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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 #1 for the helpful comments for improving our work.

*Specific Comments*

*1. A key result of this paper is the characterization of the o3-enhanced layers into those caused by biomass burning and those by transport from mid-latitudes. However, the actual criteria used to define the layers into these 2 causes is not clearly defined, and there is no discussion of the sensitivity to choices made in this criteria.*

*It is stated that categorized as from biomass burning from evidence of backward trajectories, hot spot maps and OLR values. This give the impression that this is done visually (i.e. subjectively). If this is the case this is not good enough. If it is done*

*objectively the criteria used (i.e. what values on hot spot and OLR maps are used to identify biomass burning, and how close do the trajectories have to get), and sensitivity to choice of parameters needs to be discussed.*
*Similarly, an objective measure is needed to define layers that come from transport from mid-latitudes UT/LS, and this needs to clearly described.*

We categorized that an $O_3$-enhanced layer was resulting from "biomass burning", when 1) a major part of the backward trajectories from the layer were passed over a convection region of low-OLR values less than about 190-200 $Wm^{-2}$, 2) the backward trajectories suggests upward transport from the lower troposphere in the low-OLR region, and 3) hot spot distribution obtained from the Along Track Scanning Radiometer (ATSR) data suggests that biomass burning occurred on the windward side of the low-OLR region in the lower troposphere. We considered that significant biomass burning occurred when more than 5 hot spots were found in a $5^\circ \times 5^\circ$ area. Although the numbers in the above criterion are rather arbitrarily chosen, the result does not critically depend on them.
We categorized that an $O_3$-enhanced layer was attributed to "the transport of midlatitude UT/LS air", when 1) a major part of backward trajectories from the layer indicated that the air masses in the layer were transported from latitudes higher than 20° near the subtropical jet stream and from altitudes higher than the 300 hPa level, and 2) no low-OLR region was found along the transport route between the subtropical jet region and the layer. The result does not critically depend on the numbers in this criterion.
We will revise the manuscript to show the above criteria more clearly.

*2. Figure 8 shows that the cause of a significant amount of the events, especially for Watukosek and San Cristobal, cannot be identified. More discussion of this is required. Is there a third cause of layers or is this an issue with the criteria used for*



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*above types of events? These "not identified" events need to be examined in more detail. What are the flow characteristics when these events occur? Can you at least show some examples?*

We have revised the backward trajectories by calculating them with a shorter time step (15 minutes) to improve the accuracy of them. By this revision, the number of "not identified" layers decreased by about 15%.
The trajectories showed that $O_3$-enhanced air masses in a major part of the "not identified" layers were transported within tropical latitudes less than about 20° and in the upper troposphere higher than the 300 hPa level for more than about a week. They did not pass over a low OLR region in this period. In these cases, the $O_3$-enhanced air masses can not be traced back to their sources by the trajectories. As shown in Sec. 4.1, the ozone increase might be caused by long-range transport of air masses affected by the biomass burning and the upward transport due to convection which occurred before, mixing of stratospheric air in the tropospheric tropopause layer (TTL), and nitric oxide (NO) production by lightning discharge. We will categorize these layers to be "tropical UT air" in the revised manuscript.
Other "not identified" layers included various cases: for example, backward trajectories suggest that some air masses in the layer passed over a low OLR region without biomass burning area, and other air masses were transported from lower troposphere over the tropical ocean, where $O_3$ concentration is generally low. In some cases, transport routes of air masses could not be identified because backward trajectories from 9 grid points around the layers diverged significantly. These "not identified" layers accounted for about 16, 6, and 5% of all at Watukosek, Samoa, and San Cristobal, respectively.

