We thank the reviewer for their positive and useful comments, and for their careful reading of the paper. We have addressed their questions as follows:

Anonymous Referee #2

This work presents an extensive and detailed report of the retrieval algorithm of HCHO for TROPOMI on board of Sentinel-5p. I believe that the manuscript is clearly written and well suits for the AMT so I recommend the publication with a few minor comments for clarification as follows:

L162: Please enlarge the size of tick and labels in Figures 3, 4.

Ok

L208: "the assumption of a single effective light path" any supporting literature and previous studies would be highly appreciated for this sentence.

This directly refers to the key approximations of the DOAS method, described in section 2.2.1 (Platt et al., 1994; Platt and Stutz, 2008; and references therein; Gottwald et al., 2006)

L237-239: The BrO retrieved from the first fitting is used in the second fitting and it error may affect the retrieval of HCHO in the second fitting but the error analysis associated with this was not included in the manuscript.

We made estimates of full random error calculation, when using coupled analysis intervals. The plot below shows the estimated random error on the HCHO SCD from the least squares estimation, as the limit of the first larger window is increased. Window A is the big window (328.5-...), window B is the small one (328.5-346.0).

The red line is the error in the large window (only window A). The light blue is the error when everything is fitted in the small window, without constraints (only window B).

The dark blue is the calculated random error when BrO is constrained in window B using the estimate from window A (complete estimate). The error reaches an optimal value when window A goes up to ~356nm, as done in our algorithm. The green “simple estimate” is the result when ignoring the correlations between the BrO estimate and the results in the small window.

The violet line (B ignoring BrO) is what our actual version of QDOAS provides in the case where 2 coupled fitting intervals are used. This means it just ignores the error from the BrO estimation. So for the settings we currently use, it's quite close to the result from the full calculation.

This theoretical estimate confirms the 50% reduction of the random error in the small interval when pre-fitting BrO in the large interval, as observed with real data (figure 1 of this review).

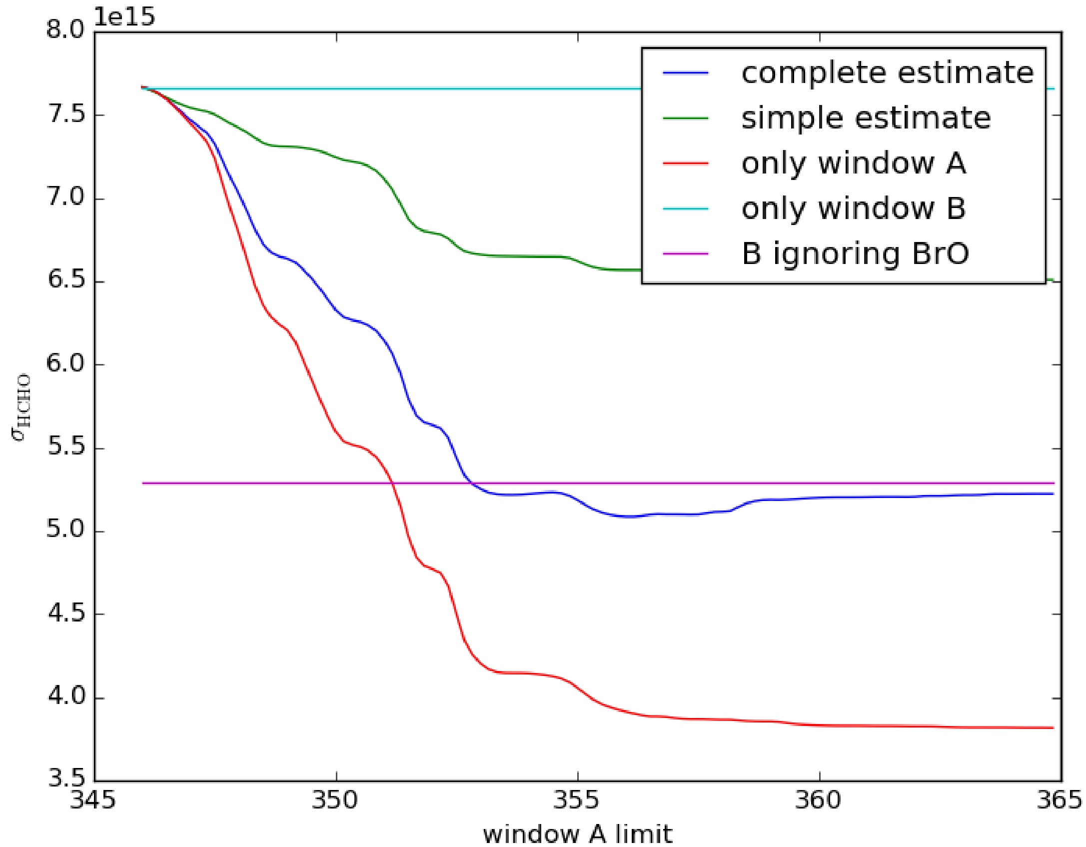

Figure 1: Estimated random error on the HCHO SCD, as the limit of the first window is increased. Window A is the large window (328.5-...), window B is the small window (328.5-346.0).

