Correction of instrument ageing in TROPOMI L01b processing

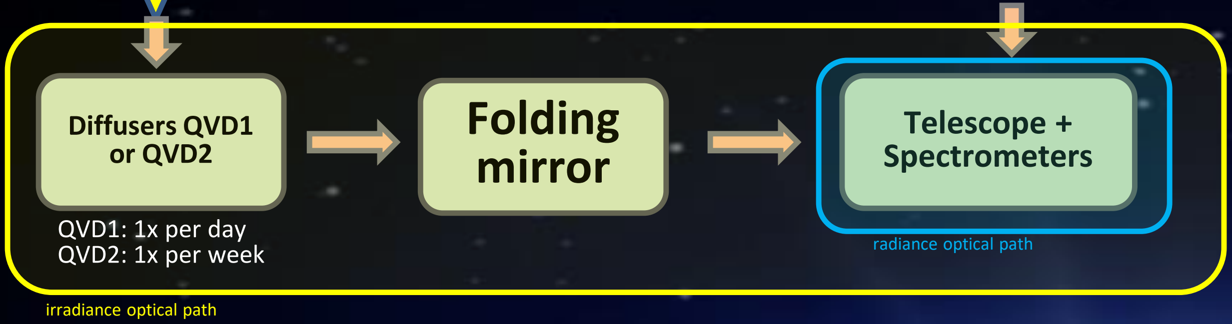
Antje Ludewig[1], Quintus Kleipool[1], Jonatan Leloux[1,2], Erwin Loots[1], Emiel van der Plas[1], Nico Rozemeijer[1,2], and Pepijn Veefkind[1]

[1]KNMI, (Royal Netherlands Meteorological Institute), [2]TriOpSys B.V.

TROPOMI

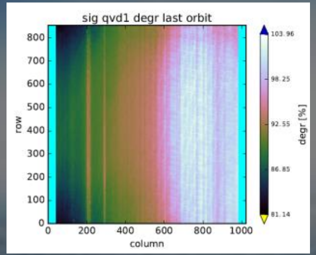
Instrument design & operation

- Radiance path fully in irradiance path
- Backup diffuser QVD2 to retrieve exposure dependent degradation



Instrument degradation

- Mainly decrease in transmission of the diffusers and other optics
- Spectral ageing in UV spectrometer (increase in signal)



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

$$D_{\mathrm{tot},q1}(k) = D_{q1}(t_{q1}(k)) \cdot D_{\mathrm{com}}(k) \cdot D_{\mathrm{spec}}(k) \cdot R_k$$

$$D_{\mathrm{tot},q2}(k) = D_{q2}(t_{q2}(k)) \cdot D_{\mathrm{com}}(k) \cdot D_{\mathrm{spec}}(k) \cdot R_k \cdot P_k$$

