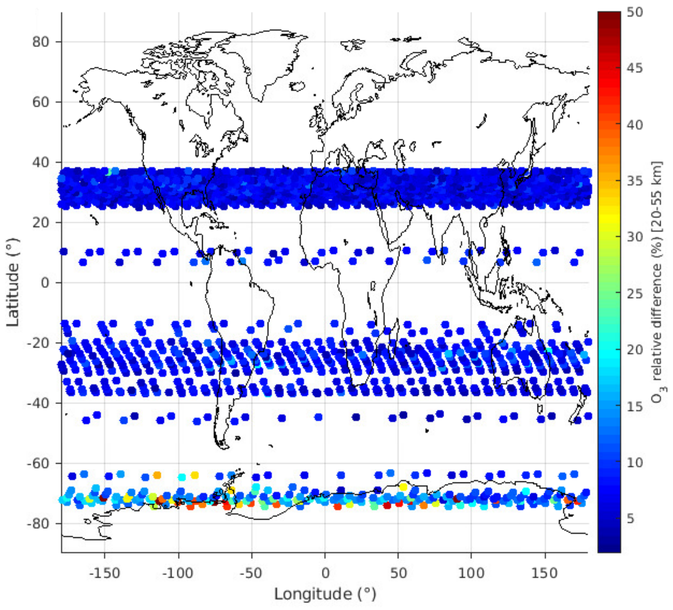
GOMOS (Global Ozone Monitoring by Occultation of Stars) was an instrument on board the ESA Envisat satellite performing stellar occultation ozone measurements. It was equipped with 2 fast (1kHz) photometers to measure the fluctuations of light due to scintillation.

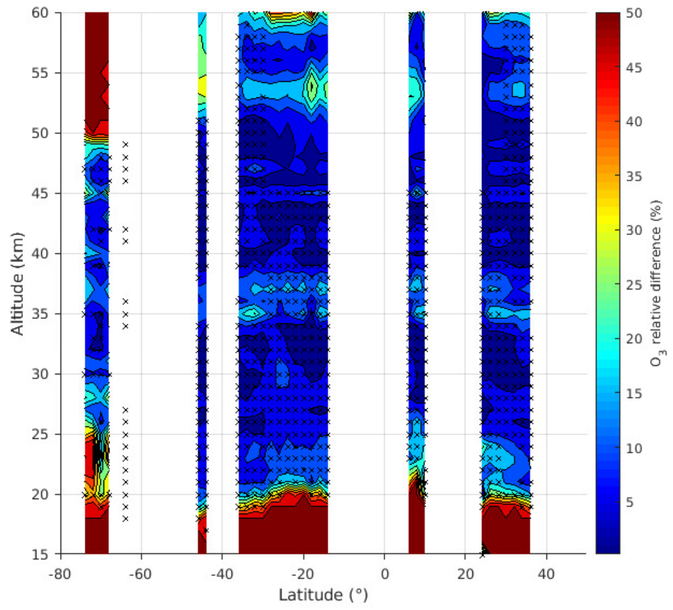
In the work below, we use GOMOS L1 with our L2P algorithm and compare our retrieval to GOMOS L2 to test the validity of the ALTIUS L2P using the L2 regularization scintillation removal (1).

This study considers 2050 GOMOS observations in 2005 with 8 of brightest and warmest stars observed.



Typical GOMOS measurements of a stellar occultation





Star	Latitude	Magnitude	Temperature (K)
Sirius	-73, -63	-1.44	11000
Canopus	-37, 37	-0.736	7000
Alpha Centauri	-28, 7	-0.01	5800
Rigel	-75, –44	0.1	14000
Achernar	-24, 32	0.45	24000
Beta Centauri	-28, 12	0.61	28000
Acrux	-25, 19	0.78	30000
Spica	-34, 1	0.98	28000

References

- Tilman Steck—Applied optics—Vol 41 N° 9—March 2002
- C. D. Rodgers, Inverse Methods for Atmospheric Sounding: Theory and Practice, Vol. 2 of Series on Atmospheric, Oceanic and Planetary Physics (World Scientific, Singapore, 2000).
- Product Validation and Inter-comparison Report (PVIR) , Ozone_cci+_PVIR_4.0

Conclusions

- Both L2 regularization and the doublet method can mitigate the scintillation effect on the retrieval.
- There is a trade-off to consider between operational constraints of using doublets and the loss of vertical resolution using a higher regularization.
- Over a full year of reprocessed retrievals, ALTIUS L2P yields profiles similar to GOMOS' L2 within the O_3 CCI+ validated bounds above 20 km, except in the polar latitudes.

Next steps

- Run the full ALTIUS instrument similator on a large number of cases to optimize the choice of measurement vector and regularization parameter.
- Calculate the error bars associated with the uncertainty on the knowledge of other atmospheric constituents (aerosols, NO_2, …).