

Response to Review 1

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We thank the referee for her/his thoughtful comments and suggestions for improvements. We revised the manuscript critically and think that the manuscript has significantly improved after the comments and suggestions have been considered.

In the following, we respond to individual comments. Original remarks of the referee have been enclosed in quotation marks, using an *italic* font. Responses are given below each comment and are marked by "Answer" in a **bold italic** font.

General part:

"However, it is required that the authors point out the main goals and the new findings of this study more clearly."

Answer: We are following the referee's suggestion and reworked the manuscript. This affects in particular the introduction and summary, but also a few changes were made in the abstract.

"There are many different analyses in this study but it is often not clear to me why these analyses are important and what the main message is."

Answer: Our study aims to report correlative observations of severe ozone losses in the winter-spring 2011 Arctic stratosphere from the SCIAMACHY instrument. Particular focus is on limb measurements that resolve the vertical distribution of stratospheric O₃, BrO, and NO₂. We are also considering other measurement techniques and model simulations. The findings are exemplarily compared to a situation of the winter-time Arctic stratosphere when ozone losses are much weaker (2010). We critically rework the manuscript in order to better highlight the main messages and to make clear why it is necessary to consider the different types of analysis.

"It would be helpful to give short conclusions for the different parts in order to highlight the gain of information obtained by the different analyses."

Answer: We agree to the referee and rework respective sections, providing short summaries to highlight the gain of information.

"You mix British and American English. Please unify the orthography."

Answer: We agree to the referee and correct orthography.

"Different acronyms for polar stratospheric clouds are used (PSC or PSCs). Please unify this and introduce the acronym only once. UKMO, MIDRAD, LINOZ, .. is not introduced when it is used the first time."

Answer: We agree to the referee. The manuscript is completed by a list of abbreviations in an Appendix A.

"I suggest that in favor of a clear description of the new aspects, the discussion of some details (that are not relevant for the overall conclusions) should be shortened."

Answer: We agree to the referee. We shortened the preface to the section describing the methods used in this study (Section 2; reduction of about one page). We will also carefully revise the results sections 3.1 and 3.2 in order to compact the message. Several aspects were mentioned already by Hurwitz et al. (2011), so that here no additional or new information is given.

Specific comments:

"Title: An important part of this study is the detailed analysis of the mini-hole event. Maybe this should be part of the manuscript's title rather than the comparison to Arctic winters in the past?"

Answer: We agree to the referee and change the title of the manuscript into "Chemical ozone loss and ozone mini-hole event during the Arctic winter 2010/2011 as observed by SCIAMACHY and GOME-2."

"Abstract: You mention the chemical transport model. What about results? Are the special conditions in 2011 reproduced by the CTM?"

Answer: We agree to the referee and add a respective statement in the abstract of the revised manuscript.

"16599-16600: Can you identify the large denitrification and chlorine activation (as noted in the Introduction) in March 2010 in your data set (OCIO and NO₂)? And how is this explained in a winter that you classify as a "warm" winter? You give some information about the conditions in the year 2010, but they are spread all over the manuscript. Maybe you can shortly discuss the year 2010 conditions also in section 3.7 and explain how the large denitrification matches to the "warm winter" and the high ozone levels."

Answer:

We think the stronger denitrification and chlorine activation in 2011 compared to other years is well visible in Fig. 10, both in the SCIAMACHY and the Ny-Alesund ground-based data. NO₂ in March is lower than in other years, and OCIO is enhanced compared to other years.

We will follow the referee's suggestion and better structure the informations about relationships between the different kinds of observations. We add an additional paragraph in the introduction, summarising our findings and how they relate to the works of others. We will also adapt the summary appropriately. We will provide more informations about conditions in the "warm winter" 2009/2010 we chose for comparison, in particular with respect to denitrification and chlorine activation as described in section 3.7. In this respect, we will also cite Dörnbrack et al. (2012), who examined in detail dynamical and chemical characteristics of the "warm winter" 2009/2010 in the Arctic stratosphere.

"16610, line 11: In Figure 2a no information about the year 2007 is given. I guess this must be 1995/1996. Furthermore, I would identify the record low in the year 2011 around day 80 and not 50."

