

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

Tim A. van Kempen et al.

t.a.van.kempen@sron.nl

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Author response

We would like to thank the referee for their time and effort in reading and reviewing our paper with constructive comments. Please find our answers to your comments below in italics.

General

A word on the structuring: In an initial draft we had set up a different structure. However, we found that this did not enhance the readability and made for some confusion on some topics (most notably backgrounds and quality, but also the readability of the ISRF proved to be confusing). We are aware of duplication of some of the data in

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some figures. But in our opinion this division improved the readability of the paper greatly and more clearly represented the work done over the first year, where a clear separation between the E1 and E2 phases are present.

SC 1 Haven't smaller spatial pixels been implemented in the mean time? This might be worth mentioning

This is correct, but the smaller pixels were implemented only after first submission. Text has been added.

SC 2 “Derivations of the ISRF”: Are the different derivation approaches for the ISRF reported in the cited article or is the plural form a typo? If there are multiple ways it might be good to write this more explicit.

The derivations are meant to indicate those of the ISRF and of Straylight. Rephrased.

SC 3 This sentence is a bit confusing and seems not very accurate. Please specify the internal sources and maybe re-phrase the sentence by starting with transmission changes.

This section has been rephrased and clarified.

SC4 It is worthwhile to mention the two internal solar diffusers here.

This section has been rephrased and clarified.

SC 5 “Background measurements”: Later you introduce background measurement with an open and a closed folding mirror, it would be useful to already introduce the two different types here.

The background measurements with the FMM open are the same as spectral radiance measurements at the night-side. Mentioned on page 2, line 32. Text has been added for clarity.

SC6 Are SLS and WLS following the complete optical path or not? The two sentences

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seem to contradict each other. What do you call the complete optical path? The path the radiance takes or the path the irradiance takes?

This section has been rephrased and clarified. TROPOMI uses a wheel to create different optical paths. The optical path beyond the wheel is identical for the SLS/WLS, the radiance and irradiance.

SC7 SLS passes over: Isn't the light reflected off the side of the solar diffuser? Or does it pass through it? Are both diffusers used with the SLS?

This is a dedicated diffuser, not one of the solar diffusers.

SC 8 Are all detector pixels illuminated and used for science?

No, they are not. In total 960 columns (spectral dimension) and 215 rows (spatial dimension) can be, illuminated.

SC 9 The terms static and dynamic are not explained. Are these terms relevant? If not, remove them.

Rephrased. Text added for clarity.

SC 10 So it doesn't depend on the exposure time but on co-addition if a correction is applied or not? The first sentence is confusing

For TROPOMI-SWIR co-addition factor and exposure time are linked due to the master cycle time of either 1080 or 800 ms. But in effect yes, the memory correction is only applied if the data is not co-added.

SC 11 The figure is specific to a certain correction? This is not clear from the sentence
Text added for clarity.

SC 12 Are these all processing steps for the SWIR module? There seems to be no non-linearity, memory effect or exposure time correction. Please adapt the caption to make clear it's a simplified scheme or complete the flow chart.

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The figure is indeed a summary/simplification. This has been added.

SC13 The term "flux" is rather ambiguous and at least in physics associated with a current through an area. The term dark current might be less ambiguous.

The term was changed to dark current. We attempted to avoid the term dark current as the 'dark flux/dark current' we measure in this paper is a combination of the inherent dark current (current from The detector itself) and the signal from the thermal surroundings.

SC14 Is this also visible in a geo-plot of the Earth? A plot would be nice to illustrate your point.

I am uncertain how a geo-plot would contribute to the improved uncertainty/spread with the FMM closed. This is only an effect of the number of inputs.

SC15 The term dark flux is used for the background radiance that can be confusing
Changed

SC16 This sentence is not entirely clear: I assume it is the signal that varies over time? The on-ground value is constant (I assume), so there is no need to refer to the difference, or is there?

The variation is dominated by the large-scale dark flux and not the individual sources, e.g. the fires. The location where the measurement is taken does vary due to the sun-synchronous orbit. Whether or not we include more land or ocean based measurements and the weather above these Sites influence it.

SC17 Is the orbit from nominal operations with open or closed FMM? What is meant by On-ground Diff.? On-ground minus in-flight or the other way around?

Nominal operations is with FMM closed. Difference is On-ground minus in-flight.

SC18 "commissioning phase": shouldn't it be E2 phase according to the orbit range

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you specify in Section 1?

The E1 phase is meant by the term commissioning phase. That has been changed.

SC19 Is the mapping between columns and spectral direction exact or is there a spectral smile? (Also Fig. 7)

There is a small spectral smile, but this is negligible.

SC20 Why is there a gap in the plot?

No background measurements were taken during that time due to scheduled other calibration measurements.

SC21 Is temperature data available? Can you confirm your assumption?

The temperature data inflight is available (see www.sron.nl/tropomi-monitoring), however, the on-ground thermal stability data was found to vary much more significantly. This data is also not public, but we confirmed the thermal difference. Whether or not that is truly the difference cannot be easily confirmed as the scheduled thermal tests during the E1 phase were not executed.

SC22 This is not very clear, is it the same as in 3.1.1 line 9? Why the requirement of 40

This is technically the same requirement. However, with FMM open, background measurement can (and were) taken every orbit. To save the life-limited-usage of FMM movements, backgrounds with the FMM closed are only taken executed in combination with other calibration measurements. These are scheduled daily/weekly/fortnight/monthly. As such not every cycle of 15 orbits contains an equal number of background measurements. During the E1 phase, scheduling also could be irregular. In addition, some issues with data transfer resulted in lost orbits. Hence the 40% requirement as background derivation with 1-2 orbits showed very poor results.

