Characterization and correction of stray light in TROPOMI-SWIR, Paul J.J. Tol et al., MS No.: amt-2017-455,

General comments

Initial paragraph or section evaluating the overall quality of the discussion paper.

The paper is well written and of good quality, with a considerable number of new interesting topics and techniques related to stray light characterization and correction, and shall certainly be published.
However, I am of the opinion that the quality of the paper can be much improved to be more useful with a comparatively small additional effort, in line with the comments and suggestions provided below. After these comments and suggestions have been adequately addressed, the paper shall certainly be published.

1. For the applications in TROPOMI SWIR it is essential to express, quantify and present stray light at L0 and L1b as a percentage of the useful signal for realistic earth atmosphere low-albedo scenes and signals within absorption peaks. This is currently not the case. For example in figure 14 it can be seen that the difference between bright and dark scenes is roughly a factor 8 (see also page 15, line 14), and the difference between rather deep absorption line and continuum is also roughly about a factor 8. Both together would make a difference of a factor 64. For example, in the legend of figure 15 (but also in other places in the paper) it is clear that the stray light is expressed as percentage of the expected continuum in the given row, not as percentage of the useful signal in the absorption lines. If the authors prefer to present the stray light like this, it is essential to at least also show the stray light as percentage with respect to the low albedo useful signal in the absorption lines. This shall be added to the paper in the text, figures and conclusions.

Not adjusted. The stray light was expressed as a percentage of the continuum after consultation of the team that does the operational trace-gas retrieval in SWIR. The reasoning can be explained as follows. In Fig. 14, the signal in the deepest absorption line is 6 % of the continuum in the cloud spectrum and only 1 % of the continuum in the forest spectrum, due to the longer air column to the ground. The used U.S. Standard atmosphere will be drier than the atmosphere in many other scenes, so the signal can be even lower. If the stray light would be expressed as a percentage of that signal, the values would be far above 100 % and extremely dependent on the exact assumptions about the atmospheric composition.
This would render the values meaningless. Therefore, the stray light is compared with the continuum (of the low-albedo spectrum), i.e. it is seen as an absolute signal contribution instead of a relative one. Then it turns out to be basically flat before and after correction (Fig. 16), so it is easier to see deviations and to compare spectra. A plot of the stray light relative to the expected signal at the same wavelength would look like an inverted radiance spectrum. Showing the absolute stray light is also in line with operational methane and CO retrieval, where the absolute difference between measurement and model is minimized.

Response 19 June 2018:
I do not agree with this response. As pointed out in the original comment I wasn't asking to change the approach, but I was merely asking for an additional figure showing the stray light in a different, in my view more meaningful, way. I do not agree that it makes sense to present percentual stray light fractions with respect to a signal obtained at a different spatial and/or spectral location on the detector. For me the only meaningful parameter is the percentual stray light contribution calculated with respect to the appropriate useful signal at the same spatial and spectral location on the detector. I took note of the authors' comments that scientifically it makes more sense to calculate the stray light fraction with respect to the continuum, but I do not agree with that statement. I agree that calculating stray light with respect to the useful signal at the same spectral and spatial location on the detector increases the stray light percentage quite considerably (which is exactly the point, actually) and makes the figure(s) look more variable (which is also actually the point), but I strongly disagree with the author's statement that this "would render the values meaningless".
As a compromise I offered to allow the authors to present the figures in their preferred way, but add one (or some) additional figure(s) showing the stray light percentages calculated with respect to useful signals at the same spatial and spectral location on the detector at which the stray light is calculated. However, the authors did not yet accept this compromise. At the current stage, having taken note of the author's response, it is my opinion that it is important to add one or more of the figures as requested by

me above and in the original comment, because to my opinion the figures showing stray light at a particular location with respect to a signal at another spatial/spectral location is not meaningful and presents an excessively overly optimistic view on the instrument stray light situation at Level-0 and Level-1b. Therefore I recommend to the editors that one or more figures are added to the paper, as requested by me in the above and earlier comment, prior to publication.

Specific comments

Section addressing individual scientific questions/issues.

2.
Page 8, figure 7:
It is recommended to (also) show the row distances similarly as the column distances as shown in figure 8, to allow a better comparison between the two. For example, it is recommended to add a figure like the lower figure in figure 7 at a horizontal scale of +/-100 pixels, to allow better comparison with figure 8.

Not adjusted. The cross sections in Figs. 7 and 8 use a limited data set, at all swath angles but only one wavelength, to show the peak area before it is averaged over wavelength to create the stable kernel. The main reflection is always somewhere on the vertical cross section, but at every swath angle at a different position. To see the average cross section outside the reflection over a large row range, the data bins have to be enlarged from 0.025 pixel to 0.5 pixel. The result is shown in Fig. 1 in this author comment. The reflection is still visible at –90 and –14 rows as bumps and at +85 rows as a second curve, formed by every second point. Other deviations from a smooth curve may also be remnants of the reflection, so the data are difficult to interpret. The different bins in the linear and logarithmic plot would also need explaining. Both points would distract from the main focus of the article. Therefore only the central part of the cross section is given in the article, with the same bins as in the linear plot. A larger range near the peak is given in the two-dimensional colour plots of Fig. 6 and the full range is shown in the stable-kernel plots of Fig. 9.

