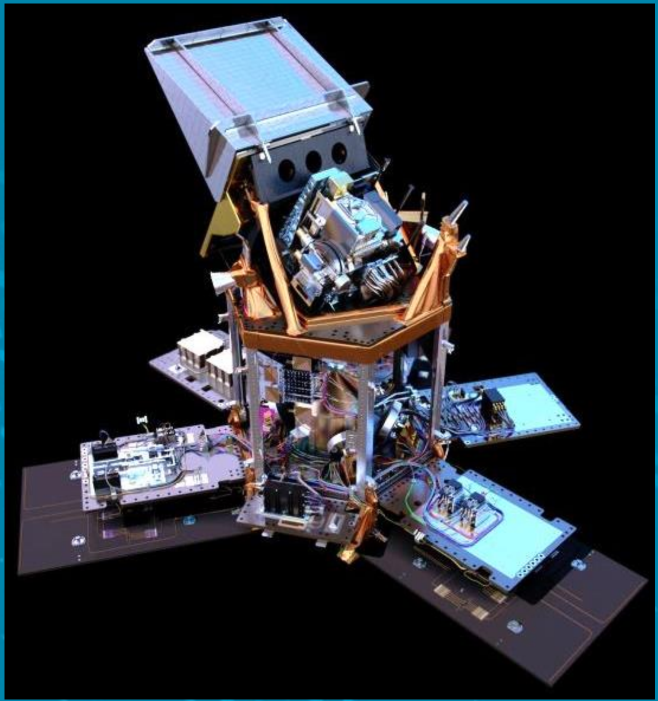

TROPOMI is ready for launch! Pre-flight performance and calibration measurements

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[1] Airbus DS Netherlands
[2] KNMI
[3] SRON

DUTCH TECHNOLOGY

Outline of the presentation

- Sentinel-5 precursor – mission and status
- The TROPOMI instrument
- TROPOMI instrument performance and calibration
  - Calibration in progress
  - A few selected calibration results
    - Intra-band co-registration
    - Deriving the instrument spectral response function
    - Deriving the instrument straylight performance
- Some concluding remarks

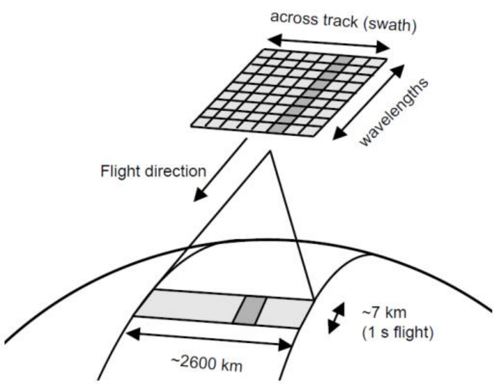
DUTCH TECHNOLOGY

Sentinel-5 precursor – mission and status

- The ESA Sentinel-5 Precursor (S-5p) is a precursor mission that focuses on global observations of the atmospheric composition for air quality and climate.
- Sentinel-5p bridges the data gap between SCIAMACHY / OMI (2002 / 2004) and Sentinel-5 (2021), with improved sensitivity and smaller ground sampling distance
- The TROPOspheric Monitoring Instrument (TROPOMI) is the payload of the S-5p mission and is jointly developed by The Netherlands and ESA. Instrument prime is Airbus DS Netherlands.
- On-ground calibration testing of TROPOMI finished on May 2015.
- The planned launch date for S-5p is end of 2016 with a 7 year design lifetime.

The instrument:

- UV-VIS-NIR-SWIR nadir viewing pushbroom grating spectrometer.
- Spectral range: 270-500, 675-775, 2305-2385 nm
- Spectral Resolution: 0.25-1.1 nm
- Spatial Resolution (nadir): 7x7km2
- Global daily coverage at 13:30 local solar time.



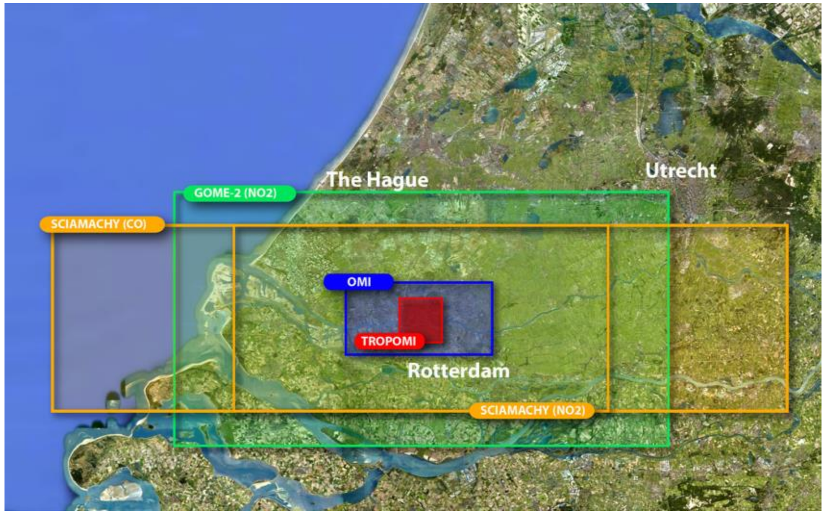
The science products

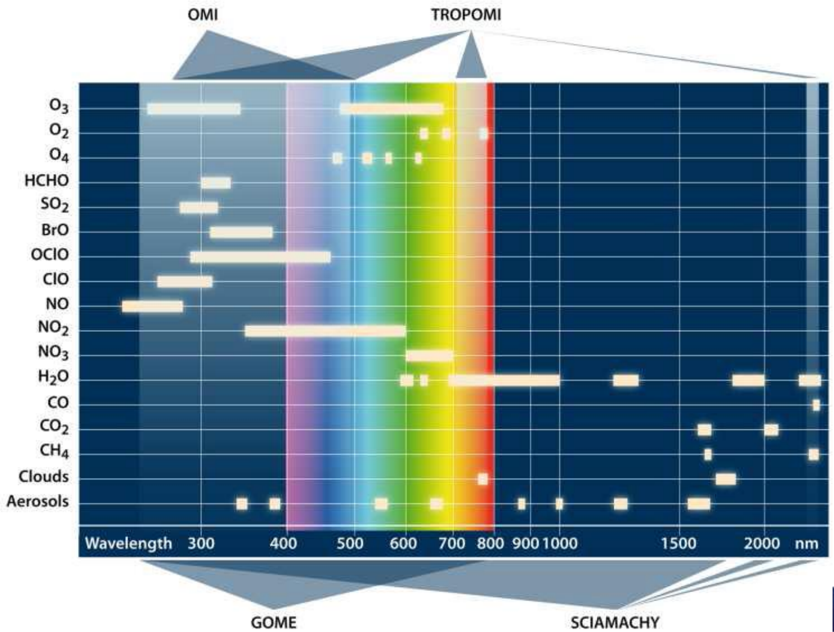
- Total column: O3, NO2, CO, SO2,CH4, CH2O,H2O,BrO
- Tropospheric column: O3, NO2
- O3 profile
- Aerosol: absorbing index, type, optical depth

