

Interactive comment on “In-flight calibration and monitoring of the TROPOMI-SWIR module” by Tim A. van Kempen et al.

Anonymous Referee #1

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General comments:

The paper gives a good overview of the in-flight calibration and monitoring of the SWIR module and it is good to see that the SWIR module of TROPOMI is that stable over time.

Specific comments:

Page 2, line 7: 'dedicated the out-gassing the instrument' Is it not more likely for preventing contamination of the instrument from e.g. the platform, multi-layer insulation mainly water outgassing by making sure the instrument - especially if cooled SWIR - detectors do not act as a cold traps and get contaminated? Usually much care is taken with the instruments during integration, assembly and testing under cleanroom

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environments that the outgassing of the instrument itself is minimised. Suggestion to rephrase.

Page 2, line 12: 'During nominal operations'. Not only during nominal operations, but the whole life time, even on-ground instruments should be monitored. Suggestion to rephrase.

Page 2, line 18: The word 'dark-flux' is used here and throughout the document, isn't it rather dark current? 'CKDs for ... were also derived on-ground.' Since some CKDs may also be derived on board, and may be updated, is the 'also' meaning also possible updated in flight? Suggestion to rephrase to make the statement more explicit and add also which CKDs are updated in flight.

Page 2, line 19: 'Signals of the sun as seen over the two diffuser' Please refer to paper with instrument design and/or add sketch of light path via diffuser for better understanding for the readers. 'internal lamps' Please explain which kind of lamps, refer to instrument design and add sketch of light paths.

Page 3, line 4: Isn't there also a CLED in the SWIR path? see e.g. Kleipool [2018] calibration unit description. Please add and shortly explain the light path.

Page 3, line 14: 'due to operational restrictions' this part is not understood, can you please detail what the restrictions are or why they are there or refer to another publication.

Page 3, line 18: according to Hees et al. [2018] this was already planned "However, as the diffuser mechanism is a life-limited item, only during the on-ground calibration campaign and during the in-flight commissioning phase, measurements will be performed with a moving diffuser." The way it is written now, it seems as if it was a later decision during operation. Suggestion to rephrase according to Hees et al. [2018].

Page 3, line 29: 'digitized typically with 12, 000' Is this binned on non-binned?

Page 4, line 1: 'Solar irradiance or signal from the on-board lights' this incl. straylight.

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Page 4, line 4: 'amount of light lost' suggestion to change to degrading due to light loss, contamination

Page 6, figure 2.: The unit used here is Spectral Photon Radiance, why not use spectral radiance unit in $[W m^{-3} sr^{-1}]$? Is this the unit used for the L1b products in the SWIR? As first image Iraq is shown, was there a special reason to select Basra? Why not e.g. another big city? or volcano?

Page 7, line 7: 'in form of blue bands' these blue bands in Fig.4 have negative numbers, is there less light in the background measurement with the absorption lines than during the on-ground measurements? was the temperature the same? Please detail in the text.

Page 8, figure 4.: Suggestion to add also the on-ground result as graph for better understanding.

Page 8, table 2: It seems difficult to compare FMM open with closed, since there are more than 1500 orbits difference, is it possible to compare open/ closed effects closer in time together? Also to have similar thermal conditions since the seasons are completely different. Otherwise there may be too many effects intermingled.

Page 9, figure 6.: Why is the uncertainty varying? Are e.g. different temperatures measured during these 6 weeks? Or are different amounts of measurements taken? please add text.

Page 10, line 10: 'clearly absent when the FMM is closed' Is then the conclusion to only measure background with the FMM closed? In case this is the conclusion, has the operational manual been adapted?

Page 10, line 24/25: 'no correction is applied for the SAA. ...' is there any conclusion about this? Currently it may be interpreted that the author would prefer to have a correction, but it might also just be a fact, that the SAA is flagged as in many other processors.

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Page 12, line 4/5: 'Note that there appears a small systematic difference between the ADCs.' Detail what is meant here, which different ADCs, where is it visible, has it to do with the positive numbers in figure 7 up to column 500 and negative numbers from 500 to 1000?