Response 19 June 2018:
The reason for asking the cross-sections as figure examples in both spectral and spatial dimensions is that the cumulative stray light is originating from the whole illuminated image on the detector, i.e. by summing all contributions from the illuminated detector into the region where the stray light is calculated, and therefore it makes sense to add the figure as requested in the original comment, to show an example of the relative intensities in spectral and spatial dimensions on comparable scales.
I therefore recommend to the editors that the requested figure with the larger scale is added to the paper, as requested in the comment, prior to publication. This is not a big change to the approach of the document (which is not disputed), but for me it adds meaningful and significant essential information to the paper.

3.
Page 11, line 20:
The number is given as 4.3% of the detected light.
In line with the general comment given above, it is recommended to provide also the percentage numbers with respect to low-albedo numbers in the absorption lines.

Not adjusted. The 4.3 % is a property of the far-field kernel, independent of the scene to which it is applied. This section describes the calibration data, among which is the far-field kernel. Application to scenes is the topic of the next section.
See item 1 regarding the general point on percentages.

Response 19 June 2018:
See response to point #1.

4.
Page 18, lines 7-10:
Again, in line with the above, this is why it is important to calculate the stray light fraction with respect to the useful signal, because the absorption lines and low-albedo scenes will be filled in with higher

signals from the continuum and the higher-albedo scenes. This may also affect the instrument spectral response functions. Please reflect this in the text.

Not adjusted. Regarding the calculation of the stray-light fraction, see item 1. The far-field kernel describing the main stray light and the instrument spectral response function are two complementary parts of the same stable kernel, which is a property of the instrument and is not affected by the scenes.

Response 19 June 2018: See response to point #1.

5.
Page 18, lines 11-12:
Again, in line with the above, this is as written not agreed. This sentence shall be removed. In case the authors want to keep this sentence, another sentence needs to be added explaining why stray light needs to be assessed as fraction with respect to the useful signal, not the signal in the continuum.

Not adjusted. See item 1.

Response 19 June 2018: See response to point #1.

6.
Section 9, conclusions.
The statement "It is expected that this brings the stray-light error in gas-column retrievals within the required budget" is not discussed or supported by analyses in the paper. Either provide more support material in the paper to corroborate this statement, or remove it from the conclusions.

Adjusted. A full retrieval analysis with statistics over different scenes using the final retrieval algorithm is beyond the scope of this article. The given conclusion is based on one challenging scene type and a non-scattering retrieval algorithm. At the end of Sect. 8 extra information is given. The old text in Sect. 8 is: "Calculations have shown that the error in the retrieved gas columns is within the allowed error budget." This is replaced by: "Applying non-scattering retrieval (without aerosol or cirrus parameters) to the forest spectrum used for Fig. 16, the error of the methane column reduces from 14 % before correction to 0.26 % after correction, within the error budget of 0.35 % for stray light. The error of the CO column reduces from 26 % before correction to 1.3 % after correction, within the stray-light error budget 2 for the given CO column of 3.0 %. The forest spectra at other rows give similar results after correction." The conclusion changes from old "It is expected that ..." to new "Simulations indicate that ...".

Response 19 June 2018: Okay for this paper, although I am of the opinion that these statements cannot be corroborated by the material presented in this paper, and should be deferred to another paper where more details are given on the analyses / simulations and their conclusions, because currently, within the scope of this paper, the numbers and statements cannot be checked or verified..

Technical corrections

Compact listing of purely technical corrections (typing errors, etc.).

7.
The legends of (almost) all figures have symbols that cannot be read. This is at least true in the pdf version. Please correct.

Not adjusted yet. We could not see the errors in the PDF on the AMT website, using several PDF viewers in several operating systems. That makes it very difficult to implement effective changes. We will act upon instructions given by the Editor.

Response 19 June 2018:
I am not sure what happened. It looks okay now, also on my side. Maybe something strange happens when printing?
Comment withdrawn, is okay now.

8.

(Almost) all equations (e.g. 3,4,5,7,8,9,10) have symbols that cannot be read. This is at least true in the pdf version. Please correct.

Not adjusted yet. The document has been generated with pdflatex in the standard way and all fonts are embedded. We could not see the errors in the PDF on the AMT website, using several PDF viewers in several operating systems. We will act upon instructions given by the Editor.

Response 19 June 2018:
I am not sure what happened. It looks okay now, also on my side. Maybe something strange happens when printing?
Comment withdrawn, is okay now.

9.
Figure 15: In the legends, please indicate if this is a fraction, percentage or something else.

Not adjusted. Subplots (a) and (b) are absolute currents in femtoampere, as given in the legend. Subplots (c) and (d) are "expressed as a percentage of the expected continuum in the given row" as written in the caption. This is too long to put in the legend, which uses "normalized [%]" instead. Perhaps this was not clear due to item 7.

Response 19 June 2018:
Looks okay now also on my side, indeed probably from point 7, comment withdrawn.