Answer: This is a mistake, the year 1997 was meant, not 2007. Both Figures 2a and 2b show the year 1997. The proper legend for that year is "1996/1997" in light blue colour. In the respective text section (section 3.1) we will adopt the paragraph discussing Fig. 2.

"16610, line 15ff: You should specify the "winter mean", at least in the figure description."

Answer: We are suggesting the following changes as shown below:

ACPD, 16610 line 15ff:

The variability in Arctic ozone evident from the compact relationship between the extra-tropical winter eddy heat flux, a measure of wave forcing of the winter residual circulation, and spring-to-fall polar cap ozone ratio, is shown in Fig. 3 (Weber et al., 2011).

....

Fig. 3. Correlation between winter eddy heat flux and spring-to-fall ozone ratio over the polar caps (update from Weber et al., 2011). Triangles are data from the SH; circles from the NH.

Proposed amendments:

The variability in Arctic ozone evident from the compact relationship between the extra-tropical winter mean eddy heat flux, a measure of wave forcing of the winter residual circulation, and spring-to-fall polar cap ozone ratio, is shown in Fig. 3 (Weber et al., 2011).

....

Fig. 3. Correlation between winter mean eddy heat flux and spring-to-fall ozone ratio over the polar caps (update from Weber et al., 2011). Triangles are data from the SH; circles from the NH. The winter mean eddy heat flux is calculated by averaging the monthly mean eddy heat flux from 43° to 75°, separately, in each hemisphere and average over the months September to March in the NH (for NH data) and March to September in the SH (for SH data).

"16610, line 21ff: "Planetary wave activity during Arctic winter 2010-11 was among the lowest in the NH (..) " Here, you can include the reference Hurrwitz et al., 2011."

Answer: This is correct. Hurwitz et al. (2012) showed this relationship. Here, we are providing no additional or new information. Will be considered in the revised manuscript.

"16611, line 13: "In March 2010 and 2011 (..) with minimum ozone found above the North Atlantic sector between Greenland and Scandinavia. (..) " I can see this for 2011, but for 2010 the statement is not really appropriate. Please rewrite!"

Answer: The referee refers to Fig. 4, showing the March mean stratospheric ozone column over the Arctic from GOME2, SCIAMACHY limb and the CTM in 2010 and 2011. We agree to the referee that in March 2010 the ozone column minimum was rather found between Scandinavia and parts over North Eastern Europe rather than over the North Atlantic, as in March 2011. We will rework the paragraph appropriately.

"16613, line 25: "The BrO vortex averaged time-series of Fig. 5 are giving us the impression that in the depicted period 2011 the BrO variability was somewhat larger than in 2010." For me this is hard to see in Fig. 5. If this is a relevant result, please verify your statement. Otherwise I suggest that you remove this sentence."

Answer: We agree to the referee and remove this phrase since it is indeed not appropriately provide the information.

"16614, line 6: Here, you argue that the decrease in BrO in April is caused by mixing of BrO poor air from the midlatitudes into the vortex (also 16619, line 7). Later (16619, line 9), you used BrO as indicator of mixing and state that the lower BrO levels in 2011 compared to 2010 are "due to slower large-scale meridional transport from the regions of its photochemical production." Can you explain this discrepancy?"

Answer: This is not a discrepancy. The referee's first mentioned two text passages (16614, line 46 and 16619, line 7) refer to the decline of vortex-mean BrO mixing-ratios in spring when mixing of air into the vortex becomes more likely, while the latter text passage (16619, line 9) refers to the interannual, or better saying year-to-year, variability of stratospheric BrO in the northern hemisphere, that is associated with the large-scale transport by the Brewer-Dobson circulation. While the latter topic is barely addressed by scientific studies yet (in contrast it is well addressed for other tracers like ozone or aerosols), the former relationship has been much better explored in recent years (e.g. McLinden et al., 2010). Because it is related to synoptic scale trace constituent advection, stratospheric dynamics, and photochemistry. However, we will carefully revise the manuscript in order to provide this message clearly and unambiguously.

