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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Chemical ozone loss in Arctic and Antarctic polar winter/spring season derived from SCIAMACHY limb measurements 2002–2009" *by* T. Sonkaew et al.

Anonymous Referee #2

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1) General comments

a) Scientific significance: good

The manuscript describes inter-annual variability of ozone loss occurring during winter and spring in the polar lower stratosphere of both hemispheres. The analysis is based on a 7-year ozone data set of the space-borne SCIAMACHY instrument on Envisat. This work, together with other related studies based on different instrumental techniques and analysis methods, has the potential to contribute to a better understanding of the inter-annual variability of chemical ozone loss, notably in the meteorologically very variable Arctic lower stratosphere.

b) Scientific quality: fair

The study comprises an in-depth analysis of polar stratospheric ozone loss in both hemispheres as observed by SCIAMACHY. The methodology chosen by the authors, based on calculation of daily vortex average ozone fields, is in general justified. I have nevertheless three major and several specific points which needs to be addressed before the manuscript can be recommended for publication in ACP:

* The basic limitation of the SCIAMACHY data set is due to the fact that ozone measurements are taken only during day-time, thus not in the polar night region. The vortex fraction sampled by the instrument increases basically from winter solstice to spring, if the vortex is stable and centred around the pole as in the southern hemisphere. Although this basic limitation is well described in the manuscript (Figures 1 and 2), the consequences for the observed ozone loss are unfortunately not properly discussed in the relevant sections, notably when comparisons are made to results obtained from other observation techniques and analysis methods providing real vortex averages. For example, SCIAMACHY samples during August and January only the sun-lit part of the vortex, that is the region where ozone loss occurs. The observed ozone loss rates are however neither representative for the entire vortex nor are they vortex averages, and this needs to be properly addressed throughout the manuscript.

* There are several specific issues which require a further iteration of analysis (see specific comments below). For example, ozone loss estimates in the Antarctic vortex 2002 are fairly large already in August, in contrast to other published studies. Also, for the Arctic winter 2004 negative ozone loss values have been obtained. Explanations are basically missing. These issues, among others, should be resolved or properly discussed and explained in the manuscript.

* Comparisons of ozone loss results with earlier work needs to be more comprehensive if this work should be of any value. So far only one winter is discussed, and only a limited number of ozone loss studies are considered. Potentially, a relatively

long satellite data as the one presented here could provide a link between ozone loss estimates published earlier for individual winters based on a variety of observational techniques. I feel that this part of the manuscript needs a major effort to become more comprehensive.

c) Presentation Quality: fair

The paper is in general fairly well written. Specific technical recommendations concerning the manuscript text are given below (technical comments).

However, the figure labels and legends are far too small for most of the figures. I think the paper should have never passed the initial ACPD technical review stage (this is only partly an error of the authors) and recommend re-submission of a considerably revised version with improved figures in publication quality.

2) Specific comments

Fig 3 and 8: The figures show that fitting a straight line to the vortex average ozone evolution is clearly inappropriate and should be omitted.

Table 1 and 2: Consequently, I suggest to remove the linear fit results from the tables and figures, as ozone loss rates are not constant with time over the entire winter/spring period. Suggest to provide rather the accumulated ozone loss (in ppmv) in the tables, for carefully selected levels (keeping the 4.5km altitude resolution in mind). The variability of the ozone loss rates could instead be shown in the figures, if the data set provides this information with reasonable quality. Tables for NH and SH can be merged and the manuscript text (e.g. p6566, p6570) should be modified accordingly.

Fig 5: The negative values of ozone loss for the 2004 winter might indicate limitations of the employed method. Uncertainties need to be discussed in the text.

Fig 7: According to this figure, the largest ozone loss in the Antarctic is observed in 2002 (already 1ppm in August, 2.5ppm by mid-September). In particular, in 2002 and 2007 ozone loss seems to occur earlier than in the other years. This results is unex-

pected, if compared to published literature on the subject, and needs to be justified, if true. The authors are advised to double-check their calculations. So far, I couldn't find a discussion of this in the manuscript.

