(Stray)Light at the end of the tunnel: Sentinel-5P/TROPOMI SWIR Straylight

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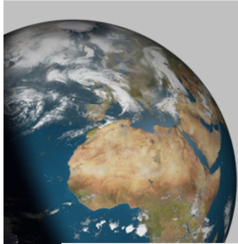


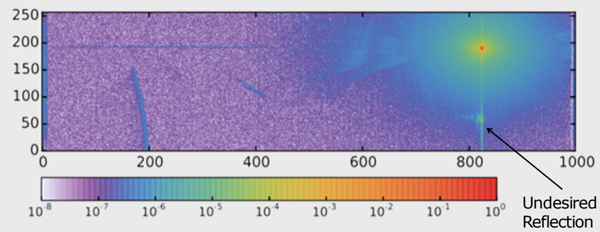
Summary:
The Short Wave Infrared (SWIR) channel of the TROPOMI instrument is used for the retrieval of atmospheric CO and methane columns. Accuracy requirements lead to strict requirements on the spectra and thus on stray light. Any stray light must be characterized and corrected for. A special on-ground calibration method was devised and performed to determine the stray light with a 10^8 dynamic range. A correction algorithm was developed based on a (de)convolution method. Validation measurement show that typically more than 90% of the stray light is corrected.

TROPOMI

The TROPOspheric Monitoring Instrument (TROPOMI) is a space-borne nadir viewing 2D push-broom spectrometer with bands in the ultraviolet, the visible, the near infrared and the shortwave infrared. It is the payload for the ESA/GMES Sentinel 5 Precursor mission, planned for launch in late 2016. The objective is to provide high-quality and timely information on the global atmospheric composition for climate and air quality applications. SRON contributed the SWIR front-end electronics, SWIR immersed grating, characterized the SWIR detector, devised the concept and design of the SWIR calibration, and participated in the calibration with the focus on the SWIR spectrometer.

Stray-light measurement and building of super frames

Special high-dynamic-range measurements were taken during TROPOMI on-ground calibration campaign, using a tunable SWIR laser. The instrument was illuminated under ± 100 different angles and ±100 wavelengths. Combining measurements from 4 different integrating times varying from 0.2ms to 2sec allow for high (10^8) dynamic range "super frames". An example shown below.

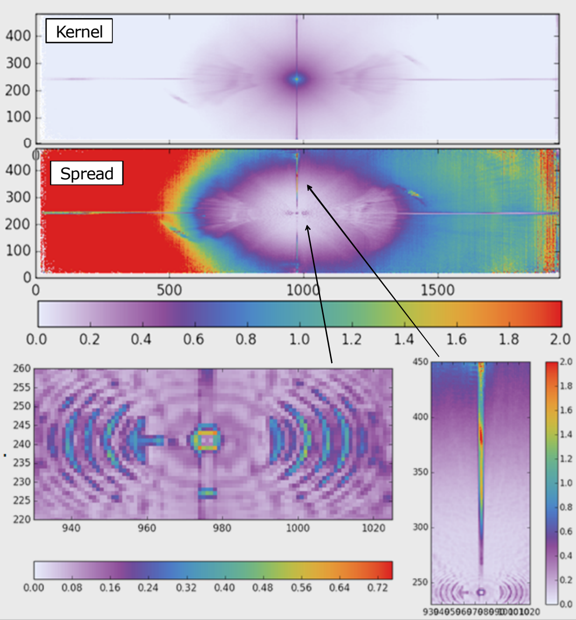


Origin of stray light

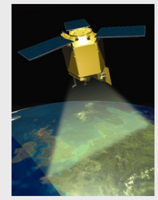
Directly around the laser peak rings can be seen due to interfering reflections. The big halo is due to scattering of all optical surfaces in the spectrometer. The vertical line is pure spatial stray light of all optics before the spectrometer slit. Various reflections can be seen. The faint horizontal line is due to the spectral limit of the immersed grating.

Correction algorithm

The ± 10000 super frames look very similar, allowing to determine an 'average' super frame. This Kernel of the stray light is shown below, together with its (zoomed-in) relative spread.
The SWIR stray-light correction is a deconvolution of measurements with the Kernel. One additional correction is made for the undesired reflection around the nadir row.



