Sentinel-5 first impressions mission data

CEOS ACVC Meeting, Leiden, 2 June 2026

R. Siddans, presenting inputs from the
S5L2PP Algorithm Development Team

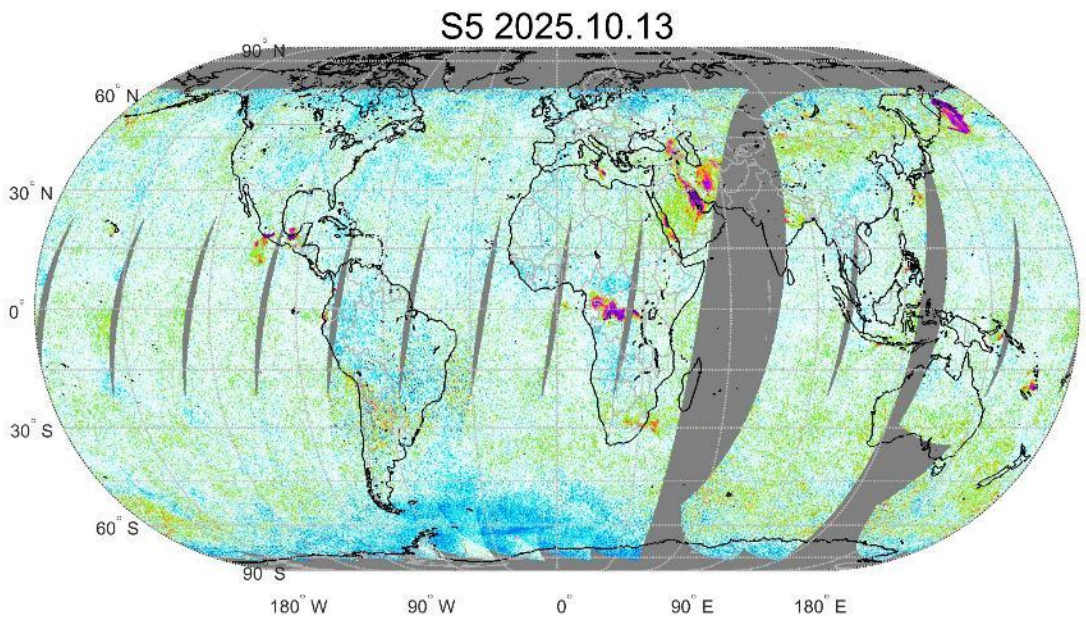
S5L2PP

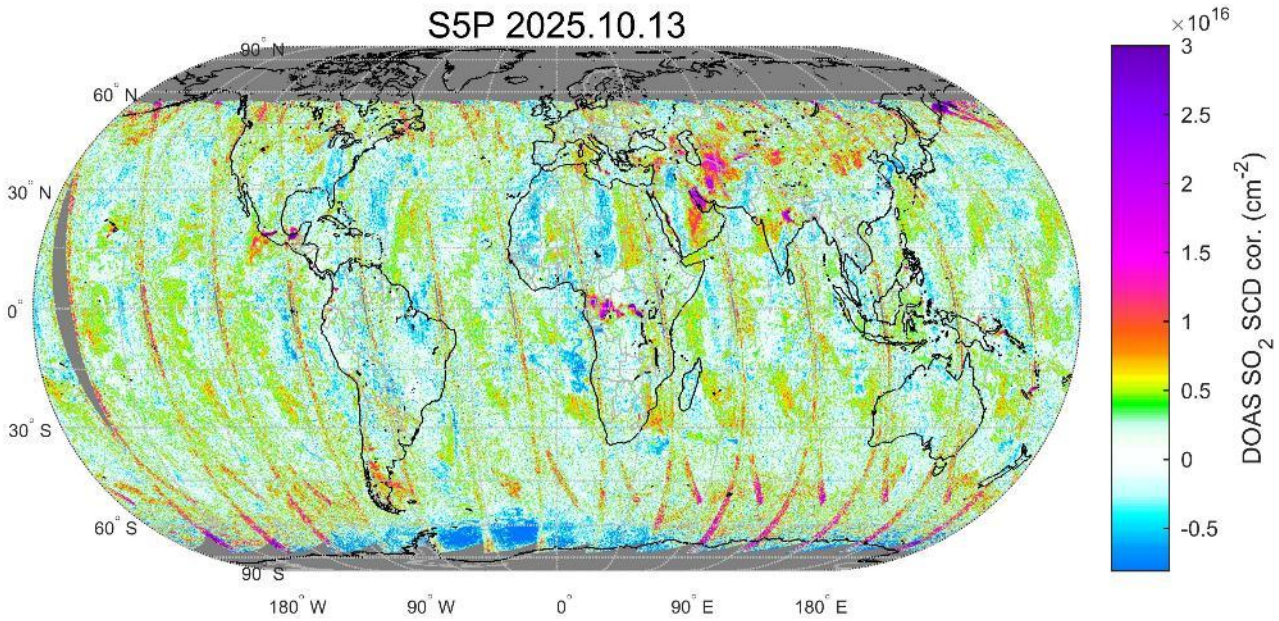
Overview

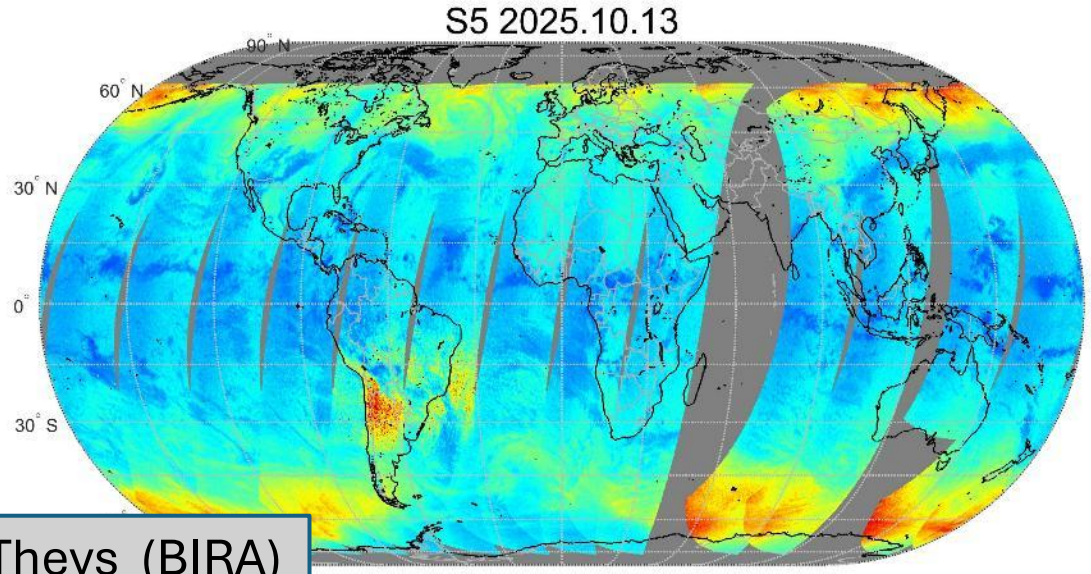
- ESA S5L2PP Product led by S[&]T to implement *prototype processors* as basis for algorithm-identical Eumetsat **operational processors**
- Algorithm development team use scientific **"breadboard" processors,** used for analysis / testing / development etc. (usually based on S5P heritage)
- Consolidate algorithms implemented as **L2PP prototype processor**
- Results here are ***preliminary snapshots of current status*** from mixture of "breadboard" and L2PP results, to emphasise S5 potential
  - L2PP close to reproducing breadboard in all cases

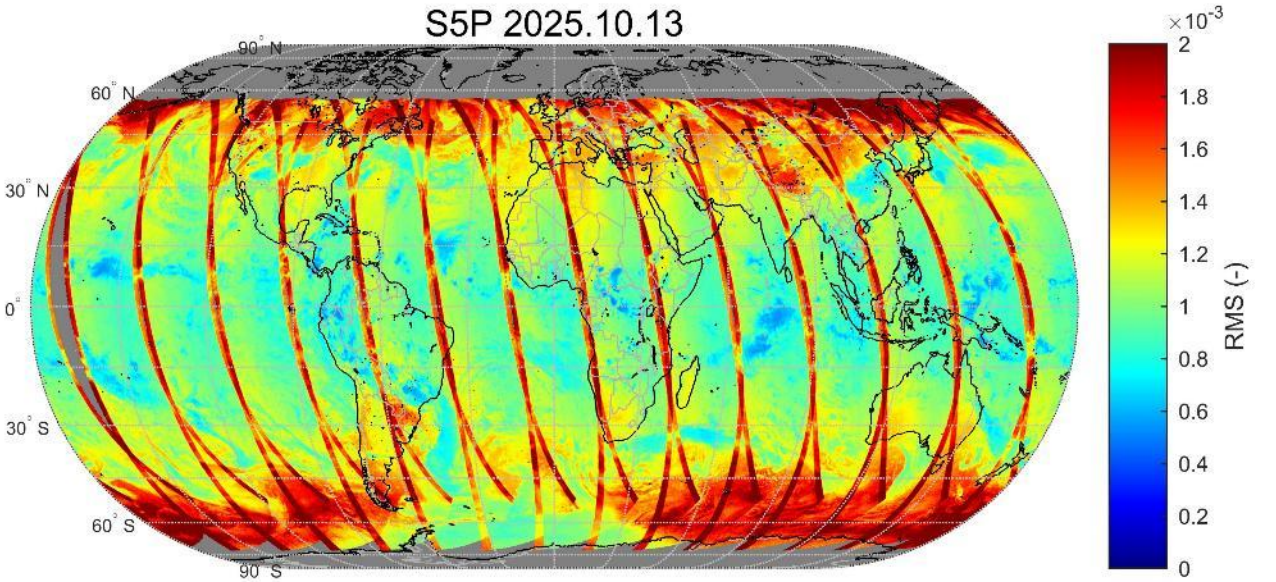
Primary S5L2PP Product	Algorithm Development	Software Implementation	Input for this presentation
SO2	BIRA	S[&]T	N. Theys
FDY (Formaldehyde)	BIRA	S[&]T	I. De Smedt
GLY (Glyoxal)	BIRA	S[&]T	T. Danckaert
NO2	KNMI	S[&]T	H. Eskes, M. ter Linden
O3 (Total ozone)	BIRA	S[&]T	T. Danckaert
O3P (Ozone profile)	RAL	RAL	R. Siddans, B. Latter
CLD (Cloud)	KNMI	TriOpSys	P. Wang, M. Sneep
AUI (Absorbing aerosol index)	KNMI	TriOpSys	M. de Graaf, P. Veefkind
ALH (Aerosol layer height)	KNMI	TriOpSys	
AOD (Aerosol optical depth)	KNMI	TriOpSys	
RFL (Surface reflectance)	KNMI	TriOpSys	G. Tilstra
UV (UV index)	FMI	TriOpSys	J. Kujanddpää
CH4	SRON	S[&]T	*See Presentation 6.7 on Thursday (J. Landgraf)*
CO	SRON	S[&]T	