Fig 12: Very nice agreement with other studies, but only for a selection of data sets. I wonder how this would look if a more comprehensive analysis would be made, taken all published results for this winter into account. How consistent are the SCIAMACHY and other published ozone loss estimates for the different winters under consideration?

Introduction

l15-22: The classification of techniques (and list of references) provided here is certainly incomplete and needs to be improved. Also, the study of Singleton et al. (published in 2007) discusses only a selection of techniques. There are for example newer techniques, e.g. using data assimilation techniques, and different methods when it comes to correction for diabatic descend. It is suggested to widen the scope of the introduction by taking more recent publications on the subject into account.

As there are various slightly different methods calculating vortex averaged ozone loss it is suggested to (at least) replace "the vortex average method" by "a vortex average method" throughout the manuscript incl. the abstract. Moreover, multiple use of "vortex average method" in the manuscript is particularly irritating as SCIAMACHY actually doesn't provide vortex averages, but samples only the sun-lit part of the polar vortex. This can certainly be improved by using more appropriate wording throughout the manuscript.

Section 2

Can you indicate typical local times of the SCIAMACHY observations in the polar regions during the relevant periods?

How good agree SCIAMACHY ozone measurements in the polar regions with other observational data sets, are there any known errors or biases?

Section 3

p6563, l18-19 "evident": please explain why SCIAMACHY sampling is sufficient for studying ozone loss in the polar vortices using a vortex average method. This is not evident at all: SCIAMACHY doesn't sample the entire polar vortex during all times, hence vortex averages cannot be calculated. According to literature, ozone loss typically starts in January (NH) or August (SH) in the sun-lit, outer parts of the polar vortex. Please discuss sampling limitations of SCIAMACHY observations more carefully. The information is already nicely provided in Fig. 1 and Fig. 2, but the authors do not draw the obvious conclusions.

Section 4

It is not so relevant to describe the different employed software packages ("SODD", "FUDD"). I would rather suggest to focus on a step-by-step description of the adopted method for calculating chemical ozone loss. E.g.: How is the vortex defined? Are ozone profiles interpolated on potential temperature levels using UKMO data? How is the diabatic correction from equation (1) applied, to individual ozone profiles or vortex averages? What is the intra-vortex variability of this correction? Some information on the method for the diabatic transport correction is already given, but other information is provided elsewhere. Suggest to regroup relevant information and rewrite this section.

Section 4.1

p6565, l9-15: The choice of the reference date for the ozone loss calculation is indeed arbitrary. For comparisons with other studies it would be better to choose a more common reference, for example the average ozone during the first 10 days or two weeks of January (NH) and August (SH). Explain why the choice of the reference should only weakly affect the derived relative ozone losses, this is not evident.

l21-23: Can mixing (within the vortex or with air from outside) play a role here? The Arctic vortex split in early March 2005, associated to a warming event.

l24: Major warming events occurred also in 2006 and 2009. Why do you get negative values only in 2004?

p6566, l1-3: What exactly is subtracted (daily averages, individual profiles) to calculate chemical ozone loss? This could already be explained in Section 4 (see relevant comment above).

p6568, l1-9 and Fig7: SCIAMACHY sampling characteristics need to be included in the discussion of the observed variability.

l14-28 SCIAMACHY ozone loss rates shown in Fig 8 do not reflect vortex averages. The vortex average ozone loss rate would be considerably smaller in August than in September when more light is available for ozone destruction. Moreover, the vortex average ozone loss can not be expected to be linear and stated values for average or fitted ozone loss rates are therefore not very helpful. The discussion of ozone loss rates should be changed accordingly throughout the manuscript. The comparison with Hoppel et al. is odd if discussion of sampling characteristics is omitted. Does SCIAMACHY vortex sampling differ between the years, which might explain some of the observed inter-annual differences?

l28 OClO is not the best indicator for chlorine activation.

p6570, l6: SCIAMACHY measurements of PSC's in 2002 are apparently inconsistent with the large chemical ozone loss for this year. Can this be explained?

l18: Attribution to the low altitude resolution of SCIAMACHY: This is certainly one effect to be taken into account, leading potentially to smaller ozone loss, but other effects (e.g. spatio-temporal sampling) need also to be discussed.

