

Responses to Referee #1

Review of “Interpretation of Aura satellite observations of CO and aerosol index related to the December 2006 Australia fires” by Luo et al., submitted to Atmospheric Chemistry and Physics Discussions.

The manuscript evaluates the potential of CO data from TES and MLS, and AI data from OMI, in interpreting the evolution of plumes from fire events in Australia during December 2006. The manuscript provides a good overview of the relative abilities of three satellite instruments, utilising different viewing geometries and measurement techniques, for studying such events. It also notes the challenges in interpreting these data in conjunction with chemical transport models, which do not fully represent physical processes such as pyro-convection. It is not clear, however, if the conclusions drawn by the authors, related to the limitations of satellite data to a study such as this, are valid just in this case or more generally.

Thanks for the careful review of the manuscript and the meaningful summary. As Dr. Cooper suggested, we reworded our conclusions regarding the future satellite measurements of the fire events. We pointed out that a geostationary satellite that is designed to monitor the diurnal variations of the chemical pollutants will also make contributions in understanding the evolutions of the fire events. These fire events are becoming bigger issues affecting local air quality in the dry seasons of almost all places around world. The observations will contribute to the improvements in regional and even global models in simulating the distributions of the chemical tracers.

My specific comments on the manuscript are as follows:

Page 23666, line 12: “The enhanced CO observed by TES in...”

We appreciate referee #1 catching this error. This has been corrected as shown in the revised manuscript.

Line 17: is drastic the appropriate word to use?

Drastic is an appropriate word to use in this sentence since the word ‘drastic’ describes the large extent for which GEOS-Chem underestimates UT CO. For clarity, we added the word ‘plumes’ at the end of the sentence.

Lines 24-26: not required in the abstract – better suited to the conclusions

We removed this sentence from the abstract and added it as the last sentence of the last paragraph in the conclusion section.

General comment on the Introduction: the introduction is a little over long and I feel that the extensive discussion of biomass burning events in North America, Europe and northern Africa is not particularly relevant to a manuscript focusing on Australian fires during one burning season – I suggest that this discussion should be removed.

We appreciate referee #1’s suggestion. We removed those parts of the introduction.

Page 23667, line 11: extra space “(OH)”

Referee #1 may have interpreted the dot, representing the lone electron, on OH as a space.

Page 23671, line 8: punctuation – “CO observations from TES and MLS, and UV absorbing indices (AI) obtained from OMI, on the...”

We appreciate referee #1 catching our missing commas, which are now incorporated in the manuscript.

Lines 10-12: suggest specifying nadir-viewing/limb-viewing rather than nadir/limb

We appreciate referee #1’s suggestion and we incorporated it accordingly.

Line 20: “...hundred...”, “...thousand...”

We appreciate referee #1’s suggestion and we incorporated it accordingly.

Line 22: “215 hPa”

We appreciate referee #1’s suggestion and we incorporated it accordingly.

Lines 27-28: use of the word taken is a bit vague – suggest changing to measured

Line 28: “...a one-day on followed by one-day off mode” isn’t very clear – change to explain that TES global surveys are measured every other day.

‘TES Global Survey’ is an operational mode, so ‘taken’ should be proper. We change the sentence to ‘TES Global Survey (GS) observations along Aura orbits are taken approximately every other day (26 hours on, followed by 22 hours off)’.

Page 23672, line 1: clarify that the MLS data used in the study are co-located to the TES observations. Also, what do you mean by “field patterns” in the following sentence? The figure shows the gridded CO distributions from TES and MLS.

We do not state that the MLS footprints are co-located to the TES observations. We state ‘MLS data are selected closest to those of TES’, but because of the different viewing geometries (limb and nadir) the observations are not simultaneously co-located. We changed ‘field patterns’ to ‘CO spatial distribution patterns’. Thanks for making this clear.

Line 4: “degrees of freedom for signal” – DOF should be changed to DOFS on this line and elsewhere in the manuscript.

We appreciate referee #1’s suggestion and we incorporated it accordingly.

Lines 5-7: the ranges for the latitude bands should be defined in the first sentence.

We appreciate referee #1’s suggestion and we incorporated it accordingly.

Line 7: suggest the authors use Rodgers (2000) rather than Rodgers (1998) as it is a more general reference for retrieval theory.

We appreciate referee #1’s suggestion and we incorporated it accordingly.

Line 8: “from remote sensing spectra” is not necessary,

We appreciate referee #1’s suggestion and we incorporated it accordingly.

Line 10: “In cases 49 to 72...” is not very clear – suggest “For the latitude band

between 49 and 72...”.

We appreciate referee #1’s suggestion and we incorporated it accordingly.

Lines 11-12: “influenced heavily by the true CO values at 400–250 hPa” isn’t very clear – the averaging kernels show that the CO retrieved from TES is largely sensitive to 400-250 hPa.