SC23 So there are no shielded or non-illuminated pixels on the detector which can be

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used for monitoring? *There are, but these are too few and showed too little variation within a single orbit to be usable.*

SC24 So there is a different ADC for the two sides of the detector? This should be mentioned. Are the ADCs located at different places? Is the effect included in the L1 offset correction?

This is described in Hoogeveen et al., 2013. The effect is included (by default) in the offset correction.

SC25 The definitions in line 9 and 12 of in-flight noise are not the same. *Corrected*

SC26 What are the criteria for 'proper' and 'excessive'? The explanation is not any clearer than 'sufficient quality'. Please provide quantitative criteria. *For each quantity, the pixel is graded on a sliding scale. A combination of performances will determine if a pixel is flagged or not.*

SC27 Why are non-illuminated pixels described as non-functional? *This was an adopted definition. We expanded the text to be more clear*

SC28 Does this plot include the non-illuminated pixels? *No, we added a note in the text about this.*

SC29 So the non-illuminated pixels are included in these numbers? Please list them separately. *No, this was a mistake in the table. It was meant to exclude the non-illuminated pixels.*

SC30 The number of bad and dead pixels decreased compared to on-ground. Is this caused by detector annealing during the de-gassing? *That is possible. Although we cannot exclude other origins. These have been described now.*

SC31 *This has now been illustrated in section 2.*

SC32 On page 3 line 9 it is described that the DLED light does not pass through the grating, and now the grating is seen as the cause for the feature. How is this possible?

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The referee is correct that it is not possible. This has been changed.

SC33 What do you refer to as “the complete light path within the module”? Where is the primary mirror? From the TROPOMI L1 ATBD I get the impression, that the primary telescope mirror is included in all optical paths for all sources (apart from the DLED)
The inclusion of a new figure in Section 2 should clear this up.

SC34 From the page mps.tropomi.eu/calendar measurement search I find 4 WLS modes with three different exposure times for SWIR using DIFM SLS (4) or DIFM NOM (1). The longest exposure time I find is 88ms; this isn't entirely consistent with your statement. *That is correct. We rephrased this statement as the measurements with longer exposure times are not used in This paper. They are so long to accommodate usages of the WLS for UVN calibration.*

SC35 Please add that the stray-light is normalized to the peak value and that a spectral band as opposed to a spot (on-ground) is illuminated. *Straylight is normalized to total value, and not peak value. As that statement was also missing, it has been added.*

SC36 The measurements in Figure 5 are performed with oscillating diffuser? Yes

SC37 There are no examples provided on the in-depth analysis, so I would either remove this sentence or provide the examples. *Done*

SC38/SC39/SC40/SC43 *Yes, this was done on purpose. The dates in the text should have reflected that. It has been fixed.*

SC41 Large scale variations. . . : It might be useful to show how the module behaves in non-nominal situations. The data could be shown in a different colour in the same plot. Or is this inflating the scale? *This very strongly inflates the scale. It is also considered to be beyond the scope of this paper as the origins are known and characterized.*

SC42/SC45/SC49/SC50/SC51 *We disagree with these assessments. As the structure of the paper is set up in time, with results beyond orbit 2818 are included here and early results described earlier. The continuity in the figure illustrates the stability.*

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SC44 Are all the numbers on dead and bad pixels without the shielded pixels? *Yes, the text has been changed to better describe this.*

SC46 Why should a relative irradiance factor change over time? Shouldn't that show in a seasonal effect? This hypothesis should be explained better or be removed. Did you exclude heating up of the calibration unit or offset effects? Usually degradation effects are observed to be proportional to exposure; however both diffusers seem to show the same slope. So a change in diffuser reflectivity with the same slope for both is unexpected. Do you observe any change with a similar slope for radiance?

This section has been updated. However, seasonal effects of the irradiance should be accounted for, and not be included in the monitoring product. Note that an identical slope in both diffusers can be caused in degradation in the common path not related to the diffusers. It is too small to be quantified with the radiance.

SC47/SC48 The DLED and the solar irradiance cover different optical paths, to exclude the detector responsivity cannot be concluded by the increase in solar irradiance. The increase could be much larger covering a decrease. Is there another means to exclude the detector? Maybe radiance data? Ok, the WLS confirms the DLED degradation. Does the WLS then exclude heating or degradation of the calibration unit?

We are excluding the detector responsivity to be the main culprit for the DLED response. The increase seen in the solar irradiance can indeed be caused by improved detector responsivity, hiding behind the DLED degradation. The WLS could confirm this, if it was less variable. It, in combination with the temperature info from the Monitoring results, does appear to exclude heating of the calibration unit. Radiance data may be usable, but was considered to be beyond the scope of this paper. This will be done in a future publication.

SC52 Can the outlier around orbit 7000 be explained? No, it cannot.

SC53 *Only a few events took place. Given the timescale and scheduling of calibration*

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measurements around these, no CKD derivation can be done. As such, we can only take a look at recovery in days after this event. This was included and no outliers have been found (note that orbit 7000 is not this event and therefor cannot be explained.)

SC54 Changes to the processor will be described in a future paper by Ludewig et al., The word 'ample' is a language issue. This has been rephrased.

Formatting: (Note that all new figures are indexed one higher due to the insertion of a new figure 1.) Fig 2. And 3. This was tried, but we did not get a satisfying figure. Fig. 4,5, 7, 9, 10 and 12: We prefer to use value and explain the exact meanings in the caption. A change in these The term very quickly causes confusion. Fig. 6 changed

Fig. 16/17: This is correct, but we are not plotting the same thing with in-flight being red and reference being blue (see Fig. 15). For Figure 16 a choice had to be made to either reference Fig. 17 in-flight or Fig. 15 in-flight. We choose Fig. 15.

Typos All were corrected if they were still present in the text.

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