S5 SO_2 Sland column density (background corrected) compared to S5P





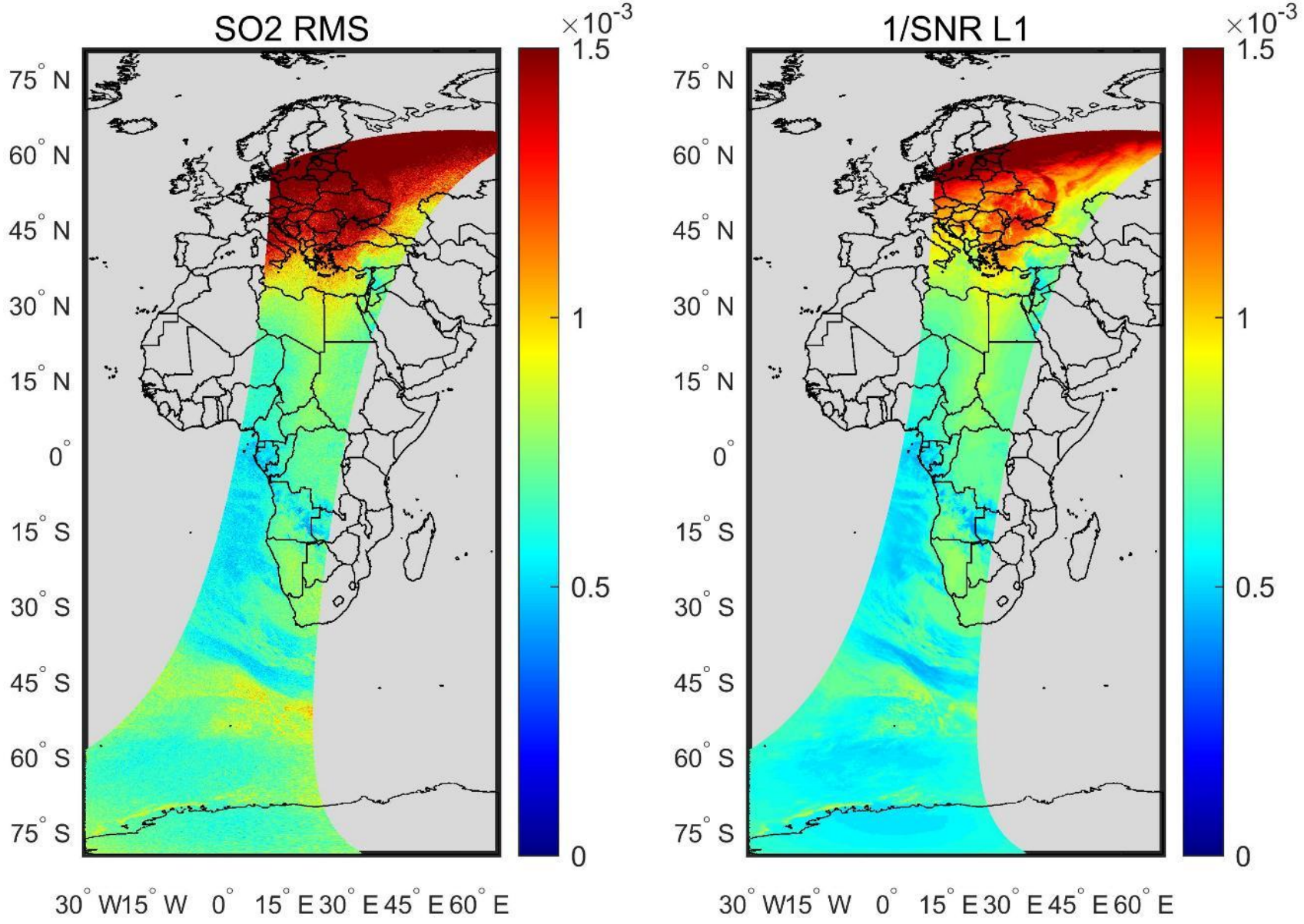




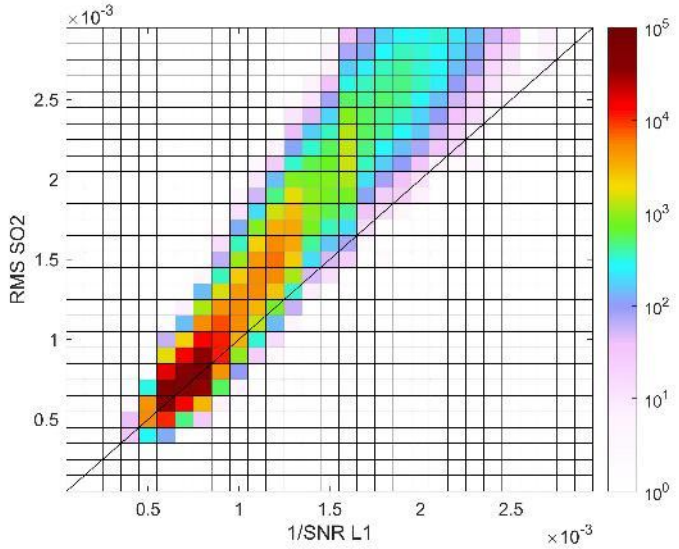
N. Theys (BIRA)

DOAS fit RMS residuals compared to L1 predicted measurement noise

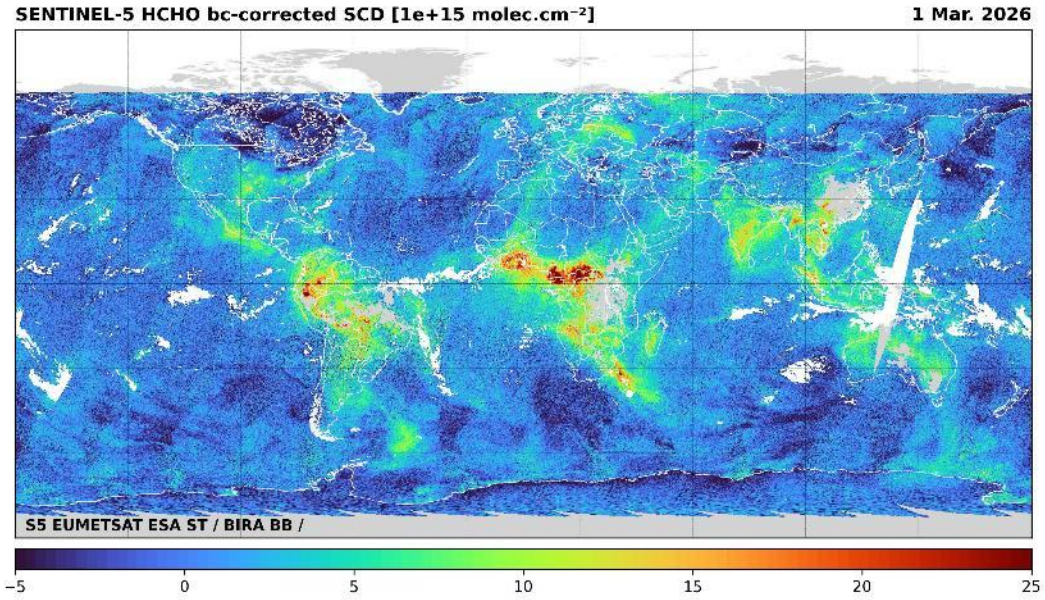
N. Theys (BIRA)

