TROPOMI is ready for launch!

Pre-flight performance and calibration measurements

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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
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
The TROPOMI Instrument performance parameters

<table>
<thead>
<tr>
<th>Spectrometer</th>
<th>UV</th>
<th>UVIS</th>
<th>NIR</th>
<th>SWIR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band ID</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Spectral range [nm]</td>
<td>270-300</td>
<td>300-320</td>
<td>310-405</td>
<td>405-495</td>
</tr>
<tr>
<td>Spectral resolution [nm]</td>
<td>0.5</td>
<td>0.5</td>
<td>0.55</td>
<td>0.55</td>
</tr>
<tr>
<td>Spectral sampling [nm]</td>
<td>0.06</td>
<td>0.06</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Spatial sampling [km²]</td>
<td>21x28</td>
<td>7x7</td>
<td>7x7</td>
<td>7x7</td>
</tr>
<tr>
<td>Signal-to-noise (required)</td>
<td>100</td>
<td>100-1000</td>
<td>1000-1500</td>
<td>1500</td>
</tr>
</tbody>
</table>

IWGMS-12; Kyoto; June 7-9, 2016
TROPOMI SNR for dark scenes (2 - 5 % albedo)
Instrument H/W is only useful after proper calibration

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 success!
Calibration in progress

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

Preparing TROPOMI

TROPOMI Wrapped in MLI

TROPOMI on the cradle

Setting up the optical table
Some results of the measurements campaign

Co-registration

Spectral response

Straylight
Intra-band co-registration: within specification

- **UV**
  - Post Env 0 deg
  - Pre Env 0 deg
  - Post Env -50 deg
  - Pre Env -50 deg
  - Post Env 50 deg
  - Pre Env 50 deg
  - Requirement upper boundary
  - Requirement lower boundary

- **UVIS**
  - Post Env 0 deg
  - Pre Env 0 deg
  - Post Env -50 deg
  - Pre Env -50 deg
  - Post Env 50 deg
  - Pre Env 50 deg
  - Requirement upper boundary
  - Requirement lower boundary

- **NIR**
  - Post Env 0 deg
  - Pre Env 0 deg
  - Post Env -50 deg
  - Pre Env -50 deg
  - Post Env 50 deg
  - Pre Env 50 deg
  - Requirement upper boundary
  - Requirement lower boundary

- **SWIR**
  - Pre Env 0 deg
  - Pre Env -50 deg
  - Pre Env 50 deg
  - Post Env -50 deg
  - Post Env 50 deg
  - Requirement upper boundary
  - Requirement lower boundary
**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:**

![Graphs showing ISRF for different wavelengths](image)
CO gas cell (spectral assignment) and ISRF SWIR band
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:
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 $\pm 4$. 

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**Resulting average straylight kernel**

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

Sentinel-5p/TROPOMI