Response to the Reviewer #2

We thank the Reviewer for the constructive review and address the comments below.

General Comments:

In this work, a new retrieval algorithm of the slant column densities (SCDs) of OClO is proposed. This algorithm, aimed to be applied to TROPOMI DOAS measurements, takes into account different spectral effects not considered in previous retrievals. A corresponding error analysis of some retrieval settings has been performed. The authors also present a comparison between OClO SCDs, obtained by TROPOMI trough the new algorithm, and from ground-based zenith DOAS measurements at Kiruna and Neumayer stations. The results show a very good agreement with these instruments (especially at Kiruna). The SCDs of OClO obtained in this work have been also compared to preliminary S5p+I OClO products during different periods of the year, showing similar SCD evolution but presenting an offset between both datasets.

All the manuscript (text and figures) is clearly presented. The new concepts and settings introduced in this new algorithm are exhaustively explained (appendixes), as well as the corresponding error analysis and sensitivity studies. I think that the results exposed in this work will be useful for the treatment and analysis of the OClO SCDs obtained by TROPOMI. Thus, I think the the paper should be publish in AMT. However, I think that some questions should be better clarified.

My main concern is that the authors of this work claim that the new algorithm improves the retrieval results, but looking at the comparison between SP5+I and the results of this work, can that be really stated? The new algorithm takes into account several fine effects that, in principle, should improve the OClO SCDs retrieval and decrease the corresponding errors. But, in practise, how can we say that the results of these work are better than those of SP5+I? For high SCDs, results are very similar, and for low SCDs the offset between both datasets cannot be explained. It is true that, as the authors explained, OClO observation is not expected when the temperatures are still warm, as it is observed in the results of this study (Figure 10). Contrarily, SP5+I results show a background level of OClO. But, it can be affirmed that the results of this work are better than those provide by the SP5+I? Did the authors compared the results of both algorithms with independent measurements (as those of Kiruna or Neumayer)? Please, explain better.

In our opinion there is a misunderstanding here: We do not claim that our algorithm improves the retrieval results only looking at the comparison between our results and the preliminary SP5+I data. To claim that one algorithm is better (or not), not only the results themselves but also the errors should be considered. Since SP5+I is in development and a complete error analysis is not available yet (published), we cannot judge on this. Also given that our algorithm is developed independently of the SP5+I project, we just present the data of the comparison and state in conclusions that “A nearly perfect correlation (correlation coefficient being practically unity) is obtained with the comparison to the preliminary data of the operational S5P+I retrieval algorithm. In the S5P+I data however a systematic positive offset is found.” Besides the statement that OClO observation is not expected when the temperatures

are still warm, we also do not state that our results are better than those of SP5+I and we do not want explicitly to pretend to give such a statement. We will now add "with respect to the presented algorithm" before "is found" of the cited sentence. The better agreement at high SCDs can very likely be explained by the different air mass factors leading to the regression slope being different from 1:1 and considering the regression offset. To better explain this we will add to the text in Sect. 4, L320: "The slope different from unity and the offset of the regression thus explain the good agreement at high OClO SCDs and the offset at low SCD values". To answer the last question, we have made a comparison of the data of both TROPOMI algorithms to the ground based measurements (see below) which however we think is not necessary to be shown in the paper as this would distract reader from the main focus of the paper on the current retrieval.

We found that the differences in the agreement of the TROPOMI datasets with the ground based data are limited to high SZAs for time periods with low OClO. Fig. R1 shows that the discrepancies for the S5P+I data are larger than those of our algorithm in comparison with the Kiruna data. The reason for this finding is that generally lower OClO SCDs are observed in Kiruna than for Neumayer where, due to many days with very high OClO SCDs, a much better overall agreement is achieved.

