Response to the Reviewer #2

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

In this paper, the new TROPOMI OClO slant column density (SCD) product developed by the MPIC group is compared to meteorological data for both Antarctic and Arctic regions for the first three winters of the S-5p satellite mission (November 2017–October 2020). A good qualitative correlation is generally obtained in both hemispheres between the OClO SCD and the selected meteorological parameters, namely the minimum polar hemispheric temperature, the polar vortex area, and the area where air temperature is below the temperature of nitric acid trihydrate (NAT) PSC particles formation. In addition, the TROPOMI OClO SCDs are also found to coincide well with PSC observations from the CALIPSO Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) PSC observations. The various high OClO level periods observed in both Northern and Southern polar winters are discussed in terms of polar vortex activation and deactivation processes and stability.

This study fits well with the scope of ACP. Moreover, the manuscript is clearly structured and the method and results are generally presented and discussed in an appropriate and balanced way. Therefore I recommend the paper for publication in ACP after addressing the following comments:

General comment: This is a suggestion for a future study rather than a comment to address here but it would be interesting to include also the TROPOMI BrO and O_3 column data sets in the loop. Comparing those data sets with the presented OClO and PSC observations and meteorological parameters could provide a unique opportunity to investigate the relationship between halogens activation, stratospheric ozone depletion and meteorological conditions during the last three winters, especially in the Northern polar region where the polar vortex can be highly variable.

Many thanks to the reviewer for this suggestion! We will consider this in further studies.

Specific comments:

Page 2, line 46: Maybe you should give the typical solar zenith angle threshold value above which the OClO abundance can be detected from passive DOAS measurements. A number for the detection limit (in molec/cm2) should be also given here.

This statement is to say that OClO can best be investigated at high SZAs because for such conditions the signal to noise ratio of the retrieved OClO SCDs can become largest. The detection limit and thus the SZA threshold, for which enhanced OClO SCDs might be detected, vary from instrument to instrument. Also different statistical processing like averaging over certain space and time intervals may change it. For TROPOMI we can retrieve OClO down to 65° SZA with a typical detection limit below 2E13cm-2 for a 20x20 km2 area.

We added this information to the manuscript by modifying and expanding the paragraph at line 95:

"The detection limit and thus the SZA threshold, for which enhanced OClO abundances might be detected, vary from instrument to instrument. Further it varies with SZA due to different signal to noise ratio, also different statistical processing like averaging over certain space and time intervals may change it. A detection limit of about 0.5—1x10^14 cm-2 have been estimated at SZA of 90° for SCDs gridded on a resolution of 20x20 km^2 which is well suited for measurements in the stratosphere. We can retrieve OClO slant column densities (SCDs) with a typical detection limit below 2x10^13 cm-2 for the 20x20 km^2 area down to 65° SZA."

Page 4, lines 93-97: Did you apply any filtering on cloudy pixels in the construction of your OClO SCD gridded product? Since the OClO formation is enhanced in the presence of PSCs, how the latter can influence the quality of your OClO retrieval? Please elaborate.

No filtering with cloudy pixels is performed because the effect of clouds is very limited (please see also the answer to Reviewer 1). To retrieve OClO SCDs no input about the atmospheric properties is needed. Above clouds even the signal to noise ratio is typically increased because of more backscattered light, thus the quality (i.e. retrieval error) of the retrieved OClO is even better.

Concerning OClO in the presence of PSCs it is true that the measured OClO SCDs not only depend on the OClO concentration but also on the length of the light path (which can be affected by PSCs). The latter dependency, however, is difficult to quantify for each measurement because of the high atmospheric variability and the missing detailed information about it.

While evaluating the radiative transfer effects concerning the spatial sensitivity (see also the corresponding comment by the reviewer #1), we checked also the effect of PSCs. We found that the PSC effect is limited, and thus still a semi quantitative comparison (as presented in the paper) is meaningful.

We added this information to the text (as formulated in the response to the comment by the reviewer #1) and provided details of the sensitivity study in Appendix A.

Page 4, line 120: The SZA range (89-90°) used for the selection of OClO SCD should be better justified. Did you test other SZA ranges since both the altitude of the air mass probed by the TROPOMI sensor and the altitude of the maximum OClO concentration peak depend on the SZA?

The selected SZA range is motivated by a larger ratio between the OClO SCDs and the detection limit in this range, i.e. the amplitude of the observed OClO SCDs decreases faster with decreasing SZA than the detection limit does. Similar ranges (around SZA of 90°) are used in previous studies e.g. by Kühl et al. 2004b and Hommel et al., 2014. We agree that it would be interesting to investigate also lower SZAs (especially given the better performance of TROPOMI) but we have limited this study to this one SZA range to keep the study in limits.

We added this information to the text of the manuscript (before L120):

“OClO SCDs for SZAs between 89 and 90° during different winters are analysed. This SZA range is motivated by a larger ratio between the OClO SCDs and the detection limit in this range, i.e. for smaller SZA the amplitude of the observed OClO SCDs decreases faster with decreasing SZA than the detection limit does. Similar ranges (around SZA of 90°) are used in previous studies e.g. by Kühl et al. 2004b and Hommel et al., 2014. Although given the better performance of TROPOMI, it would be possible to investigate also lower SZAs. However, we decided to use only the above mentioned SZA range in order to keep this study in limits.”

Page 5, lines 135-137: In order to select meteorological quantities, it is assumed that the retrieved OClO SCDs are mostly sensitive to the 475K potential temperature level, which corresponds roughly to an altitude of 19-20km. How far this assumption is valid? It needs also to be better justified.

Selecting this level we follow earlier studies (Wagner et al., 2001, 2002, Kühl et al., 2004b) where a strong anti-correlation between minimum temperatures and OClO SCDs has been found for this PT level. The altitude corresponds well to the peak of the ozone number density profile at high latitudes (Yang, K. and Liu, X.: Ozone profile climatology for remote sensing retrieval algorithms, Atmos. Meas. Tech., 12, 4745–4778, https://doi.org/10.5194/amt-12-4745-2019, 2019.). At the chosen SZA range (89-90°) the measurements also show a very high sensitivity to the investigated altitudes. We added this information to the manuscript.

Technical corrections:

Page 4, line 91: ‘coveradge’ -> ‘coverage’

Corrected

Some sentences are very long and difficult to follow (e.g. first sentence of Section 3, page 5).

We split the sentence: “In addition, we relate the retrieved OClO SCDs with the Level 2 Polar Stratospheric Cloud provisional version 1.10 product (Pitts et al., 2009). The PSC product, freely provided by (NASA/LARC/SD/ASDC, 2016), is retrieved from the…”

The color bar scale values of the subplot stratospheric $T - T_{NAT}$ (3rd subplot from the top) in figures 4, 7, 10, and 13 are difficult to read.

We modified the figures to eliminate the overlap of the scale values.