DUTCH TECHNOLOGY

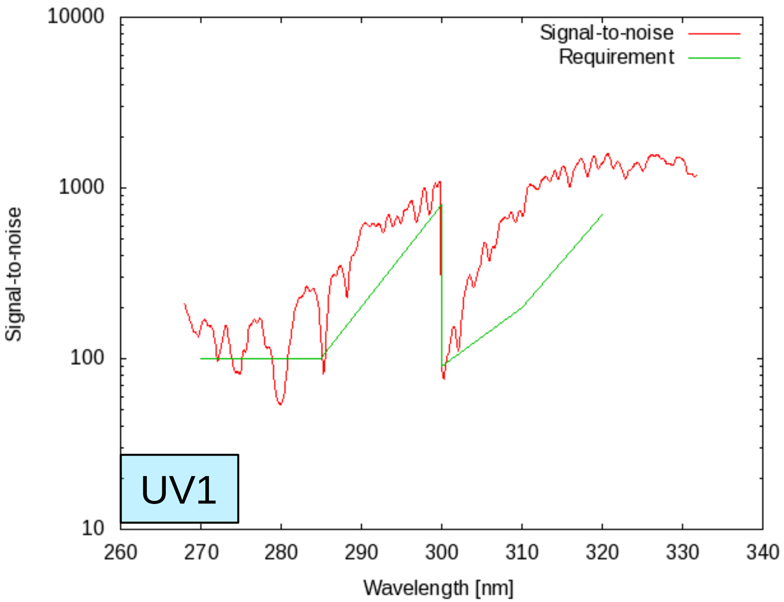
The TROPOMI Instrument performance parameters

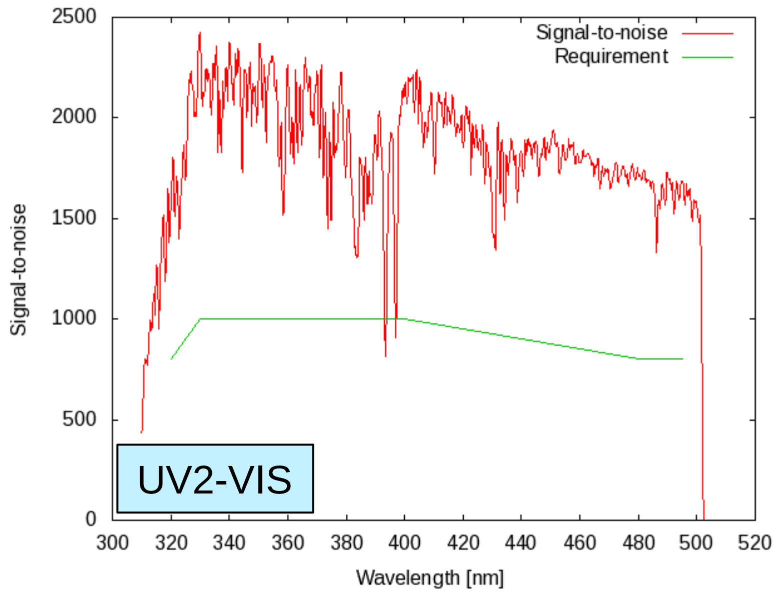
Spectrometer	UV		UVIS		NIR		SWIR
Band ID	1	2	3	4	5	6	7
Spectral range [nm]	270-300	300-320	310-405	405-495	675-725	725-775	2305-2385
Spectral resolution [nm]	0.5	0.5	0.55	0.55	0.5	0.5	0.25
Spectral sampling [nm]	0.06	0.06	0.2	0.2	0.1	0.1	<0.1
Spatial sampling [km^2]	21x28	7x7	7x7	7x7	7x7	7x1.8	7x7
Signal-to-noise (required)	100	100-1000	1000-1500	1500	500	100-500	100-120

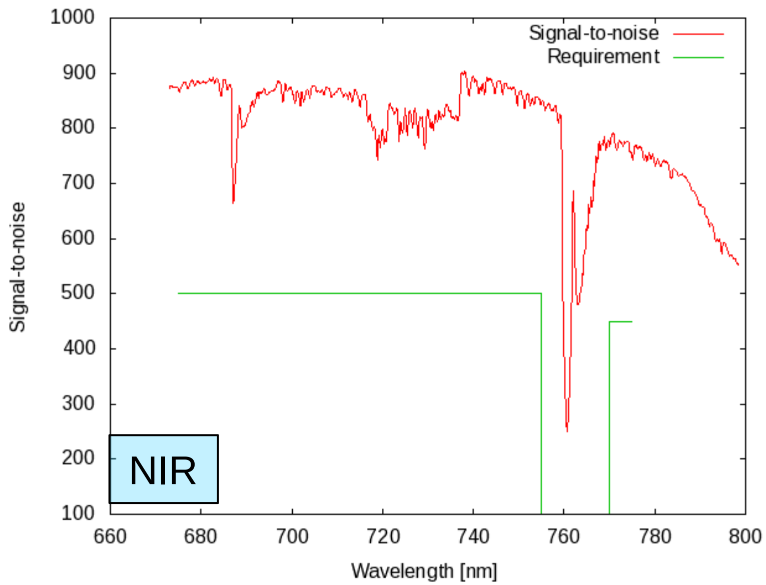


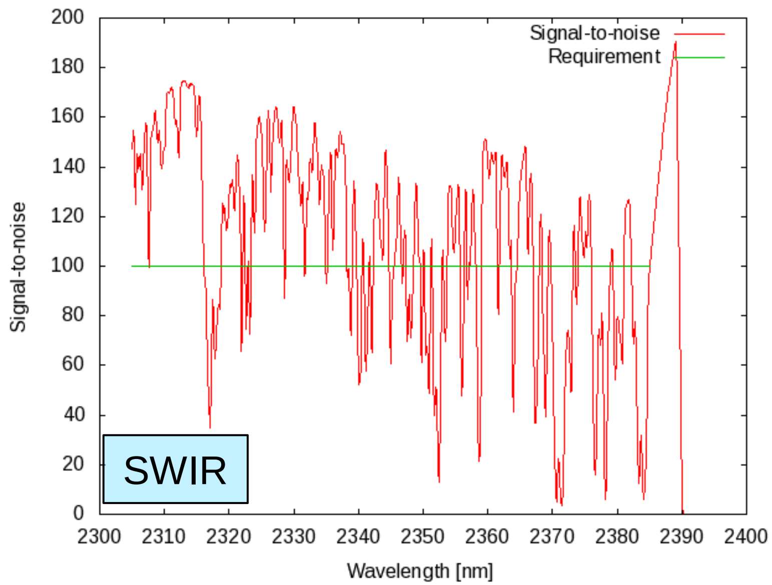


TROPOMI SNR for dark scenes (2 - 5 % albedo)



