Author comments in reply to the anonymous referee on "Simultaneous assimilation of satellite NO$_2$, O$_3$, CO, and HNO$_3$ data for the analysis of tropospheric chemical composition and emissions" by K. Miyazaki et al.

We want to thank the referee for the helpful comments and suggestions. We have revised the manuscript according to the comments, and hope that the revised version of the manuscript is now suitable for publication. Below are the referee comments in italics with our replies in normal font.

Reply to Referee #1

This is a very comprehensive piece of work and a valuable contribution to the data assimilation literature. It is suitable for publication in ACP once the authors address the following: (i) more references need to be introduced to defend statements made (examples given in the specific comments below); (ii) consider splitting the conclusions section (which is a bit too long) into a discussion and a conclusion proper, the latter providing the main message of the paper (e.g. the last 2 paragraphs of the current conclusions could form the basis for this revised conclusions section); and (iii) introduce acronyms when first used, both in the abstract and in the main manuscript.

Based on the reviewer's comment, more references have been added. The conclusion section has been separated into two parts. All acronyms have been defined.

The authors should also address the specific comments below. Specific Comments:
P. 16132, L. 24: Provide references for why ozone is important for air quality and climate.
  IPCC (2007) added.

P. 16133, L. 18: Provide references discussing the large uncertainties in bottom-up inventories.
  Jaegle et al. (2007) added.

P. 16134, L. 27: Provide references on the value of MLS (and other limb sounders) for the UTLS.
  Waters et al. (2006) added.

P. 16135, L. 2: Provide references for data assimilation (e.g. Kalnay, 2003).
  Kalnay (2003) added.

P. 16136, end of section 1: I suggest you indicate in which section the conclusions are provided.

The following sentence has been added.

"Section 6 concludes this study. Section 7 discusses future challenges."

P. 16137, Eq. (2): I suggest you motivate the introduction of the xtrue term (the text does not appear to discuss it).

Introduced.

P. 16137, L. 11: Is the measurement error the random error? Is it assumed the measurements have no bias?

The measurement error includes both random and systematic errors. The sentence has been replaced by "where the observational error ϵ is the sum of the measurement error and the representativeness error (both random and systematic), and $\mathbf{x}_{true}$ represents the true atmosphere profile."

P. 16138, L. 4: Provide references for the poorer resolution for GOME-2 and SCIAMACHY.

Richter and Burrows (2002) and Boersma et al. (2008) added.

P. 16138, L. 12: Provide a reference for the product specification document.

Boersma et al. (2011b) added.

P. 16139, L. 13: Provide references for the statement about TES DOFs in the tropospheric tropics.

Jourdain et al. (2007) added.

P. 16141, L. 10: What is the impact of not applying the bias correction?

The sentence has been rewritten as "No bias correction is applied to MOPITT data in this study, which may lead to slight bias in the estimated \chem{CO} emissions."

P. 16147, L. 13: Mention the non-linearity of H when H is first introduced (p. 16136).

Introduced.

P. 16151, L. 24: Quantify the statement that the DOF is "large".

"($\sim O(10^6)$)" added.

P. 16153, L. 23: What is the "above-mentioned"?

"above-mentioned" deleted.

P. 16157, L. 20: Is the statement about the OmF and bias reflected in the OmA statistics?

Yes. The sentence has been written as "The large reduction of the ¥chem{O_3} OmF bias for TES ¥chem{O_3} data in the middle and upper troposphere, which reflected the reduction of the OmA bias, implies that TES ¥chem{O_3} has meaningful information for…"

P. 16159, L. 27: Be more specific than "non-CO".

Modified.

P. 16161, L. 22: Provide references for the separation of the troposphere and stratosphere.

Bethan et al. (1996) added.

P. 16163, L. 2: Provide references for the statement about ozone precursors.

Liu et al. (1987) added.

P. 16173, L. 8: I suggest you remove "dramatic".

Removed.

P. 16174, L. 16: I suggest you identify the bottom-up inventories.

"(EDGAR3.2+GFED2.1+REAS1.1)" added.