- Separate degradation in different contributions

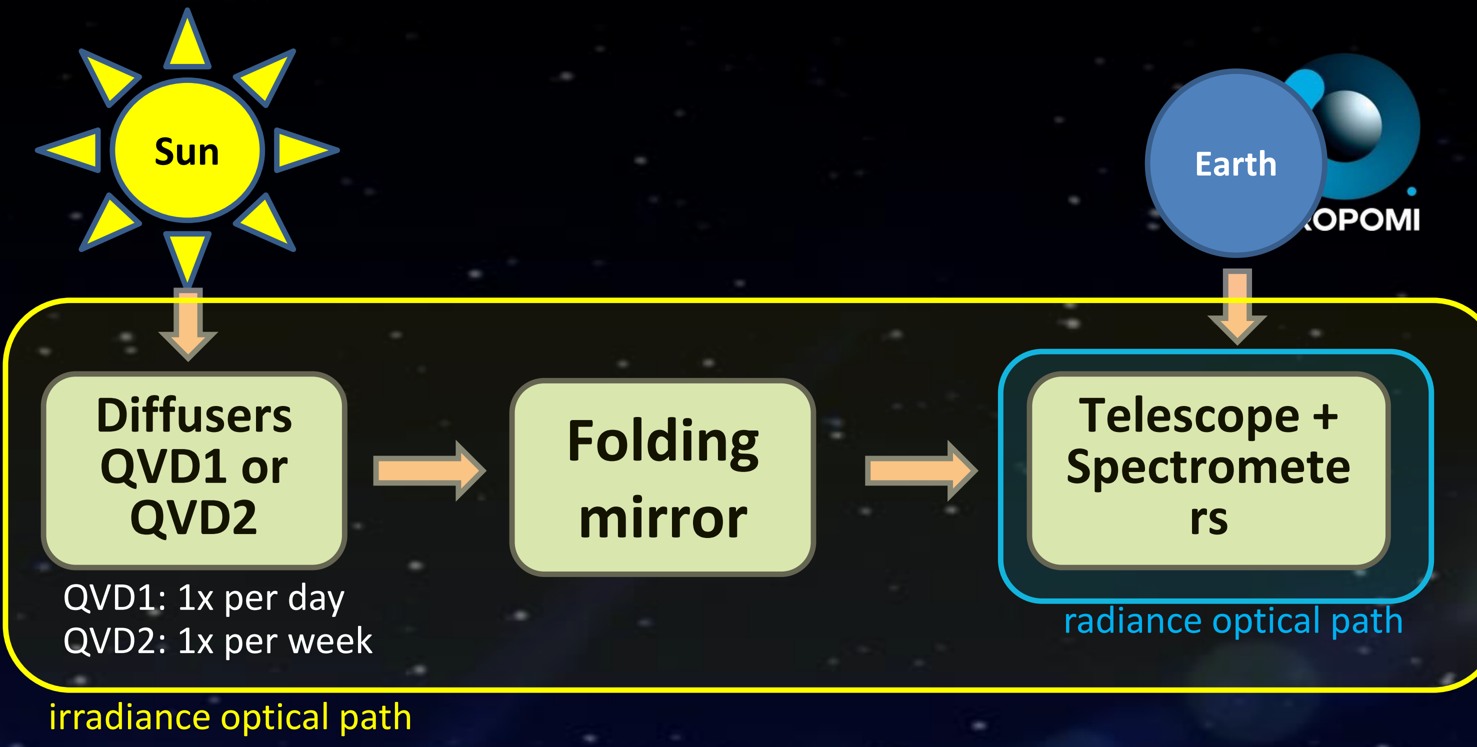
Results

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

Per 1000 orbits @18299	QVD1 + common [%]	common only [%]	spectral ageing [%]
Band 1	0.776	0.326	-0.143
Band 2	0.588	0.234	-0.538
Band 3	0.411	0.158	–
Band 4	0.182	0.076	–
Band 5	0.032	0.018	–
Band 6	0.027	0.016	–
Band2:317 nm	0.572	0.227	-0.733
Band3:317nm	0.568	0.230	–

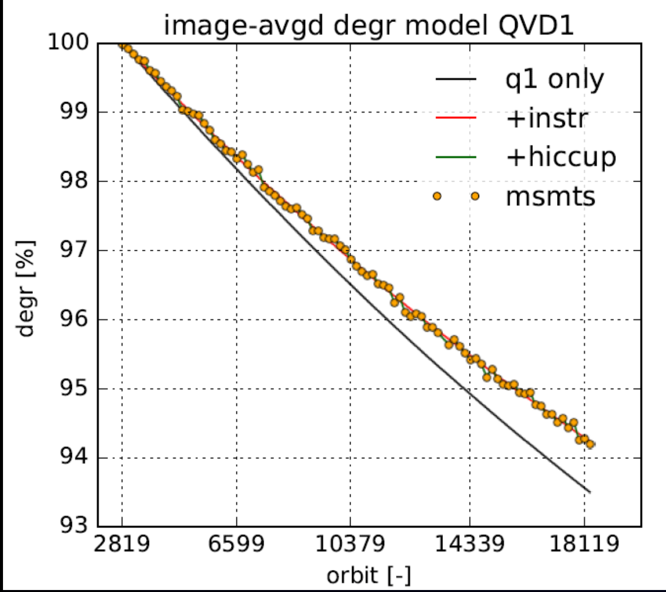
Instrument & operations

- 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)

