Geosci. Model Dev. Discuss., 7, C1838–C1844, 2014
www.geosci-model-dev-discuss.net/7/C1838/2014/

Geoscientific Model Development Discussions
Open Access

Interactive comment on "Tropical troposphere to stratosphere transport of carbon monoxide and long-lived trace species in the Chemical Lagrangian Model of the Stratosphere (CLaMS)" *by* R. Pommrich et al.

R. Pommrich et al.

ro.mueller@fz-juelich.de

Received and published: 26 September 2014

We thank the reviewer very much for very helpful comments. Our detailed response to the comments is given below with the reviewer's comments shown in italics.

General

The paper presents a new simplified chemistry scheme that allows performing relatively low computational cost simulations to study transport of CO and other long-lived species through the TTL. The overall characteristics of large-scale transport compare reasonably well with satellite and aircraft observations, although the simplified scheme is not able to reproduce the events of enhanced CO due to convection. The paper is well written and provides an important contribution to the model advance, which can lead to scientific advance in following works. It is recommended for publication in this journal after addressing a few comments.

We thank the reviewer for these comments; we have addressed all the comments received in the revised version of the paper.

Comments

- *The main strength of the presented scheme is to reduce the numerical cost of the simulations, yet no quantitative measure of such improvement is provided in the manuscript. Please add this information.*

  We agree and, as suggested, we have added the information to the paper. The following text has been included at the end of section 3.2: "The reduction of the numerical cost from the full stratospheric chemistry (Grooß et al., 2014) to the simplified chemistry presented here was estimated for the example of a CLaMS simulation with about 370.000 air parcels employing both 4 and 128 numerical cores. The numerical cost of the chemistry module was reduced by a factor of 33 and 12, respectively. This corresponds to a reduction of the numerical cost of the entire simulation by a factor of 17 and 2.7, respectively."

- *The authors mention the limitation of the model to capture enhanced CO linked to* *events of convection. In fact, the appearance of the tape recorder in CO is associated with convective rapid transport of seasonally varying emissions. What are the limitations of this model in reproducing the characteristics of large-scale vertical transport due to the lack of representation of convective processes? Could could this model eventually be modified to provide a more accurate representation of such events? What is the importance of the lack of convection versus the tropospheric simplified chemistry and mixing for the misrepresentation of large CO values in the model as compared to the TROCCINOX data?*

We agree with the reviewer that the tropospheric transport in CLaMS needs to be further evaluated and improved. This paper constitutes a first step in this direction. The good representation of the anomaly patterns for long lived tracers (Figs. 7 and 8) indicates that the transport of long-lived tracers is well represented. The issues regarding CO transport are discussed in detail, and we attribute the misrepresentation of large CO values in the model compared to the TROCCINOX data mainly to problems in transport (rather than to the simplified chemistry) given the lifetime of CO and the short transport timescales involved.

As suggested by the reviewer, we also discuss the question whether the simplified chemistry could have an impact on the model deficiencies in question here. We have added the following sentence to the paper (Sec. 4.1): “The simplified chemistry scheme employed here is unlikely to have an influence on the underestimated CO values, given the tropospheric lifetime of CO (about two months) and the very rapid (order of a day) timescales of convective transport”. However, some rapid convective transport of CO will be represented in the model, namely to the extent that such transport is included in the ECMWF ERA interim reanalysis data (Dee et al., 2011). Recently, for example, Vogel et al. (2014) have shown that rapid uplift in tropical typhoons is represented in the ECMWF reanalysis data.

We further agree with the reviewer that the appearance of the tape recorder in CO is associated with convective rapid transport of seasonally varying emissions.

These points are now made more strongly in the revised version. In the conclusions we state now: “However, the model simulations allow the large scale anomaly patterns of CO in the lower stratosphere to be reproduced. In particular, the simulated zonally averaged tropical CO anomaly patterns (the so called ‘tape recorder’ patterns) are in good agreement with observations. The reproduction of the tape recorder patterns in the simulations implies that the seasonality of the tropospheric sources of CO and the convective upward transport of CO to the bottom of the TTL are sufficiently well reproduced in the CLaMS model version presented here. This further indicates that on large temporal and spatial scales, the information contained in the ERA-interim winds is sufficient to describe upward transport in the tropical troposphere to the bottom of the TTL”.

Finally, work is in progress to improve the vertical transport in the troposphere in CLaMS but no results can be reported yet (see discussion at the end of the conclusions section).

In response to the reviewer’s question whether “*this model [could] eventually be modified to provide a more accurate representation of*” convective events, we we have added the following text to the conclusions of the paper: “Future work with the model will focus on an improved representation of rapid convective upward transport and of tropospheric mixing, on an improved representation of trace gas sources in the lower troposphere and on employing different and improved meteorological reanalysis schemes.”