Well, the two concepts are the same. We changed the sentence to ‘the TES CO retrievals are largely sensitive to 400-250 hPa, the TES CO retrieved values at 215 and 618 hPa are therefore both influenced heavily by the true CO values at 400-250 hPa and the a priori values at all levels’.

Lines 12-14: the final sentence looks out of place here – wouldn’t it be better suited to the discussion/conclusions? Also, can the authors be sure that high CO in the lower troposphere downwind of Australia are so unusual? My understanding is that Figure 3 shows mean averaging kernels but do the averaging kernels for those retrievals between 16 and 17 December show the same sensitivity?

The purpose of showing the plots of averaging kernels (Fig 3) is to state that TES CO retrievals are not sensitive to the ‘truth’ in the boundary layer. The enhancement of CO at 681 hPa (Fig2) is likely due to the enhancement of ‘true’ CO at 400-250hPa. From TES retrieved CO profiles, of which the values at lower trop are not independent from the values in the mid-upper trop, no conclusion can be drawn if the CO enhancement at 681 hPa is real. The Dec 16-17 AK at the high southern latitude band had similar shape as Fig 3 panel 2. We added and modified these sentences to make them clearer.

Line 15-16: needs clarifying to explain how the MLS profiles are convolved/smoothed with the TES averaging kernels – this is the first use of “TES operators” so please also clarify somewhere in the text if this means the averaging kernels and a priori profile. The reference to Luo et al 2007 looks out of place – this procedure is explained in the TES Users’ Guide or Rodgers (2000).

Yes, the application of ‘TES operators’ for inter-comparisons is described in TES Users’ Guide. We changed the reference, and added ‘a priori’ into the sentence.

Line 16: the MLS CO profiles are used as the “**truth**”

We appreciate referee #1’s suggestion and we incorporated it accordingly.

Line 23: “...are a good indicator...”

We appreciate referee #1’s suggestion and we incorporated it accordingly.

Line 27: change “11-14 December” to “11 and 14 December”

We appreciate referee #1’s suggestion and we incorporated it accordingly.

Line 28: “**This** second event...”?

We appreciate referee #1’s suggestion and we incorporated it accordingly.

Page 23673, line 2: change “identify” to “evaluate”?

We appreciate referee #1’s suggestion and we incorporated it accordingly.

Line 4: "...of **the** orbit passes..."

We appreciate referee #1's suggestion and we incorporated it accordingly.

Line 8: OMI AI data does not **contain** vertical information

We appreciate referee #1's suggestion and we incorporated it accordingly.

Lines 9-11: the values of 1.0 and 1.4 are the average DOFS for the two latitude bands used in Figure 3 – are they still representative of the full range of the DOFS over this region? Also this sentence isn't very clear - the averaging kernels show that while the TES data is relatively insensitive to the boundary layer, the information is reasonable well constrained in the mid-troposphere. Is the point being made here that there is a mismatch in the sensitivities of the different datasets? If so, this isn't clear from the text.

Yes, the DOFSs quoted are typical values for the two latitude bands. We added reference Luo et al. (2007) that shows the global values of TES DOFSs for CO. It is obvious that the profile sensitivity is different from 1.0 to 1.4. We would like to make the point that in either case the profile vertical resolution is not adequate to resolve the boundary layer CO from that of upper troposphere.

Lines 12-13: while I appreciate that it is difficult to directly compare the TES CO and OMI AI data, is it not possible to infer a relationship based on the residence time of CO and aerosol in the troposphere?

Good point. It is amazing that OMI AI can be used to track the plume transport around world for over a week according to Dirksen et al, 2009. MLS or TES did not track CO plumes that far, possibly due to OH removal processes in summer. We added some discussion on this.

Line 13: change "simultaneous" to "concurrent"

We appreciate referee #1's suggestion and we incorporated it accordingly.

Line 14: 215 **hPa**

We appreciate referee #1's suggestion and we incorporated it accordingly.

Lines 22-23: suggest changing sentence to "...air parcel trajectory model to trace high CO observations backward in time to confirm their origin"

We appreciate referee #1's suggestion and we incorporated it accordingly.

Line 23: swap model name with acronym – "...Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT)..."

We appreciate referee #1's suggestion and we incorporated it accordingly.

Lines 25-26: "wind field" unnecessary, also swap model name with acronym as above.

Page 23674, line 1: "...trajectories started **from**..."

We appreciate referee #1's suggestion and we incorporated it accordingly.

Line 6: “also marked...”

We appreciate referee #1’s suggestion and we incorporated it accordingly.

Line 10: “However, **in** the lower troposphere...”

We appreciate referee #1’s suggestion and we incorporated it accordingly.

Lines 25-29: needs rewriting to explain what supporting data are available for the period of interest, i.e. CALIPSO and CloudSat, before acknowledging the gap in the CALIPSO record.