Page 12, line 14: 'should not be used for retrieval of CO or CH4' this could be flagged, in case it is flagged and the processor is accounting for it accordingly suggestion to change to "is not used for retrieval of CO and CH4"

Page 12, line 17/18: 'Therefore, calibration measurements to determine noise levels should also be executed with the FMM closed' see previous comment: is this now operationally implemented? what are the issues with mission budget related to amount of movements of the FMM?

Page 12, line 23: 'cosmic ray impacts' aren't these flagged and can then be excluded from the processing?

Page 13, line 7: 'This includes pixels outside of the effective area, which are not illuminated.' But this does not mean they are not functional, they are/could still be used. Suggestion to reword.

Page 14, figure 10: 'similarity' why should these be the same, this is not understood? One is a difference between two methods on the same data, while the other is a difference in time and pre/post launch? Please detail.

Page 14, figure 11: It seems as if dead pixels came alive again over time, are these not rather 'pop-corn' pixels, thus in a way sometimes bad, sometimes good? Please consider renaming the dead pixels which become alive.

Page 15, table 3.: See also comment above. How can there be less dead pixels after launch than on-ground? or are these to be seen as additional number of bad/ dead quality pixels? Please detail.

Page 15, line 6/7: 'Although monitoring. ...' Why can it only be approximated? Please

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detail.

Page 15, line 8/9: 'the calibration sources.and/or diffusers.' and any other optical elements in the optical path incl. the video chain can be degraded. Please amend the text.

Page 15, line 20: 'hypothesized this is thegrating.' This is not understood, since the DLED is in direct proximity of the detector and it was understood the light path from the DLED is not via the grating. Can it not be some kind of etalloning via the protective glass of the MCT detector, and a layer which might have been on it? Or is the CLED meant here? Please consider changing text.

Page 16, figure 12.: Please detail, e.g. top DLED 2515/907, bottom DLED2515/2707. The difference in the bottom is basically 1, thus no significant change measurable in about 200 orbits, is this understanding correct?

Page 16, line 7/8: 'less stringent stability limits of the WLS system.due to the DLED.' Is it understood correctly, though the WLS with less stringent stability shows with the resulting expected larger error bars the same range as the DLED measurements? Please clarify.

Page 17, figure 14.: Would it be possible to show the differences by normalising to one measurement instead of plotting them on top of each other to better see the differences?

Page 18, line 1/2: See above, please plot also the ratios normalised to one measurement (similar as shown for the ISRF e.g. figure 15) to better support this sentence.

Page 23, figure 21.: The data seem to include 'pop-corn' pixels since number also decreasing again over time. See also comment above and consider changing the name 'dead pixels' for those who come alive again.

Page 23, figure 23.: Suggestion to check with the SLS via diffuser if the same trend is visible of increasing signal. After all 2018 was solar minimum.

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Page 23, line 1/2: 'diffusers apparently becoming more effective' In this case this should then also be visible with the SLS via diffuser measurements over time. Has this been observed? Please detail in text/ with graphs.

Page 24, figure 23.: Around orbit 3500 is one significant outlier, is something visible from the housekeeping data to explain this outlier looking at the telemetry? In addition can the jump around orbit 5500 be explained?

Page 24, figure 24.: While most figures show error bars, they seem missing in this figure. Can they be added?

Page 24, line 2: 'a rate ~ 0.8 % per year' From the housekeeping data, is in the telemetry the voltage/ amps of the LED given? Are these values stable over time? Can this be checked and added to the text.

Page: 26, figure 26.: Can the outlier with almost 3% around orbit 7500 be explained?

Page 26, line 9: '(about 60 over 5 months)' What is the reason the choose here 5 months and not either since launch or during nominal operation?

Technical corrections general:

Figures are often in previous sections or next sections from their textual descriptions. For easier readability would it be possible to place them in the same section as where they are described?

Abbreviations should be minimised and at least the first time of appearance be fully written.

Page: 1 Line 1: short-wave infrared (SWIR) tropospheric monitoring instrument (TROPOMI)

Line 3: instrument spectral response function (ISRF)

Line 5: Change 'eclipse side' to 'eclipse side'

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Line 7: 'with little to no degradation' instead suggestion to provide values, e.g. smaller than $<x>\%$

Line 16: ultra-violet, visible and near-infrared (UVN)

Line 19: 'TROPOMI will produce' change to 'TROPOMI produces'

Line 20: Change 'yeilding' to 'yielding'

Page: 2 Line 10: 'the E1 phase' change to 'phase E1'

Line 12: 'the E2 phase' change to 'phase E2'

Line 14: 'planet each day' change to 'planet Earth each day'

Line 15/16: and...and... Is used, suggestion to use a comma and then only one 'and'.

