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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Results from a new linear O_3 scheme with embedded heterogeneous chemistry compared with the parent full-chemistry 3-D CTM" *by* B. M. Monge-Sanz et al.

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Response to Referee 2

We thank the referee for his/her review. The Referee's comments are repeated below (*in italics*) and our responses are given in **bold text**.

General Comments

In this paper a new approach for developing a fast, linearised stratospheric ozone chemistry scheme (COPCAT) is introduced. As with previous such schemes, a com-

prehensive chemistry scheme is used to calculate the coefficients for the fast scheme. However, whereas previous schemes restrict such calculations to gas phase chemistry, and ozone loss due to heterogeneous chemistry is represented by alternative means, here the calculated coefficients implicitly include heterogeneous chemistry. Therefore, there is a greater degree of self-consistency involved in this approach than in previous ones. In addition, results from COPCAT are compared with results calculated with the same CTM and with the comprehensive chemistry scheme used to calculate the coefficients. Therefore, any issues with different chemistry schemes or model formulation are eliminated, and the differences in results should only identify issues with the formulation of the new, fast chemistry scheme.

Most results for the COPCAT scheme are shown for 2000, which is the same year as that used to calculate the COPCAT coefficients. This indicates that COPCAT is functioning pretty much as defined. However, a major issue is that the applicability of the COPCAT scheme to years other than 2000 has not been adequately demonstrated. This calls into question the authors' claim that COPCAT can be applied to multi years (ie a reanalysis). It also casts doubt on whether the scheme can be effectively used in NWP applications.

Since the heterogeneous ozone loss will be determined by the distribution of temperature and ODS, it is hard to see how much the COPCAT scheme, and its implicit heterogeneous ozone loss, will be applicable to years other than 2000. Some attempt at answering this question is made in Section 4.3, but there are several issues that remain unanswered:

**Figures 5 and 10 show, in the northern polar latitudes, the curious result that COPCAT produces larger errors, compared to a run with full SLIMCAT chemistry, in cold winters (1997, 2000) than in a warm winter (2001). This is despite the fact that the COPCAT coefficients are calculated using data from 2000. One could hypothesise that, if a cold winter implies more heterogeneous ozone loss, then these results show that the COPCAT scheme struggles to represent the heterogeneous loss well. In any event,*

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the poorer performance in the colder winters needs to be further discussed.

The coefficients for the COPCAT parameterisation, like all the previous linear ozone schemes, were calculated for the 15^{th} of each month. And coefficients on the 15^{th} March/September do not provide realistic loss rates for the sunlight levels found later in the month in the polar regions. This becomes more evident during cold winters, when the air processing inside the vortex has been more pronounced.

To calculate the coefficients we used zonal mean output from the 3D full-chemistry model, and coefficients were provided for every altitude/latitude, as for previous existing versions. Therefore, as longitudinal variability is not correctly simulated, features at the edge of the polar vortex will be neglected. This will especially affect Arctic winters, as vortex breaking and filamentation events are more frequent than in the Antarctic.

Thus, the underestimation of polar loss by the parameterisation points to general limitations in this kind of linear schemes, compared to the performance of a full-chemistry model, more than to the lack of adaptability of the implicit heterogeneous chemistry in COPCAT, which over the Antarctic performs very well compared to the full-chemistry 3D CTM and observations.

In view of our comparison with the parent full-chemistry model, future improvements envisaged for this kind of linear schemes were suggested in the Summary section. Further discussion on the aspects related to this comment will be included in the final ACP paper.

** The comparison between the COPCAT and ECMWF Cariolle results is only shown for 2000, the year for which the COPCAT coefficients are calculated, and so in this comparison the odds are stacked in favour of COPCAT. Further comparisons of COPCAT and ECMWF Cariolle schemes need to be made for years other than 2000. This shall make the authors' claim that COPCAT works better than the ECMWF Cariolle scheme*

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much more robust.

Figures 11 and 12 show vertical profiles from both parameterisations (COPCAT and ECMWF Cariolle), along with the profiles from the full-chemistry run. Therefore, some comparison for years 1997 and 2001 is already included in the paper. We will expand on this and will also add a comparison for year 2002 in the final version.

** The performance of COPCAT in the southern polar latitudes was made for 2000 and also 2001, a year in which the meteorology is fairly similar to 2000. Therefore, one would expect the COPCAT scheme to produce similar results. A much more meaningful assessment of the performance of COPCAT would come from running the scheme for 2002, a year in which a major warming took place in the southern hemisphere.*

I recommend, therefore, that the following changes to the paper be made:

1. Compare ECMWF Cariolle and COPCAT results for 1997, 2001 and 2002, not just 2000.

Additional results for 2002 will be added. Further discussion for the other years will also be included in the final ACP paper.