L246: I guess that the retrieved HCHO from the second interval in Fig. 3 is adjusted considering the retrieved BrO from the first interval but is not clearly written in the manuscript.

The legend of figure 3 has been modified like this:

Figure 3: Example of regional and monthly averages of the HCHO vertical columns over different NMVOC emission regions, derived from OMI observations for the period 2005-2014. Results of the retrievals in the two fitting intervals (1:328.5-359 nm and 2: 328.5-346 nm, with BrO fitted in interval-1) are shown, as well as the magnitude of the background vertical column ($N_{v,0}$).

L280, L297-298: Is the sub-interval larger or shorter than a fitting window for each species, for example, HCHO? What if estimated shifts with the shorter subintervals differ within the fitting window, how would you apply this to the calibration?

Sub-intervals are typically of the order of 10 nm wide, so shorter than the fitting window, and adjusted to sample the variation of the shift (and therefore the stretch) over a spectral range encompassing the different fitting intervals. To reconstruct the wavelength-dependent shift over the full range, a polynomial is fitted through individual shift values. This ensure optimal wavelength registration of the irradiance spectrum over the full spectral range of interest.

L299: It appears that the calibration of earth radiance follows the interpolation to the irradiance grid. But the sequence should be reversed I guess, otherwise, a possible shift can interfere interpolated radiance and needs to be corrected before the interpolation to the grids.

The final aim of the calibration procedure is to align as accurately as possible the irradiance, radiance and absorption cross-sections. Our approach uses an external wavelength reference (the Kurucz atlas) to align the solar irradiance using solar Fraunhofer lines. This step is very accurate since, in contrast to radiance spectra, the solar irradiance is not perturbed by atmospheric absorption effects and therefore can be very accurately aligned on the Kurucz atlas. Absorption cross-sections are then interpolated on the resulting grid, which ensures very accurate alignment between solar irradiance and cross-sections. The additional shift and stretch between radiance and irradiance spectra is further corrected as part of the DOAS fit itself, again making use of Fraunhofer lines but also accounting for atmospheric absorbers. This latter alignment is extremely accurate since solar and radiance spectra are recorded with the same instrument and atmospheric effects are properly accounted for. We believe that this overall approach is the most stable and accurate to deal with wavelength registration issues.

L367: Can you take into account the variation of ozone columns with latitude for AMF using the US standard?

No, we do not take this into account. But the effect on the HCHO AMF is rather small. See my answer to the same question from first reviewer.

Line 480-481: Using the measured radiance as reference spectrum instead of irradiance can reduce (or remove) row-dependent offsets. Do we need to remove stripe patterns dependent on the row when the measured radiances are used as reference?

This is almost not needed anymore (offsets are reduced from 2e16 to 1e15 molec.cm-2). We added a figure to illustrate the effect of the difference steps of the background correction (will be figure 8 in the new version).

Line 482-485, It would be appreciated if you can add some explanations about the cause for the latitudinal dependent offset. For example, Khokhar et al. (2005) suggested that the interference of O3 absorption may cause the latitudinal offset. Does this affect HCHO and BrO? Any quantitative information for the latitudinal offset? Does it also change in the two step fitting procedures with the wide and narrow fitting windows, respectively? In addition, if you used the irradiance as reference it may need to account for the latitudinal variation of O3 and BrO absorption in the fitting.

We believe that latitudinal offsets are mainly caused by spectral interference with strong ozone absorption, and non-perfect fit for the Ring effect (which is also related to ozone absorption). The magnitude of the offsets at large SZA is larger in the small fitting interval (328.5-346 nm), because ozone absorption has more weight. The magnitude and sign of the offsets vary in space and time, depending on the cause (Ozone or Ring). Absolute values can reach 1 to 2e16 molec.cm-2 for SZA larger than 70°.

Concerning radiance or irradiance as reference, there is not much difference regarding the latitudinal variations, since radiance as reference are selected only around the equator. In both cases, a correction is needed.

As said above, we added a figure. More explanations can also be found in De Smedt et al., 2015.

Figure 8: It appears that not all M' is linear. So the question is how you include values for the nonlinear M' in the lookup table.

We do not consider M' as linear. We have calculated a LUT of M' using adapted grids for albedo, surface elevation, profile height….

Table 12: it is not clear what the use of x indicates.

We added in the legend:

Table 12: Data/Measurement types used for the validation of satellite HCHO columns. The information content of each type of measurement is qualitatively represented by the number of crosses.