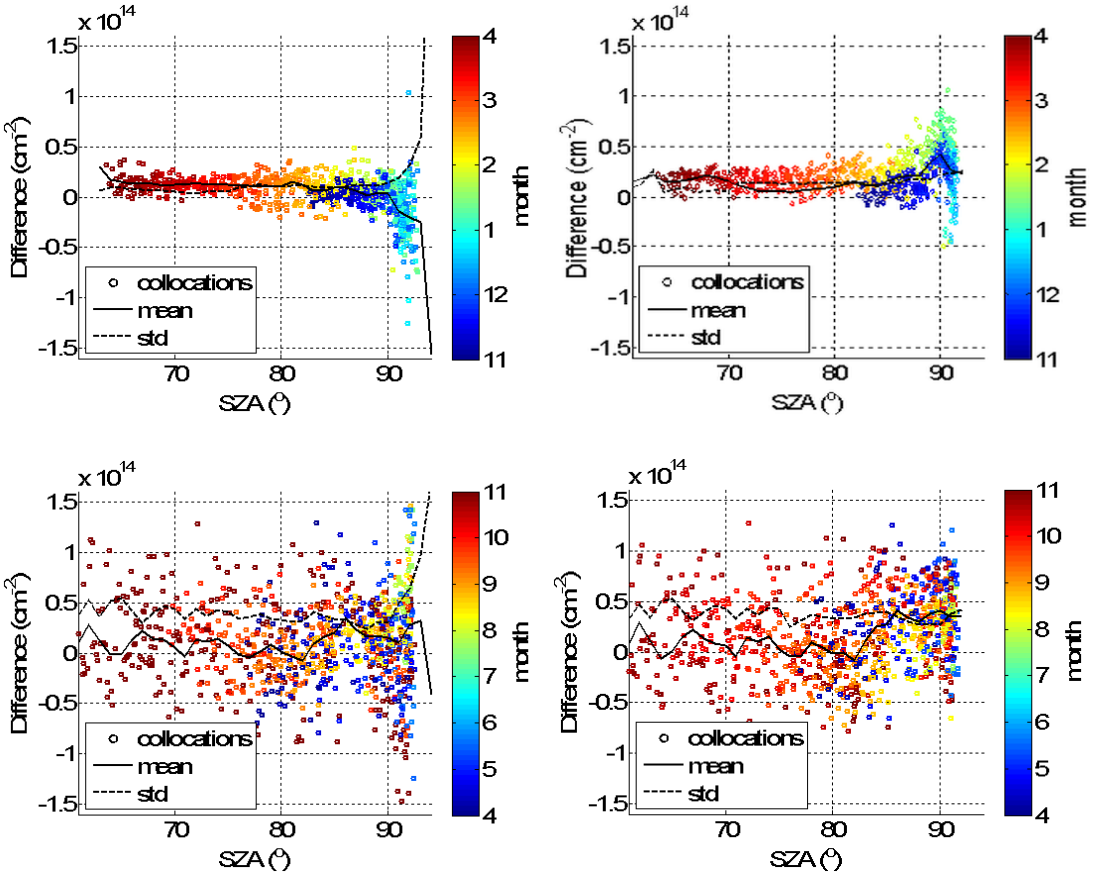

Fig. R1. The same as Fig. 9 (in the manuscript), with differences between TROPOMI OClO SCDs of our algorithm (left plots) or the preliminary S5P+I data (right plots) with zenith sky OClO SCDs measured at Kiruna (top) and Neumayer (bottom).

We will add/modify the statement about the discrepancies in the manuscript in the last paragraph of Sect. 4: "A comparison of S5p+I OClO SCDs with the ground based data (not shown here), performed in the same manner as the comparison in Sect. 3 between this study and the ground based data, showed generally a very similar agreement between S5p+I and the

ground based data. Larger differences between the S5p+I OClO SCDs and the ground based data than for our analysis was found for observations at high SZAs with low OClO SCDs, thus consistent with the findings in this section. As a consequence, the application of the solar irradiance instead of the earthshine spectrum as Fraunhofer reference cannot likely explain the differences because it would provide a similar offset for all SZAs. Also the use of a Ring spectrum as defined in the S5p+I preliminary product (not shown here) did not provide a better result. Thus we can speculate that the differences could be related to the usage of different fit windows, together with still uncompensated higher order effects in the current version of the S5p+I OClO fit as the consideration of the wavelength dependency of fit parameters becomes more challenging in larger fit windows. The differences might also be related to the implementation of the empirical terms in the S5p+I retrieval or instrumental effects, but such detailed investigations are beyond the scope of this study."

Specific Comments:

I would like also to clarify some questions:

- *Figure 1: Some days of different periods of the year for both, NH and SH, have been presented. Are those days representative of the corresponding periods? If it is the case, do you think that the bias introduced by SZA at each season could be, at least partially, corrected somehow?*

Yes, the days are representative for the corresponding periods. We make this more clear in the manuscript modifying the sentence on L145 "The days are selected to represent different atmospheric conditions" by adding "…at different time periods". So far we have not found a possibility to correct for the offset otherwise we would have done this already. Nevertheless the systematic error is low also in relation to other error components as shown later in the manuscript (e.g. at the end of Sect. 2.2.3). And as shown in the sensitivity studies the offset varies in a similar range depending on various fit parameters.

- *Page 11, line 225: why for clear sky cases the signal to noise would be lower?*

Typically clear sky cases have lower albedo, hence the backscattered or reflected light by clouds or Earth surface is lower. We add in brackets "due to a typically lower effective albedo"

Technical Corrections:

- *Page 4, line 102: "Earthshine" instead "Earth-shine", for coherence.*

  Corrected as suggested

- *Page 6, lines 123-124: A wavelength l=379 nm is selected for evaluation. Please, explain briefly why.*

  We add that "because this wavelength provides a good trade-off between precision and accuracy (see also the sensitivity studies in Appendix B1 and B2)"

- *Legend of Figure 1: ".. indicated in the legend on the right.", instead "left plot".*

  Corrected as suggested

- *Page 7, line 161: "In an ideal case,.."*

  Corrected as suggested

- *Page 17, line 316: "(Sect. ??)"*

  Here should be a reference to the manuscript https://acp.copernicus.org/preprints/acp-2021-600/ which in an earlier stage of the manuscript here was presented as a separate section to which a reference here was made. After suggestion by the former editor, we split the original paper into a technical part (AMT) and a part with TROPOMI results and their meteorological interpretation (ACP). We oversaw the old formulation while splitting. We add now the correct reference to the second manuscript.

- *Page 25, line 476: "depends on both", instead "depends both on".*

  Corrected as suggested

- *Page 25, line 489: "Within the chosen OClO fit window,..".*

  Corrected as suggested

- *Page 25, line 490: "cross section" instead "cross-section", for coherence.*

  Corrected as suggested throughout the paper