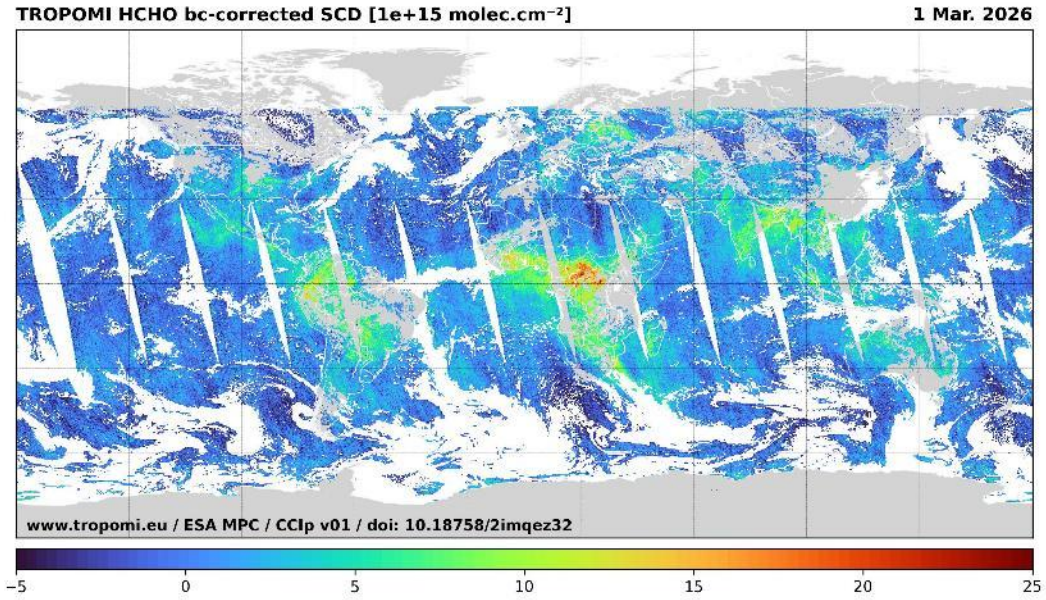


RMS compatible with radiance_noise from L1

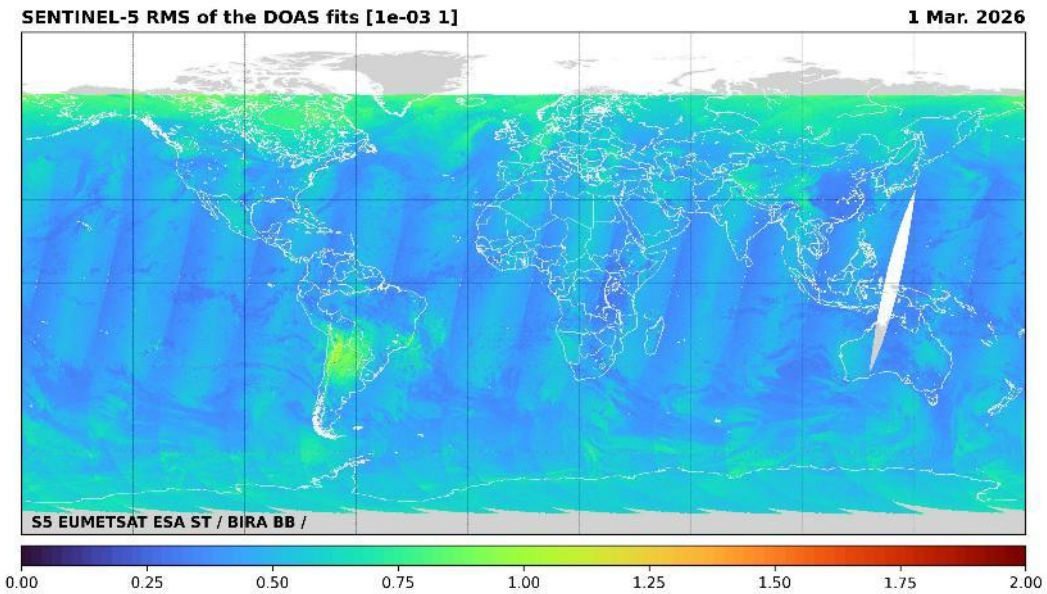


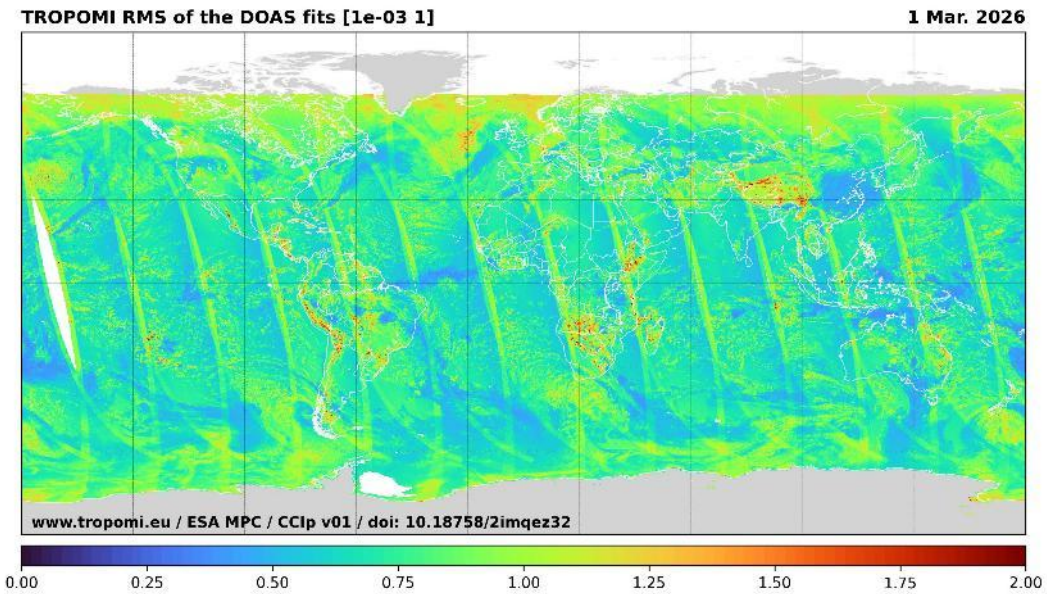
Formaldehyde (HCHO) SCD: S5 S5P





Bias corrected Slant column density





RMS of spectral fit

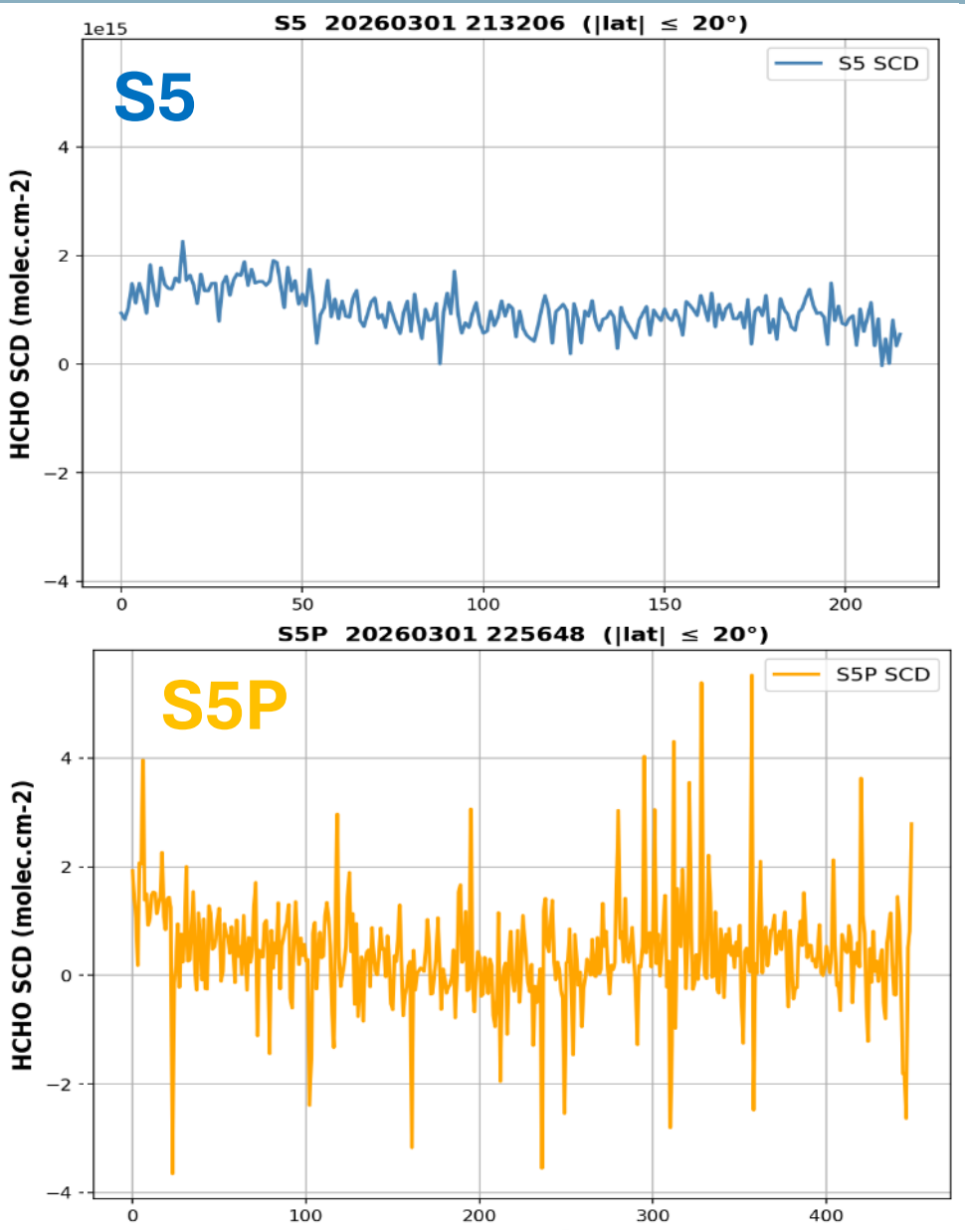
Disclaimer for S5 maps: no proper filtering of clouds and snow/ice scenes.

I. De Smedt (BIRA)

S5 L1B : HCHO slant column quality

- ✓ DOAS algorithm using mean radiance as I_0 reference.
- ✓ Reduced stripes compared to S5P.
- ✓ Low residuals (50% lower than S5P)
- ✓ *Reduced heterogeneity effects in RMS and SCD.*
- ✓ SCD noise is 50% lower than S5P (20% when considering the coarser spatial resolution)

- Latitudinal correction needed (morning OVP – large SZA)
- SAA impact visible (more than S5P)
- S5 SCD tend to be larger than S5P over tropical emission regions, as already observed in morning/afternoon HCHO climate data records.
- L2 clouds and AUX data need to be included for a proper comparison.



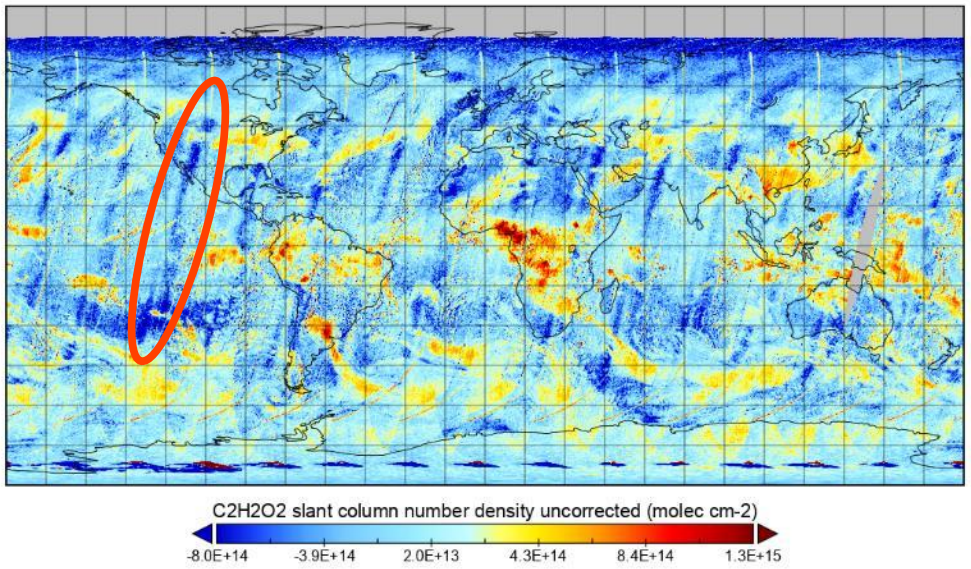
I. De Smedt (BIRA)

Glyoxal

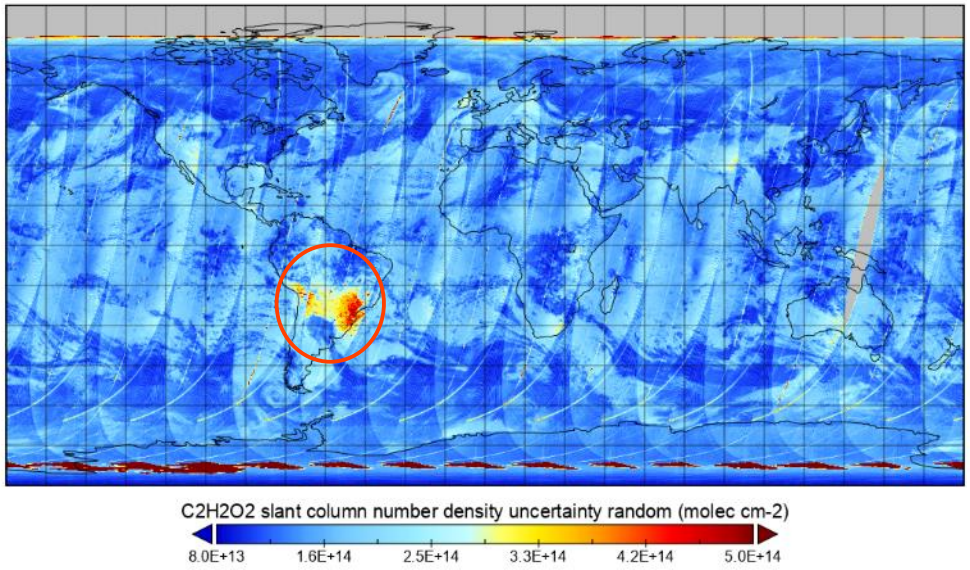
- S5 fit residuals comparable to expected noise (using radiance as references)
- 3/3/2026 grids at 0.25° resolution
- No cloud / qa filter
- Striping at eastern edge of every S5 orbit (1 highlighted)
- SAA effects S5 SCDE
- S5, S5P SCD random uncertainty comparable when binning to same spatial resolution.

S5 R011 (PP)