P. 16175, L. 2: Provide references for these previous inverse modelling studies.

e.g., Kopacz et al. (2010) added.

P. 16176, L. 24: Provide references describing twin experiments.

Ghil and Malanotte-Rizzoli (1991) added.

P. 16177, L. 2: What do you mean by a perfect model scenario? In standard nomenclature, no $\boldsymbol{Q}$ error covariance matrix included, but a $\boldsymbol{B}$ error covariance matrix is included?

Yes, the perfect model eliminates Q. The sentence has been rewritten to explain this.

P. 16197, Table 4: What is "num" in the caption? What number of ensemble members did the "loc" experiments have? I suggest you identify in bold the smallest number in each column.

"num" has been replaced with "ens". num=48 was used in the "loc experiment". The smallest number has been indicated in bold font in the revised manuscript. The caption has been rewritten as follows:
"The performance of the data assimilation for different parameters: the horizontal localization length

(loc) and the ensemble number (ens). Ten-day mean (averaged over 20--30~January 2007) global mean RMS innovation of the OmF for each assimilated data are shown. The control (CTL) simulation was conducted with loc¥,$=$¥,450¥,¥unit{km} for ¥chem{NO_x} emissions and with 600¥,¥unit{km} for ¥chem{CO} emissions, lightning ¥chem{NO_x}, and the concentrations, and ens¥,$=$¥,48. The simulations with different loc values were conducted with ens¥,$=$¥,48. The smallest RMS innovation for each comparison is shown in bold."

P. 16208, Fig. 6: Indicate in the caption what the vertical bars show.
  The caption has been revised as "$¥chi^2$ value (in vertical axis) estimated for each assimilated data set (in horizontal axis) averaged over the 10--30~January (black) and July (red) in 2007.".

P. 16210, Fig. 8: Indicate in the caption what red/blue colours show. Also, as I understand it, the "control run" is marked as "free" in the figure. Either change the figure or indicate this in the caption. Same for Figures 9 and 10
  Corrected.

P. 16213, Fig. 11: Indicate in the caption that the upper and lower panels discussed comprise of 9 members each, e.g., use the form "upper 9 panels".
  Indicated.

P. 16214, Fig. 12: Fig. 12 is not quite like Fig. 11 (different number of panels), so please rephrase.
  The caption has been replaced with
"The mean relative difference of the vertical $¥chem{O_3}$ profiles between ozonesondes and the data assimilation with (red dashed) and without (red solid) the bias correction for TES ¥chem{O_3} data during 7--30~January 2007 (left) and 7--30~July 2007 (right)."

P. 16215, Fig. 13: Indicate in the caption that the control run is the model run (as shown in the figure). What is the size of the bin?
  The figure changed. The size of the bin is 30 hPa, which is noted in the revised manuscript.

P. 16216, Fig. 14: Use the form "upper 6 panels" and "lower 6 panels".
  Corrected.

P. 16217, Fig. 15: Indicate in the caption what red/blue colours show. Indicate that O3, CO and NO2 are shown in the left, centre and right panels, respectively.

Corrected.

Technical points:

P. 16139, L. 27: should be "upper troposphere".

P. 16141, L. 24: Should be "...recommendations in Livesey...".

P. 16149, L. 16 and 17: "...forecast atmospheric concentrations of...".

P. 16150, L. 15: conduced-> conducted.

P. 16155, L. 14: Use the subscript "3" for ozone.

P. 16156, L. 22: matricies-> matrices

P. 16159, L. 24: are larger->have higher values

P. 16162, L. 5: should be "...O3 are found...".

P. 16162, L. 28: Omit "the" after "Since".

P. 16163, L. 7-8: should be "...data assimilation experiment with a bias...".

P. 16172, L. 12: remove repeated "the"; L. 16: should be "...knowledge of...structure is...".

P. 16174, L. 14: great-> large

P. 16195, Table 2: many-> several

P. 1698, Table 5: Could this be made bigger? Same for Tables 7 and 8.

*P. 16203, Fig. 1 caption: Should be "**Yo**".*

Corrected.