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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Chemical ozone loss in the Arctic winter 1991–1992" *by* S. Tilmes et al.

S. Tilmes et al.

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Response to Referee 2.

General Comment: We thank the referee very much for pointing out an important issue in this study, which gives us the possibility to clarify the text and to better support our findings with further analysis. We agree with the referee that the validation of HALOE observations was not discussed well in the paper as it stands at the moment. This will be improved in the revised version of the manuscript and material will be added as described below. Further, we will discuss the uncertainty of HALOE observations and give a comprehensive error analysis. These arguments support our finding that HALOE observations can be trusted in the considered region and season and that the deduced ozone losses are reliable.

Specific Comments: 1. The paper by Hervig et al., 1995, indeed only gives a preliminary discussion about the uncertainty of HALOE data due to the stratospheric aerosol

loading caused by the eruption of Mt. Pinatubo. We agree with the referee that Hervig et al., intended to give only a brief estimate of the uncertainty of trace gases measured by HALOE and that this paper cannot be considered a detailed validation study.

We will change this discussion in the revised version of the paper. Most importantly, we will add further information about the already performed extensive validation of HALOE observations and in the revised version of the manuscript. Bruehl et al., JGR, 1996, performed a detailed evaluation of HALOE, Version 17 of ozone profiles. They performed a "state of the art" validation of HALOE profiles as asked for by the referee. In the case of heavy aerosol loading HALOE data show differences to other data no more than 20 % in the lower stratosphere. ‘‘In the first year of data, large errors sometimes occur in the lower stratosphere due to the necessary correction for Pinatubo aerosol effect, but these differences do not exceed 20%". Although Bruehl et al. used an earlier HALOE version than the one we used (Version 19), the improvements made in the newer data version, should not deteriorate the quality of the aerosol correction. Major modifications were made between Version 17 and 18 and the Version 19 data. Version 19 data have a better accuracy for the retrieved species at altitudes below 70 hPa (J. Russells, personal communication).

2. In this paper, we cannot repeat the extensive validation effort already performed by Bruehl et al. and using the HALOE Version V19 instead. Rather, the goal is to show that HALOE ozone and methane data are reliable in comparison to other observations (aircraft, balloon, ozone sonde data) and can be trusted to derive reliable chemical ozone loss in the region of question. The major concern of the referee is that this was not demonstrated well enough so far. Therefore, to strengthen our arguments, we added a comparison between HALOE ozone observations and a comprehensive set of ozone sonde data in the Arctic polar vortex between January und March 1992 and add a new Figure to show the results, which can be viewed under: http://acd.ucar.edu/˜tilmes/index.html

This Figure shows a comparison between HALOE observations (diamonds), ER2 ob-

ACPD

7, S5983–S5989, 2007

servations (colored lines) and ozone sonde data in the Arctic vortex core, for January (top), February (middle) and March/April (bottom). The averaged ozone sonde profile is shown as a grey solid line with a standard deviation shaded in grey and maximum and minimum mixing ratios as dotted lines.

The referee is concerned about the comparison of profiles taken at not matching days and locations. Of course, due to the variability of ozone mixing ratios for different locations and seasons, this argument is strong if considering situations outside the vortex. However, the polar vortex can be assumed to be largely isolated from air outside the vortex. Using an established criterion by Nash 1996 to localize vortex profiles, ozone sonde data taken within the polar vortex indeed show a rather homogeneous distribution with a standard deviation between 0.1 and 0.2 ppm for January and March and up to 0.34 ppm in February (as discussed in the revised version of manuscript and in the new Figure 2, grey shaded area). On the other hand, profiles that are located closely together but are separated by the polar jet show significant difference in mixing ratios (not shown).

We average ozone sonde data taken for each of the three months inside the polar vortex and calculate an averaged ozone sonde profile and its standard deviation. This is compared with available HALOE and ER2 aircraft ozone profiles inside the polar vortex. This profile, the standard deviation of the averaged ozone sonde profiles and extreme values are shown in the new Figure, shaded area. For both, January and February, one HALOE profile is available in the vortex. The January profile is located close the polar vortex edge. For January and February, HALOE profiles are slightly lower compared to the range of standard deviation of the average ozone sonde profile of all data in the polar vortex in of most of the considered altitude range. Ozone mixing ratios are lower than the average ozone sonde profile especially between 400 and 450 K up to 0.4 ppm ozone mixing ratios around 420 K, however still in the range of minimum observed ozone sonde data. Between 350 and 400 K, a region where the HALOE ozone profiles were most strongly influenced by high aerosol loading, February

ACPD
7, S5983–S5989, 2007

EGU

profiles agree well with ozone sonde data and deviate by less than 0.2 ppm from the mean ozone sonde profile. ER2 observations agree well with ozone sonde data. For March and the beginning of April, HALOE observations are in agreement with ozone sonde data within the range of observed ozone sonde profiles. As in February, HALOE observations are slightly lower, on average between 0.2 and 0.3 ppm between 380 and 500 K, with less deviation towards lower latitudes.

This figure clearly demonstrates that: "In summary, HALOE ozone measurements are within the range of the ozone sonde measurements in the polar vortex and show deviation of less than 0.2 ppm ozone mixing ratios below 400 K. This analysis supports our conclusions that HALOE ozone observations are reliable in the Arctic polar vortex and ozone loss can be derived from this data set. The influence of the uncertainly of 0.25 ppm on derived chemical ozone loss is discussed below." (Revised version of the manuscript.)

The original Figure 2 of the paper was intended to discuss the location of available ozone and methane observations and not to validate the data. We will change the sentence P10108, L11 in the revised version of the manuscript to: "ER-2 ozone mixing ratios (Fig.3 panel d) are slightly larger in February compared to HALOE observations for the same potential temperature level. This can be a result of a different sampling of air masses in the vortex, because HALOE ozone observations in February are in the range of ozone sonde data observed in the vortex core, as discussed above (see Fig.1, panel b)."