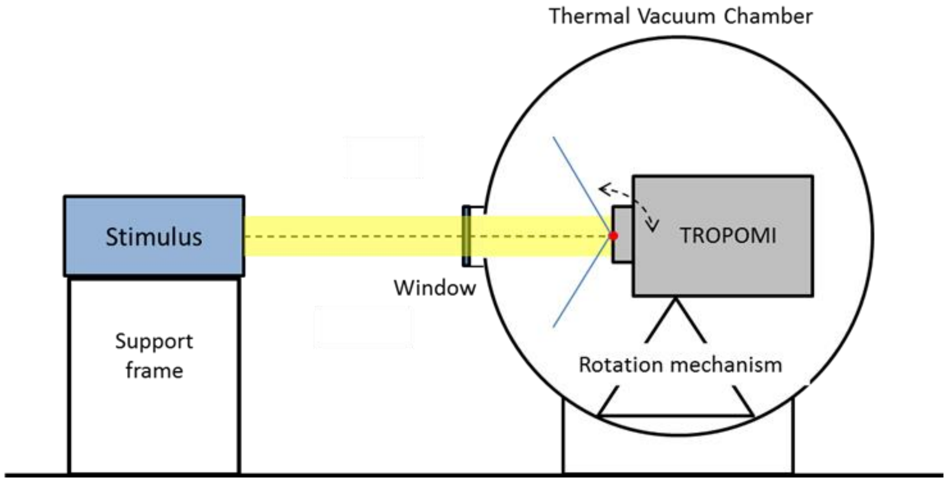


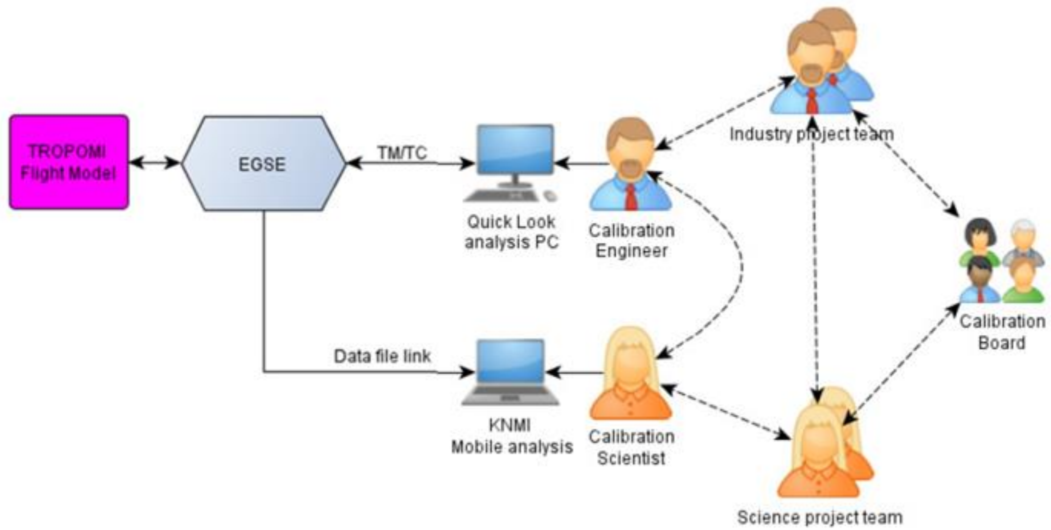




DUTCH TECHNOLOGY

Instrument H/W is only useful after proper calibration





DUTCH TECHNOLOGY

Efficiently organized performance / calibration measurement campaign

- ❑ Only 125 days to get all and the best possible necessary Calibration Key Data

Cooperation

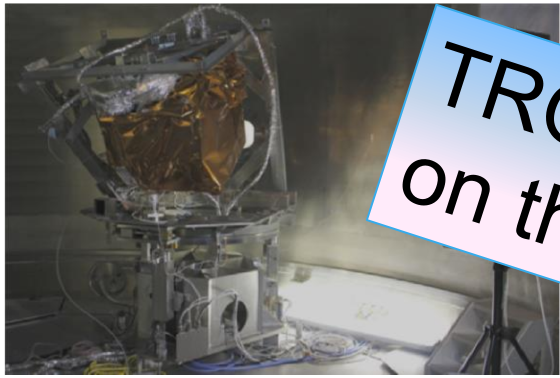
- ❑ Airbus DS: measurement campaign and management
- ❑ KNMI / SRON (PI): measurement definition

Happily cooperating teams: key to succes!

Calibration in progress

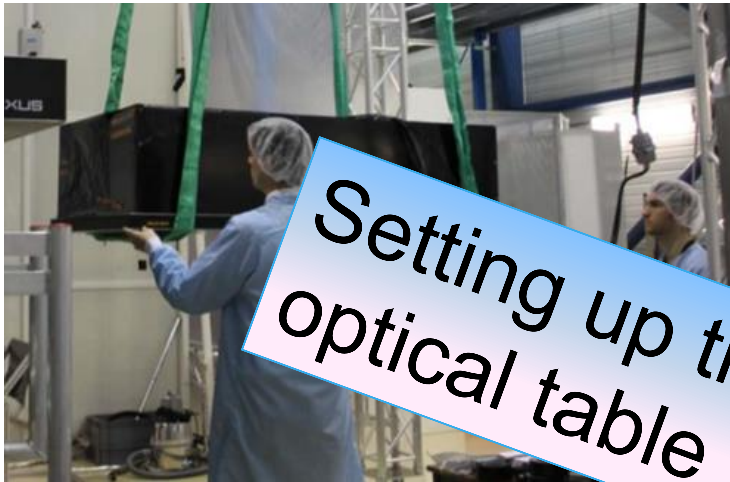
- Automated measurements in 6 m ∅ vacuum vessel at CSL in Liege, Belgium