"16615, line 9ff: You ask the question "Why this is influencing an isentropic ozone loss estimate, developed to infer the strength of the chemically-induced polar ozone destruction independently from reasons related to the dynamics of the atmosphere", but in my opinion you don't answer it clearly in section 3.8. Is the chemically-induced ozone loss during the mini-hole event unrealistic? Or does it represent the contribution from enhanced PSC occurrence and chlorine activation due to the adiabatic cooling? If there is enhanced PSC occurrence (see Fig. 9), why is it not possible that there is a chemical ozone loss in the illuminated part of the vortex? You should consider this for your discussion later on."

Answer: We agree with the referee's opinion that the question we raised in the discussion about ozone losses from limb observations (Section 3.3.2) has not been appropriately answered. This is in particular true for Section 3.8.4, which was aimed to exactly specify the reasons why a dynamical situation can affect the chemical ozone loss estimate. We will revise this section critically with the aim to better highlight our results. In order to achieve this and to keep the things simple, we remove the above cited question and clearly state in Section 3.3.2 that further, more detailed investigations are made later in the manuscript.

Given the fact, that in the examined 12-day period in 2011 the low ozone has been measured over the largest portions of the sunlit polar vortex by the height resolved limb profiles, the ozone mini-hole situation is expected to be also reflected in the ozone loss estimate. Because the modelled accumulated diabatic descent of ozone on isentropes below 700 K cannot not account for sporadically occurring, synoptic-scale adiabatic processes in the tropopause region. Hence, horizontal redistribution of ozone over the regions that have been "pushed" from below by a tropopause elevation is necessarily evident in our isentropic analysis. The coarse horizontal distribution of the CTM (2.5°x 3.75° longitude/latitude), however, is improperly resolving the situation, since meridional dispersion of ozone across the isentropes is smeared by numerical diffusion.

In the revised manuscript we will more precisely state that the method we used to infer chemical ozone loss is impacted in January 2011 by an unusually dynamical situation. All other measurements in the period considered in our analysis are not affected and associated potential changes in ozone are attributable to chemical processes.

Additional material on the subject, further elucidating our position, can be obtained from our institute's web sites, providing all available limb profile measurements of stratospheric ozone from the SCIAMACHY instrument, graphically depicted for each orbit. For instance, on 25 January 2011, orbit 46557 is showing clearly how ozone was diminished during the mini-hole event throughout the polar ozone layer: http://www.iup.uni-bremen.de/~sciaproc/STROZONE/O3_2011.html (last access 16 December 2013).

Furthermore, in the revised manuscript we also have to point out more precisely why the enhanced occurrence of PSCs did not contribute substantially to an immediate ozone reduction during the time when ozone was low in January 2011, regardless of whether the vortex was illuminated or not.

"16616-17, a general question to section 3.4: If you compare the differences between the year 2010 and 2011 in your solar occultation data set, do you get the same conclusions as for the limb measurements?"

Answer: We do not know because we did not process other years or month as these shown in our manuscript (Jan-Apr 2011). To speculate: Yes, we would expect to retrieve the same year-to-variability.

"16617, line 11-24: In your discussion you explain that you would expect lower BrO and larger NO₂ mixing ratio in occultation measurements compared to limb measurements. However, you observe larger mixing ratios in both gases. How can you explain the discrepancy in what you expect and what you observe?"

Answer: The referee correctly states that from a photochemically point of view we would expect to see smaller BrO mixing ratios in solar occultation measurements than in limb measurements, because occultation measurements are performed during local sunset when much of the day-time BrO have been partitioned already into bromine reservoir species during night (mainly bromine nitrate, BrONO₂). However, also the answer is given in the section why our measurement actually see larger BrO mixing ratios from occultation measurements (see comment below). We will revise the section in order to eliminate ambiguities.