Section 5

p6571: Check inconsistencies between Fig 10 and 11.

p6571-6572: A comparison with other studies should be more comprehensive. See

general remarks. E.g. for the NH 2005 winter there are published results from Manney et al., Jin et al., Singleton et al., Rosevall et al., Rex et al., etc.. I think a comprehensive literature research and comparative discussion of SCIAMACHY results for this and other winters would certainly help to improve this paper.

Section 6 and Fig 13:

Zonally averaged PSC occurrence rate at 40-65N? Again, sampling needs to be taken into account. Ideally, vortex average PSC occurrence should be related to vortex average ozone loss. The authors should further explain why they think their result (obtained for mid-latitude PSC occurrence) is relevant.

Conclusions

p6574, l24-26: Obvious contradiction - the ozone loss in the Antarctic vortex was not similar in each year. The conclusions are inconsistent with the Figures.

Given the large number of specific comments listed here, it is recommended that this section is rewritten once the manuscript has been revised.

3) Technical corrections

Figures 1,2,3, 5, 8, 10: Labels unreadable!

Figures 3 + 6: date.month should be "date"

Fig 7, caption: There are no "periods" indicated in Fig 6.

Check English in captions. Are data "daily" averages? Any smoothing applied (splines)?

Fig 4 and 9. What is shown here? Which level? What are the units? Colorbar is missing. Latitudes and longitudes should be indicated.

Fig 5 and 10: Reference dates for the ozone loss shown? Indicate in caption!

Fig 3, 6, 8, 11: Uncertainties of the measurements (error bars)?

Fig 14: Caption accumulated vortex average chemical ozone loss? For which period? PSC detections at 40-65N? I doubt there were PSC's at mid-latitudes, is this a typo?

p6557

Abstract

The abstract can be improved by providing relevant quantitative information on the inter-annual variability of observed ozone loss:

e.g. l11: (on Arctic) More quantitative: how much ozone loss was observed in the years with considerable ozone loss, and over which periods of time? How do these periods vary from year to year? How much ozone loss was observed in the other years, for comparison?

l17: (on Antarctic) "do not vary much" (how much?)

l19: what is an anomalous year? Reformulate!

l22-24: see specific comments on relevant section!

p6558

l4 dominates

p6559

l8 satellite

l16 remove "the"

p6560

l7 mid-mesosphere (?)

l14 "Stratozone" (?)

p6561

l3 latitude - longitude bin of ...x... ? (provide resolution, as used in this study)

l25 SCIAMACHY samples the vortex also in warm winters (reformulate)

p6562

l16 Winter 2008-09? (omitted)

l19 "..., and from the National..."

l23 What about the major stratospheric warming in winter 2003-04? (omitted)

p6563

l21 suggest to remove "Using the vortex average method,"

p6564

l23, eq (2): Explain Q and O3d

p6565

l6 Spline interpolation? Should be shown in the figure along with original data.

p6566

see specific comments

p6567

l11 remove "using the vortex average method"

l14 a simpler reference date in January would make comparisons with other data sets easier.

l15 describe situation in all winters more comprehensively (for example in comparison with findings of previous studies, see specific remarks)

l17-l24 belongs rather in the introduction (more comprehensive description of chlorine

induced ozone loss)

l24-29 Did SCIAMACHY observe PSC's above 20km?

p6568

l6-14: Provide motivation why you're deriving the total ozone mass loss. Isn't calculation of an average loss (in Dobson units) more common?

l10 "ozone mass loss for a certain isentrope range": Which isentrope range? How is the ozone mass loss derived for such an isentrope range? This needs some further explanation or rewording.

l25 Mixing of air inside and outside the vortex can also happen before March, this is highly variable between different years.

p6571

l16 remove " a vortex average method"

p6572

l2 remove "employed here"

Use of "ozone losses" / "ozone loss": check usage throughout paper.

Interactive comment on Atmos. Chem. Phys. Discuss., 11, 6555, 2011.