Review of "An Inversion of NOx and NMVOC Emissions using Satellite Observations during the KORUS-AQ Campaign and Implications for Surface Ozone over East Asia" by Souri et al.

**General comments:**

This paper presents an optimization of $NO_x$ and VOC emissions over East Asia based on OMPS HCHO and OMI $NO_2$ during the 2016 KORUS-AQ campaign, interprets the emission changes (relative to the 2010 inventory) based on recent emission controls, and evaluates the potential impact of those emission changes on surface ozone. The use of satellite-based trace gas retrievals in a multi-species inversion is state-of-the-science, and the results are of sufficient importance to warrant publication in ACP. However, the presentation as is requires some additional work. Below is a list of specific comments that mostly denote areas where I think clarification or additional information is needed. I also think the authors could devote more space in the manuscript to the evaluation of the satellite observations and optimized simulation, including a comparison of the MDA8 $O_3$ to observations if possible. Additionally, the manuscript is quite long. I would suggest the authors consider combining/condensing the "Comparison of the model and the satellite observations" section and the "Updated Emissions" section along with the associated Figures, as there is significant overlap in the discussions between the two. The grammar could also be improved—I've noted some specific instances below where the authors should consider rewording the text, and there are plenty of other places where the language could be more concise and direct. I would recommend publication once these comments are addressed.

**Specific comments:**

Line 31: Averaging kernels themselves do not indicate whether emissions are "greatly improved" in an inversion—I would instead mention the comparisons to in situ data here.

Line 32-33: "The amount of total $NO_x$ emissions is mainly dictated by values reported in the MIX-Asia 2010 inventory." I'm not sure what this means—this inventory is used as the prior, but the results point to large decreases over much of East Asia, so surely the total $NO_x$ emissions also went down?

Lines 41-42: "We revisit the well-documented positive bias in the model in terms of biogenic VOC emissions." Can the authors be more specific here about what their results say about this positive bias?

Lines 114-116: From this, it sounds like the authors used the GEOS-Chem prediction for each specific day for the reference sector correction, rather than the climatological monthly-mean GEOS-Chem values used in Gonzales Abad (2016)? What impact does this have on the performance of the retrieval? Did the authors do any comparisons?

Line 169: The authors denote that the observational error covariance matrix corresponds to the instrument uncertainty, but model (i.e. transport) uncertainty also contributes here. Do the authors account for any model uncertainty in this term?

Line 173: “it does not allow the a posteriori to deviate largely from the a priori…” I would delete or reword this phrase, because of course this depends on how uncertain one assumes the prior emissions to be (as the authors clarify later in the paragraph).

Line 176: One question I have at the end of this paragraph is how the authors weight the relative contributions of the HCHO and $NO_2$ observations to the cost function? This seems to be an important consideration in multi-species inversions that deserves some discussion.

Line 182: Is there any metric used to support the decision to iterate three times?

Lines 192-198: Evaluation of the satellite observations with the KORUS-AQ aircraft data is a strength of this study that could use more attention in the manuscript, especially since the authors describe the satellite observations as “well-characterized”. I think a figure showing the satellite-aircraft comparison would be helpful and would also serve to justify the decision to uniformly scale the HCHO and $NO_2$ columns up by the specified amounts.

Lines 227-228: “We do not consider the interconnection between the zonal emissions and concentrations due to computational burdens.” I’m not clear what exactly this means. That the K matrix is assumed to be diagonal?

Lines 304-307: I found this sentence confusing. How does one determine the yield of HCHO from the OMPS data, and why does it suggest that the anthropogenic emissions dominate in NCP?

Lines 360-366: Here I think the authors are attempting to highlight the advantages of their iterative, multispecies inversion approach over simpler scaling methods, but the language is unclear and could be interpreted in the wrong way. Consider using stronger language here to show how this work advances on previous satellite-based $NO_x$ emission optimizations.

Lines 367-376: Because the OMI data are used in the inversion, this comparison is not an independent validation. I would consider moving Fig. 5 to the supplement (or perhaps combining it with Fig. 4) and focus more on the in situ comparison here.

Lines 374-376: The authors derive quite large relative changes in $NO_x$ emissions over remote regions, so it seems incorrect to say the inversion is more weighted toward the prior emissions here. Also, higher a priori error would allow for larger deviation away the prior, not toward it as the authors say. Instead, could background conditions and/or lightning sources be a significant contributor here? What does the literature say?

Lines 377-384: Why not include a figure showing the $NO_x$ comparison to aircraft data? I suggest including this comparison with or in place of the current Fig. 5.

Lines 406-412: As for $NO_x$, the HCHO validation should focus more on the in situ comparison here than on the comparison to OMPS. Consider moving Fig. 7 to the supplement (or combining it with Fig. 6).

Lines 419-428: Consider combining Figs. S2-S7 into one Figure and including it in the main text, to be referenced here.

Lines 491-504: Is there any reliable O3 data in the region to which you can compare the modeled MDA8 O3? Does the a posteriori simulation compare better to O3 measurements made during KORUS-AQ?

Lines 551-564: While it is good to highlight the remaining uncertainties and research needs at the end, this last paragraph kind of gets into the weeds in a way that ends the paper on a low note. Consider shortening this section to focus on the strengths of this study with an eye toward future improvements.

Figures 2 and 3: The caption says the upper right panels in these figures is the logarithmic ratio of model/obs, but what's actually plotted is the inverse of the ratio (obs/model). Consider replotting with the model/obs ratio, as this would be more consistent with how it is discussed in the text.

Figure 8: Can the color scale be adjusted to better indicate the values that fall above/below the transition line of 2.7?

Figures 9 and 10: Consider combining these into one Figure.

Figures S2-S7: The captions need to include some more information about what exactly is being plotted here. Are these mean profiles for the entire KORUS-AQ campaign? Was any type of filtering applied to the data?

**Technical corrections**

Throughout the manuscript: the phrase: "in terms of" is used excessively—suggest deleting it to make the discussion more concise.

Line 46: Suggest changing "an ~ 53%" to "a ~53%"

Line 51: Delete "the" before "southern China"

Lines 54-56: These sentences are a bit awkward—consider rewording.

Lines 64-71: This is a long, cumbersome sentence—consider breaking it up for better flow.

Line 69: Delete "the" before "effect"

Line 137: Delete “an” before “analytical”

Line 151: Reference should Guenther et al. (2012) instead of (2006)

Line 152: “diurnally lateral chemical conditions” should maybe be “diurnally-varying lateral chemical conditions” (?)

Lines 225-227: This description is awkward—consider rewording.

Lines 287-289: This sentence is awkward—consider rewording.

Lines 317: Change “satellites” to “satellite”

Line 320: Delete the first instance of “associated” in this sentence

Line 400: Change the word “owning” to “owing”

Line 423: Add “The” before “same tendency”

Line 447: Delete the word “condition” before “regimes”

Line 463: Insert the word “on” before “par”

Lines 472-475: The sentence is awkward—consider rewording.

Line 479: Change “forming” to “form”

Lines 486-488: The sentence is awkward—consider rewording.