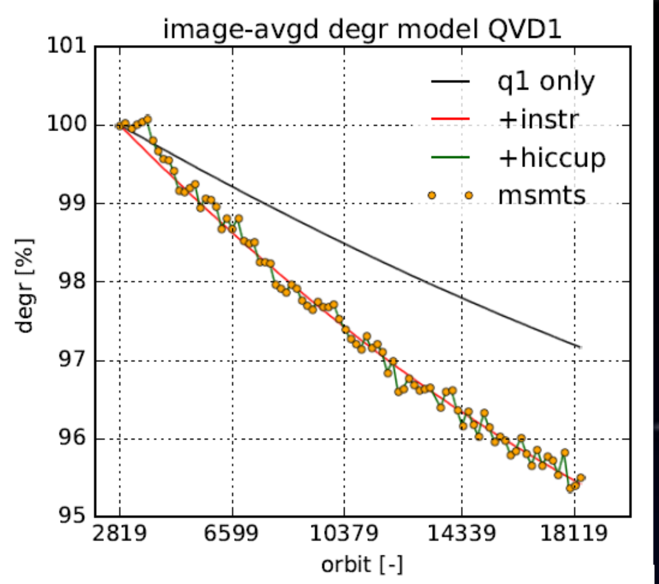


TROPOMI spectral bands – based on calibration data

Spectrometer	UV		UVIS		NIR		SWIR	
Band ID	1	2	3	4	5	6	7	8
Spectral range [nm]	267-300	300-332	305-400	400-499	661-725	725-786	2300-2343	2343-2389
Spectral resolution [nm]	0.45 - 0.5		0.45 - 0.65		0.34 - 0.35		0.227	0.225
Spectral sampling [nm]	0.065		0.195		0.126		0.094	
Spatial sampling [km^2]	5.5 x 28	5.5 x 3.5	5.5 x 3.5		5.5 x 3.5		5.5 x 7	
Detector binning factor	16	2	2	2	2	2	1	1