*3. The discussion/analysis in section 4.3 is not that convincing. All that is shown is* *a few examples. How are we to know these examples are typical? Can't trajectories for multiple cases of the same type of events be shown on the same plot? It would actually be even better if some type of cluster analysis was done to show the different types of events.*

To indicate the transport routes shown in Fig. 14 are typical, we will modify Figs. 9(b)-9(d). In these figures, the number of trajectories is increased, the trajectories similar to those shown in Figs. 14(a)-14(f) are shown by different color curves. We will also revise the manuscript to show the percentage of each typical transport route shown in Figs. 14(a)-14(f) in all "midlatitude UT/LS air" cases: the transport routes shown in Figs. 14(a) and 14(b) accounted for 81% and 7% at Watukosek, that shown in Fig. 14(c) accounted for 88% at Samoa, and those shown in Figs. 14(d)-14(f) accounted for 36%, 31%, and 22% at San Cristobal. The transport of midlatitude air was often occurred along the route shown in Fig. 14(b) between November and December in 2000, and we had considered the route of Fig. 14(b) was typical in this period. However, it occurred along that shown in Fig. 14(a) in the same period of the other years. Because the percentage of the route of Fig. 14(b) was small, we consider it to be not "typical" and will modify the manuscript.

*Minor Comments*

*pg 17185, line 20- This paragraph is a confusing. First it is started that 90% of o3-enhanced layers have lower RH, but then latter it is stated that 40% of cases at Watukosek has higher RH. These statements appear contradictory. These sentences need to be reworded so clearer.*

We will revise the manuscript to show above statements are not contradictory to each other. Although the $O_3$-enhanced layers with lower RH accounted for more than 90% on yearly average, those with higher RH was about 40% in December and January at Watukosek and about 20% in March and October at San Cristobal.

*pg 17186. Why is section 4 called Discussion when it is still presenting results? Figs 5 to 7 should be on same latitude-longitude scale, and these 3 figures could be combined into a single figure. Quantities shown in figs 6 and 7 could even be on same plot. Similarly for figs 11 to 13.*

We are considering modifying the manuscript: some parts of the Sec. 4.1 and 4.2 are transfer to the Sec. 3.
We will modify the latitude and longitude scales of Figs. 5 to 7 and Figs. 11 to 13 to be identical, respectively. We will combine Figs. 6 and 7 into a single figure.

*pg 17194: Why reference Palmen and Newman 1969 here and not some of the more relevant papers mentioned in the Introduction.*

We will also refer Waugh and Funatsu (2003) and Waugh (2005) here.

*Same page: It is not true that previous studies have shown PV only reaching around 20 degrees and not to the equatorial region. For example, the events in Waugh and Polvani were defined as high PV at 10 degrees, so in all their events high PV gets to at least 10 degrees. Also examples shown in several papers show high PV at lower latitudes.*



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Baray et al. (1998) showed the ozone increase at around 20$^\circ$ occurred with the transport of high PV air from midlatitude, but their studies remains case studies. This study shows that ozone increase near the equator occurred in association with the transport from the midlatitude UT/LS region, based on the 6-year ozonesonde data. Waugh and Polvani (2000) showed that high $|$PV$|$ ($>$ 2 PVU) reached to equatorial region lower than 10$^\circ$ on the 350 K level, altitude near the tropopause. It is quite rare that such a high $|$PV$|$ ($>$ 2 PVU), LS air is transported to the equatorial middle/lower-troposphere, where this study shows that $O_3$-enhanced layer frequently occurred in association with the transport of midlatitude UT/LS air masses. We will revise the manuscript these points more clearly.

*In the conclusions it is stated that differences in meteorological conditions cause differences in seasonal differences in occurrence of enhanced layers at Watukosek and San Cristbal, but no details are given. How does the meteorology change, and why does this cause a difference? This is buried in 4.3, but needs to be more clearly stated in the conclusions.*

The occurrence of the transport of midlatitude UT/LS air was relatively high in the period from May to December at Watukosek and in the three periods from February to March, from August to September, and from November to January at San Cristobal, as shown in Fig. 8. These periods corresponded to those when the meteorological conditions leading to the transport as shown in Figs. 14(a), 14(d), 14(e), and 14(f) typically occurred. We will modify the manuscript to show this point with the meteorological conditions more clearly.



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*References*

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Interactive comment on Atmos. Chem. Phys. Discuss., 7, 17179, 2007.