Atmos. Chem. Phys. Discuss., 5, S3191–S3198, 2005
www.atmos-chem-phys.org/acpd/5/S3191/
European Geosciences Union

Atmospheric Chemistry and Physics Discussions

Interactive comment on "The mean meridional circulation and midlatitude ozone buildup" *by* G. Nikulin and A. Karpechko

G. Nikulin and A. Karpechko

Received and published: 13 October 2005

We thank both referees for their helpful comments and suggestions for improving the paper.

Response to Referee #1

General comments

Referee #1 suggests that the abstract and the "Summary and Discussion'' Section should be stand out of the detailed analysis and more focused on two major results: 1) the local onset of the buildup over the North Pacific in October and 2) eddy heat flux at other pressure levels than 100 hPa as well as other quantities that are associated with the mean meridional circulation can improve correlation with ozone tendency.

We agree with referee #1 and have corrected the abstract and Section 7 “Summary and Discussion’’ focusing on the major results and avoiding the detailed analysis.

Specific comments

p. 4224, line 2: corrected

p. 4225, line 29: *It is not clear here what is meant with “calculations’’ here, I guess the author were thinking of “dynamical models’’ or “models’’ that describes this better.*

In this sentence under “calculations’’ we meant calculations of the residual circulation from different data sources (no “dynamical models’’ or “models’’). To make the sentence clear we have changed it to “Despite large uncertainties in the estimations (Eluszkiewich et al., 1996, 1997), there is a broad agreement between the residual circulations obtained from different data sources as well as between the circulations and theoretical expectations.’’

p. 4226, line 19: corrected

p. 4226, line 24: a link and reference to the TOMS/SBUV merged data set have been added.

p. 4228, lines 12-13: *The authors mention here larger uncertainties in the residual velocities under conditions close to radiative equilibrium. The authors should clarify and say if these data are still be used or do they have to exclude them. They should avoid the use of “questionable results’’ and rather talk about “larger uncertainties’’.*

Since there is no method to estimate quantitative uncertainties in the diabatically-derived residual velocities we use the calculated circulation as it is. Necessary explanations have been added in Section 2 “Data and method’’. Also the use of “questionable results’’ is avoided in the revised paper.

p. 4228, line 18: corrected

p. 4228, line 20: corrected

ACPD

5, S3191–S3198, 2005

p. 4228, line 25: corrected

p. 4230, line 1: corrected

p. 4231, line 5: *There were five occurrences of vortex break up (or final warmings) in March between 1980-2002. Does that mean that the vortex break-up is most frequently occurring in April. If yes, that information should be given here. What defines a vortex breakup?*

Yes, for the studied period (1980-2002) the vortex breakup most frequently occurred in April (14 times), seven times in March and twice in May. The vortex breakup is defined as the date when the maximum wind speed averaged around the vortex edge drops below 15.2 m/s, following the method of Nash et al. (1996). The definition and full statistics of the vortex breakup for the 1980-2002 period have been added. Also there was a misprint concerning the number of the breakup occurrences in March. The number is seven, not five as it was in the submitted paper (corrected).

p. 4234, line 20: corrected

p. 4236, line 20: corrected

p. 4237, line 3: corrected

p.4238, lines 22-26: The description of the iterative procedure has been moved to Section 2 “Data and method’’.

p. 4241, line 4-8: *The authors state that the correlation between December ozone tendency (50-60N) and eddy heat flux as well as the vertical residual velocity is somewhat lower than in other winter months. One possible explanation could be that total ozone measured from UV viewing satellites (TOMS, SBUV, and GOME) under high solar zenith angle condition can have larger errors and this may affect ozone tendency for that month. However, this is also true for January.*

Perhaps there is some misunderstanding here. We state that in December temperature

ACPD

5, S3191–S3198, 2005

tendency and eddy heat flux have weaker correlation (r_{max}=0.45) with ozone tendency while the vertical residual velocity shows correlation with ozone tendency ($|r|_{max}$ =0.7) which is similar to that in other months. If total ozone measured under high solar zenith angles have larger errors in December that should be mirrored in weaker correlations with all parameters. However the correlation between the vertical residual velocity and ozone tendency is stable during winter. In the revised paper we examine correlation between the residual streamfunction and ozone tendency (suggested by referee #2). The obtained correlations are also stable during winter as for the vertical residual velocities.

We have changed “maximal’’ to “maximum’’ and “optimal’’ to “optimum’’ in the revised paper.

Response to Referee #2

General comments

The article is well presented and well written. However it sometimes lacks a precise definition of the parameters studied and how they are calculated. The article is heavily based on the computation of correlation between various parameters. It is rather lengthy and clear conclusions on the results obtained together with a physical explanation of the correlations obtained are sometimes lacking.

We have corrected several places (mainly according to Detailed comments) giving definitions of the parameters and clearer physical explanations of the correlation obtained.

Detailed comments

2. Data and method

p. 4228, line 10: *The sentence here is not clear enough. What do the mean by the period depends on total ozone distribution.*

We have removed this sentence from the revised paper.

p. 4228, line 15: *The iterative computation of the residual circulation should be ex-*

ACPD

5, S3191–S3198, 2005

plained here.

Explanations of the iterative computation procedure have been moved here from Section 6 “The residual circulation and ozone tendencies’’.

p. 4228, line 12: *What do the authors mean by “really questionable’’? What is the amplitude of the uncertainty?*

Eluszkiewicz et al. (1997), examining differences between the residual circulations obtained from different data sources concluded that at present the residual circulation is still fraught with large uncertainties mainly due to uncertainties in heating rates. In addition we have showed that uncertainties in the residual circulation can be larger in regions close to radiative equilibrium. However we can not estimate quantitative uncertainties in the diabatically-derived residual velocities because there is no method to do so. Necessary explanations have been added in Section 2 “Data and method’’. Also the use of “questionable results’’ is avoided in the revised paper.

