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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Increased UV radiation due to polar ozone chemical depletion and vortex occurrences at southern sub-polar latitudes in the period (1997–2005)" *by* A. F. Pazmino et al.

A. F. Pazmino et al.

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Dear Reviewer,

Thank you for the useful and constructive comments. Here are our answers to your comments:

1) Why did the authors consider a zonal mean climatology for their baseline? Why not use a spatial (lat-lon) climatology? Over the SH the stratosphere and the ozone layer have a distinct asymmetry determined by the presence of the quasi stationary wave 1. Furthermore, as noted in Malanca et al. (2005), this important aspect of mid to high latitude TOC has changed over time both in intensity and longitudinal location, affecting the baseline needed for the instrusion analysis. As these authors noted the evolution

of the midlatitude TOC depends also on season, June and October showing different trends. Would it not have been better to consider such TOC climatology for the analysis? The authors are encouraged to consider and discuss this issue in the analysis in order to consolidate their conclusions. Also, why use only the moving average for TOC and not UV?.

We agree with your comment. Longitudinal asymmetry in ozone fields are now taken into account. We have thus computed a 1°x1° latitude-longitude ozone climatology of situations outside of the vortex from TOMS and ATOLL model, which is used in the new version of the manuscript. However, the results and conclusions are generally very close to the initial ones: the mean TOC differences are mostly similar with differences on the order of 1-3% while the mean POC differences show somewhat lower changes with differences ranging from 3-7% in absolute value (see new Tables 1a and 1b, respectively). For section 6 "Combined effect of cloud cover and vortex occurrences on UV radiation", the main difference is observed in September for the region 3 (Australia and New Zealand) with higher values of regional average ozone change (27.5% instead of 22.7%). Nevertheless, the main conclusion considering the region 1 (South of America continent) as the area the most affected in a cloudiness decrease scenario still holds (see new Table 2) (not only in the cloudiness decrease scenario) The new ozone climatology is explained in section 2.1. In page 6507, line 12 we have replaced the sentence: "The TOC outside vortex climatology ... A moving average ... values" by "The TOC outside vortex monthly climatology is computed with a resolution of 1°x1°. A climatology varying with latitude and longitude was chosen in order to reflect TOC climatological changes as a function of longitude as noted in Malanca et al. (2005). A monthly average is performed in order to take into account the dependence of TOC with season and to avoid the weak number of situations outside of the vortex for the higher latitudes" The following Malanca et al. reference was added. Malanca, F.E., Canziani, P.O., and Argüello, G.A.: Trends evolution of ozone change between 1980 and 2000 at mid-latitudes over the Southern Hemisphere: Decadal differences in trends, J. Geophys. Res., 110, D05102, doi: 10.1029/2004JD004977, 2005.

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Note that we do not use a moving average and polynomial fit for the ozone climatology. The monthly average of TOC at each 1°x1° is computed for the 1997-2005 period.

2) To what extent the presence of snow cover in Tierra del Fuego and southern Patagonia, whose sparsely vegetated soil, particularly in winter, could also have a high reflectivity, may have affected the choice of clear-sky days during polar vortex intrusions, limiting the size of the sample?

The following sentences were added in page 6515, line 21 to clarify this issue: Given that snow-covered surface over the southernmost region of South-America is still frequent during spring, and the fact that TOMS algorithm overestimates the actual cloud cover in cases of high reflectivity (e.g. Herman et al., 1999), it is possible that some clear-sky days over the continent were wrongly missed in our analysis. Nevertheless, the number of such data should be very small, as on average less than 5% of the time the sky has less than 10% cloud cover along this region during September, October and November, and the average surface UV albedo is lower than 40% (Luccini et al., 2006).

The following references were added: Herman, J.R., Krotkov, N., Celarier, E., Larko, D., Labow, G.: The distribution of UV radiation at the Earth's surface from TOMS measured UV-backscattered radiances. J Geophys Res 104: 12059-12076, 1999. Luccini, E., Cede, A., Piacentini, R., Villanueva, C., and Canziani, P.: Ultraviolet climatology over Argentina, J. Geophys. Res., 111, D17312, doi: 10.1029/2005JD006580, 2006.

3) Why use LIMS HNO3 rather than more recent UARS retrievals?