2. Examine the performance of COPCAT at southern polar latitudes in 2002, as well as 2000 and 2001.

Results for 2002 at high southern latitudes will be shown and discussed in the final ACP paper.

3. Recalculate coefficients for a year other than 2000, and redo COPCAT runs for 1997, 2000, 2001, 2002, in order to understand the sensitivity of the COPCAT results to the year chosen for the calculation of the coefficients.

Coefficients calculated for year 2004 will be used to repeat the multiannual runs and a comparison with results obtained with coefficients for year 2000 will be

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shown in the final manuscript.

Incorporation of these changes will lead to a considerably enhanced assessment of whether the COPCAT scheme can be easily applied to reanalysis or NWP applications, or whether coefficients need to be continually calculated and updated, or indeed whether a more sophisticated representation of heterogeneous ozone loss than currently appears in COPCAT is needed. Without such changes, the paper is not suitable for publication.

Minor Comments

Introduction: The arrangement of the paragraphs in the Introduction leads to repetition and thus a loss of clarity. Currently, discussion of the current methods of including heterogeneous loss in parametrized chemistry schemes appears in paragraph 3 and again in paragraphs 5 and 6, and the approach adopted by COPCAT appears in paragraphs 4 and 7. Paragraphs 3, 5 and 6 should be reordered so as to be contiguous, and likewise with paragraphs 4 and 7.

Text will be edited and reordered to make it clearer and avoid repetition.

P12994, l 15-16: Break this into 2 sentences: change ", however" to ". However".

This will be changed.

P13002, l 7: Change "range" to "ranges"

This will be changed.

Section 3.1 and 3.2: Add a description of the errors in the HALOE and TOMS ozone products.

A brief description will be added to the final version.

Section 4.1, para 1: Add a short summary of what SLIMCAT run 323 is - Monge-Sanz (2008) is not as widely available as some other publications, and therefore it is not

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straightforward to check out what run 323 is via this reference.

A brief description of run323 was already given in Section 2.1 paragraph 1. The reference Monge-Sanz (2008) in this sentence of Section 4.1 was given because it included a comparison between run323 and TOMS observations.

We will edit the text to make it clearer.

P13005, l 14-21: Geer et al included an investigation of the impacts of different ozone and temperature climatologies on the performance of parametrized ozone chemistry schemes. How do the results presented here agree or disagree with Geer et al's findings?

Geer et al (2007) showed that, outside the polar night region, the climatologies are the main controlling factor for the upper stratosphere and mesosphere. In these regions the short photochemical lifetime of ozone causes a fast relaxation to the reference state. Our results agree with their findings in that the main influence of changing to the new climatology in our simulations is most evident above 10 hPa (e.g. as shown in Figure 7). However, in our simulations we also find that changing the climatology affects the performance of the scheme over the Antarctic spring (p. 13005, lines 21-23), and this was not implied by the Geer et al. (2007) study.

Geer et al. (2007) tested the different ozone schemes within a data assimilation system (the U.K. Met Office troposphere-stratosphere assimilation system). Therefore, the main interest in testing different climatologies was evaluating possible interferences with the assimilated observations. In our case the interest to test a different climatology was to evaluate the influence of some biases in the model used to calculate the coefficients (see next comment below), which had not been possible to evaluate in any previous linear ozone scheme.

We will add a discussion on these aspects to the final ACP paper.

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Figure 7 shows that SLIMCAT appears to underestimate tropical ozone, not just with parametrized chemistry but with full chemistry as well. These results require further discussion: are the differences due to biases in the correlative measurements, the SLIMCAT chemistry, or both?

For the default COPCAT-SLIMCAT simulation shown in Figure 7 the underestimation cannot be due to any observations influence, as the f(overbar) reference comes from the full-chemistry run323.

The underestimation already present in the full-chemistry run is amplified by the parameterisation, mainly through the local ozone term (second term on the right hand side of Eq. 2). As the coefficient c1 is always negative, the reference state used for f(overbar) imposes an upper limit beyond which this term will act removing ozone. This fact was the main motivation for the comparison with an additional climatology based on observations (the Fortuin-Kelder climatology used in CHEM2D-OPP).

This discussion will be added and developed in the final version of the paper.

P13008, l 7: Change "this kind" to "these kinds".

We will change it.

Figures 6, 7, 11 and 12: The solid blue lines here are so dark that they are hard to distinguish from solid black ones. Use a much lighter shade of blue.

This colour problem did not show in the article proofs we printed out, we will redo the figures using more clearly distinguishable colours to make sure it does not depend on the specific printer.

Interactive comment on Atmos. Chem. Phys. Discuss., 10, 12993, 2010.