Summarising why there is no discrepancy:

Looking at the limb and occultation plots one can see that NO₂ retrieved from solar occultation measurements is generally slightly higher than seen in the day-time limb measurements, and this is as expected. In case of BrO the picture is more heterogeneous. Below about 500 K the mixing ratios seen in limb and occultation observations are quite similar, but above this isentropic level occultation data show larger mixing ratios. The main reason for unexpected differences between limb and occultation BrO is the difference in the sampling (as shown in Fig. 7, the limb measurements allow sampling the Arctic vortex and higher latitudes) so that the meridional gradient in stratospheric BrO mixing ratios below 30km* (e.g. Sioris et al., 2006) will affect the comparison. In the northern hemisphere, BrO mixing ratios are larger in the mid-latitudes and lower values are found near the pole, north of 65°N. Thus, the average of the profiles measured within the vortex has to be larger in the solar occultation time-series (Fig. 6) than in limb time-series (Fig.5).

* Note, from SCIAMACHY limb BrO is not retrieved above 30 km (Rozanov et al., 2011).

"16618, line 12: Here, a short conclusion of the relevant information that is obtained by analyzing the occultation measurements, would be helpful."

Answer: We will separate the last sentence of this section from the last paragraph and add more statements to shortly summarise why SCIAMACHY solar occultation measurements do not reflect vortex conditions.

"16618/19, general comment on section 3.5.1: In this section you compare the model results and the observations. However, in between you don't discuss differences between the model and the observations, but between the years 2010 and 2011. This is confusing."

Answer: We are not sure what the referee means. To answer this, please let us first briefly explain the structure of Section 3.5.1.:

We start with an overview what we compare, explain how we extracted the results from the model grid in order to mimic the shown limb measurements. Then, we compare O₃ qualitatively and quantitatively (16618, line 19-25). In the following (16619, line 1-15), we compare BrO. In the last paragraph we compare NO₂ (lines 16-23). This is the same structure we use in Section 3.3.1, showing and discussing SCIAMACHY limb vortex-averages (introductory part, O₃, BrO, NO₂). Such a matching structure was exactly our intention. For each of the three species in both sections we compare the conditions in the two years separately.

For now, we not see what is confusing in this section but we will revise the section carefully and rework whatever is necessary to make the message more clear.

"16619, line 11-15: Here, you explain that the modeled BrO mixing ratios above 475K are larger in 2011 than in 2010 because of lower modeled NO₂ mixing ratios and a reduced formation of BrONO₂. The question arises why this is only true for the model and not for the "real" atmosphere where also lower NO₂ mixing ratios are observed in 2011 compared to 2010. In the lines 16-22 you explain that the model underestimates the NO₂ mixing ratio which answers the question above. Therefore, I suggest that you reorganize the second part of section 3.5.1."

Answer:

We will follow this suggestion and reorganise the section in order to better describe the relationships between CTM modelled BrO and NO₂, and the comparison to the limb time-series. In particular the year-to-year variability of the modelled BrO mixing ratios was not well enough described, we will be more carefully here.

"16619-20: To avoid confusion later on, I would suggest that you discuss the difference between the calculated ozone loss in the model and in the observations in the beginning of section 3.5.2 before the results are compared."

Answer: We will follow the referee's suggestion and rework the entire section in order to better highlight the message. The difference in the ozone losses is discussed first, followed by more qualitative evaluations.

"16621, line 20: In Figure 9 I can't see the maximum on 22 March 2011. It must be 22 February 2011."

Answer: Yes, the reviewer is right, this should read "22 February 2011" rather than "22 March 2011".

"16622, line 11ff: You don't need to use the "type I, a, b and II" term, just write NAT, ice clouds etc. Furthermore, if you use the abbreviations NAT and STS, you should explain them."

Answer: We add the required descriptions for abbreviations used in the paper. However, we prefer to mention both possibilities to name PSC types in this section of our manuscript, because specifically here we are referring to several other studies in which different naming conventions are used. That may help the reader to better compare our data.

"1622/23: Please shorten the discussion to the information that is relevant for your study."

Answer: We will carefully revise respective section about PSC observations from SCIAMACHY and their relation to the observed ozone losses.

"16630, line 11: "... and much larger ridge of tropospheric air ..." -> larger than what?"

Answer: Larger than the ridge over the Asian landmasses we describe in detail in relation to low polar ozone in January 2011. We will clarify this fact in the revised manuscript.

