Atmos. Chem. Phys. Discuss., 12, C6978–C6982, 2012
www.atmos-chem-phys-discuss.net/12/C6978/2012/


Atmospheric Chemistry and Physics Discussions

ACPD

12, C6978–C6982, 2012

Interactive Comment

# *Interactive comment on* "Variability in upwelling across the tropical tropopause and correlations with tracers in the lower stratosphere" *by* M. Abalos et al.

**Anonymous Referee #3**

Received and published: 14 September 2012

General comment:

The paper by Abalos et al. investigates variability on daily to seasonal timescales of tropical upwelling velocity and relations to variability of tropical temperatures, ozone and CO. Analyzing the transformed Eulerian mean (TEM) thermodynamic and tracer continuity equations the authors show that vertical advection due to tropical upwelling is the dominant term in the equations and therefore strong correlations exist between upwelling variability and the variability of temperatures, ozone and CO. This paper adresses the causes for trace gas variations in the tropical lower stratosphere, a question of high relevance to current atmospheric research and within the scope of ACP, which was controversely discussed in the recent past. I find this paper a valuable contribution to this discussion, fluently written, very well structured and clear in describing the methods and results. Therefore, I highly recommend publication in ACP. However, before publication the following two specific comments need to be thouroughly discussed.

Specific comments:

1) Vertical upwelling vs. horizontal transport as ‘forcings’ of variability

At several points in the paper the authors refer to the related work of Konopka et al. (2009) and Ploeger et al. (2012), in the following KP for brevity, and state a contradiction between their own results and these papers (e.g., p18820/L18). At first glance, indeed there seems to be a contradiction, because Abalos et al. (2012) and Randel et al. (2007), in the following RA, argue that the ozone annual cycle is forced by vertical upwelling acting on the vertical background ozone gradient, whereas KP find that the ozone annual cycle disappears if horizontal transport from mid-latitudes into the tropics (in-mixing) is neglected in their model studies. However, I don't think that there has to be necessarily a conflict between RA and KP, as the frameworks in which the different results are deduced are very different. RA consider the TEM tracer continuity equation, analyze the ozone budget at a particular level and rate the different terms in the budget, finding that the ozone tendency $\partial_t \bar{\chi}$ closely follows the vertical advection term $\bar{w}^* \partial_z \bar{\chi}$. KP on the other hand consider tropical ozone from a Lagrangian point of view (back trajectory studies) and find that without accounting for horizontal transport of ozone-rich extratropical air into the tropics the tropical ozone summer maximum vanishes.

I agree with the results of RA that the TEM ozone budget at a particular level is dominated by the vertical advection term. But the vertical advection term is not independent of horizontal transport into the tropics at levels below, because such in-mixing affects the ozone mixing ratio profile $\bar{\chi}$. Therefore, the TEM tracer continuity equation at a par-



ACPD

12, C6978–C6982, 2012

Interactive Comment

ticular level does not properly separate the effects of tropical upwelling and horizontal transport. Even if the vertical upwelling velocity $\bar{w}^*$ was the only seasonally varying quantity in the TEM ozone 'forcing' terms on the rhs of Eq. (5), with all other variables constant in time (e.g., $\nabla \cdot M$ and $\bar{v}^*$, representing horizontal in-mixing into the tropics), slower upwelling during NH summer would cause more in-mixing of extratropical ozone during summer compared to winter and therefore an annual cycle of in-mixed ozone. This combined effect of upwelling and in-mixing is encrypted in the often used terminology of this paper 'upwelling as dominant forcing'. Although in the TEM budget the vertical advection term appears to be the dominant term, I am convinced that neglecting horizontal in-mixing in model simulations will result in an erroneous tropical ozone distribution.

Clearly, a thourough discussion and analysis of these points is beyond the scope of this paper and could be the base for interesting future work. But I would encourage the authors to be more careful with their wording throughout the paper (e.g., instead of p18829/L13 *...highlights tropical upwelling as a primary forcing term...* the authors could write *...as a primary forcing term in the TEM tracer continuity equation...*, similar parts are marked in the 'technical corrections' part). Furthermore, I would avoid emphasizing a contradiction between AR and KP (avoid wording like 'in contrast to', ...) and briefly comment on why there is not necessarily a contradiction. The paragraph on p18835/L14 goes into that direction and could be slightly extended.