We have introduced a more recent HNO3 profile from AURA MLS v2.2 (Santee et al., 2007) to ATOLL model in order to compare it with the LIMS HNO3 used in our study. The HNO3 profile corresponds to the zonal mean values averaged in the 60°S to 90°S latitude band for all seasons (Fig. 22 of Santee et al., 2007). The HNO3 profile is used in the model to compute the cold tracer representing the presence of PSC. In order to evaluate the effect of HNO3 profile in ATOLL simulations, the volume of PSC

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(VPSC) was computed with the old and new profile of HNO3 in the ATOLL model. Then, the simulation used in the manuscript presents an overestimation of VPSC of 4% in average as compared with the simulation using Santee et al. HNO3 profile in the 1997-2005 period, which has a negligible impact on ozone loss in the studied period. Furthermore, the heterogeneous ozone loss was adjusted to reproduce correctly the ozone evolution at various stations (see section 2.2.2). Santee, M. L., Lambert, A., Read, W. G., Livesey, N. J., Cofield, R. E., Cuddy, D. T., Daffer, W. H., Drouin, B. J., Froidevaux, L., Fuller, R. A., Jarnot, R. F., Knosp, B. W., Manney, G. L., Perun, V. S., Snyder, W. V., Stek, P. C., Thurstans, R. P., Wagner, P. A., Waters, J. W., Muscari, G., de Zafra, R. L., Dibb, J. E., Fahey, D. W., Popp, P. J., Marcy, T. P., Jucks, K. W., Toon, G. C., Stachnik, R. A., Bernath, P. F., Boone, C. D., Walker, K. A., Urban, J., and Murtagh, D.:Validation of the Aura Microwave Sounder HNO3 measurements, J. Geophys. Res., 112, D24S40, doi: 10.1029/2007JD008721, 2007.

4) Your comments regarding the Marambio and Lauder stations when compared with the ATOLL model outputs are interesting. On the one hand the fact that the model is able to reproduce the complex behaviour of ozone near the vortex edge is an important aspect of the model validation, which should be stressed. On the other hand, it is important to note that ozone at Lauder does not show significant depletion trends and that ozone variability there is primarily determined by the midlatitude dynamic variability.

We agree with both your comments. Concerning the first comment, in order to stress the good agreement, we have replaced the following sentences in page 6512, line 19: "ATOLL reproduces generally well the ozone destruction at MAR and the large ozone variability linked to the location of the station at the edge of the vortex is well followed by the simulation." by "ATOLL reproduces generally well the ozone evolution observed by ozonesondes at Marambio, which sample air masses inside and outside. The good agreement highlights the ability of the model to reproduce the complex behavior of ozone near the vortex edge."

For Lauder, we agree that ozone amounts are much less affected by chemical ozone

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loss compared to e.g. Marambio. Nevertheless, this loss can still be detected from the difference between the red and green curves (see Fig. 2) representing the ATOLL ozone and ATOLL homogeneous chemistry tracers. The following sentence was added in page 6512 line 23: The ATOLL simulations shows that the ozone amounts at Lauder are much less affected by chemical ozone loss compared to e.g. Marambio, but the difference between ATOLL ozone (red curve) and ATOLL hom. Ozone (green curve) is clearly visible on the Figure. It reaches 0.5 ppm or more at 475 K.

5) The longitudinal analysis in section 3 is very relevant. Inspection of the figure shows a certain degree of longitudinal variability in peak occurrence from year to year. It would be of interest to compare this variability with the variability in the position of the quasi-stationary wave 1 discussed in Malanca et al. (2005) at least for the years where the samples overlap.

It is a good suggestion but our study is mostly focused on the analysis of the effect of polar chemical ozone loss on average ozone and UV levels in the southern mid-latitudes. As it can be seen in Table 1b, the effect of ozone loss due to heterogeneous chemistry is dominant as compared to the homogeneous chemistry and the dynamical variability in the September-November period.

6) In section 5 again the zonal mean approach is considered. Please refer here too to the comparison with a spatial climatology.

In page 6517, line 22 we have replaced: "The climatology is determined for situations outside the vortex and the values are zonally averaged." by "The monthly climatology is determined for situations outside the vortex with a spatial resolution of 1°´1° in latitude and longitude."

7) Figure 6 is a bit hard to visualize due to the small size of the maps. Would it be possible to device an improved visualization without significantly increasing the size of the figure?

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The size of figure was determined by ACPD Production to have Fig. 6 and its legend in only one page. We have seen that the height limited the size. But in order to have a somewhat more visible figure, the color bars were put on the right of each figure.

