Correction of instrument ageing in TROPOMI L01b processing

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Instrument design & operation

- Radiance path fully in irradiance path
- Backup diffuser QVD2 to retrieve exposure dependent degradation
- QVD1: 1x per day
- QVD2: 1x per week

Correction in L01b processor

- Add a time axis to the calibration key data
- Extension to later date dependent on instrument effect: extrapolation or fixed value
- Regular updates: configuration change only

Degradation model

- Assume: Exposure dependent degradation
- Make use of spectral overlap between UV and UVIS spectrometer
- Separate degradation in different contributions

Results

- Correction maps per detector
- Degradation up to 12% in UV

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Instrument & operations

- Single payload TROPOMI on-board Sentinel-5 Precursor
- Hyperspectral imager with 4 spectrometers (spectral overlap UV-UVIS)
- Daily measurements of the Sun via main diffuser
- Weekly calibration measurements via backup diffuser
- Radiance path fully part of irradiance path
- Pushbroom with ~ 2600 km swath
- High spatial sampling (down to 5.5 km x 3.5 km)
- Sun synchronous orbit (MLTAN 13.30)

### TROPOMI spectral bands – based on calibration data

<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>267-300</td>
<td>300-332</td>
<td>305-400</td>
<td>400-499</td>
</tr>
<tr>
<td>Spectral resolution [nm]</td>
<td>0.45 - 0.5</td>
<td>0.45 - 0.65</td>
<td>0.34 - 0.35</td>
<td>0.227</td>
</tr>
<tr>
<td>Spectral sampling [nm]</td>
<td>0.065</td>
<td>0.195</td>
<td>0.126</td>
<td>0.094</td>
</tr>
<tr>
<td>Spatial sampling [km²]</td>
<td>5.5 x 28</td>
<td>5.5 x 3.5</td>
<td>5.5 x 3.5</td>
<td>5.5 x 7</td>
</tr>
<tr>
<td>Detector binning factor</td>
<td>16</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>
Degradation in diffusers and “common path”

- Decreases transmission
- Stronger for shorter wavelengths
- Exponential decay
- Degradation observed also in radiance
- So far not observed in SWIR

Spectral ageing in UV

- Increases signal (“bleaching”)
- Correlated with solar spectrum
- Partly outweighs diffuser degradation
- Strongest at 317 nm
**Degradation model**

- Separate degradation in different contributions: diffuser 1 & 2, common part (spectrometer & folding mirror), spectral ageing (UV), residuals
- Assume: Exposure dependent degradation
- Main diffuser used about 6x more often than backup diffuser
- Make use of spectral overlap between UV and UVIS spectrometer for UV spectral ageing
- Solve linear equations for each (super) pixel

**Correction in the L01b processor**

- Add a time (=orbit) axis to the calibration key data
- Interpolate between calibration points for degradation
- Extension to later date dependent on instrument effect: extrapolation or fixed value
- Regular updates: configuration change only, no software updated needed
- Expected to be operational end of June 2021

\[
D_{\text{tot},q1}(k) = D_{q1}(t_q1(k)) \cdot D_{\text{com}}(k) \cdot D_{\text{spec}}(k) \cdot R_k
\]

\[
D_{\text{tot},q2}(k) = D_{q2}(t_q2(k)) \cdot D_{\text{com}}(k) \cdot D_{\text{spec}}(k) \cdot R_k \cdot P_k
\]
Calibration maps derived from irradiance data

UV common & spectral ageing

UVIS common

14/06/2020
## Degradation status

<table>
<thead>
<tr>
<th>Status orbit 18299</th>
<th>QVD1 + common solar [%]</th>
<th>QVD2 + common solar [%]</th>
<th>common solar only [%]</th>
<th>spectral ageing [%]</th>
<th>residual (max)[%]</th>
<th>residual (std)[%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band 1</td>
<td>12.02</td>
<td>6.33</td>
<td>5.05</td>
<td>-2.21</td>
<td>0.19</td>
<td>0.06</td>
</tr>
<tr>
<td>Band 2</td>
<td>9.10</td>
<td>4.61</td>
<td>3.63</td>
<td>-3.33</td>
<td>0.20</td>
<td>0.06</td>
</tr>
<tr>
<td>Band 3</td>
<td>6.37</td>
<td>3.15</td>
<td>2.45</td>
<td>0.00</td>
<td>0.42</td>
<td>0.13</td>
</tr>
<tr>
<td>Band 4</td>
<td>2.82</td>
<td>1.47</td>
<td>1.17</td>
<td>0.00</td>
<td>0.42</td>
<td>0.13</td>
</tr>
<tr>
<td>Band 5</td>
<td>0.49</td>
<td>0.34</td>
<td>0.27</td>
<td>0.00</td>
<td>0.37</td>
<td>0.12</td>
</tr>
<tr>
<td>Band 6</td>
<td>0.41</td>
<td>0.31</td>
<td>0.25</td>
<td>0.00</td>
<td>0.36</td>
<td>0.12</td>
</tr>
<tr>
<td>Band2:317 nm</td>
<td>8.85</td>
<td>4.47</td>
<td>3.52</td>
<td>-11.34</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Band3:317nm</td>
<td>8.79</td>
<td>4.50</td>
<td>3.57</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

### Per 1000 orbits @18299

<table>
<thead>
<tr>
<th>Status orbit 18299</th>
<th>QVD1 + common [%]</th>
<th>common solar only [%]</th>
<th>spectral ageing [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band 1</td>
<td>0.776</td>
<td>0.326</td>
<td>-0.143</td>
</tr>
<tr>
<td>Band 2</td>
<td>0.588</td>
<td>0.234</td>
<td>-0.538</td>
</tr>
<tr>
<td>Band 3</td>
<td>0.411</td>
<td>0.158</td>
<td>-</td>
</tr>
<tr>
<td>Band 4</td>
<td>0.182</td>
<td>0.076</td>
<td>-</td>
</tr>
<tr>
<td>Band 5</td>
<td>0.032</td>
<td>0.018</td>
<td>-</td>
</tr>
<tr>
<td>Band 6</td>
<td>0.027</td>
<td>0.016</td>
<td>-</td>
</tr>
<tr>
<td>Band2:317 nm</td>
<td>0.572</td>
<td>0.227</td>
<td>-0.733</td>
</tr>
<tr>
<td>Band3:317nm</td>
<td>0.568</td>
<td>0.230</td>
<td>-</td>
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</tbody>
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more on TROPOMI calibration: Kleipool et al. 2018 https://doi.org/10.5194/amt-11-6439-2018