"16633, line 6-11: You state that the OMH-like situation has a direct impact on the chemical ozone loss later in spring. In Figure 9 however, the PSC occurrence rate decreases after this event and is in the range of other winters in the beginning of February. Furthermore, I cannot detect an impact on the chlorine activation in Figure 10. There is a steadily increasing OClO mixing ratio averaged within the vortex and the variability is too large to identify a clear change in the time evolution during the OMH situation. Please explain in more detail how you come to this statement."

Answer: The increase in the PSC occurrence rate is indeed seen after January 22/24 and this may be related to the OMH. However, as we can see in Fig. 11 (assuming that the sampling of SCIAMACHY is similar to that of GOME-2, which is a good assumption) the vortex is probably not well sampled at this time of the season. If – because of the OMH – vortex air masses (including PSCs) are shifted to lower latitudes and become detectable with SCIAMACHY, the actual relative increase in PSC occurrence in the vortex can be assumed to be lower than the behaviour actually seen in the SCIAMACHY PSC data. In conclusions, the increase in PSC occurrence rate observed by SCIAMACHY is probably caused by the OHM, but the actual relative change in PSC occurrence within the vortex may well be significantly lower.

We agree with the reviewer that there is no discernible signature in the SCIAMACHY OCIO measurements in Fig. 10a. We will revise this paragraph.

"16633, line 12-16: You explain that the short-term BrO decrease is caused by the "thinning effect" of the OMH-event. What about the transport and mixing of air from the mid-latitudes? Would this reduce the "thinning effect"?"

Answer: When we interpret this comment correctly, this refers to the influence of mixing across the vortex edge, which in principle is possible but strongly depend on the strength of the vortex. Under strong vortex conditions, like in winter 2011, such mixing is rather negligible but may play a role later in the year when the vortex is becoming more unstable.

We might have not clearly enough pointed out in this section that lateral mixing over the vortex boundary does not influence the ozone mini-hole condition much (which is also influencing other tracers through horizontal redistribution/advection over the affected region). Remind, that the observed BrO mixing-ratios in January 2011 are just another prove that the event has been caused by tropopause elevations. Lateral mixing at the vortex boundary is playing a role later in spring, as we point out in Section 3.3.1 ("... In April of the two years, the vortex-mean BrO abundance drops quickly. This is because the vortex is becoming unstable and to a certain degree allows BrO poor air from mid-latitudes to be mixed into the vortex. ..."; page 16614, line 6ff). Will will rework the paragraph or section to make this clear.

Would this reduce the "thinning effect"? In our opinion not in January 2011, but potentially during other winters when the vortex is less strong and for whatever reason large tropopause elevations occur below the vortex.

"16633, line 20-22: No comparable ozone loss in the polar stratosphere will be expected, when the stratospheric chlorine loading has reached the natural background level, even if the occurrence of PSCs will increase. But in the first half of the 21st century, when the chlorine amount is still high, this might be relevant. I suggest that you rewrite the part "even when the ozone layer recovers to values of the pre-CFC era"."

Answer: This is correct. We will rewrite accordingly.

"16636, line 7ff and in general: "(..) there are several detailed issues to be resolved (..)" Did you learn new details about the model performance? It seems to me that you already knew the deficits of the model before."

Answer:

This is a good point. Yes, we learned a lot from the model study but these issues were more of technical nature and are not really addressable in a paper like this. Deficits of a complex model system that has been evaluated in several studies before (cited in Section 2.8) are, of course, known in most cases, but also unforeseeable model behaviour is not unlikely to occur when a new study has been set up and addresses a different field of research. From the scientific point of view, we are lucky that the model system behaved well. Nevertheless we are not satisfied with the low bias in NO₂, we cannot explain easily. We knew the problem from earlier studies, but these focussed on the tropics (e.g. Aschmann et al., 2011). However, an investigation of such inconsistencies to observations would go far beyond the scope of this study and should be subject for separate, more model specific studies. We hope, that answers the question.

"16636, line 10: "Finally, the observation of a large OMH coupled to a large Northern Hemisphere polar ozone hole is not a coincidence." You should be more careful with this statement. You have argued that this OMH event could have triggered the severe ozone loss in March 2011. This may be true for 2011 (even if it's hard to verify). However, even if the ozone loss in spring is larger with a preceding OMH event, a OMH event will not necessarily lead to a large ozone loss. Furthermore, you have to keep in mind that you have only one example and no statistically significant proof for this connection. You should write it as a hypothesis and not as a proven fact."

