Response for the Review (acpd-14-c1674-2014)

Kazutoshi Sagi

Dear Reviewer,

Thank you very much for your comments on our paper. We will introduce all suggested corrections. Below we present the responses to your specific comments and questions.

Major issues

Reviewer:

7890/6: The concept of “ozone loss due to the instability of the vortex" is not very clear. There could be chemical ozone loss by various processes but the instability of the vortex itself does not generate ozone loss. It may cause mixing between air masses with different ozone amounts or simply transport of air from mid-latitudes into the vortex.

Author:

>> This is badly formulated. We have removed the text, “due to the ~~~” from the revised manuscript. The original intension was to attempt to explain that due to its instability the vortex became accessible to SMILES, despite the limited latitude coverage.

Reviewer:

7896: The choice of ω as a symbol for vertical velocity for different vertical coordinates is confusing, as it is typically used as the vertical velocity in pressure coordinates ($\omega = dp/dt$). It is further well known that slow vertical motions in the stratosphere as the tropical ascent in the Brewer Dobson Circulation but also the descent in the polar vortex can be described best using the heating rate and potential temperature as vertical coordinate. Therefore it would be better to leave out this discussion and refer to the literature.

Author:

>> Indeed. We changed the symbol to w. On the other hand, we need to keep the explanation since it describes the modifications to the model compared to earlier versions.

Reviewer:

7896, formula 3: This can only be a necessary condition and is not a sufficient condition. E.g. by increasing the $\Delta\Theta$ to a very large number you could fulfil this formula, but you may not be able to simulate vertical descent.

Author:

>> We agree. The text has been modified in the revised paper.

Reviewer:

7897/17: The US-standard atmosphere profile does significantly differ from a polar ozone profile that should rather be used here

Author:

>> This is wrong explanation. We have changed the sentence.

Reviewer:

7900/4ff: I don't see how you can derive statements about equilibrium between processes from the shown quantity that is an integral of ozone loss rate since the beginning of the winter. Also, the photochemical production in polar spring is probably very low. With the shown method, you cannot discriminate changes between chemical ozone loss or transport of/mixing with air-masses from lower latitudes that did experience earlier Ozone loss (e.g. due to NOx)

Author:

>> We agree that this statement is probably an exaggeration. We have changed it. However, we believe that our method can roughly separate the changes between chemical loss and transport. Indeed it is difficult to bring out the detailed mechanism behind the loss by assimilation alone. Hence we showed other information such as temperature or ClO.

Reviewer:

7900/15ff: The process of polar ozone depletion by chlorine activation and subsequent polar ozone depletion is generally known and must not repeated here. Especially it is not necessary to provide detailed information on PSC types or denitrification.

>> We removed the text.

Reviewer:

Chlorine activation can be triggered by different PSC types, most important are the liquid particles. The only shown data for that are the SMR ClO data. From the SMR ClO nighttime data, the chlorine activation is best visible if temperatures rise and thermal decomposition of the night reservoir Cl2O2 becomes important. This cannot be verified as the chemistry is not simulated by the model. However, there are several papers that describe ozone depletion, denitrification of the winter 2009/2010.

Author:

>> We agree. Since the partitioning of ClO/Cl_2O_2 is temperature dependent, the enhancement of nighttime ClO in the end of Jan. has to be the result of thermal decomposition of Cl_2O_2. The peak of ClO at 475K on 28-29 Jan. corresponds to the rise of temperature after SSW. On the other hand, the nighttime ClO increased from 16 Dec. (-15DOY) below 500K with 0.1 ppbv. The average of ClO during the period from 16 Jan. (15DOY) to 15 Feb. (-45DOY) is approximately 0.25 ppbv. This increase of ClO during night should be caused by the chlorine activation on PSC. We have modified the statements in the revised paper.

Reviewer:

Do you use equivalent latitude >70◦N as definition vortex edge throughout the paper? Is this justified for all times and altitudes? Please give an indication of the breakdown time of the polar vortex in the different altitudes.

Author:

>> Yes, we used equivalent latitude of 70N as the vortex edge for all times and altitudes. In the revised paper we have also presented ozone loss derived with a potential vorticity criteria (38PVU) in the conclusion chapter.
We have attached the additional pages at the end of this response for more details. Please see the pages for the vortex edge criteria.

Reviewer:

Classify the results with respect to other published ozone loss estimates.

Author:

>> Another reviewer also suggested including a comparison with other studies. We will add a new section for the comparison at the end of the discussion part.

Minor Issues

Reviewer:

7890/11: Mention which data from ECMWF are used (operational analyses, re-analyses...)

Author:

>> We used the operational analyses of ECMWF. We have mentioned that in the revised paper.

Reviewer:

7890/13: “cross-isentropic tracer transport": Do you mean vertical tracer transport or isentropic transport across the vortex edge?

Author:

>> We mean the vertical component of the cross-isentropic transport.

Reviewer:

7890/25: rather write “... release of active chlorine species (Cl, ClO)"

Author:

>> We changed it.

Reviewer:

7891/1: The Arctic vortex is also stable. Write rather “less stable"

Author:

>> We changed it.