C2H2O2 slant column number density uncorrected

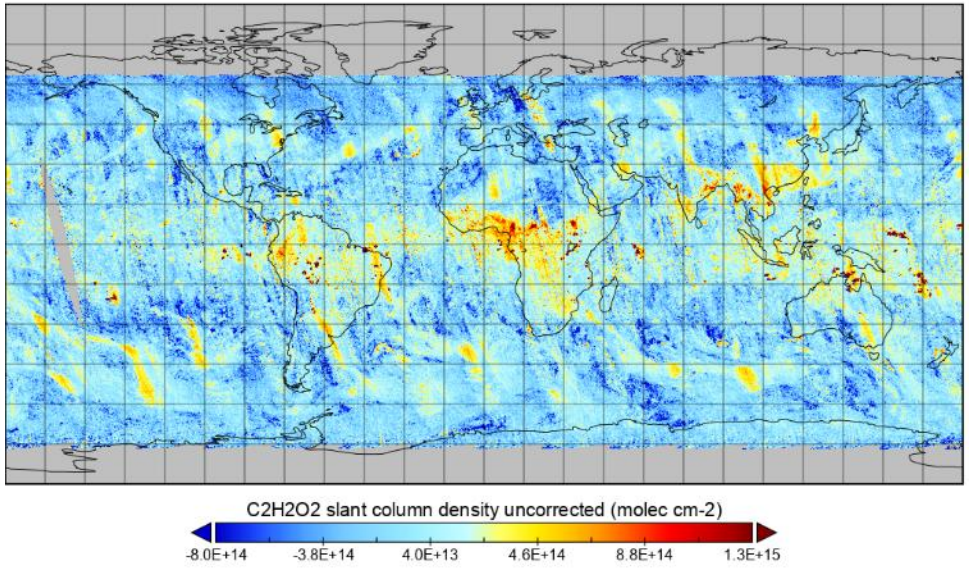


C2H2O2 slant column number density uncertainty random

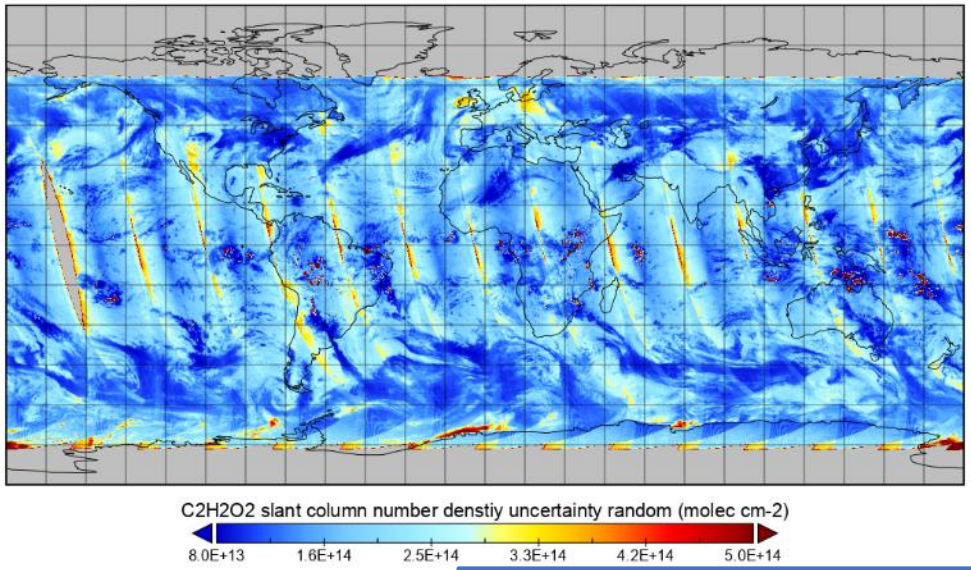


S5P (PAL)

C2H2O2 slant column number density uncorrected (S5P)



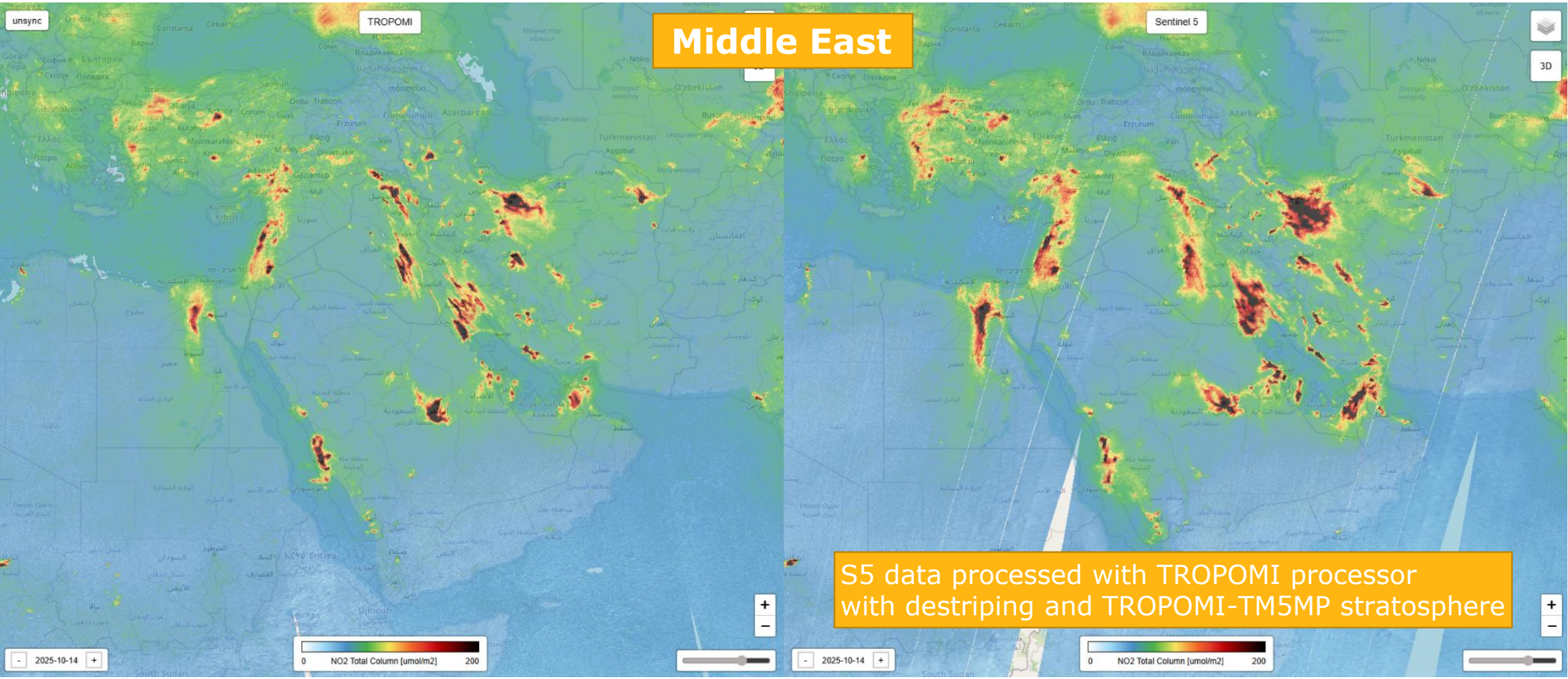
C2H2O2 slant column number density uncertainty random (S5P)



T. Danckaert (BIRA)

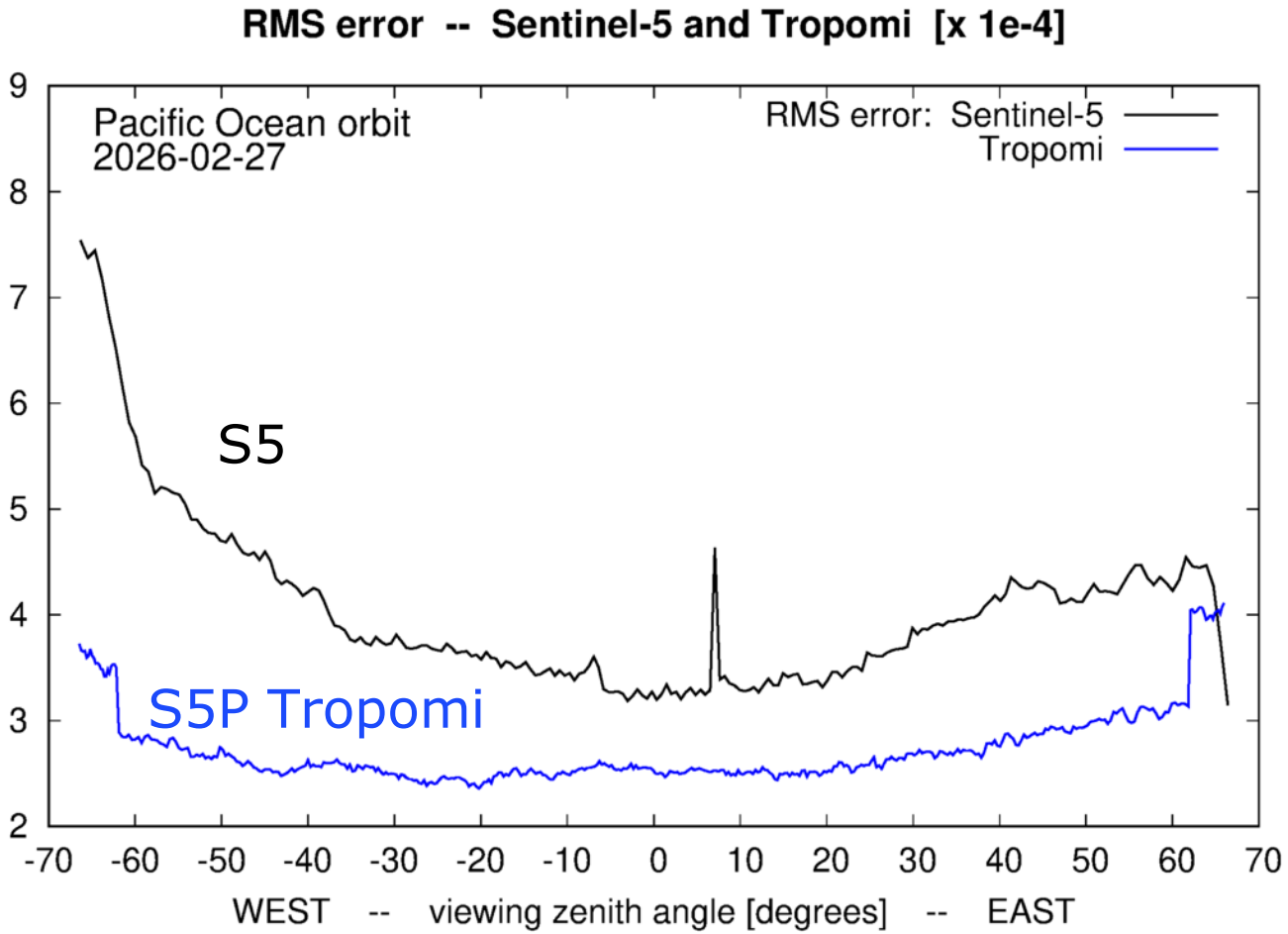
TROPOMI NO2

Sentinel-5 NO2



M. ter Linden (KNMI)

NO2: RMS fit compared to S5P



NO2 retrieval based on reflectance (radiance normalised by irradiance)

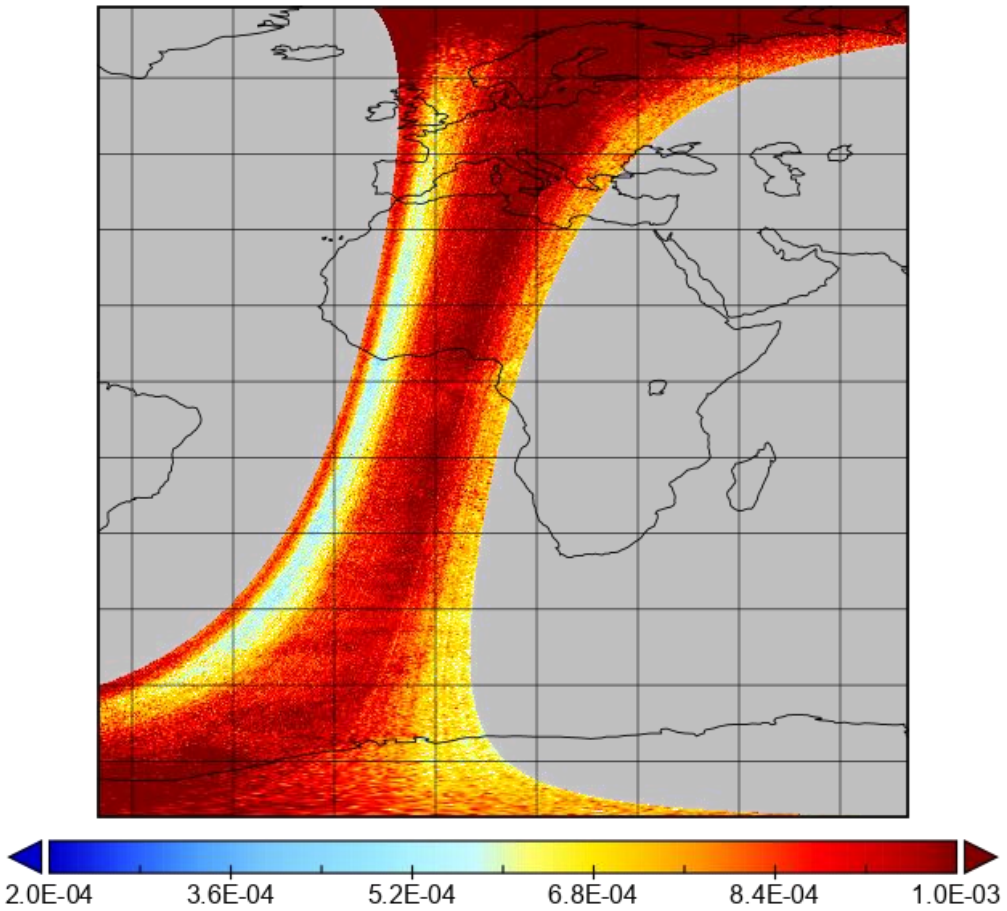
The across-track variability of the SCD and RMS error is larger than for TROPOMI (to be investigated)

(The outer rows of TROPOMI have different binning, explaining the jumps seen there.)

