Reply to Anonymous Referee #2:

We thank the Anonymous Referee #2 for those valuable comments. We have carefully considered each of the comments in our revision. Our responses are provided below inline in italics.

Major Points

1. The chemical lifetime of CO in the model domain ranges from 1-3 months at the lower boundary to orders of a day or less at the top of the domain. The chemical lifetime of ozone at the bottom of the model domain is rather large, but it also decreases in the tropics to about 10 days at 10 hPa and less than a day at the top of the domain. The chemical loss and production rates are imprinted from the WACCM simulation. That means that the model results relax to the WACCM results with the time constant given by the chemical lifetime. Therefore it is clear why the results, especially in the upper model domain are virtually identical. In order to understand this problem and to interpret the model results, it would be necessary to show the chemical lifetimes e.g. similar as given in figure 2. As the purpose of the paper is not the validation of the WACCM model, the focus of the plot should more clearly be the regions in which the transport time scales are faster than the chemical time scales.

Reply:
We agree with the reviewer. Now Fig. 2 has been updated to include the respective O_3 and CO lifetimes, as shown below. It is apparent that transport dominates at the lower UTLS region, where chemical species has longer lifetime. This is the region of the focus of our paper. At upper air (especially above 10 hPa) chemistry dominates so the chemical lifetimes are very short.

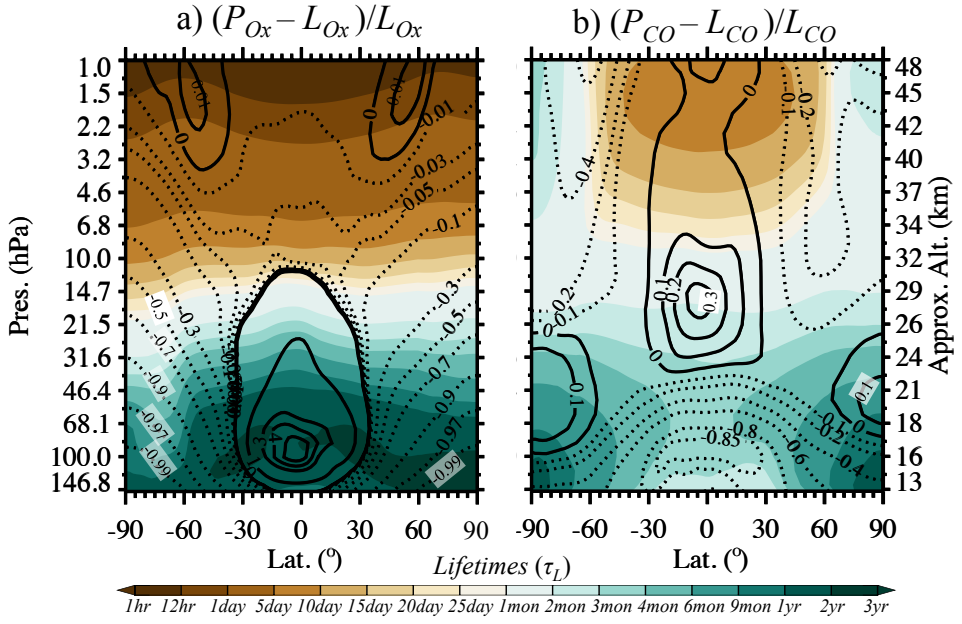

Fig. 2. The ratio of chemical net tendency (production rate minus loss rate) to loss rate from WACCM for **(a)** O_x and **(b)** CO. Negative numbers are dashed to highlight the net chemical decrease and positive numbers indicate net chemical increase, while zero lines indicate comparable amount of production and loss. For reference, the respective O_x and CO lifetimes are contoured in color.

2. The model setup does not consider any mixing (if I understand it correctly). It may not be so important for most results shown here which are mostly averages, but it is not clear, how in general the neglect of mixing influences the results. Especially in correlations like those displayed in fig 10, the process of mixing should change the results.