8) In the discussion of preferred locations for vortex intrusions at midlatitudes reference should be made of the following paper: Moustaoui, M., H. Teitelbaum, and F.P.J. Valero (2003), Vertical Displacements Induced by Quasi-Stationary Waves in the Southern Hemisphere Stratosphere during Spring, Quart. J. Roy. Met. Soc., 131, 2279-2289. This paper includes a relevant dynamic analysis of the issue. This paper has also a very relevant discussion on the behaviour of quasi-stationary wave 1 which may be of interest to the authors. Furthermore, the following paper has discussed where the Antartic ozone loss has large impacts at southern mid to high latitudes: Ajtic;, J., B. J. Connor, B. N. Lawrence, G. E. Bodeker, K. W. Hoppel, J. E. Rosenfield, and D. N. Heuff (2004), Dilution of the Antarctic ozone hole into southern midlatitudes, 1998-2000, J. Geophys. Res., 109, D17107, doi:10.1029/2003JD004500.

Other studies on this issue were referenced in the introduction, but as recommended Moustaoui et al. and Ajtic et al. references are added in page 6514 at the end of section 3. The following sentence was included: Other studies have analyzed the preferred regions of vortex displacements. The work of Moustaoui et al. (2003) has shown that regions over South America are preferred for wave breaking linked to the behavior of quasi- stationary wave 1 using a mean relative deviation between reconstructed PV from high resolution simulation and PV obtained from reanalysis. The waves induce upward displacements that produce polar-vortex-edge dilatation over those regions. Ajtic et al. (2004) have discussed where the Antarctic ozone depletion has the largest impact in the southern mid-latitude regions during the dilution of the ozone hole. They have shown that the impact is most pronounced in the regions encompassing South America and Africa (see Table 2 of Ajtic et al. for 15 October-14 November period).

Ajtic J., Connor, B. J., Lawrence, B. N., Bodeker, G. E., Hoppel, K. W., Rosenfield, J. E., and Heuff, D.,N.: Dilution of the Antarctic ozone hole into southern midlatitudes,

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1998-2000. J. Geophys. Res., 109, D17107, doi: 10.1029/2003JD004500, 2004. Moustaoui, M., Teitelbaum, H., and Valero, F.P.J.: Vertical Displacements Induced by Quasi-Stationary Waves in the Southern Hemisphere Stratosphere during Spring, Mon. Weather Rev., 131, 2279-2289, 2003.

9) What is the basis for a possible decrease in cloudiness in the future? According to models run under the IPCC scenarios (IPCC, 2007), in particular regional model downscaling, the stormtracks will probably move south increasing precipitation in southern Patagonia and Tierra del Fuego. This on the contrary could imply more cloud cover in the region, particularly during winter and probably also during spring. What will happen with cloud cover there is a matter of speculation. Thus the valid speculation on cloud cover and hence surface UV changes ought to be presented with a strong caveat.

As the reviewer indicates, presenting the UV and TOC changes in a more realistic scenario of future cloud-cover conditions using simulation made in the frame of IPCC would be interesting. Nevertheless, our objective was to identify the most vulnerable regions to a cloud cover decrease scenario prior to the recovery of the ozone layer. Indeed, we were interested to decorralate both effects: total ozone loss due to polar chemistry and cloud cover. Furthermore, regional model simulations are still not very accurate so future evolution of cloud cover in the southern mid-latitude regions is still very speculative. Nevertheless, the following sentence was added in page 6519, line 19:

It should be noted that according to regional models run under the IPCC scenarios (IPCC, 2007), the stormtracks should move South, increasing precipitation in southern Patagonia and Tierra del Fuego. The same IPCC report presents results that show a decrease in precipitation (so it is expected a decrease in cloud cover) in the middle western part of Patagonia. Cloud-cover changes in the future will be different depending on the region. Our study is thus only speculative. The objective was to identify the most vulnerable regions in case the cloud cover would decrease in the southern mid-latitude regions prior to the recovery of the ozone layer.

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IPCC (Intergovernmental Panel on Climate Change), IPCC Fourth Assessment Report: Climate Change 2007, Geneva, Switzerland, 2007.

And in page 6523, line 13 (section 7): Note that our results represent a simple case of cloudiness decrease in regions in the southern hemisphere. More realistic scenarios could be taken into account for each particular region.

Minor comments

We agree with all referee minor comments. Recommended changes have been made in the new version.

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 6501, 2008.

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