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Atmospheric Chemistry and Physics Discussions

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Interactive Comment

Interactive comment on "Ozone-enhanced layers in the troposphere over the equatorial Pacific Ocean and the influence of transport of midlatitude UT/LS air" *by* H. Hayashi et al.

H. Hayashi et al.

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We would like to thank the referee #2 for the constructive comments. Taking into account these comments, we have improved our work.

My main reserve on this paper on the accuracy of the back trajectories.
The author should precise if they use ERA 40 reanalyse data.
If yes, in my opinion, it is impossible to do an quantitative estimation of the origin of the air masses using the vertical velocity of ECMWF with a so long time step (take 15 minutes or less), and a so large resolution (2.5 degrees is too large, but 2 fields by day is not enough). With the parameters indicated by the authors, it is not possible to have a good representation of the diffusivity and then and then of the

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stratosphere-troposphere exchange influence.
In fact the stratosphere troposphere can occur at different time and space scales. With the methodology used by the authors (lagrangian approach based on trajectory and PV analyse), it could be possible to quantify the stratosphere-troposphere at the mesoscale, under the condition of the parametrization of the trajectories are well adapted, and with a PV advection using the trajectories. It is not the case here, and the authors recognise implicitly it excluding the ozone peaks whose the thickness is less than 1 km (page 17185, line 2). Then the climatology is only quantifying the large scale sources of ozone, excluding the meso-scale.
In my opinion, the paper address relevant scientific question within the scope of ACPD. The data presented are interesting, but the tool used is not adapted to the objective of the study. Substantial conclusions could be reached, if the trajectories are improved. The title, abstract and overall presentation and OK for me.

We used the ECMWF TOGA basic level III-A dataset to calculate the trajectories.
We agree that the stratosphere-troposphere exchange (STE) is difficult to quantify accurately by using trajectories, because it is sensitive to errors in the meteorological data (e.g., Stohl et al., 2004). However, "the transport of the midlatitude upper-troposphere and lower-stratosphere (UT/LS) air" in this study is mainly attributed to the transport of relatively high $|PV|$ (about 1 PVU) air in midlatitude UT region, although the cross-tropopause transport of stratospheric air may contribute to it. While $|PV|$ values larger than 1.5-2 PVU were adopted as an indicator of the stratospheric air in previous studies (e.g., Baray et al., 1998; Waugh and Funatsu, 2003; Postel and Hitchman, 1999; Waugh, 2005), $|PV|$ about 1 PVU indicates the UT air close to tropopause. We think that the trajectories used in this study can indicate the adiabatic transport of the tropospheric air parcels. To indicate dependence of the trajectory on the time resolution of the meteorological data, we calculated 10-day backward trajectories from the measurement time and altitude of all O_3-enhanced layers observed at the three

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ozonesonde sites in the period from March to June 2003 by using two ECMWF data sets with two different time steps: 12-hour resolution data with 1-hour time step (the same as this study), and 6-hour resolution data with 15-minute time step. Based on these two kinds of backward trajectories, we have individually categorized the origin of each O_3-enhanced layer to the biomass burning, the transport of midlatitude UT/LS air, and the others (not identified) as in the sections 4.1 and 4.2 of our paper. Although routes of some trajectories were significantly modified with the time resolutions and time steps, the origin category of all the layers were not changed with them. Therefore, we consider that our results did not critically depend on the resolution of the meteorological data and the time step. However, a shorter time step improves the accuracy of the trajectory calculation, especially when the wind velocity is fast around the subtropical jet region. We revised the trajectory calculation by adopting the time step of 15 minutes, and we have re-categorized the origin of each O_3-enhanced layer as shown in Fig. 8. We found that about 10% of the all O_3-enhanced layers changed the category of their origin: the number of "not identified" layers decreased, and the number of "midlatitude UT/LS air" layers increased. The number of "biomass burning" layers a bit decreased. Although our conclusion does not significantly changed with the revised trajectories, we are now revising our manuscript with this new result.
We excluded the O_3 peaks whose vertical thickness was less than about 1 km from our analyses, because it is difficult to investigate these small-scale events by trajectory analyses. We consider that these small peaks are insignificant because the number of excluded O_3 peaks accounted for only about 6% of all observed O_3-enhanced layers and because they do not have as much O_3 as the thick layers.
To avoid misunderstanding, we will revise the manuscript to show the above points more clearly.

Some minor remarks :

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What is the exact significance of the term “midlatitude UT/LS air mass ” for the authors? Does it mean stratospheric origin? An air mass coming for the upper troposphere of midlatitude and arriving in the tropics is not necessarily an enhanced ozone layer.
The introduction could be improved : - Page 17180, 1st sentence : the tropospheric ozone concentration in the tropics is generally low. In comparison with what? Cite a reference.

As shown above, "the transport of the midlatitude UT/LS air" in this study is mainly attributed to the transport of relatively high $|PV|$ (about 1 PVU) air in midlatitude UT region, which is close to the tropopause where influence of the LS air is significant. We think that the transport of the midlatitude UT air cause O_3 increase in most cases. As shown Fig. 2, O_3 concentration over the equatorial Pacific Ocean is less than 40 ppbv in general, and is lower than those in midlatitude free troposphere (e.g., Brasseur et al., 1999; Kondo et al., 2002).
We will revise the manuscript to show above points and will the cite the above and other adequate references, e.g. Fishman et al. (1990).

- Page 1782, lines 10-14. It is exact that all is not clear concerning the ozone balance in the tropics. But I am not sure that what is not clear is the transportation of midlatitude UT/LS in the tropics. I think that what is not clear is the influence of tropical convection on tropospheric ozone, and the quantification of meso-scale and global scale processes on ozone.

Although it is true that the influence of the tropical convection and the meso-scale and global scale processes on tropospheric O_3 balance are not clear, general discussion on these processes is beyond a scope and aim of this study. In this study,

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the contribution of tropical convection is partly discussed by showing that the plumes affected by biomass burning were often transported upward to the free troposphere by the tropical convection, and by showing its contribution to the observed O_3-enhanced layers.
Concerning the influence of the midlatitude UT/LS air on ozone budget in the equatorial region (15°N-15°S), several studies (e.g., Postel and Hitchman, 1999; Waugh and Polvani, 2000) had suggested that the midlatitude UT/LS air may be transported to the equatorial region based on the PV analyses. However, because these studies were not based on the direct ozone observation, they did not confirm the ozone increase. Several studies (e.g., Baray et al., 2000; Waugh, 2005; Waugh and Funatsu, 2003) showed the ozone increase at around 20° occurred with the transport of high PV air from midlatitude, but their studies remains case studies. This study indicates that significant parts of the observed O_3 layers in equatorial region were attributed to the transport of the midlatitude UT/LS air, based on the 6 year ozonesonde data.

The presentation of the trajectories is not very clear, as example fig 5. The vertical level could be given as function of time (and not longitude), or could be given with colour on the horizontal plot latitude x longitude.

In this figure, we present vertical level of the trajectories as a function of the longitude to show the region where they suggest upward motion of air masses, and OLR values were low in this region as shown in Fig. 7, indicating that the upward motion occurred due to the convection. We indicated the progress of air mass transport with time by dots on the representative trajectory.

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