Answer: We thank the referee for highlighting this issue. We will revise respective section carefully. We agree, stating that "...it is not a coincidence..." is debatable based on the facts we described in the manuscript.

Technical corrections:

"16605, line 24: More detailed information on the PSC detection method can be found in von Savigny et al. (2005a). Repeated in line 11, 16606."

Answer: Correct. The sentence in line 24 will be deleted.

"16606, line 18: "(.) references spectrum (.)" -> reference spectrum"

Answer: Typo, will be corrected.

"16606, line 21: I suggest writing "(.) merged O3 total column data set, retrieved (.)"

Answer: We will follow this suggestion.

"16607, line 1: Remove "having"

Answer: We will follow this suggestion.

"16607, line 8: "(. . .) that extends from 1978 to present which agrees to within 2 % with (.)" Better two sentences: "...to present. It agrees within 2 % with . . ."

Answer: We will follow this suggestion.

"16609, line 28: "below 80 N" -> south of 80 N"

Answer: Correct. We will change.

"16610, line 4: "Results and Discussion". I suggest that you entitle this section "Results."

Answer: We understand this suggestion. In this manuscript we describe our results in a continuous manner, not distinguishing between sections showing pure results only, accompanied by an additional section discussing the relationships. However, we will consider this point and reexamine the manuscript's structure.

"16610, line 23: "(.) heavily perturbed Antarctic ozone hole (.)" -> Maybe better: "perturbed Antarctic vortex"

Answer: We will will rewrite the paragraph.

"16610, line 20-24: "Planetary wave activity during Arctic winter-spring 2010/2011 was among the lowest in the NH in the thirty years of satellite data (.) As a result, ozone transport from its source (. . .) was weaker in the second half of 2010 than in other years." The second half of 2010 is July - December. Strictly speaking the ozone transport in summer and autumn 2010 is not a result of the planetary wave activity in winter-spring 2010/11. Please rewrite this sentence accordingly."

Answer: We will will rewrite the paragraph.

"16611, line 4: "that" -> this"

Answer: We will consider this suggestion.

"16611, line 16: "(..) was very high, an effect (..)" -> Two sentences: "(..) very high. This effect is (. . .)"

Answer: We will consider this suggestion.

"16612, line 6: "(..) with the two instrument's data (..)" -> Maybe better: "with the data of the two instruments"

Answer: We will consider this suggestion.

"16613, line 7: Remove "being"."

Answer: We will consider this suggestion.

"16614, line 6: "In April of the two years (..)" -> Maybe: "In both years in April (..)"

Answer: We will follow this suggestion and rewrite the sentence.

"16614, line 13: NO_x should be specified here and not on page 16615."

Answer: Correct, we will consider this suggestion.

"16614, line 14: "NO_x, and hence NO₂, will (..)"

Answer: We will consider this suggestion.

"16615, line 2ff: "(..) in April 2011, relative to values measured the first day of the year (..) . Please add "ozone" ("relative to ozone values") otherwise the "values measured" are related to the loss."

Answer: We will consider this suggestion.

"16615, line 27: "on the order of" -> in the order"

Answer: Typo, will be corrected.

"16617, line 2: "White limb dots mark measured profiles outside the vortex, those considered in the vortex-averages are marked in black." The description of Figure 7 says however: "(..) Limb measurements lying within the vortex are shaded dark grey ." Please unify. Furthermore, the small and large dots in Figure 7 are hard to distinguish, maybe due to the light grey frame? What does the color code of the large dots mean? Some of the measurements clearly don't lie within the vortex, but are still dark grey shaded. Please clarify this."

Answer: We thank the referee to pointing that out. Here, the figure caption is correct, respective phrase in Section 3.3.2 is not. We will also follow the referee's suggestion and rework Fig. 7. Following changes have been made:

- The location of limb profiles within the vortex are now marked black (the previously used greyish shading conflicted too much with the colour coding of the PV contours).
- Solar occultation profiles are now marked with a different symbol to be better distinguishable from limb profiles.
- Previously, solar occultation measurements had no separate colour coding to distinguish profiles lying inside the vortex from profiles outside. This has been changed.