This paper by Abalos et al. is indeed a very valuable diagnostic study of the various terms in the TEM tracer continuity equation, but it should not lead a fast reader to the misinterpretation that the tropical ozone budget could be simulated by only taking vertical advection into account, and that horizontal transport is unimportant for tropical ozone.

2) Pressure vs. potential temperature coordinates

A brief paragraph in the discussion section could be devoted to the use of potential temperature instead of pressure coordinates. Konopka et al. (2009) showed that a large part of the annual ozone amplitude on a particular pressure level results from the relative movement of pressure and potential temperature surfaces, and that on a potential temperature level the annual ozone amplitude appears much weaker. In this sense, I think that e.g. the statement on p18829/L11 *...the residuals ... do not show large annual variations...* will not hold that strictly on potential temperature surfaces.

Technical corrections:

P18820, L9: There is also some controversy about the role of ozone for amplifying the tropical temperature cycle (see, Fueglistaler et al, 2011).
P18820, L18: Wording: *...in contrast with...*, see specific comment.
P18820, L18: *...(CLaMS) and on back trajectory calculations,...*
P18822, L1: Perhaps better: *...ERA-Interim yields less noisy vertical velocities...*?
P18824, L7: Why is the neglection of the eddy transport term a good approximation?
P18824, L15: ERA-Interim temperatures appear to be cold biased around the tropical tropopause. This could bias the vertical velocity calculation.
P18825, L13: How large is the difference in vertical upwelling velocity to the case without adjustment?
P18826, L18: Wording: *...results primarily from forcing by vert. upwelling...*, see my specific comment.
P18829, L7: Avallone and Prather (1996) and Konopka et al. (2010) considered the combined effect of advective transport and irreversible mixing into the tropics. In order to compare Fig. 6 to their results it would be more appropriate to draw an additional line showing the sum of advective and eddy transport (residual plus $\bar{v}^*\partial_y\bar{\chi}$). Furthermore, even if there is no seasonality of this term on pressure levels there could be a distinct seasonality on potential temperature levels (specific comments).
P18833, L4: Perhaps the wrong Fig.-reference here? Fig. 7 shows CO.
P18833, L16: Wording: *...dominant forcing mechanism ...*, see specific comment.
P18835, L20: Strictly speaking, Konopka et al. (2009,2010) and Ploeger et al. (2012)



ACPD
12, C6978–C6982, 2012

Interactive Comment

show that horizontal transport (in-mixing) is necessary to explain the annual cycle of tropical ozone, with about 50% of the summer ozone mixing ratio originating in mid-latitudes. On the one hand, there is an annual cycle in in-mixing rates which would cause an annual ozone cycle even in the absence of seasonality in upwelling. On the other hand, for time constant in-mixing rates the amount of in-mixed ozone would also show an annual cycle if upwelling is seasonally varying, because more mid-latitude ozone would be in-mixed into the slower ascending tropical air masses during summer. Neither Konopka et al. (2009,2010) nor Ploeger et al. (2012) separated these two effects. Their results show that upwelling alone in combination with photochemistry is not able to reproduce the observed ozone cycle. So be careful with the wording here.
P18836, L4: Wording: *...central role of tropical upwelling...*, see specific comment.
P18839, L2: *... Geophys. Res. Lett. ...*
P18839, L11: *... Grooß, J.-U., ...*
Fig. 4 caption: *... as a function of pressure.*

References:


Konopka, P., Grooß, J.-U., Ploeger, F., and Müller, R., Annual cycle of horizontal in-mixing into the lower tropical stratosphere, *J. Geophys. Res.*, *114*, (D19111), 2009.

Ploeger, F., Konopka, P., Müller, R., Fueglistaler, S., Schmidt, T., Manners, J., Grooß, J.-U., Günther, G., Forster, P. M., and Riese, M., Horizontal transport affecting trace gas seasonality in the TTL, *J. Geophys. Res.*, *117*, (D09303), 2012.

Randel, W. J., Park, M., Wu, F., and Livesey, N., A large annual cycle in ozone above the tropical tropopause linked to the Brewer-Dobson circulation, *J. Atmos. Sci.*, *59*, 4479–4488, 2007.

Fueglistaler, S., Haynes, P., and Forster, P. M., The annual cycle in lower stratospheric temperatures revisited, *Atmos. Chem. Phys.*, *11*, 3701–3711, 2011.



Interactive comment on Atmos. Chem. Phys. Discuss., 12, 18817, 2012.





ACPD

12, C6978–C6982, 2012


Interactive Comment