Reply:
During the trajectory integration we didn't consider mixing of parcels, which allows us to trace parcels back or forth to see the full history or future evolution of parcels. However, there is an effective 'mixing' when many parcels are averaged within grid boxes to be compared with either observational or Eulerian model results. The mixing in extra-tropical tropopause is very important, but we mainly focused our results around the tropical tropopause, where the strong vertical gradients of chemical species indicate less mixing occurring. In fact, it is because Lagrangian models producing non-diffusive transport and thus are especially accurate in regions where there are strong tracer gradients (e.g., the edge of polar vortex, the tropopause).

Fig. 10 shows the tracer relations at 68-hPa, where both O_3 (Randel et al., 2007) and CO (Abalos et al., 2012) exhibit strongest vertical gradients. At this level our results agree with MLS very well (see Fig. 4 and Fig. 9), so Fig. 10 might state the true atmospheric tracer relations.

3. The model air parcels are initialized at the 370-K level from the MLS climatology. This is typically between 100 and 150 hPa in the considered range (40◦N-40◦S). A comparison of the model results with data at 100 hPa is close to just comparing the initial conditions. Differences at 100 hPa (figs 4b, 9b) are potentially more due to vertical interpolation of the data than due to any process reflected by the model. What is the typical age of the trajectories at 100 hPa in the plot?

Reply:
We totally agree with the reviewer on this point. Parcels at tropical 100-hPa are usually very young with ages of 2-3 months. The reason that we chose 370-K as the initial level is based on the total diabatic heating shown in Fig. 1, in which MERRA's negative heating at 150-130 hPa makes a transport barrier that prevents air ascending to the stratosphere. Therefore, we have to choose a relatively higher initialization level (370-K) to avoid this negative heating altitude. Because this paper presents comparison of using both MERRA and ERAi circulation, for fair comparison we ought to use the same initialization level.

However, we could have initiated parcels at lower altitude, such as 355-K, when using ERAi circulation (shown in figure below). The brown line marked "TRAJ_ERAi i355K"

indicates the ERAi run with parcels initialized at 355-K level. Compared with the ERAi run initiated at 370-K (orange) it is clear that the 100-hPa O_3 and CO are well represented even it is close to the initialization level. We have added this in the Discussion.