Preparing TROPOMI



TROPOMI on the cradle

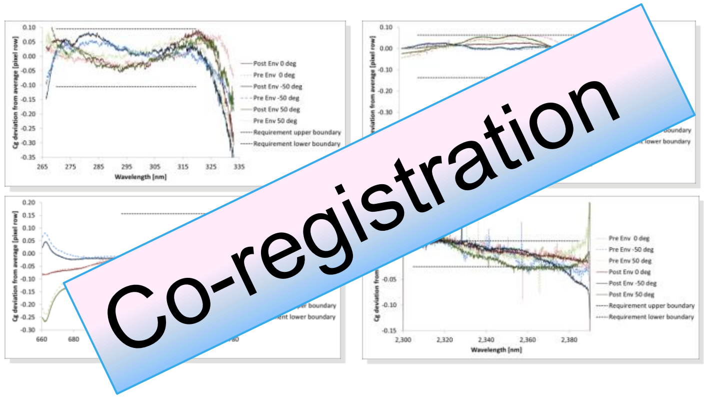
TROPOMI Wrapped in MLI

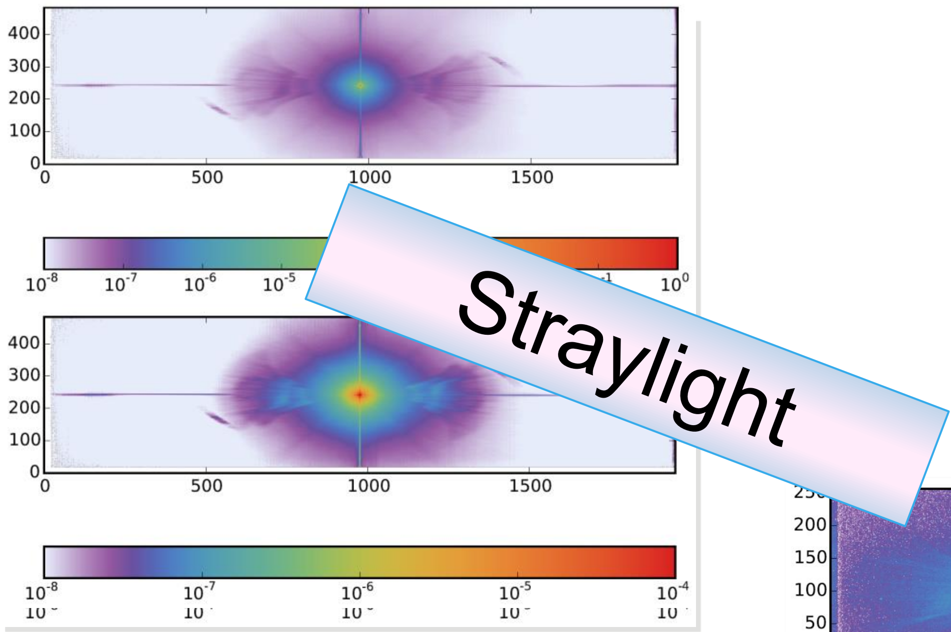


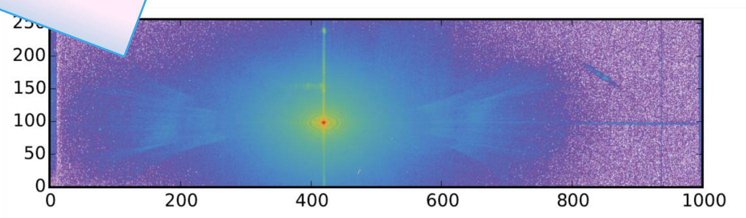
Setting up the optical table

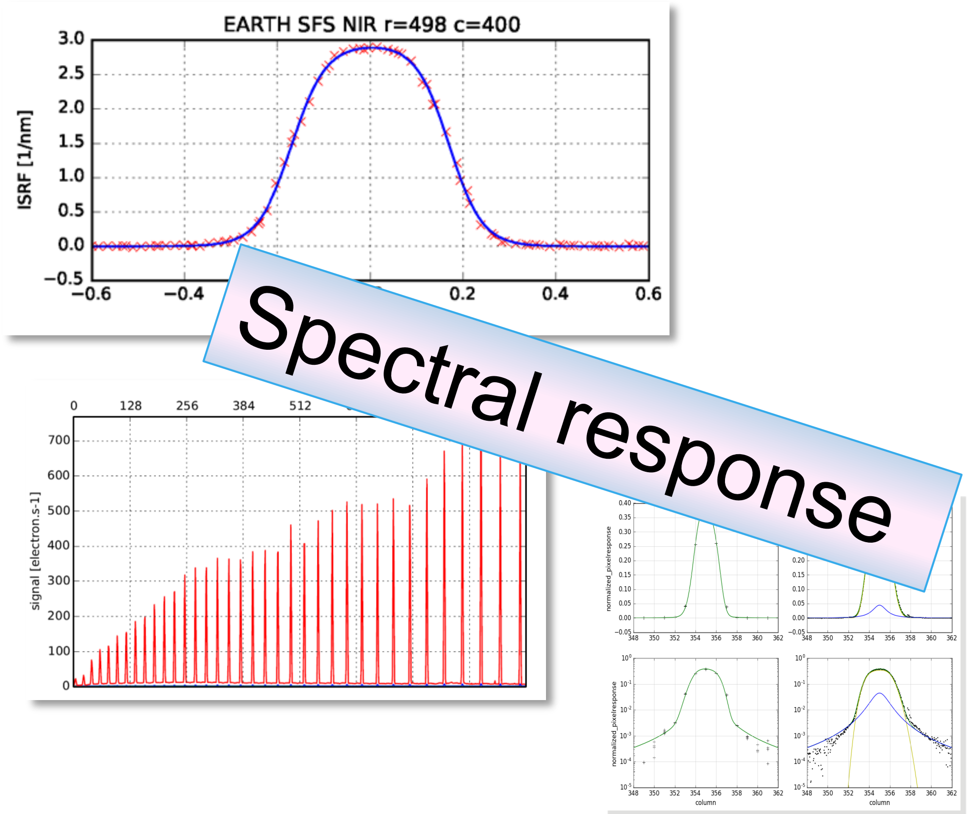
DUTCH TECHNOLOGY

Some results of the measurements campaign