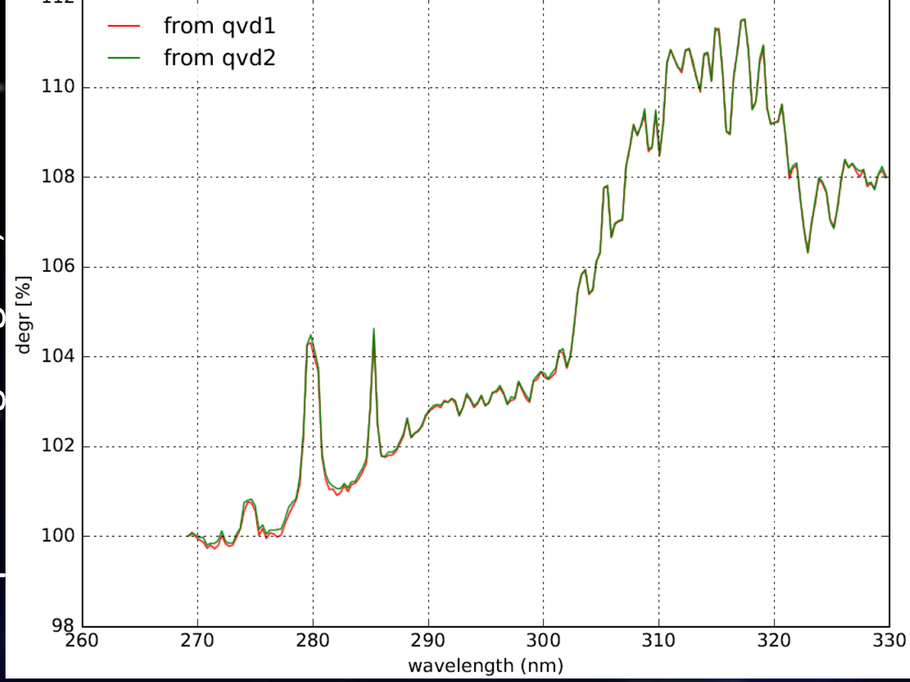


UV



UVIS

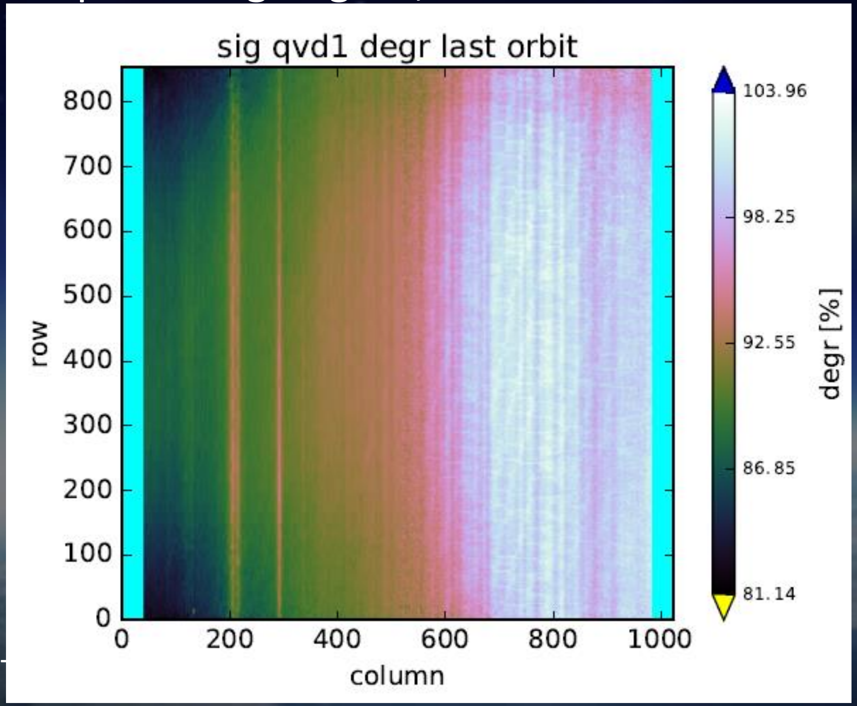
spectral ageing UV, orbit 18299



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 UV, orbit 18299



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

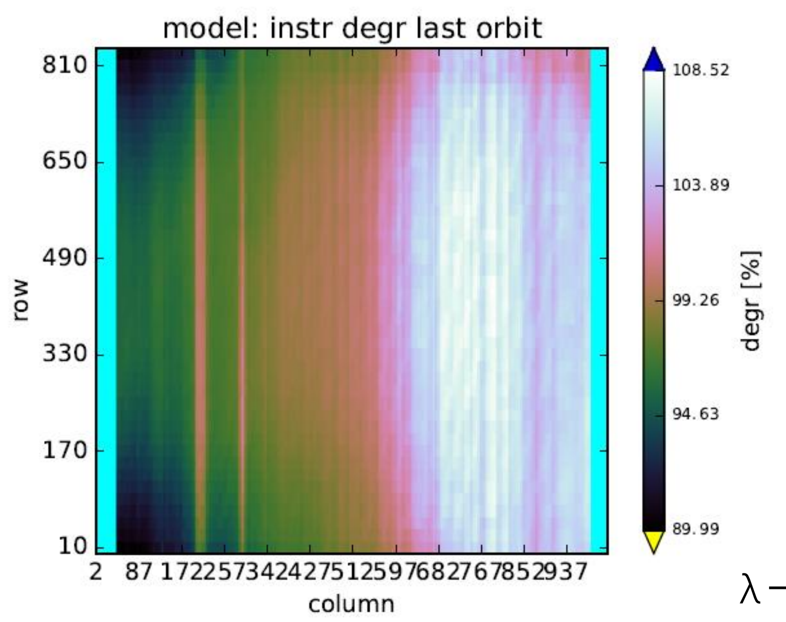
- Add a time (=orbit) axis to the calibration key data
- Interpolate between calibration points for degradation
- Extension to later date dependent on instrument effect: extrapolation or fixed value
- Regular updates: configuration change only, no software updated needed
- Expected to be operational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