Profiles that are influence by air form outside the vortex show a different characteristic than observations inside the polar vortex. To clarify the discussion, we modify the original Figure 2 and separated different panels by different months considered: http://acd.ucar.edu/~tilmes/acpd-2007-0163-f02.gif

P10107, L 28: The balloon profile taken on 5 March does not show significant deviations form the reference profile for altitudes below 500 K. (We will add the altitude in-

ACPD

7, S5983–S5989, 2007

formation in the revised version of the manuscript). Here, it will be noted again that the reference profiles is described by the profiles observed in December (red and black). In the revised version of the text we will explain that a deviation from the reference CH4 profile can be identified as descended air masses. The agreement of the balloon profile on 5 March and the reference profiles, below 500 K, indicates that this balloon profile measures air masses from outside the vortex where descent did not occur. Therefore, the air mass observed by the profile below 500 K is characterized by air from outside the vortex and are not comparable to observations inside the polar vortex, as also discussed by Schmidt et al., 1994, and Bauer et al., 1994. The referee is right to find large discrepancies, because ozone measurements outside the vortex are not comparable to measurement inside the polar vortex. We will clarify this issue in the revised version of the text.

The analysis in Figure 2 describes the characteristics of observed air masses. The reviewer is right that speculations are not necessary. We will change these sentences to clear statements based on our analysis in Figure 2 in the revised version of the manuscript:

Further, we have improved the readability of the figures in question, have added a new figure focusing on ozone measurements and quantify the differences between HALOE and sonde measurements in the text (see discussion above). To our knowledge a V20 is planned for HALOE but not expected to be released in the foreseeable future. Additionally, vertical profiles of differences between HALOE observations and correlative measurements are shown in Bruehl et al., 1996, a paper that we refer to now.

3. Figure 5 a) and the corresponding text was not very clear in the original form of the paper, which resulted in a misunderstanding of the text by the reviewer. We thank the reviewer for his/her concern to clarify the text and Figure. First, we will change Figure 5, a) and include all profiles taken on December 5 and 12, 1991, that were used to calculate the early winter reference function, and that were not included before. Indeed, the early winter reference function was derived based on 25 data points instead of 14.

ACPD

7, S5983–S5989, 2007

Further, in a revised version of this figure, we will indicate the location of each data point with a colored signature. The observations taken inside the polar vortex core are shown in green, in the entire vortex in red, and in the outer part of the vortex boundary region in black. This will clarify the location of the data points. The uncertainly is calculated by the sigma value of the derived fit through all 25 data points. Even though the profiles were not located in the vortex core for most of the points below 2 ppm ozone, they agree well with the few points observed within the vortex core and the entire vortex. The fit is an empirical derived fit with a constant sigma value. The uncertainly of the conversion from n2o to ch4 is about 50 ppb and will be considered in deriving the uncertainty of chemical ozone loss. We will add the following sentence to the manuscript: "The uncertainty of the CH4/N2O tracer relation is sigma ˜50 ppbv and will be included in the error estimation of chemical ozone loss derived below." Note, the individual parameters of the empirical fit have no meaning themselves (there is no a-priori reason for a quadratic or cubic fit other than the quality of the description of the measurements); therefore attributing individual error estimates to the parameters is not meaningful.

As noted above, we will also discuss the uncertainty of 0.25 ppm of the HALOE observations in spring, based on this deviation form the averaged ozone sonde profiles, to perform a more detailed error analysis. We further add information of the standard deviation of the ozone loss results.

We further modified the original Figure 5 and 6 and separated results of different months in different panels to make them easier to understand.

In Section 6.3 we will add: "All derived ozone loss values have an uncertainty of up to +/- 11 DU. This estimated uncertainty is derived from the combination of the uncertainty of he early winter reference function used, the uncertainly of a N2O to CH4 conversion of balloon observations in the early winter and an uncertainty of HALOE ozone observations in comparison to ozone sonde data in spring of about 0.25 ppmv. The standard deviation of ozone loss is 27 DU in March and 18 DU in April, between

ACPD

7, S5983–S5989, 2007

380 and 550 K, and 21 DU in March and 10 DU in April, between 400 and 500 K potential temperature."

Minor specific comments: P 10100/ L19-22: We considered all relevant balloon and aircraft profiles that measured ozone and ch4 or n2o data to apply the tracer-tracer correlations. But as described above, in the revised version of the manuscript we will add a comparison between HALOE ozone and ozone sonde data.

P 10104/L5-7: For balloon observations we used n2o observations. For aircraft observations we used both ch4 and n2o observations. This was already described in the original manuscript: see p 10103: l 22 and l 24.

P 10105/ L4-5 and 10108 L14/16 We add in the revised version of the manuscript that descent results in increasing ozone and decreasing CH4 mixing ratios below about 600 K, the region important for chemical ozone loss due to catalytic ozone destruction.

Discussion about 14 January HALOE profile: The HALOE profile was actually measured 19 January, and not 14 January, we corrected this mistake. We changed all figures in the revised version of the paper correspondingly.

Technical corrections will be added in the revised version of the manuscript. Figure 2 b: we will add the missing points Figure 4: We will change Kiruna to be not highlighted. Further, the figure caption will be corrected. Available HALOE observations are shown, to indicate the coverage of the day, shown. We will delete the March plots in this Figure and describe the findings in the text.

Interactive comment on Atmos. Chem. Phys. Discuss., 7, 10097, 2007.

ACPD

7, S5983–S5989, 2007

Interactive Comment