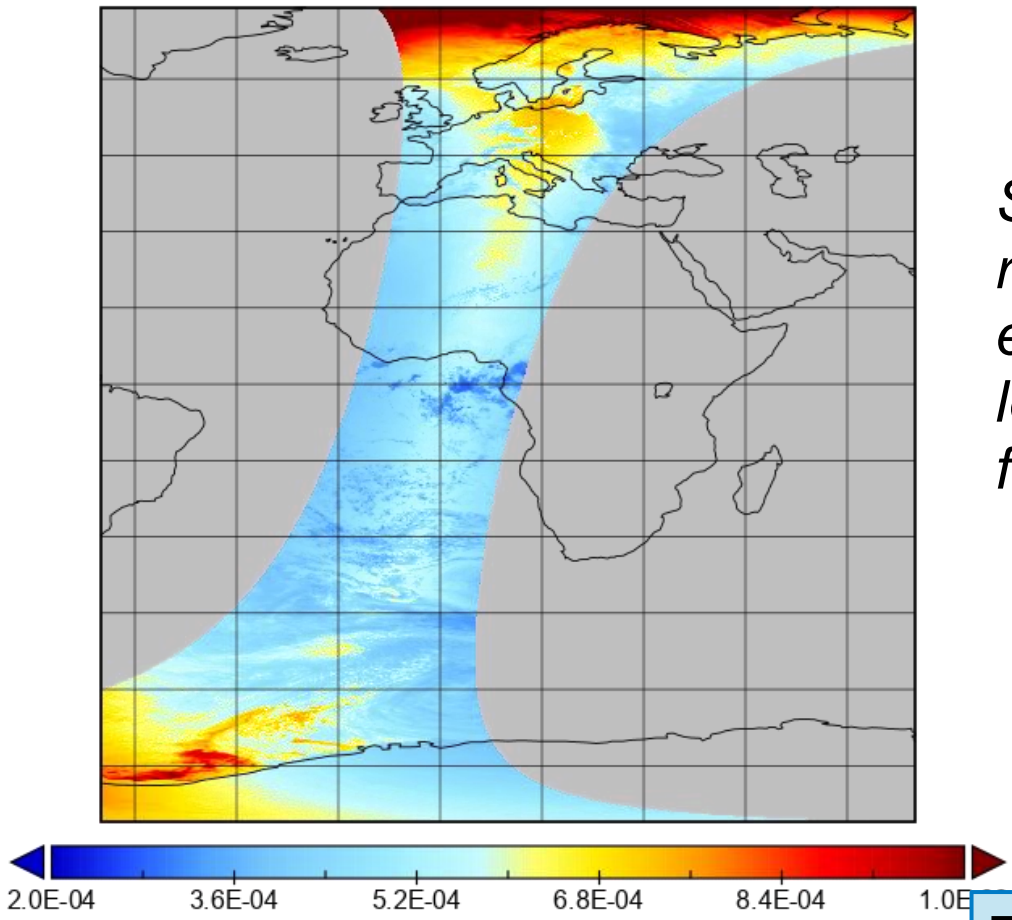
S5 Total Ozone:

2 step algorithm:
(1) DOAS slant column fit using daily irradiance as reference.
(2) Vertical column fit based on air mass factor and ghost column, using profile climatology

26/02/2026 DOAS RMS (S5 R011 O3 L2)



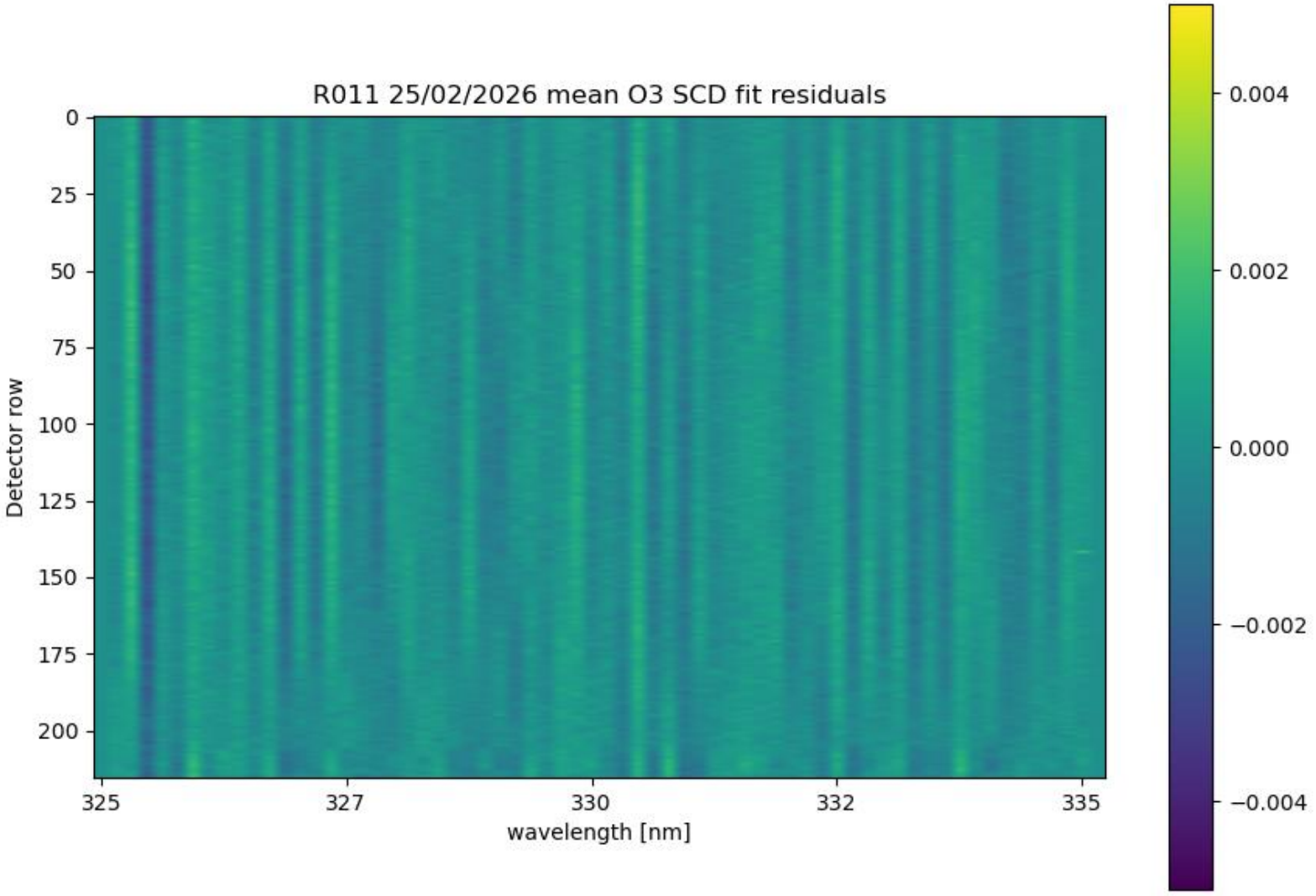
26/02/2026 1/SNR in O3 fitting window (S5 R011 L1b)



SCD fit RMS residual exceeds expected noise level, almost by a factor of 2.

T. Danckaert (BIRA)

Systematic spectral patterns in Ozone fit residuals



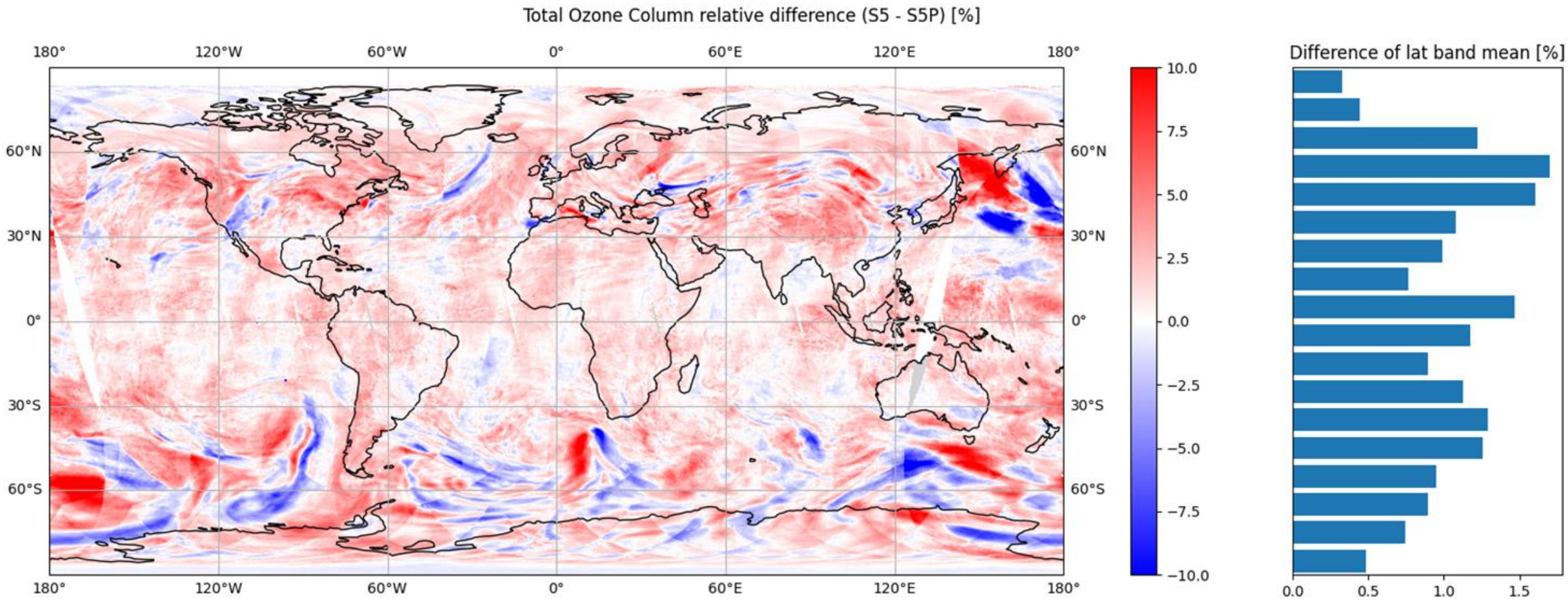
Systematic bias in reflectance

→ RMS residual too high. This inflates the estimated random error (may be worked around using pseudo cross section)

→ Very likely affects estimated slant columns as well.