Reviewer:

7891/5: As indicated also later, this is only true for the beginning of the winter (Dörnbrack et al., 2012)

Author:

>> We agree. We changed the text.

Reviewer:

7891/24: This latitude range cannot be true. It should be also in the Northern hemisphere

Author:

>> We agree and changed to the correct value.

Reviewer:

7892/5: rather write “SMILES does not measure inside the vortex..."

Author:

>> We changed the text.

Reviewer:

7892/17: remove “us"

Author:

>> done

Reviewer:

7893/6: please re-phrase, as it could be mis-understood. The limb emission is neither coming from the ISS nor from the 340-360km range.

Author:

>> We changed this.

Reviewer:

7895/25ff: This is a strange concept. The diabatic descent of the air masses in the polar night is caused by the radiation imbalance (no solar irradiance). This must be re-phrased.

Author:

>> We think the statement is correct but it might lead the misunderstanding. We have changed the text in the revised article.

Reviewer:

7897/26: rather write “...vortices did reconnect by..."

Author:

>> done

Reviewer:

7897/28: rather write “lowest temperatures"

>> done

Reviewer:

7898/11: rather write “...would be perfectly simulated..."

Author:

>> done

Reviewer:

7899/5: If there is a known bias, please mention the order of magnitude

Author:

>> We have modified the text.

Reviewer:

7899/9: Probably you mean 65◦N

Author:

Yes. Changed.

Reviewer:

Figs 3 and 6: The figures should be displayed larger such that the details can be visible

Author:

>> Figures have been modified.

Reviewer:

Fig. 8: Are the data displayed in Fig. 8 also averages for equivalent latitude >70◦N?

Author:

>> Yes, we use equivalent la titude of 70^{O}N for all vortex mean calculations.

Appendix: The vortex edge criteria

Here we explain how the equivalent latitude of 70^{O}N works for the vortex edge in the 2009/2010 Arctic winter.

There are several descriptions for the vortex edge used in previous studies. Here we show two candidates.

1. Equivalent latitude (EQL) criteria : 70^{O}N for this study.
2. Lait's potential vorticity (PV) criteria : 38PVU [1PVU=10^{-6} $Km^2kg^{-1}s^{-1}deg^{-1}$] (eg. Hommel et al. 2014)

Figure 1 shows the assimilated N2O maps computed by DIAMOND using Odin/SMR N2O measurements on selected dates and different potential temperature levels. The black and white lines indicate the EQL of 70^{O}N and PV of 38PVU, respectively. The PV edge (=38PVU) and EQL edge (70^{O}N) match until ~20 February. After that period the EQL edge covers a larger area than the PV edge. In this winter, the vortex was split into two parts after a major SSW in mid-February. Then these parts were merged on 1 March. From the date when the vortex was reunited, the EQL edge differs from the PV edge. The EQL value corresponding to the PV edge is approximately 80^{O}N. Comparing with the EQL edge, the PV edge is more consistent with the area where N2O has a relatively high gradient. This means that our estimation of loss using the EQL criteria probably contains a larger contribution from the transition area near the vortex edge after 1 March.

Figure 2 shows the vertical profiles of accumulated ozone loss derived from the assimilation of SMILES and SMR ozone measurements as of the end of February (58DOY) and the end of March (89DOY). The solid lines are for using the EQL edge and the dashed lines are for the case of the PV edge. Major differences between the two criteria can be seen above 800K on 28 February and below 550K on 31 March. The PV criteria show roughly 0.2 ppmv higher loss above 800K. The N2O maps on potential temperature of 800K for 10 days before 28 Feb. (not shown here) show large variations and the standard deviation of the ozone inside the vortex (not shown here) is large for the period of the vortex separation. Probably the horizontal mixing causes the difference. The other major difference on 31 March below 550K is approximately 0.3 ppmv. It is likely that the air near the vortex edge moderates the loss of ozone using the EQL criteria. However the losses derived with two criteria agree with each other within 10%.

We will replace figure 9 in the manuscript to the loss profiles shown in this supplement and modify the text.