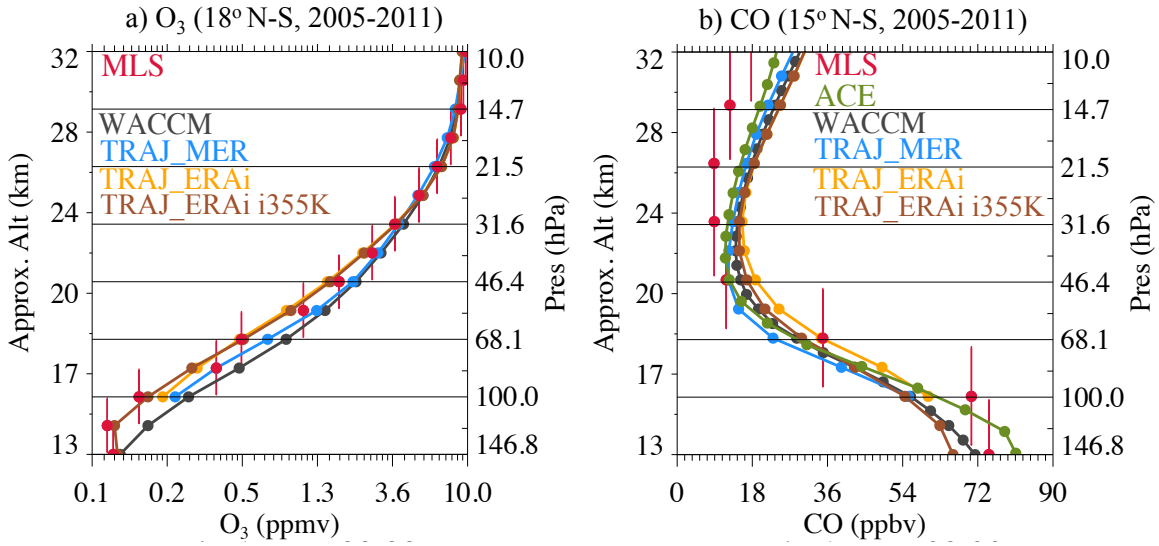

Figure. Tropical vertical profile of MLS, WACCM, and trajectory modeled (a) O_3 and (b) CO driven by MERRA and ERAi wind (initiated at 370-K isentrope), averaged over the deep tropics from 2005 to 2011. A test run driven by ERAi wind and initiated at 355-K isentrope is shown in brown as reference. Vertical bars in red indicate the MLS vertical resolutions at each of the MLS retrieval pressure levels.

4. Is in the comparison with ACE-FTS (e.g. fig 8) the latitudinal sampling taken into account? The plots could be either zonal mean cross sections (as indicated in the caption) or based on model interpolations onto the exact observation locations. The pattern of sampling times and latitudes of ACE-FTS may cause some of the shown difference.

Reply:
The ACE CO in Fig. 8 is a zonal mean cross section, and our comparisons are simply with zonal mean results from the trajectory model (not sampled like ACE). Park et al (2013) have recently shown similar model comparisons to ACE results, and demonstrated that there is almost no difference if the model is sampled identically to ACE measurement locations.

5. The critical point in the simulation is the method, how the diabatic heating rates are determined. It is said that they are determined including all radiation, latent heat etc. Please verify that this is the case for all reanalysis data sets. This is not trivial, since not all terms are equally saved in all data sets and must be reconstructed.

Reply:
In this study we took the total heating term directly available from each reanalyses. The

details of the diabatic heating results from different reanalyses have recently been discussed by Wright and Fueglistaler (2013), and this is highlighted in our revised manuscript.

Minor Points

1. 5999/ fig 4a: The error bars probably denote the vertical averaging kernel. From that it seems that one cannot decide whether vertical velocities derived from ERAi or MERRA are better. Error bar/uncertainty of the mixing ratio would also be interesting.

Reply:
The error bars denote the MLS vertical resolutions associated with each pressure level. They are obtained from the MLS data quality statement in Table 3.17.1 (http://mls.jpl.nasa.gov/data/v3_data_quality_document.pdf). We cannot decide whether ERAi or MERRA vertical velocities are better from this figure, but we can get some clue from Fig. 10.

We used to add error bars/shading to each datasets but it turned out to be too busy to read, and all those error bars actually didn't tell us more information. So we decided to only use profiles with MLS vertical resolutions as references.

2. Fig. 1: right y axis label (pressure) is not completely visible

Reply:
Thanks for reminding us. This is probably due to the formatting by the journal online version. We will make sure to remind the journal typesetting to adjust it in the next version.

3. 5995/fig1 caption: different latitude ranges are given. Is it 15 or 18 degrees?

Reply:
For the tropical vertical profiles we prefer averages within 18^o N-S. One exception is Fig. 9a, in which we added ACE CO for comparison. We obtained the ACE CO data directly from Park et al., [2013], in which the gridded CO is only available at 15^o N-S. For fair comparison, here we used all other datasets within 15^o N-S, too. Noted that there is barely any difference if we averaged over 18^o N-S.

[References]

Abalos, M., Randel, W. J., Kinnison, D. E., and Serrano, E.: Quantifying tracer transport in the tropical lower stratosphere using WACCM, Atmos. Chem. Phys. Discuss., 13, 13245-13283, doi:10.5194/acpd-13-13245-2013, 2013.

Park, M., W. J. Randel, D. E. Kinnison, L. K. Emmons, P. F. Bernath, K. A. Walker, C. D. Boone, and N. J. Livesey (2013), Hydrocarbons in the upper troposphere and lower stratosphere observed from

ACE-FTS and comparisons with WACCM, J. Geophys. Res. Atmos., 118, 1964–1980, doi:10.1029/2012JD018327.

Randel, W., 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., 64, 4479–4488, 2007.