T. Danckaert (BIRA)

Total Ozone: S5 (R011) vs S5P OFL (6/3/2026)



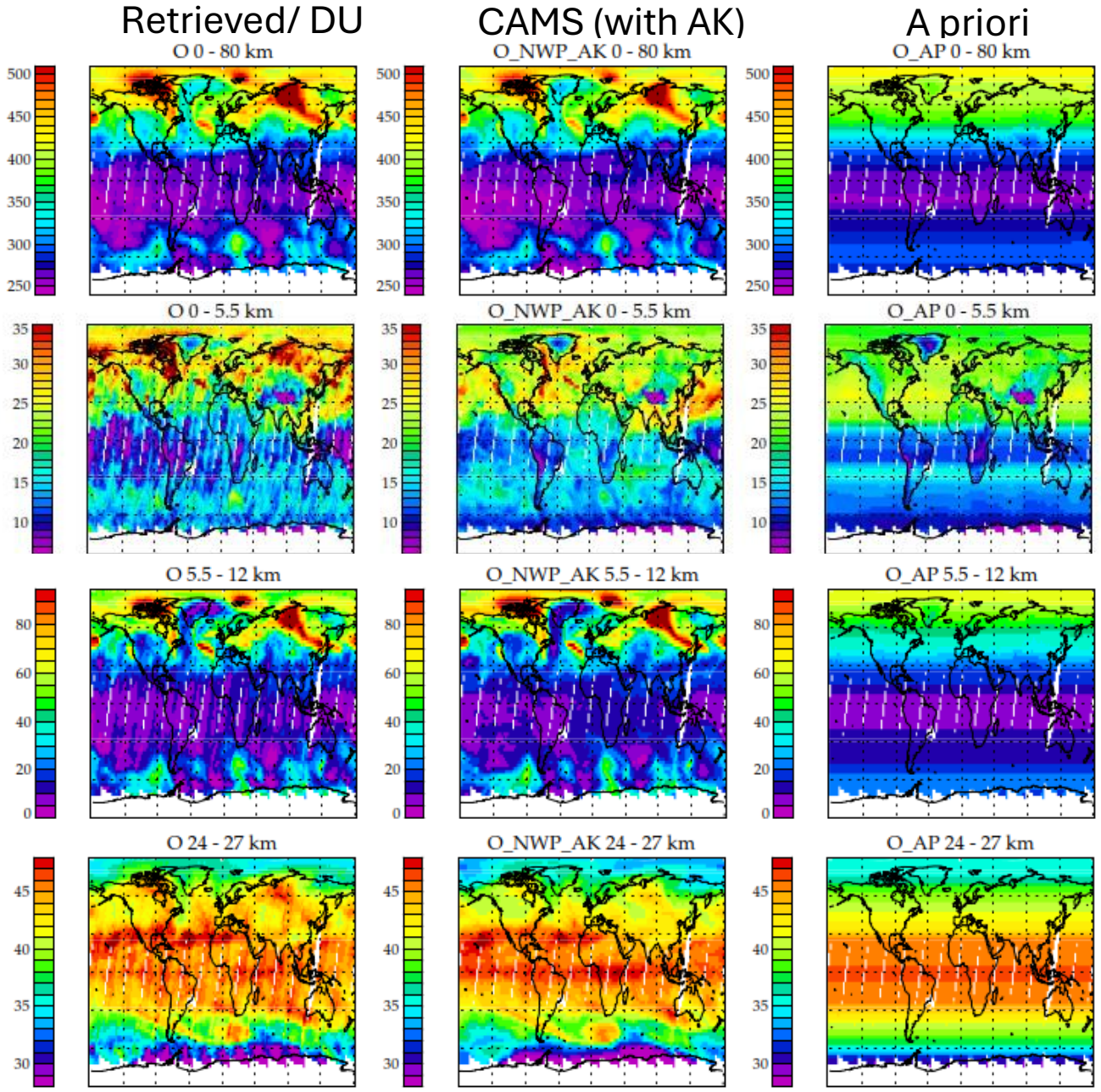
- S5 VCD ~1% above S5P OFL

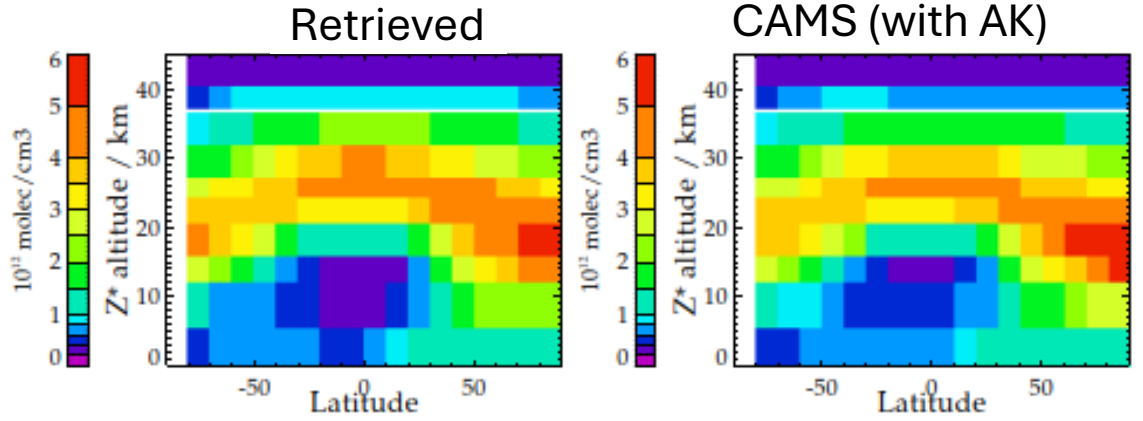
T. Danckaert (BIRA)

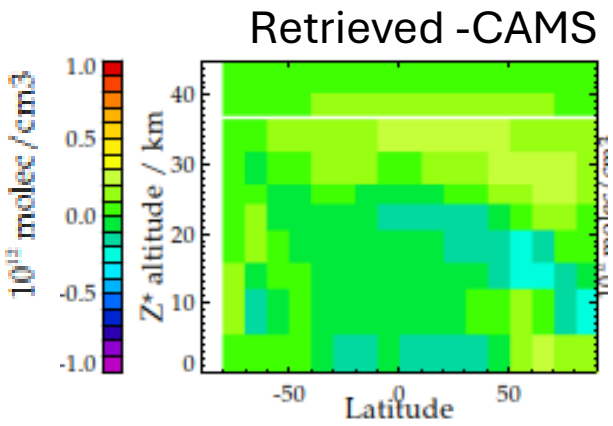
RAL: Ozone Profile: E.g. results for 21/04/2026

After applying corrections to L1

R. Siddans, B. Latter (RAL)





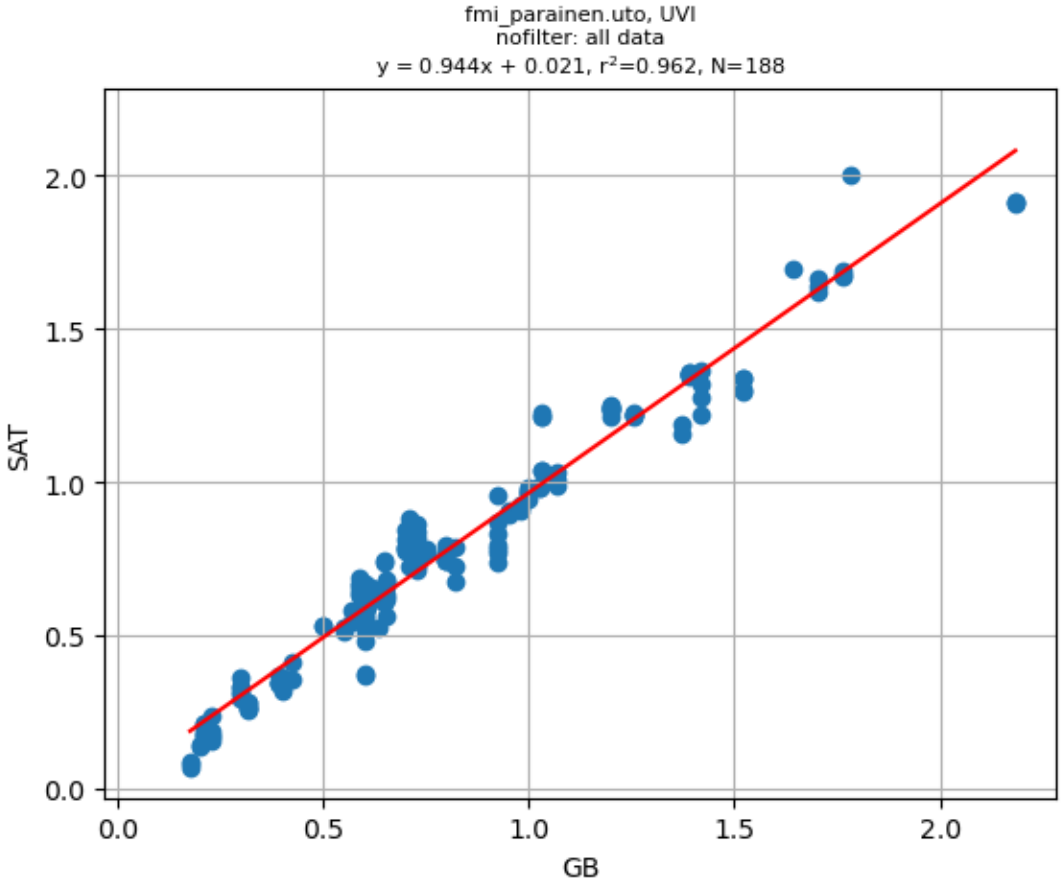


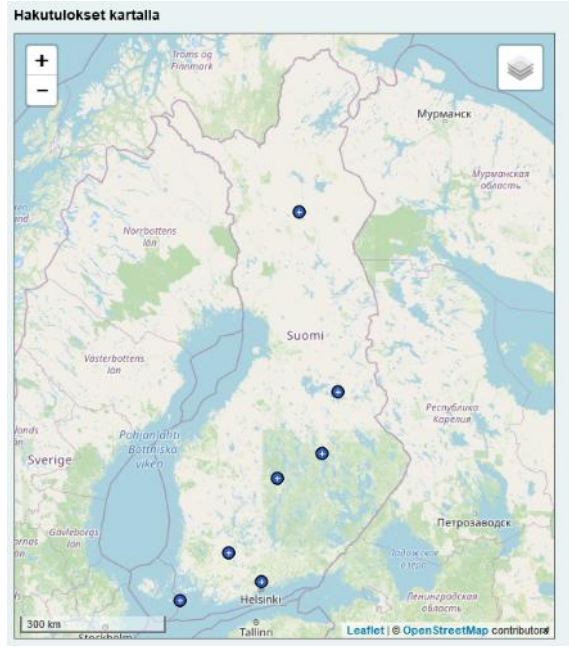
No L2 cloud used (assumes cloud free, explains some negative bias in troposhere)

*As total ozone, main issue is **L1 spectral features** (errors) in 315-340nm range, currently handled by including fixed empirical spectra in the ozone fit. **These increased in magnitude in last L1 release (R013)***

Intercomparison of Sentinel-5 UV product with FMI broadband UV Index measurements

- Sentinel-5 UV_ product
- R011 and R012 data
- Covering 27.2 – 31.3.2026
- Three overpasses over Finland / day
- UV index calculated from overpass time erythemal irradiance