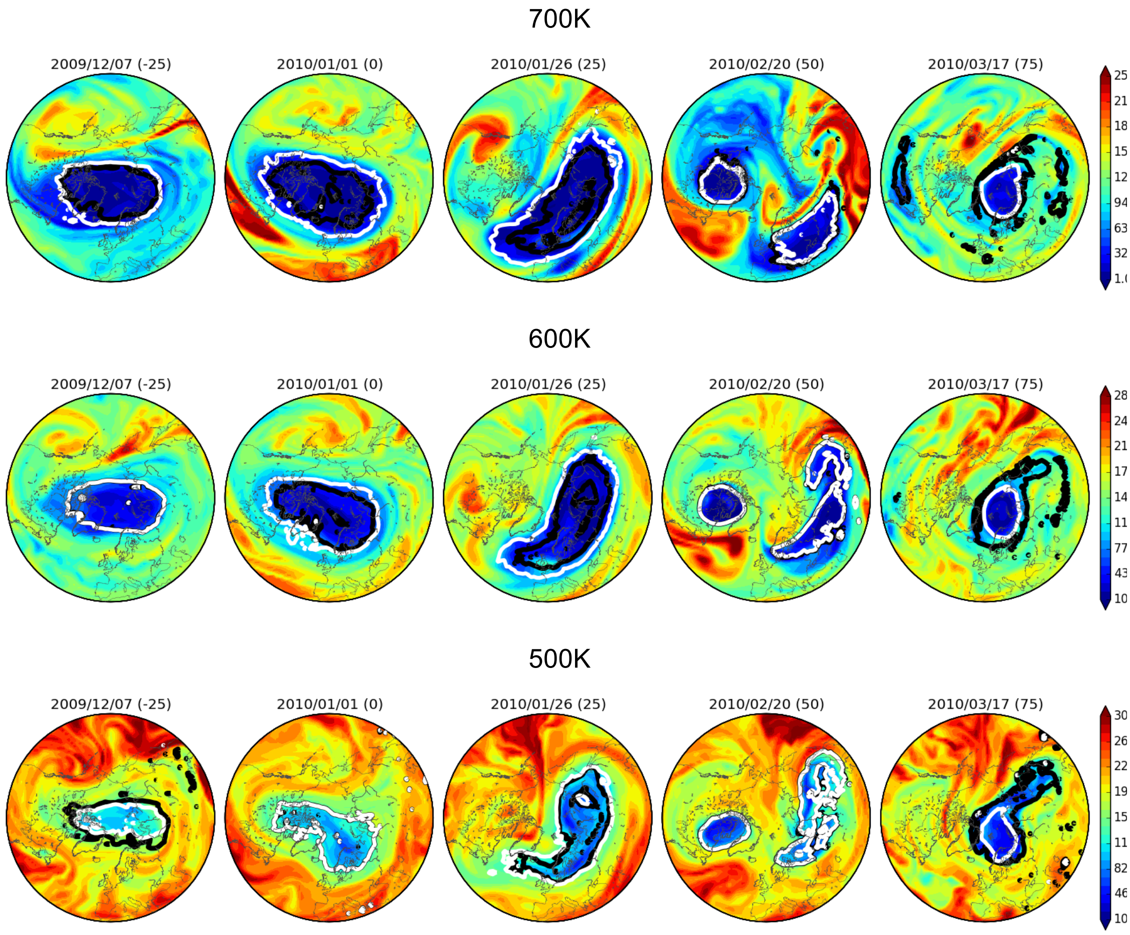

Figure 1. Assimilated N2O maps for selected dates and potential temperatures. Black and white solid lines show the equivalent latitude of 70^{O}N and the Lait's potential vorticity of $3.8*10^{-5}$ $Km^2kg^{-1}s^{-1}deg^{-1}$, respectively.

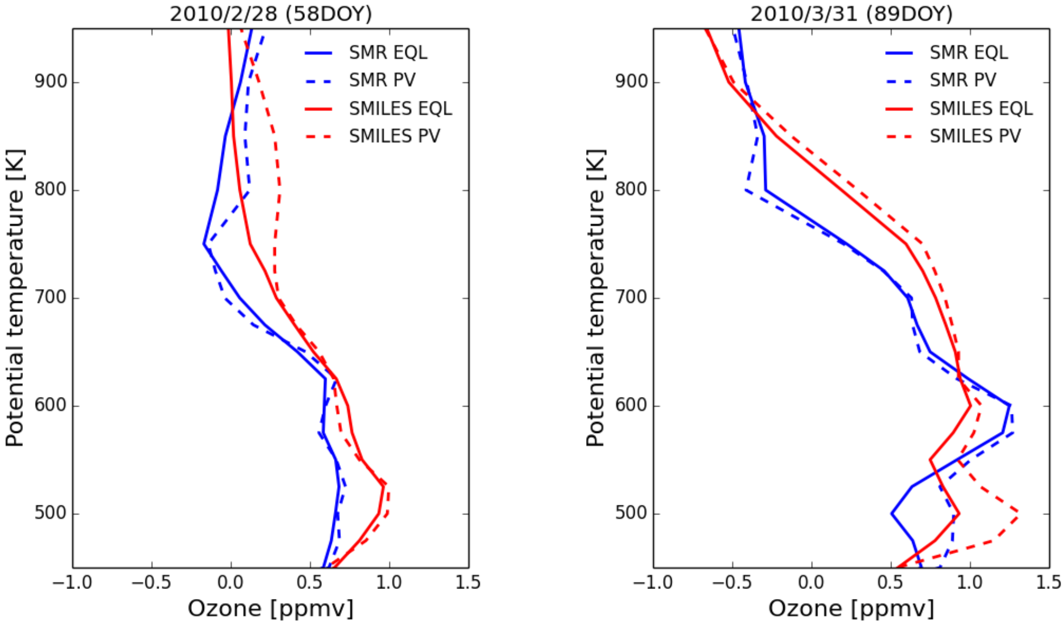

Figure 2. Vertical profiles of accumulated loss on selected dates (58DOY and 89DOY). Red and blue colors indicate the result derived from SMILES and Odin/SMR measurements, respectively. Solid lines show the results obtained with the EQL criterion and dashed lines are for the PV criterion.