Line 33: 'radiance' change to 'spectral radiance'

Page: 3 Line 1 'irradiance' change to 'spectral irradiance'

Line 4: Add detector LED after DLED similar to the other two sources.

Line 17: 'oscillation mode' This sounds as if there is a motor installed on the diffuser mounts? Please refer to a paper with the instrument design, where this is described in more detail or suggestion to add text.

Line 26: 'each pixel is read out individually' does this imply it is a CMOS detector? Please add a little more detail about the detector and possibly refer to another publication.

Page: 4 Table 1.: PRNU - pixel to pixel non-uniformity

Line 10: Add '.' after 'complex correction algorithm.'

Line 4/5: 'Straylight is defined as any outside signal that does not follow the intended path onto the detector and is thus not part of the useful signal' The 'outside signal' may be confusing, since straylight may be ghosts, in-band straylight, out of field, out of

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spectral band etc. straylight. Suggestion to rephrase for better understanding for the readers.

Page: 5 Figure 1.: Last part of flow, 'Useful radiance' : Radiance assumes already processed to spectral radiance units, with the help of CKDs, is this meant here? Possibly rephrase or add steps for generating spectral radiances.

Line 4: 'dark-flux' possibly other naming? Are dark current correction meant here? Flux maybe confusing.

Page: 6 Line 4: 'November 2019', is November 2017 meant here?

Page: 7 Line 4: 'dark flux' see previous comments.

Page: 8 Line 2: 'thedifferent' change to 'the different'

Table 2: 'On-ground diff.' unit missing. Please add

Page: 9 Figure 5.: 'during the commissioning phase ...' during nominal operation, since you stated before "Nominal operations started at orbit number 2818." Please change text.

Figure 6.: 'commissioning phase' according to text above this is already nominal operational phase. Please change wording.

Page: 10 Line 18/19: 'thermal variations as a function of the orbital phase' suggestion to show a graph over the 1 1/2 year time with the thermal fluctuations from the housekeeping telemetry of the SWIR instrument.

Line 30: 'if the data taken in the SAA are excluded from the analysis' suggestion to add that this can be done due to the SAA flagging.

Line 31/32, last sentence: before a statement says they are different from Hoogeveen [2013], seems contradicting : "The amount of dark flux detected differs from the measured value reported in Hoogeveen et al. (2013)." Please bring in line, or detail.

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Page: 11 Figure 7.: nominal operation phase, see comment above.

Figure 8: nominal operation phase, see comment above.

Page: 12 Line 5: ADC analogue digital converter.

Line 6: 'acceptable' suggestion to change word, like this it can be interpreted as 'unacceptable', since stated to be below acceptable levels.

Page: 13 Line 8: 'impacts or other hardware degradation' suggestion to eliminate the 'other' and change to 'impacts or hardware degradation'

Page: 14 Figure 11.: Please add dead (bottom red dots) and bad (top green dots).

Page: 15 Line 15: Add '.' after sentence.

Page: 16 Line 7: 'end of E1' change to end of phase E1' Is the WLS also in orbit 2515 similar to the DLED? Please provide orbit.

Page 18, line 15: Add 'phase E1' instead of 'E1'

Page: 19 Line 2: 'but conclusions apply to results obtained' it is assumed 'but conclusions also apply. . .' if correct please change text.

Page: 20 Line 1/2: Please in one line 'The' with a space in front.

Page: 21 Line 15: 'from April 30th. . . ' isn't this already from an earlier date, since starting already at orbit 1800 or so. Please change.

Line 17/18: 'Larger-scale variations seen. . . manoeuvres.' Please provide orbits when this happened linked to the figures.

Page: 23 Figure 22.: Instead of 'Top' change to 'left' and 'bottom' to 'right'.

Page: 25 Line 4: '5.6 %' might it be better to just state 6%, since with the kind of step degradations seen in figure 24 the number 5.6 may suggest a higher accuracy of the assumed linear prediction of degradation? Consider changing.

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