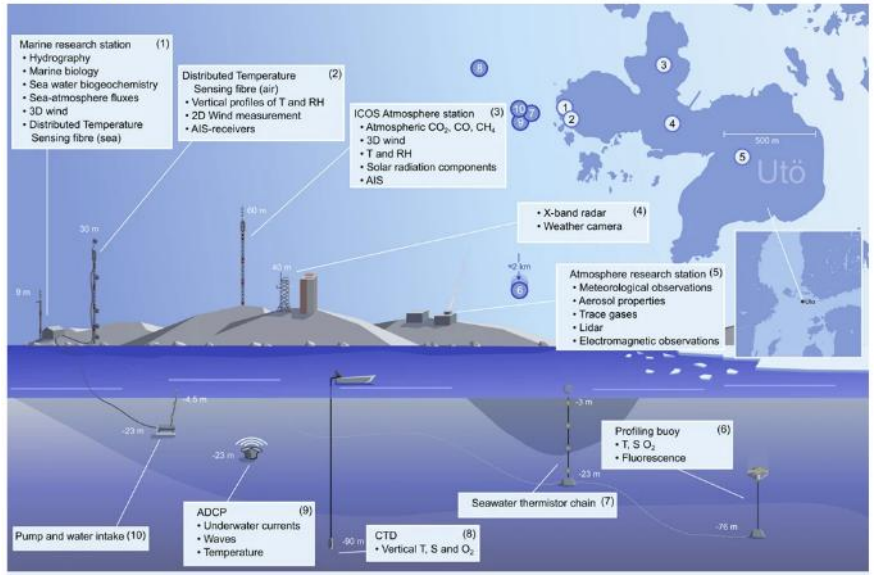




Solar Light 501a

- Utö site, part of FMI broadband UV measurement network
- Measurement every 1 min
- Time-averaged to S5 overpass +- 7.5 min (15 min window), spatially within 10 km radius to S5 pixel centre
- Yearly calibration against Helsinki Brewer, no angular response correction

Utö observations

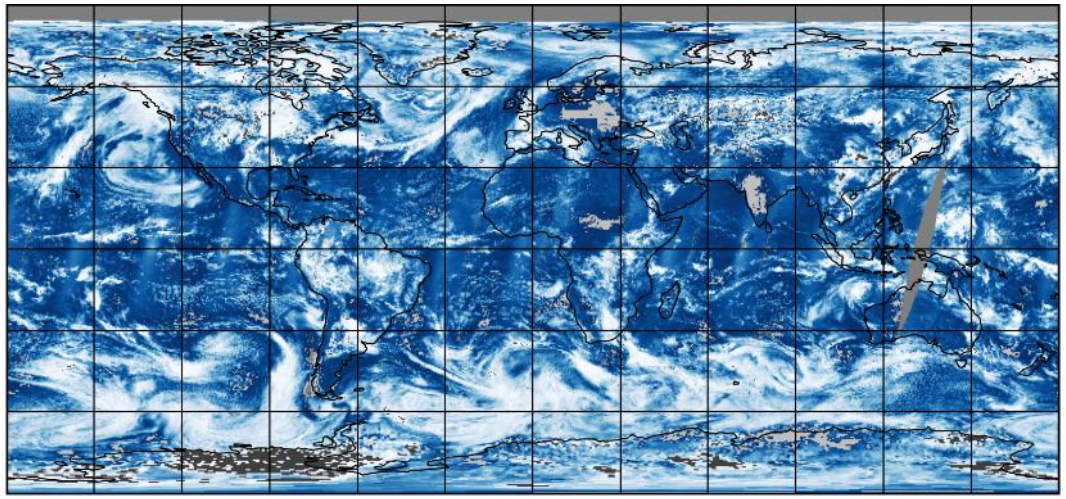


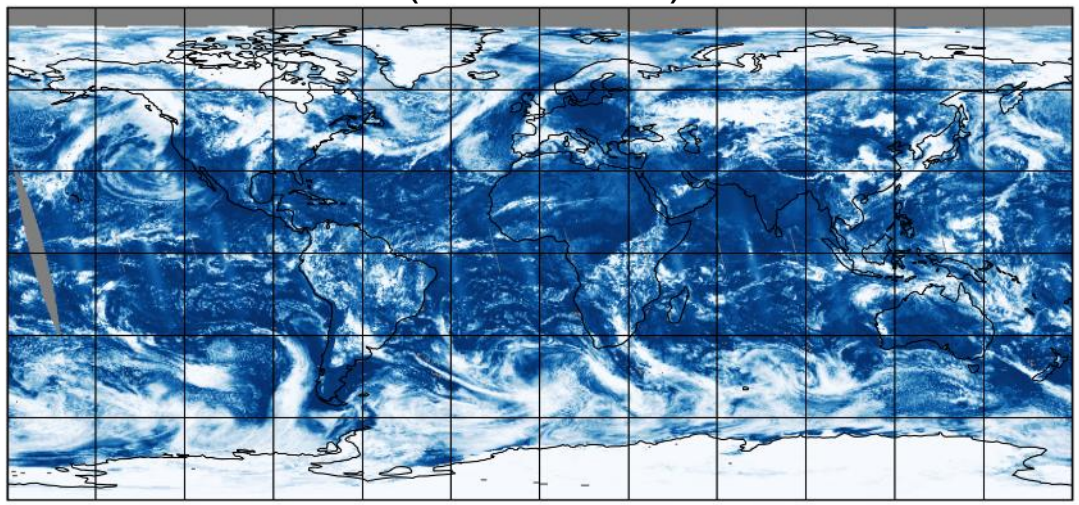
https://en.ilmatieteenlaitos.fi/uto

J. Kujanddpää (FMI)

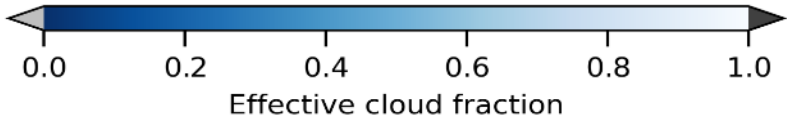
S5 CLD Band 3A (O2-B band) 6 March 2026 S5P (FRESCO-S)

Cloud fraction

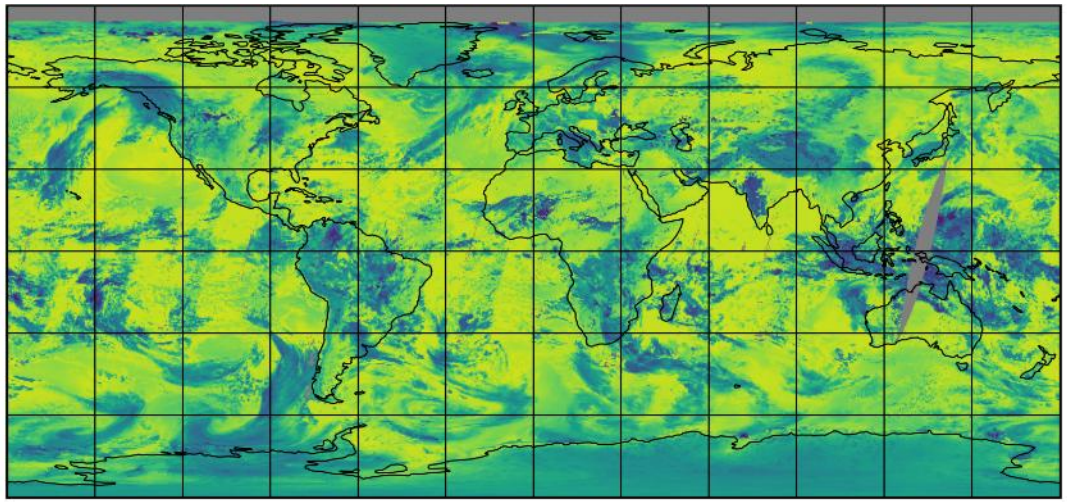


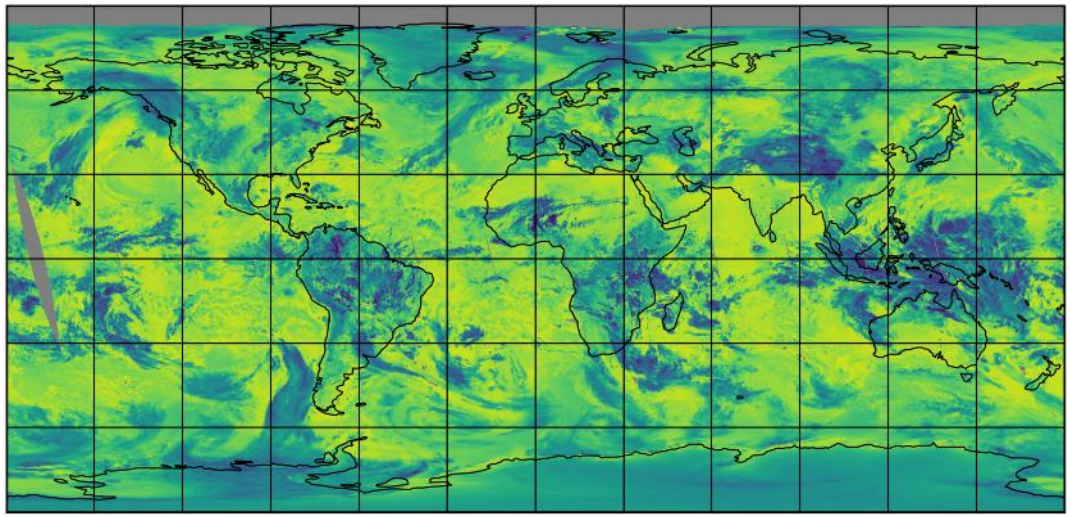


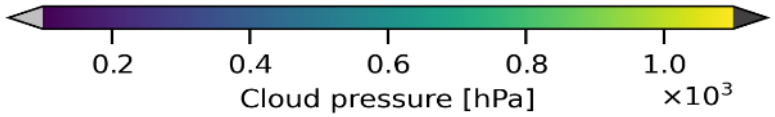
The grey color indicates S5 $C_{eff} < 0$ or no data, black color $C_{eff} > 1$.