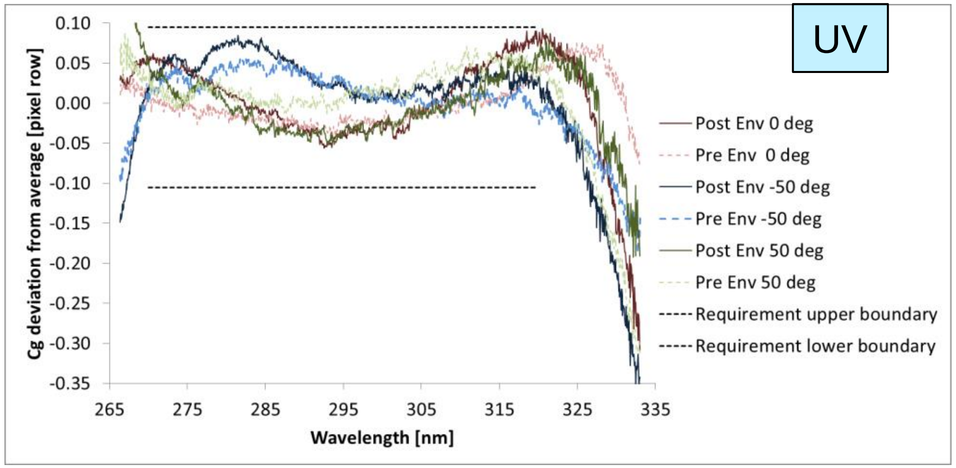


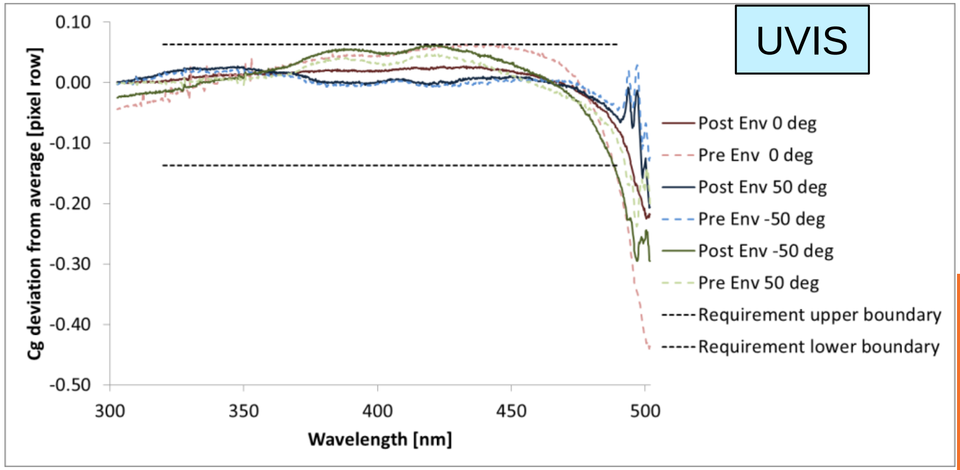


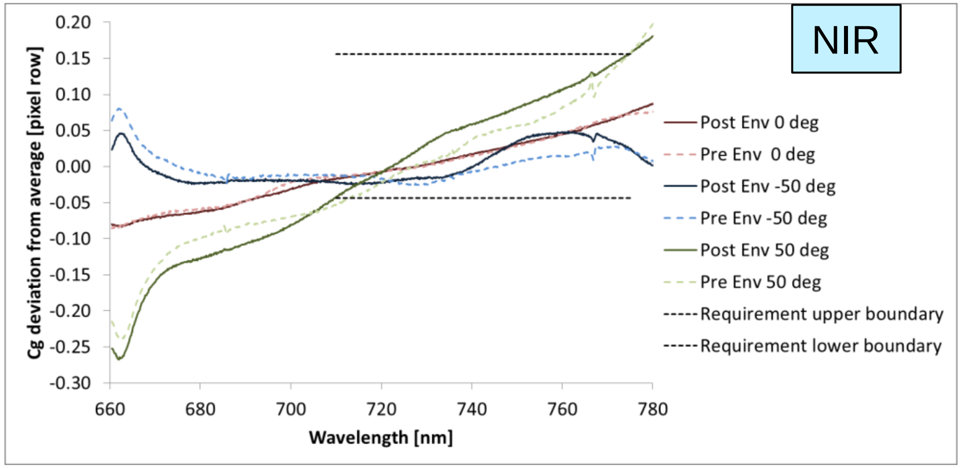


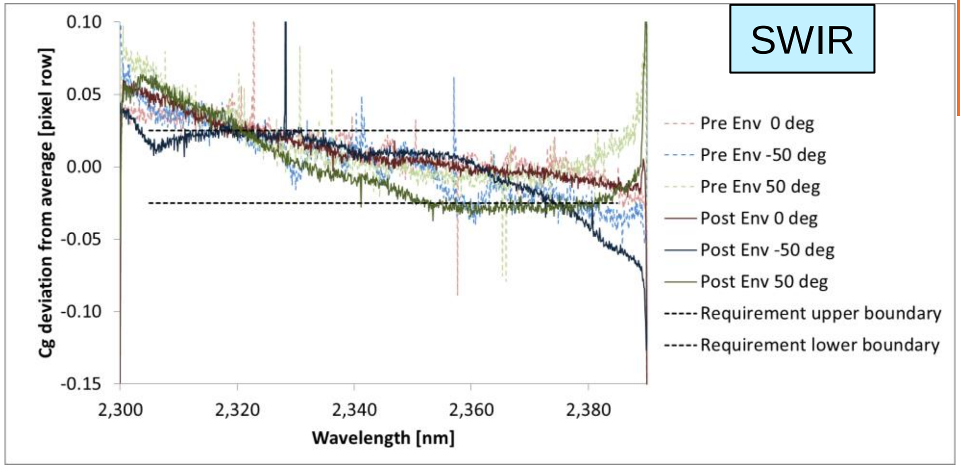


Intra-band co-registration: within specification







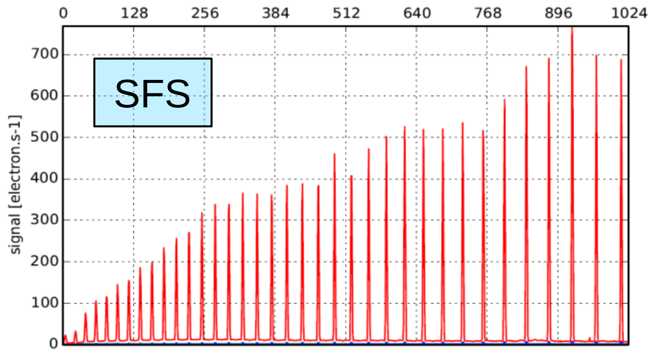


DUTCH TECHNOLOGY

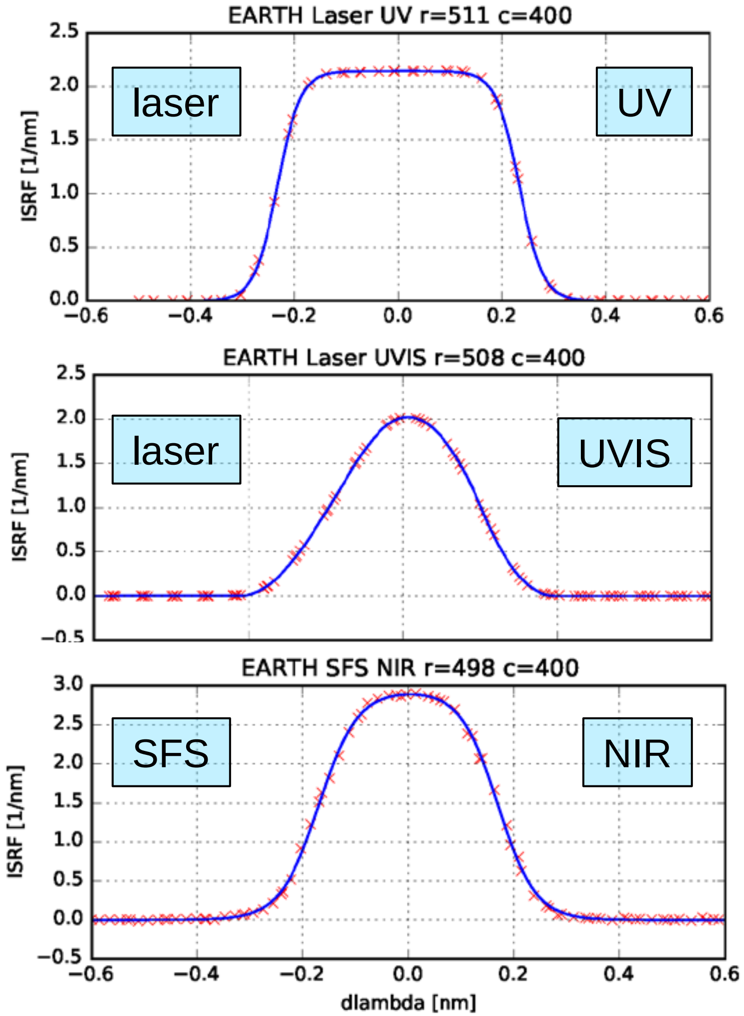
Deriving the UVN ISRF

Method:

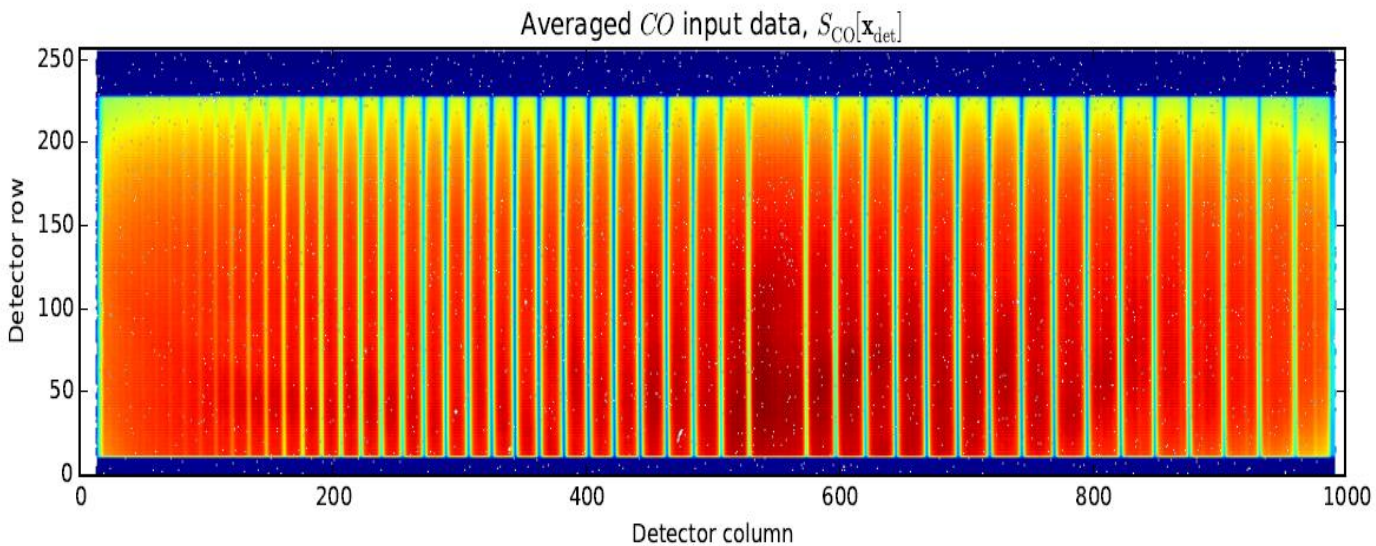
- A narrow spectral line is tuned in small steps.
- Line source may be a either a laser or a dedicated slit function stimulus (SFS)
- During tuning, the signal of each individual pixel is followed as the laser scans over this pixel. This is the Instrument Spectral Response Function (ISRF) for each pixel.
- ISRF is function fitted iteratively
- Data selection and 2D fitting is needed to remove laser features.

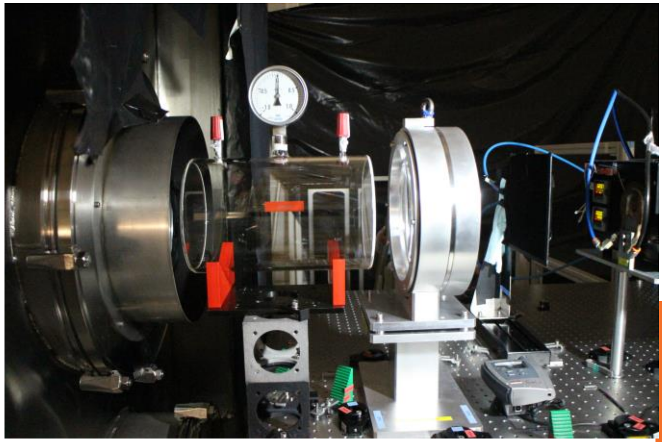


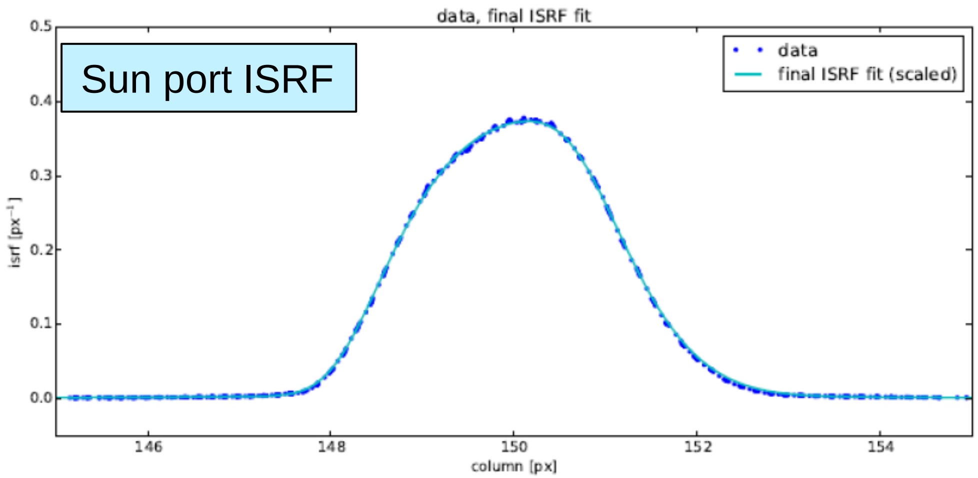
Results:

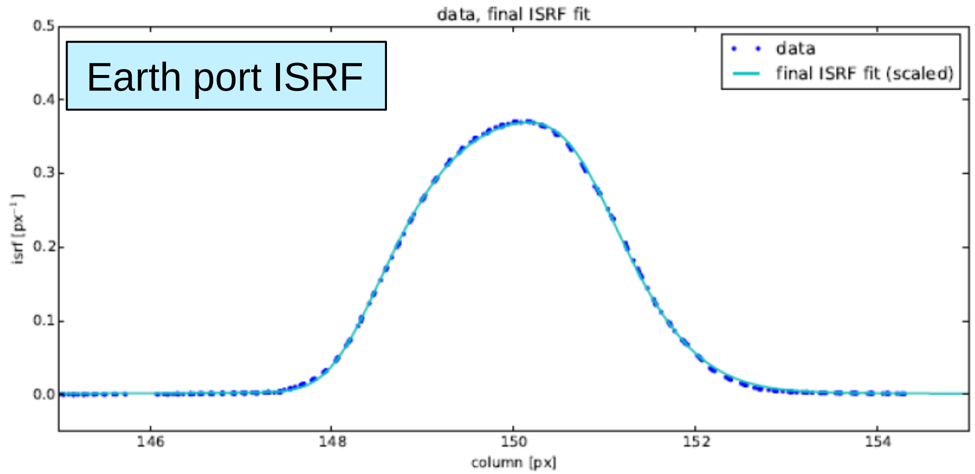


CO gas cell (spectral assignment) and ISRF SWIR band









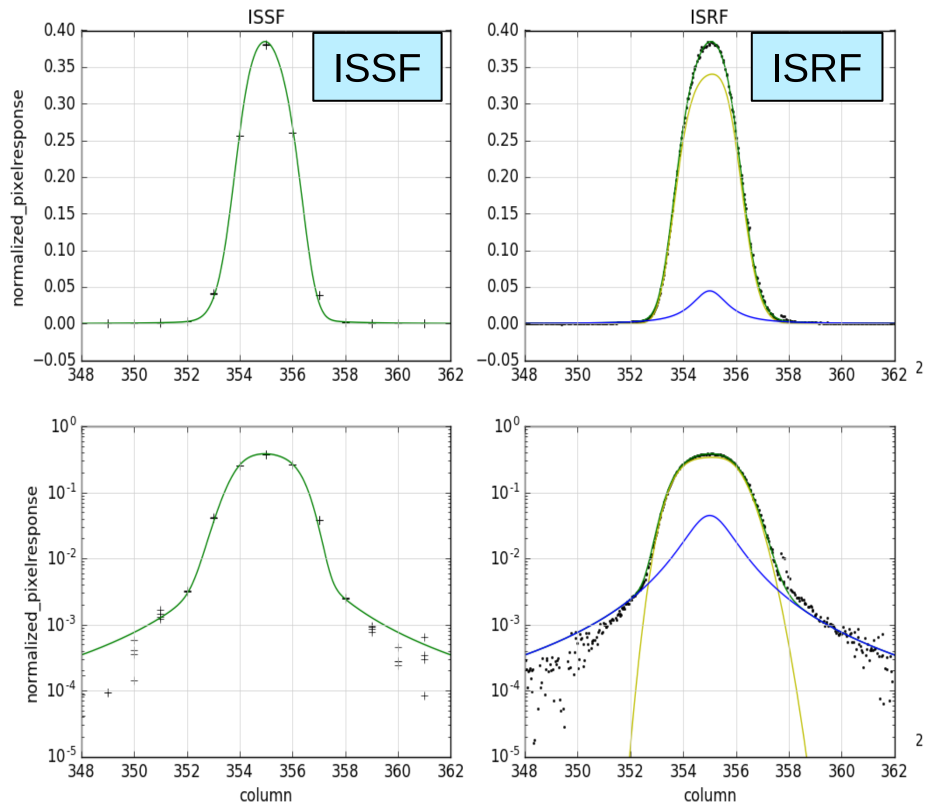
DUTCH TECHNOLOGY

Deriving the SWIR ISSF and ISRF

Method:

- A tunable SWIR laser scans the complete wavelength in small steps.
- The Instrument Spectral Spread Function (ISSF) is measured for illuminated pixels.
- During laser tuning, the signal of each individual pixel is followed as the laser scans over this pixel. This is the Instrument Spectral Response Function (ISRF) for each pixel.
- ISSF and ISRF are function fitted iteratively
- Data selection and 2D fitting is needed to remove laser features.

Results:



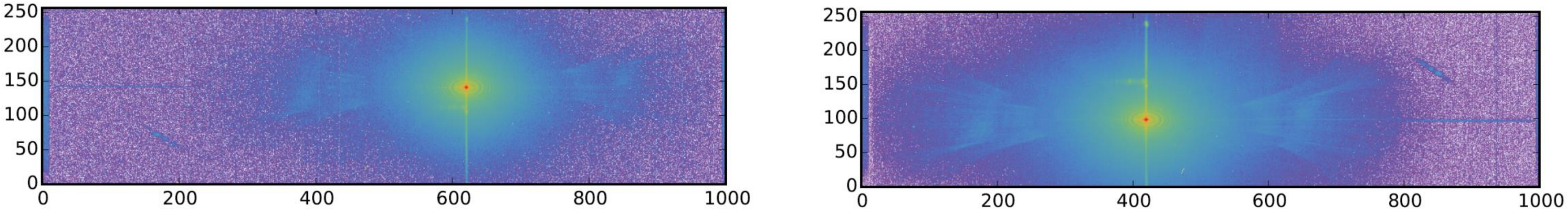
DUTCH TECHNOLOGY

Stray light SWIR: laser measurements

Method:

- ❑ Use a tunable monochromatic source (laser)
- ❑ Measure at ± 100 spatial positions in the FoV and at ±100 spectral positions in the band. Total ± 10,000 point measurements.
- ❑ Measure laser peak with very short exposure time (0.2 ms) and stray light with longer integration time (4, 100, 2000 ms).
- ❑ Combine unsaturated data: 10,000 'superframes' with 10^8 dynamic range, see next page.
- ❑ Superframes look very similar! This allows to:
  - Derive 'stray-light kernel' based on 'average' superframe.
  - Deconvolve measurements with kernel.

Example of two 'superframes'

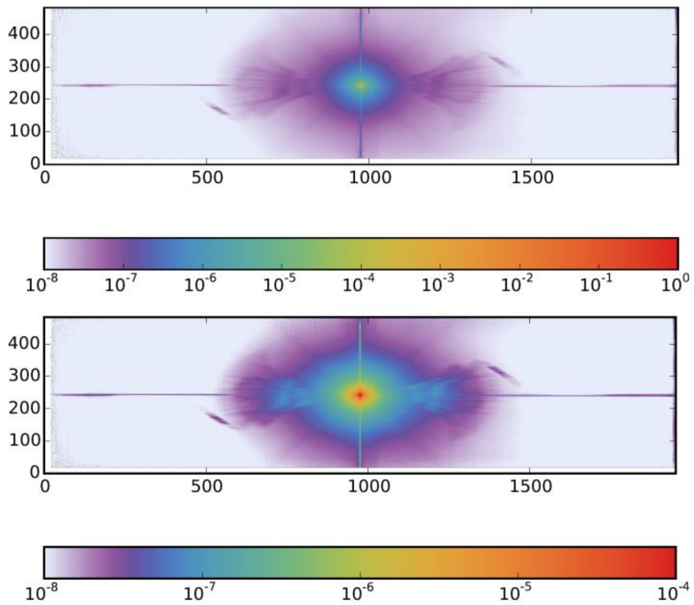


SWIR Stray light kernel and correction

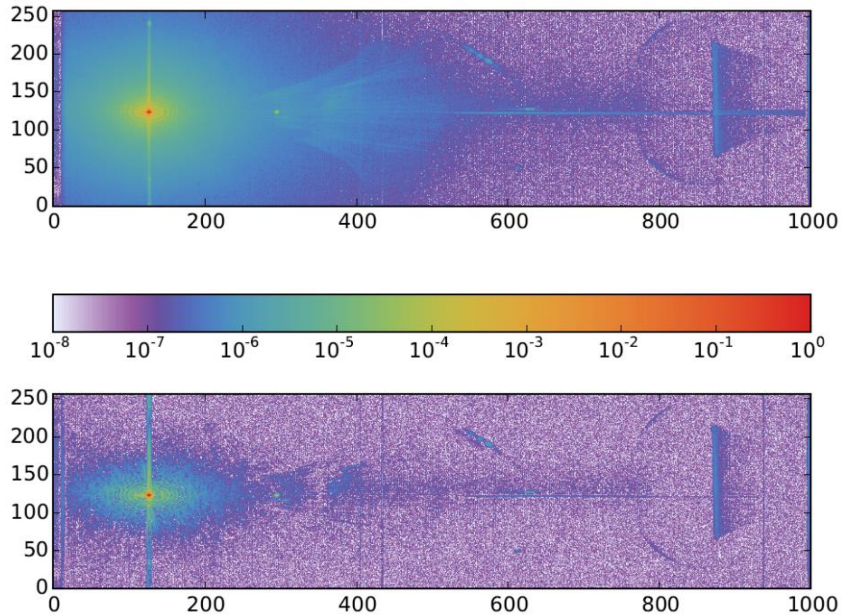
Results:

- In-field and in-band SWIR stray light measured with high dynamic range (8 orders) using a tunable laser and 10^4 difference in exposure times.
- Stray light caused by scatter of optical surfaces, pre-spectrometer optics, reflections, grating.
- On Level-1b stray light out-of-spec by factor of ± 4.