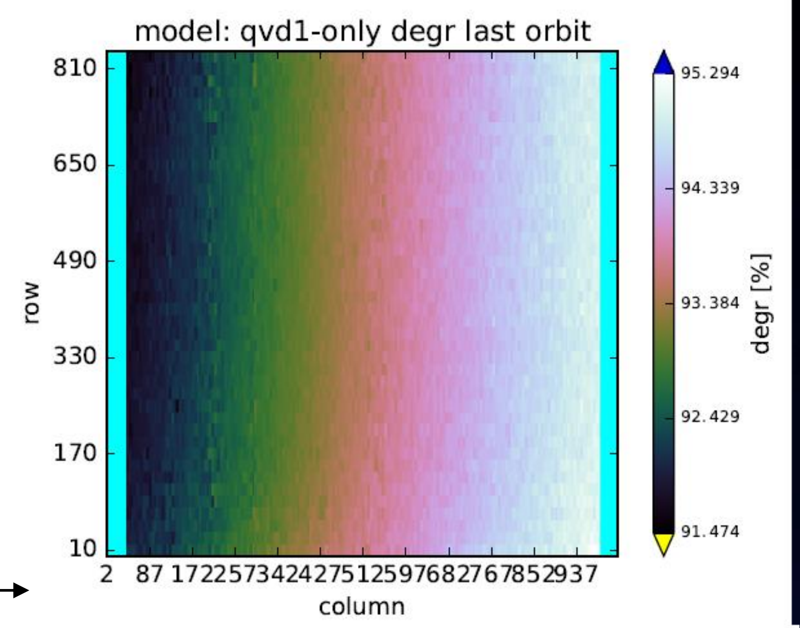
$$D_{\mathrm{tot},q1}(k) = D_{q1}(t_{q1}(k)) \cdot D_{\mathrm{com}}(k) \cdot D_{\mathrm{spec}}(k) \cdot R_k$$

$$D_{\mathrm{tot},q2}(k) = D_{q2}(t_{q2}(k)) \cdot D_{\mathrm{com}}(k) \cdot D_{\mathrm{spec}}(k) \cdot R_k \cdot P_k$$