With respect to the referee's statement some of the shown profiles within the vortex would actually not lying in it, we have to state the following:

- We revised the data and the figure and state that all locations of limb profiles within the vortex (greyish small dots) are indeed located in regions where PV is larger than 38 PVU (our definition of the vortex edge boundary, Section 2). The colourbar of Fig. 7, however, used 36 PVU as colour coding index, which does not help much to interpret the figure in an appropriate manner. We will change that and better indicate the vortex edge by the chosen colours. But this also means, there is no error in the markers distinguishing limb profiles inside/outside the vortex.
- Potentially this point was also raised by the improper colour shading of the solar occultation markers, which are hard to distinguish from limb markers, see comment above. This will be changed.

"16617, line 8/9: "(..) are concentrated near the pole, thus only a few limb profiles capture (..)"

Answer: We will consider this suggestion.

"16617, line 19: anticorrelated or anti-correlated"

Answer: We will follow the referee's suggestion and rework respective phrase.

"16617, line 27: "Although the variability (..), but the low ozone period (..)". After "although" I would not expect a "but". Please rewrite this sentence!"

Answer: We will follow the referee's suggestion and rework respective phrase.

"16619, line 20: Please use quotation marks: "Noxon cliff"

Answer: We will follow the referee's suggestion and rework respective phrase.

"16620, line 6: "They compared to loss estimates ..": Remove "to"."

Answer: We will follow the referee's suggestion and rework respective phrase.

"16621, line 10-16: This is a bit confusing. First you discuss the PSC occurrence in January 2010. Then you state that the total supply of PSCs was larger in 2011 than in 2010. Then you note that in 2010 the occurrence rate was 20% larger, but only during a short period. And at the end you explain that in 2011 the PSC period was longer than in 2010. It would help the reader, if you rewrite this part and discuss first the conditions in 2010 and then compare it to 2011 and avoid switching between the years."

Answer: We agree, the statements are a bit confusing in this paragraph. It will be reworked.

"16621, line 22: "Not exactly similar to the periods seen by SCIAMACHY, but largely overlapping." This is only a fragment of a sentence. Please rewrite."

Answer: We will follow the referee's suggestion and rework respective phrase.

"16622, line 10, 16: The English word "information" does not have a plural form!"

Answer: Typo, will be corrected.

"16622, line 12: "stated" -> "started"

Answer: Typo, will be corrected.

"16624, line 19: "no sign of increase in NO2" -> no increase in NO2"

Answer: We will follow the referee's suggestion and rework respective phrase.

"16625, line 14ff: "(..) similarly as the long-lasting low ozone period in March and April 2011. However, even if enough ODS (..)" "Also, why then should .." -> Furthermore, it cannot be explained by ozone chemistry why ozone recovers a few days later at approximately (. . .)"

Answer: This paragraph will be reworked to make clear what we want to say here.

"16630, line 6: ".. as id did not emerged .." -> as it did not emerged"

Answer: Typo, will be corrected.

"16631, line 23/24: "(..) behavior number densities, (..)"?"

Answer: Sentence will be rephrased.

"16632, line 18: "This led to a situation that (..) " -> Maybe better: "Thus a larger area of the vortex was illuminated by the sun and hence observed (..) compared to a polar centred vortex. ""

Answer: We will follow the referee's suggestion and rework respective phrase.

"16634, line 4: "(..) by employing the vortex-average technique (..)" I think, more important to note for the calculation of the chemically-induced ozone losses is that you use the diabatic descent rates."

Answer: Correct. Will be revised.

"16636, line 3-5: *"To understand the chemical composition of the Arctic stratosphere improves our knowledge (..)"* "

-> *"The understanding of the chemical composition.."*

Answer: We will follow the referee's suggestion and rework respective phrase.

"16647: *If possible change the colors for the years 1995/96 and 1996/97 for a better distinction of the curves.*"

Answer: We will follow the referee's suggestion and rework respective figures.

References

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