Resulting average straylight kernel



Example ‘superframe’ [top] and correction [bottom]



DUTCH TECHNOLOGY

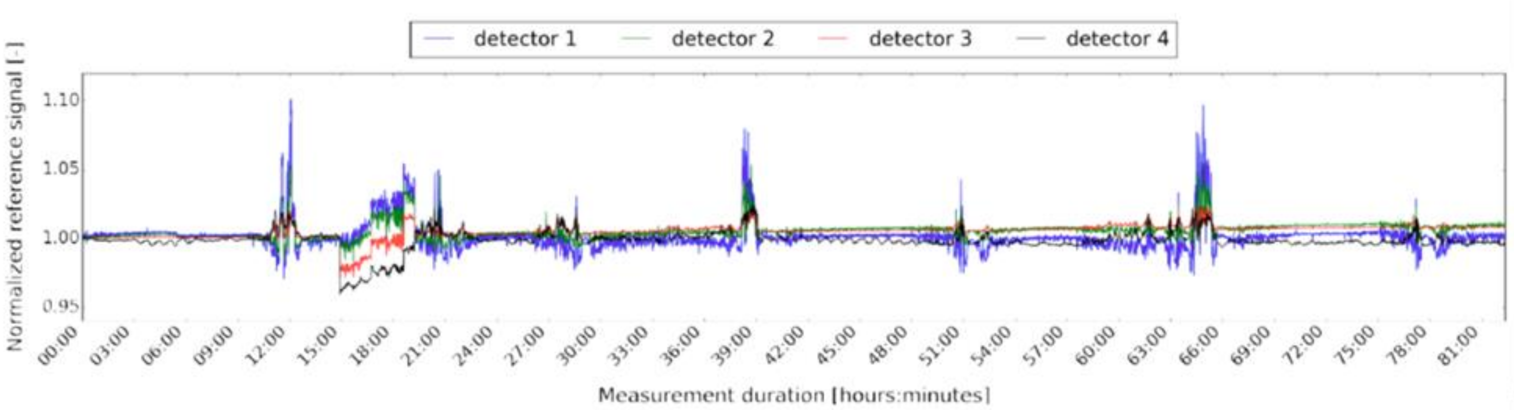
Successes and drawbacks

Successes:

- ❑ No functional failures of the TROPOMI instrument
- ❑ Efficient use of versatile light sources
- ❑ Measurement efficiency: (measurement time / total time): 85 %
- ❑ Total 80 % of the planned data acquired

Drawbacks:

- ❑ Instability of Xe lamp
- ❑ Failure of tunable laser



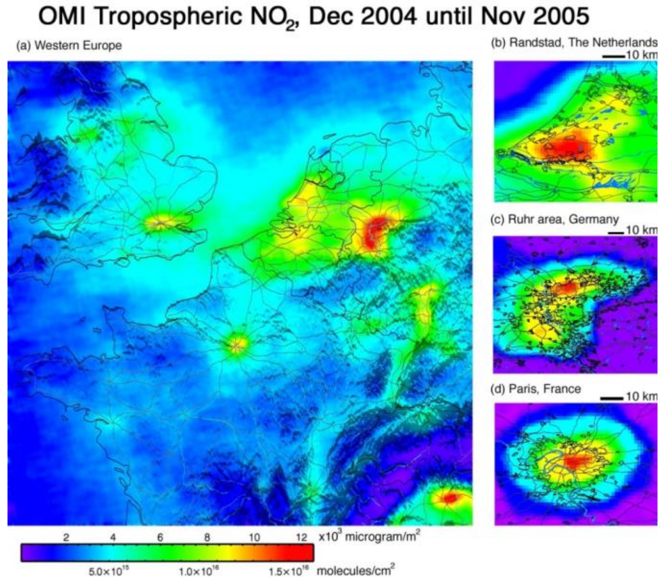
DUTCH TECHNOLOGY

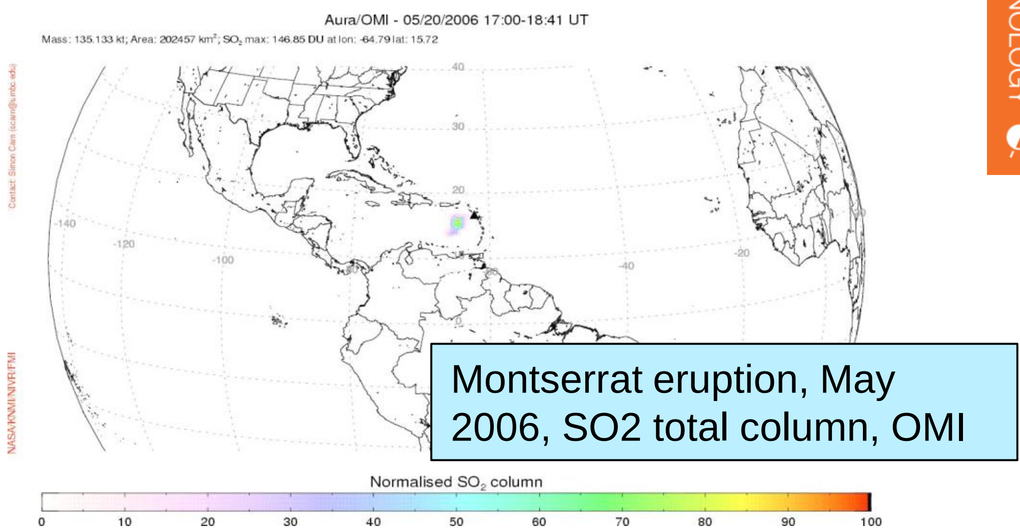
TROPOMI is well calibrated, ready for launch and use

- Launch planned October 2016, from Plesetsk in Russia

- TROPOMI trace gas / aerosol / cloud data:
  - Climate research
  - Air quality data (independent)
  - Medium range weather forecasts

- With the imminent launch of TROPOMI, the near future for greenhouse gas measurements from space looks bright.





Montserrat eruption, May 2006, SO2 total column, OMI

DUTCH TECHNOLOGY