Calibration maps derived from irradiance data

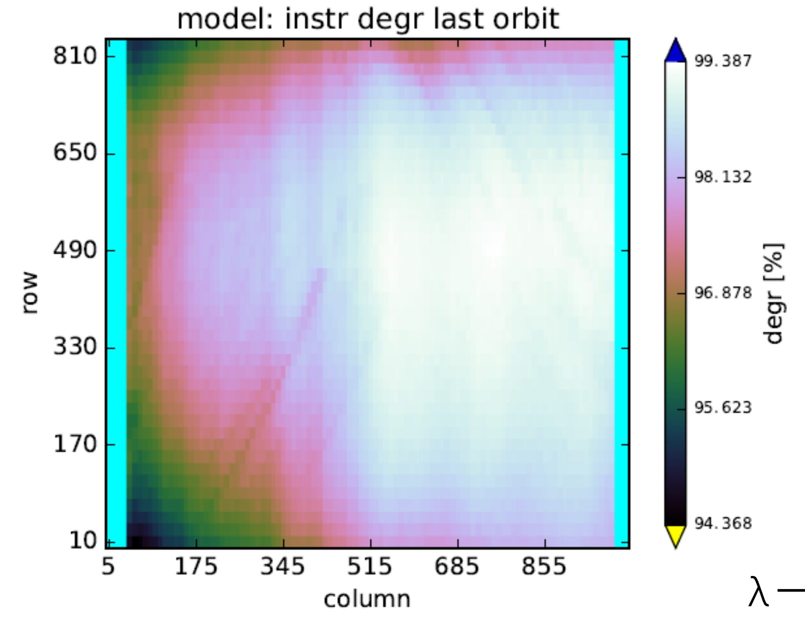
UV common & spectral ageing

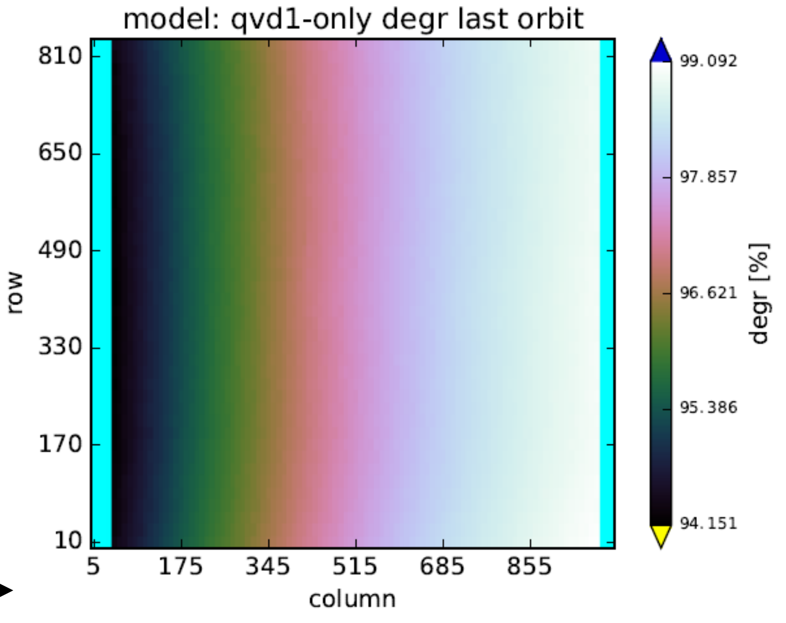




UV main diffuser

UVIS common





UVIS main diffuser

Degradation status

Status orbit 18299	QVD1 + common solar [%]	QVD2 + common solar [%]	common solar only [%]	spectral ageing [%]	residual (max)[%]	residual (std)[%]
Band 1	12.02	6.33	5.05	-2.21	0.19	0.06
Band 2	9.10	4.61	3.63	-8.33	0.20	0.06
Band 3	6.37	3.15	2.45	0.00	0.42	0.13
Band 4	2.82	1.47	1.17	0.00	0.42	0.13
Band 5	0.49	0.34	0.27	0.00	0.37	0.12
Band 6	0.41	0.31	0.25	0.00	0.36	0.12
Band2:317 nm	8.85	4.47	3.52	-11.34	0.00	0.00
Band3:317nm	8.79	4.50	3.57	0.00	0.00	0.00

Per 1000 orbits @18299	QVD1 + common [%]	common only [%]	spectral ageing [%]
Band 1	0.776	0.326	-0.143
Band 2	0.588	0.234	-0.538
Band 3	0.411	0.158	–
Band 4	0.182	0.076	–
Band 5	0.032	0.018	–
Band 6	0.027	0.016	–
Band2:317 nm	0.572	0.227	-0.733
Band3:317nm	0.568	0.230	–

more on TROPOMI calibration: Kleipool et al. 2018 https://doi.org/10.5194/amt-11-6439-2018
Ludewig et al. 2020 https://doi.org/10.5194/amt-2019-488