

Interactive comment on “Quantifying tracer transport in the tropical lower stratosphere using WACCM” by M. Abalos et al.

Anonymous Referee #2

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General comment:

This paper investigates the variability of ozone, CO and temperature in the tropical lower stratosphere using data from the WACCM model, together with various observations. The thermodynamic and tracer budgets are analyzed based on the TEM framework (with pressure as vertical coordinate) and on the isentropic zonal mean formulation. Using model data allows to calculate all terms in the budget explicitly, even the eddy transport terms, and hence this paper goes much farther than the related recent study by Abalos et al. (2012). In particular, the vertical and seasonal structure in the horizontal transport contribution (which is shown to be mainly eddy) is an important new result and a step towards a better understanding of transport in the lower stratosphere. By showing the effect of summertime monsoon related horizontal transport

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around the tropopause, these results are also a step towards reconciling the contrasting viewpoints in the literature regarding the origin of the seasonality in tropical ozone. Overall, this paper is very well written and presents interesting new results, and is appropriate for publication in ACP. In the following, I have a few minor comments, which the authors might take into account.

Specific comments:

1) Variability linked to upwelling in p/θ -coordinates

The difference between the 'upwelling' on pressure coordinates and the 'upwelling' on isentropes could be highlighted at some point in the paper. In isentropic coordinates the upwelling is purely diabatic, which is not true in p -coordinates. At some points, the wording (like e.g., '...component of variability tied to upwelling is removed in isentropic coordinates...', p13261/17, also p13264/19), could be misleading. What is removed is the variability linked to the 'adiabatic part of upwelling'. The fact that the remaining part of the variability (linked to the diabatic part of upwelling) is much smaller shows that a large part of variability linked to upwelling is related to the relative movement of pressure and θ -surfaces.

2) Horizontal transport impact on 400/440K

The discussion of isentropic (quasi-horizontal) ozone transport at different altitudes (400 and 440K) suggests that the impact of this transport on tropical ozone is, at least, equally important on 440K than on 400K, which I think is not true (Figure 9 even suggests a stronger impact at 440K). First, at 440K ozone concentrations are much higher than at 400K and I guess the 6ppbv/day at 400K in summer will have a stronger impact on tropical ozone than the 12ppbv/day at 440K in winter (in Fig. 9). Wouldn't the relative tendency (relative to the tropical mean concentration) be a more appropriate measure for this impact in Fig. 9 (similar to Fig. 7)? Furthermore, there is a seasonal movement of subtropical transport barriers (which is discussed later), with transport barriers more polewards during summer than winter. Consequently, the hori-

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zonal transport effects (e.g., Fig. 9) reach deeper into the tropics at 400K compared to 440K. Overall, I think horizontal transport affects tropical ozone much more significantly at 400K than at 440K, and this could be made clearer.

P13246, L22: *...highlighting cross-isentropic mean advection as the main term in the balance*, I would add: 'at higher levels (2km above the tropopause)'. Near the tropopause hor. transport causes the summer ozone maximum (as you discuss later).

P13251, L13ff: Can you speculate about the reasons for the temperature/tropopause bias in WACCM, and about related biases in tropical upwelling?

P13255, L10: For ozone, eddy transport makes a substantial contribution in NH subtropics.

P13255, L15ff: For ozone, the largest contribution due to advection occurs slightly below the region of maximum vertical gradients. Is this an indication that horizontal advection is not totally negligible (the maximum meridional gradients occur slightly below)?

P13257, L6ff: Figure A1 shows a clear summer maximum also in the advective horizontal transport contribution.

P13259, L10ff: The fact that hor. transport of ozone occurs mainly at levels around the tropopause is consistent with Konopka et al. (2009,2010) and Ploeger et al. (2012). E.g., Fig. 4/5 of Ploeger et al. (2012) show the main effect of hor. transport related to the Asian monsoon between about 370-420K.

P13260, L26ff: How does Fig. 13 look if the tendencies are taken from the isentropic formulation of the continuity equation?

Technical corrections:

P13247, L18: 'separating' better than *limiting*?

P13247, L23: I think Rosenlof et al. (1997) argue that rapid horizontal transport ex-

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tends up to 450K.

P13248, L25: *...in upwelling, in turn resulting from variations in wave driving*.

P13254, L14: Perhaps mention that ∇ is the horizontal gradient.

P13257, L2ff: *...Fig. A1*.

P13258, L2: There is a summer maximum in isentropic transport still at 420K, coinciding with the ozone tendency maximum.

P13259, L11: *...lower stratosphere (around 70hPa)*.

P13262, L7: *...higher levels around 70hPa*.

P13264, L6: *...correlated with temperature for O₃,...*

Fig. 7 caption: Are there any *dashed: negative* contours in the figure.

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