Specific comments

- p. 5109, L18: “and in-mixing from mid-latitudes”: We agree that we have to be more explicit here. At the altitude region in question, the vertical gradient is indeed due to inmixing from mid-latitudes (mostly), but of course the mid-latitude air shows reduced tracer values because it has passed through the region of chemical loss at greater altitudes in the stratosphere. We reformulated the section and have added a reference: “Mixing ratios of long-lived tracers exhibit a vertical gradient in the tropical lower stratosphere. This vertical gradient is mostly due to in-mixing of photochemically aged mid-latitude air (which exhibits reduced tracer values), with some contribution of local (tropical) photochemical loss (Volk et al., 1996)”.

- *Fig.2 and P5103 L23-25: why are the values in the winter hemispheres so different in model and observations?* The reviewer points to an important issue here. Unfortunately, at this point in time, we cannot offer a possible reason for the obvious discrepancy. We have added the following comment to the paper: “. . . compared to MLS, the model clearly overestimates the anomaly fields in the winter hemisphere at mid-latitudes. The reason for this discrepancy is unclear at this point in time.” However, we note that recent studies on similar questions have refrained from comparing with MLS data in this altitude regime in higher latitudes (Liu et al., 2013; Wang et al., 2014). We argue that a further discussion of this point should be postponed until the advent of the new upcoming MLS CO data version.

- *Fig.3: the differences between CLaMS and MLS are explained in the manuscript by the too strong vertical velocity in the reanalysis. However, the differences go beyond this effect and the patterns above 70hPa look quite different. This should be at least mentioned in the text.* We agree that the differences between CLaMS and MLS patterns above 70hPa should be explicitly mentioned in the paper. We have added the following text to the discussion of Fig. 3: “Moreover, there are some differences between the CLaMS simulated anomalies and the MLS measurements noticeable in Fig. 3., which cannot be attributed solely to problems in the rate of tropical upwelling”.

- *Why is Fig.3 shown in pressure coordinates and Figs. 7&8 in isentropic coordi-*

nates? Would be better to uniformize or at least explain the choice.: We agree with the suggestion and have changed all the plots to pressure as the vertical coordinate. Pressure is the vertical coordinate that MLS date are reported on.

- *Fig. 6: change x axis label to “CO measurements"*: done

All further technical corrections have been implemented as suggested.

References

Dee, D. P., Uppala, S. M., Simmons, A. J., Berrisford, P., Poli, P., Kobayashi, S., Andrae, U., Balmaseda, M. A., Balsamo, G., Bauer, P., Bechtold, P., Beljaars, A. C. M., van de Berg, L., Bidlot, J., Bormann, N., Delsol, C., Dragani, R., Fuentes, M., Geer, A. J., Haimberger, L., Healy, S. B., Hersbach, H., Holm, E. V., Isaksen, L., Kallberg, P., Koehler, M., Matricardi, M., McNally, A. P., Monge-Sanz, B. M., Morcrette, J. J., Park, B. K., Peubey, C., de Rosnay, P., Tavolato, C., Thepaut, J. N., and Vitart, F.: The ERA-Interim reanalysis: configuration and performance of the data assimilation system, Q. J. Roy. Meteorol. Soc., 137, 553–597, doi: 10.1002/qj.828, 2011.

Grooß, J.-U., Engel, I., Borrmann, S., Frey, W., Günther, G., Hoyle, C. R., Kivi, R., Luo, B. P., Molleker, S., Peter, T., Pitts, M. C., Schlager, H., Stiller, G., Vömel, H., A., K., and Müller, R.: Nitric acid trihydrate nucleation and denitrification in the Arctic stratosphere, Atmos. Chem. Phys., 14, 1055–1073, doi: 10.5194/acp-14-1055-2014., 2014.

Liu, J., Logan, J. A., Murray, L. T., Pumphrey, H. C., Schwartz, M. J., and Megretskaia, I. A.: Transport analysis and source attribution of seasonal and interannual variability of CO in the tropical upper troposphere and lower stratosphere, Atmos. Chem. Phys., 13, 129–146, doi: 10.5194/acp-13-129-2013, 2013.

Vogel, B., Günther, G., Müller, R., Grooß, J.-U., Hoor, P., Krämer, M., Müller, S., Zahn, A., and Riese, M.: Fast transport from Southeast Asia boundary layer sources to Northern Europe: rapid uplift in typhoons and eastward eddy shedding of the Asian monsoon anticyclone, Atmos. Chem. Phys. Discuss., 14, 18461–18497, doi: 10.5194/acpd-14-18461-2014, 2014.

Volk, C. M., Elkins, J. W., Fahey, D. W., Salawitch, R. J., Dutton, G. S., Gilligan, J. M., Proffitt, M. H., Loewenstein, M., Podolske, J. R., Minschwaner, K., Margitan, J. J., and Chan, K. R.: Quantifying transport between the tropical and mid-latitude lower stratosphere, Science, 272, 1763–1768, 1996.

Wang, T., Randel, W. J., Dessler, A. E., Schoeberl, M. R., and Kinnison, D. E.: Trajectory model simulations of ozone (O_3) and carbon monoxide (CO) in the lower stratosphere, Atmos. Chem. Phys., 14, 7135–7147, doi: 10.5194/acp-14-7135-2014, 2014.

Interactive comment on Geosci. Model Dev. Discuss., 7, 5087, 2014.