Cloud pressure



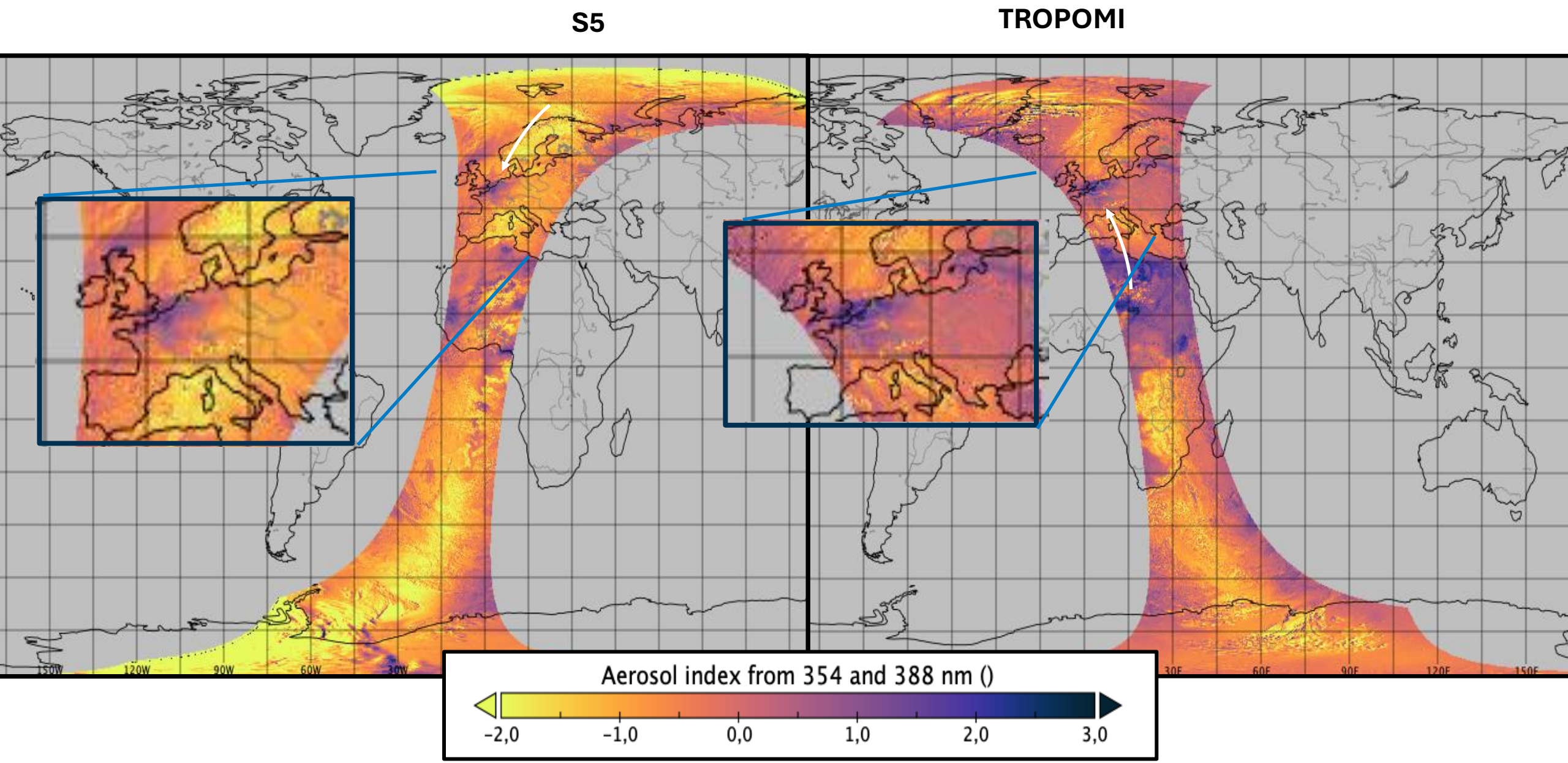




P. Wang (KNMI)

Absorbing Aerosol Index (AAI)
Saharan dust over Europe 6 March 2026

M. de Graaf (KNMI)



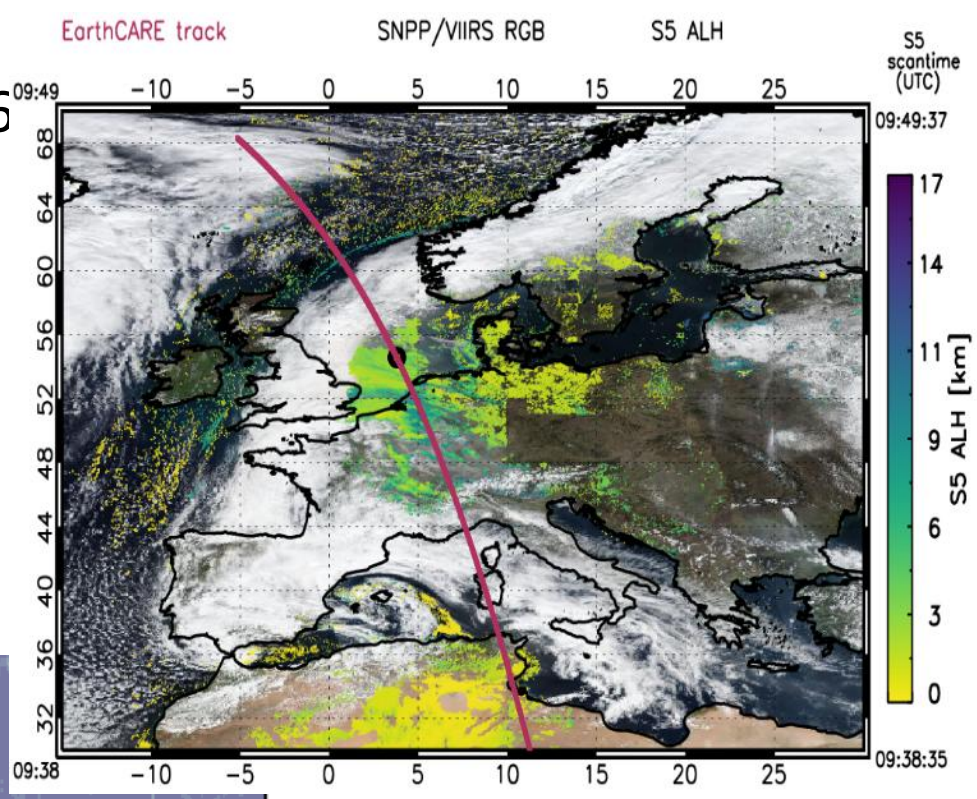
Sentinel-5 L2 ALH: Saharan dust over Europe 6 March 2026

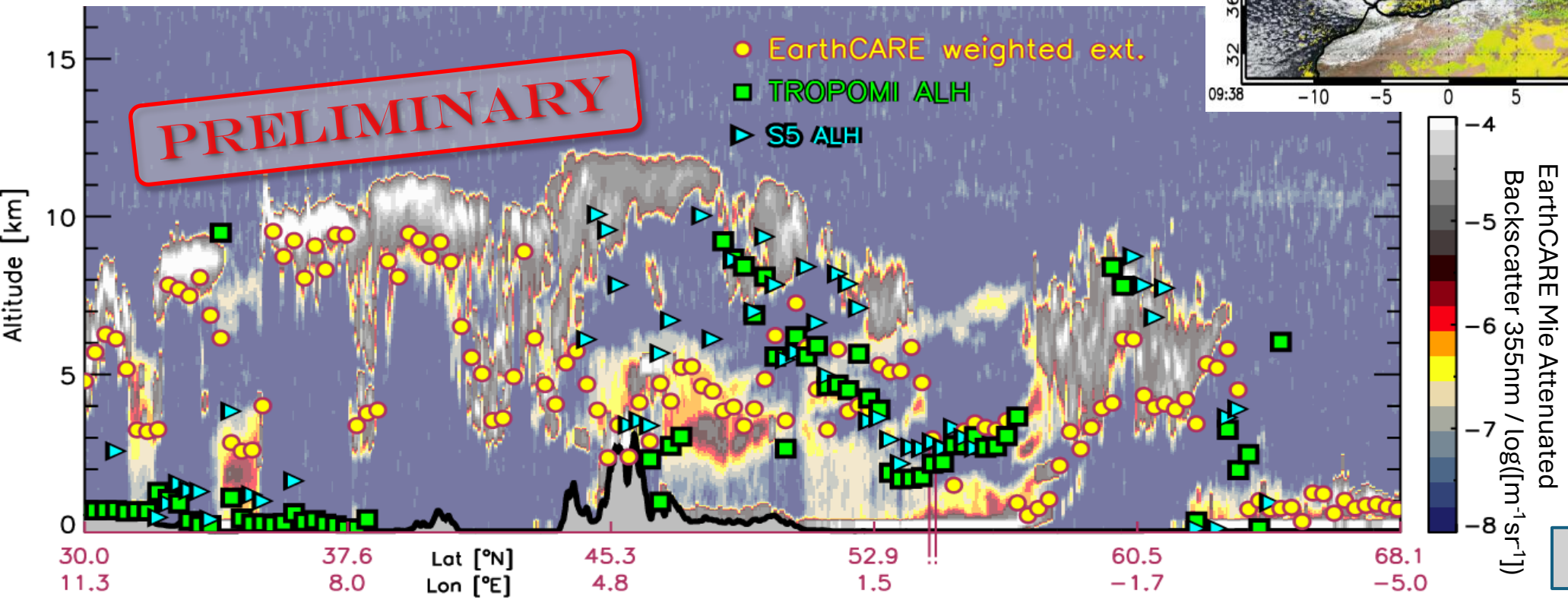
The plume is overpassed by EarthCARE in the night

The very first S5,S5P ALH verification with Atlid looks very promising, even with different overpass times:

- EarthCARE ~01:00; Sentinel-5 ~09:40; S5P ~12:20

NB METimage based cloud screening not yet included

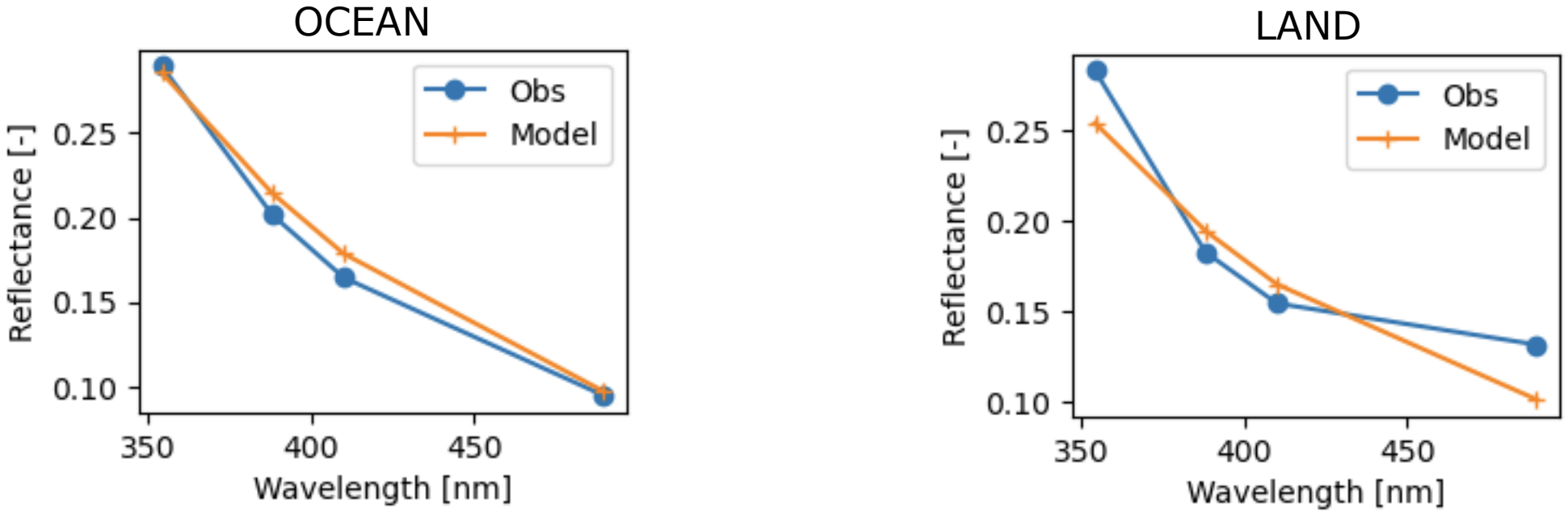




M. de Graaf (KNMI)

P. Veefkind (KNMI)

Aerosol Optical Depth (AOD)
Examples of Observed and Modelled Reflectances



Blue: S5 observations
Orange: aerosol-free model of the scene.
Orange data is expected to be *lower* than the observations

Further evaluation underway including via comparison of L2 Reflectance (RFL) to previous LER climatologies (based on SCIAMACHY, GOME-2, TROPOMI)…

Summary

- The potential of the S5 instrument to provide high-quality trace gas, cloud and aerosol is clear
- UV-VIS trace-gas products which use reference scene radiance for DOAS (**SO2, formaldehyde, glyoxal**) show excellent spectral fit quality, close to theoretical signal to noise and even better than S5P, demonstrating ***high quality and stability of S5 UV-VIS channels***
  - Slit homogenizer largely removes effects of scene inhomogeneity (pseudo-noise around cloud edges)
- UV-VIS products which require irradiance for reflectance calibration (**NO2, Ozone column and profile**) are promising but limited by residual spectral features (larger than experienced for S5P), suggesting ***spectral artefacts from calibration in radiance and/or irradiance*** (under investigation)
- S5 cloud and aerosol processors work as expected:
  AUI has very reasonable value ranges + aerosol plumes;
  Layer height showing good agreement with S5P and EarthCARE (but based on very limited, recent data);
  AOD seems limited by absolute calibration in the 354-490 nm range
  Absolute calibration under investigation via comparison to other instruments and ground sites.
- Benefits expected but not yet demonstrated from:
  - S5 derived surface (directional) reflectance product (needs months/year of stable L1)
  - METimage for cloud filtering (especially for aerosol, methane)
    (METimage products only recently available to S5L2PP)
- *For SWIR products (CH4 and CO) see presentation 6.7 on Thursday (J. Landgraf)*