3. Ozone tendencies

p 4229, line 14: The confidence level in Table 1 is estimated by the Students’s t-tests. We have added an explanation in Table 1.

4. Heat flux and ozone tendencies

p. 4231, line 14: We have added a definition of eddy heat flux and how it is computed in Section 2 “Data and method’’.

The correlation patterns in Figure 3 seem to follow roughly the location of the edge of the polar vortex where the eddy heat flux should be maximum. Do the authors have an explanation for this? Also it is interesting to note that the high correlation patterns persist up to 3 hPa.

This is a very helpful comment in order to clarify the position of the high correlation patterns between eddy heat flux and ozone tendencies. On Fig. 3 we have superimposed

ACPD

5, S3191–S3198, 2005

zonal mean zonal wind whose maximum values can approximately represent the edge of the polar vortex and found that the high correlation patterns are located either equatorward (October, November, January) or poleward (December, February) of the edge of the polar vortex. High correlations persist up to 3 hPa in the equatorward position while they are limited to the lower stratosphere in the poleward position. We suggest that such distribution of the high correlation patterns may be related to the existence of either the midlatitude or polar waveguides for upward propagating waves from the troposphere. These new findings have been included in Section 4 “Heat flux and ozone tendencies’’

What is the point of using HF at 10 hPa instead of 100 hPa as is usually done?

Perhaps there is some misunderstanding here since in the paper we have not suggested using eddy heat flux at 10 hPa instead of 100 hPa. In order to optimise HF as a proxy for a statistical model, it is necessary to examine, at first, where on the latitude-altitude cross section the strongest correlation between HF and ozone occurs.

5. Heat fluxes and the residual circulation

Since it is widely accepted that the heat flux should correlate with the parameters of the residual circulation such as w, v* and dT/dt, the authors should emphasize what are the new results there and focus the paragraph more on these results.*

Though it is widely accepted that the heat flux should correlate with the strength of the residual circulation, it is not a fact that the heat flux should correlate well with the diabatically-derived residual velocities assuming large uncertainties in the estimated w* and v*. In Section 5 we have shown that there is a good agreement with the expected response of the diabatically-derived residual circulation to wave forcing in the middle and upper tropical stratosphere as well as in the polar winter stratosphere but not in the lower tropical stratosphere which is close to radiative equilibrium. Explanations have been added in the beginning of Section 5 “Heat fluxes and the residual circulation’’.

ACPD

5, S3191–S3198, 2005

Strong coupling between dT/dt and wave forcing has already been shown in several studies (e. g. Randel 1993; Salby and Callaghan, 2002) and we use dT/dt only to test a suggestion that the interannual variability of w* is not well captured in the lower tropical stratosphere because of larger uncertainties.

6. The residual circulation and ozone tendencies.

The discussion is somewhat fuzzy here and tentative physical explanation of the correlation patterns is needed. For example, what is the interest of using separately v and w* to evaluate the residual circulation. Wouldn't a stream function be more appropriate?*

The point of using v* and w* separately to evaluate the residual circulation is to answer the question: Which of vertical or horizontal advections by the residual circulation is preferable for describing interannual variability in ozone tendency? We have elucidated this point in the beginning of the section. As shown w*, gives better results. In the revised paper we also examine the correlation between the residual streamfunction and ozone tendencies. Using the residual streamfunction gives an identical result to that using w*.

What is the explanation for the large negative correlation pattern in the midlatitude in Figure 8c, which indicates that ozone at mid-latitudes is more influenced by vertical transport than polar ozone. Is there an explanation in the latitudinal gradient of ozone as a function of altitude?

Probably there is some misunderstanding here. Figure 8 presents one point correlation between ozone tendency (averaged over 50-60N) and w* at each grid point on the latitude-altitude cross section. So information about polar ozone as well as about the latitudinal gradient of ozone is not presented in Fig. 8.

7 Discussion

The authors should give here their conclusions on what is the best proxy for the study

ACPD

5, S3191–S3198, 2005

of ozone variability in the stratosphere.

In the revised paper we have concluded that w* or the residual streamfunction look referable to HF as proxies for total ozone in midlatitudes, since the correlation patterns and the maximum correlation coefficients between and w* or the streamfunction are stable throughout winter.

References

Eluszkiewicz, J., Crisp, D., Grainger, R. G.., Lambert, A., Roche, A. E., Kumer, J. B., and Mergenthaler, J. L.: Sensitivity of the residual circulation diagnosed from the UARS data to the uncertainties in the input fields and to the inclusion of aerosols, J. Atmos. Sci., 54, 1739-1757, 1997.

Nash, E. R., Newman P. A., Rosenfield J. E., and Schoeberl, M. R.: An objective determination of the polar vortex using Ertel's potential vorticity, J. Geophys. Res., 101, 9471-9478, 1996.

Randel, W. J.: Global variation of zonal mean ozone during stratospheric warming events, J. Atmos. Sci., 50, 3308-3321, 1993.

Salby, M. L. and Callaghan, P. F.: Interannual changes of the stratospheric circulation: relationship to ozone and tropospheric structure, J. Climate, 15, 36738211;3685, 2002.

Interactive comment on Atmos. Chem. Phys. Discuss., 5, 4223, 2005.