Validation

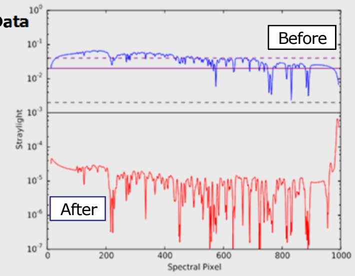


Validation of the correction algorithm and calibration key data is performed in steps:

1. Using synthetic data
2. Closed-loop validation on super frames
3. Validation of spectral correction using internal lasers
4. Validation of spatial correction using white light

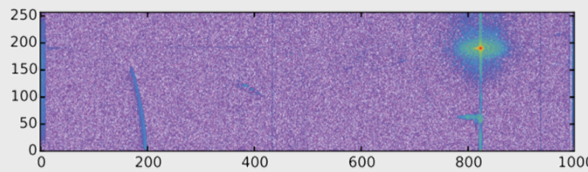
Validation using Theoretical Data

Using synthetic data the correction can reduce the stray-light by three orders of magnitude. In practice, this implies that the algorithm is perfect and the correction is limited by the instrumental variations of stray light (spread in the Kernel).



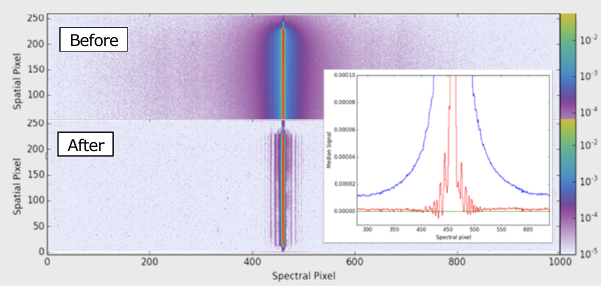
Closed-loop validation on superframes

The same measurement as on left, but now corrected for stray light. What remains are variable parts in the Kernel and the reflection at the left.



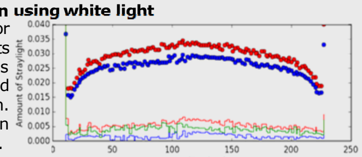
Validation of spectral correction using internal lasers

TROPOMI has 5 on-board diode lasers for in-flight ISRF and stray-light monitoring. The algorithm removes 90% of stray light, with 5% remaining near the laser and 5% as a tiny offset.



Validation of spatial correction using white light

Stray light is corrected for typically 80-87%, see red dots and line. Remaining signal seems dominated by a spectral and spatial white offset of TBD origin. Including an offset correction increases correction to 94 - 97%.



Conclusions:

- New measurement : Stray light with 10^8 dynamic range
- Correction algorithm based on (de)convolution
- Correction works very good in spectral dimension.
- Algorithm reduces stray light by factor 10 -20, requirement: factor 20.
- Correction limited in spatial dimension due to TBD offset.
- Stray light factor 3 - 10 too high after correction, due to high stray light at instrument level (factor 3.5 too high).
- In-flight measurement will show final result. Improvement possible on pure spatial stray light.

Authors:

More information

This document has been produced with the financial assistance of the European Union. The views expressed herein can in no way be taken to reflect the official opinion of the European Union and/or ESA. The Sentinel 5 Precursor mission, a collaborative effort of ESA and the Netherlands Space Office (NSO), is part of the GMES Space Component Programme. ESA and the Netherland Space Office share the procurement of the TROPOMI payload and its processing software, whilst ESA is responsible for the procurement of the platform and the development of the ground segment. The consortium composing the mission comprises Astrium Ltd (Stevenage - UK), as Mission Prime, and an integrated team of Dutch Space (Leiden - NL) and TNO (Delft - NL) is responsible for the Payload. Major subcontractors are SSTL (Sevenoaks – UK) for the development of the SWIR Channel, and RUAG (Switzerland and Sweden) for the Payload electronics. The Royal Netherlands Meteorological Institute (KNMI) and the Netherlands Institute for Space Research (SRON) are the Principal Investigator institutes on behalf of the Netherlands' national programme.