We added introduction to CALIPSO and CloudSat before mentioning their data.

Page 23675, lines 4-5: this sentence doesn’t make sense, please clarify.

We changed sentence to ‘the two data sets have very few opportunities to capture the same event.’

Lines 11-12: please emphasise that this is the case for this study. The statement reads as though it is not at all possible to use satellite data in this way.

We changed the sentence to ‘For this particular event, it is therefore difficult for the sparse satellite observations to comprehensively describe the process of pollutant transport.’

Line 14: the sentence reads as though the GEOS-Chem output is provided by Bey et al (2001), please clarify.

We moved the reference to after GEOS-Chem model (Bey et al., 2001) ...

Line 15: clarify that the GEOS-Chem output is sampled at the times and locations of the TES profiles.

‘...CO sampled at the TES profile footprints and times (within ± 1.5 hours) from December 12th-19th, 2006 in the lower troposphere (681 hPa) and in upper troposphere (215 hPa)’

Lines 23-25: this procedure has been described earlier in the manuscript, also it’s not clear that this sentence adds anything to the discussion – why not show the GEOSChem output smoothed by the TES averaging kernels?

Yes, the sentence is not necessary here. It’s removed. The model profiles with TES operator applied (vertically smoothed by the averaging kernels) are not shown here because they do not affect the conclusions.

Page 23676, lines 1-4: please clarify if this sentence is describing the TES data or the GEOS-Chem output. If it is GEOS-Chem then the word “observed” should not be used later in the sentence.

This paragraph is to describe the comparisons between GEOS-Chem simulations of CO (Fig 8) and TES/MLS observations (Fig 2). We re-wrote most of the paragraph to discuss comparisons of Fig 8 and Fig 2.

Line 5: how does the GEOS-Chem output in this study compare to the TES data? It’s

not clear how the first sentences link to the results of Nassar et al (2009).
See above. The discussions of Nassar et al (2009) to the Indonesia fires were modified.

Page 23677, line 1: rearrange the sentence to read “Dirksen et al. (2009) used the TM4 chemistry transport model, constrained by OMI O2-O2 and AAI retrievals, to...”
We appreciate referee #1’s suggestion and we incorporated it accordingly.

Line 9: change to read “where it is actually being observed”
We appreciate referee #1’s suggestion and we incorporated it accordingly.

Lines 18-19: too many uses of “CTM”
We appreciate referee #1’s suggestion and we incorporated it accordingly.

Lines 17-22: suggest combining the two sentences in this section of text as the use of the Hyer et al (2007) reference is a little repetitive.
We appreciate referee #1’s suggestion and we incorporated it accordingly.

Page 23678, line 9: “...Australian fires of December 1996”
We appreciate referee #1’s suggestion and we incorporated it accordingly.

Lines 22-26: this section will need rewriting to be consistent with the changes suggested for page 23672, lines 12-14, at present it’s not clear what conclusion the authors are drawing from Figures 2 and 3.
As we described above for Fig3 (p 23672, lines12-14), we cannot conclude that the enhanced CO of TES retrieval in the lower trop high southern latitudes, e.g., at 681 hPa, is due to the ‘true’ CO enhancement locally in the boundary layer. We conclude ‘TES reported high CO values in the lower troposphere away from the fire sources are, therefore, partially due to the enhancement in CO in the mid-upper troposphere.’

Page 23679, lines 2-3: change to read “...model output co-located to the location and time of the TES profiles”
‘... extracting model data along TES observation footprints and times’.

Lines 16-18: while this is a valid point, the authors need to acknowledge that improved spatial and temporal coverage is already being provided by instruments such as GOME-2 and IASI. Also the final sentence of the abstract should be included here at the end of the conclusions.
We have addressed similar concerns given by editor Dr Cooper and modified this paragraph in conclusions.

Figure 1 caption: point out that the colour scales of the two plots are different?
Noted. The MLS CO is biased high, and the improvements will be in the new version data (V003).

Figure 2: please add missing units to the plots; “TES operator applied” should be consistent with the main text of the manuscript; “footprint” is ok for TES but not for MLS – do you mean the tangent point?

The missing unit (ppbv) is added. Yes, tangent points for MLS.

Figure 3: the plot axes and titles should be darker; clarify that the pressures in the colour bar are for the TES retrieval levels?; the text describing the profile selection criteria should be in the main body of the text and not in the caption.

The plot axes and characters are made darker. The pressure levels are a subset of TES reported levels. We kept the descriptions of the profile selection criteria in the caption so readers can keep track of paper content from the figures.

Figure 5: needs replotting as the axis and colour bar text is not very clear; change “illustrations” to “plots” in the caption.

This is similar to Dr Cooper’s request. We replotted the figure and changed ‘illustrations’ to ‘plots’.

Figure 7 caption: it’s not clear what “(or zero)” refers to.

Changed to ‘zero hour’.