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Atmospheric Chemistry and Physics Discussions

# *Interactive comment on* "Inverse modeling of $SO_2$ and $NO_x$ emissions over China using multi-sensor satellite data: 1. formulation and sensitivity analysis" *by* Yi Wang et al.

**Anonymous Referee #2**

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This manuscript presents joint inversion results of SO2 and NOx emissions over China using the GEOS-Chem adjoint model and OMPS satellite observations for October 2013. The inversion results were compared against assimilated OMPS observations and independent OMI observations. Several sensitivity calculations were conducted to optimize the joint inversion framework. The joint inversion approach is unique, while the comparison against the OMI observations is interesting. I would, however, advise the authors to revise the manuscript. These revisions should be made before the manuscript can be considered for publication in ACP.

[ Major comments ]



The model horizontal resolution (2°x2.5° resolution) is clearly too coarse for current regional (not global) emission research, which could lead to serious problems for many applications (e.g., systematic biases in the downscaling analysis (Part 2)). In the previous study by the author's group (Qu et al, 2019), regional Chinese regional emissions were estimated at 0.5°x0.667° resolution using a hybrid 4D-Var/Mass balance approach to save computational resources for the multiple-year calculations, while conducting a one-month adjoint calculation at 0.5°x0.667° resolution using the same adjoint model with a nested domain for East Asia. In the same way, one-month inversion calculation at 0.5°x0.667° resolution using OMPS observations must be doable and should be tested in the present study. This is essential for evaluating the joint inversion performance using in-situ observations (please see my comment below), as already performed by Qu et al. (2019) for OMI assimilation results. It could also provide improved information (e.g., reduced systematic errors for each grid point, considering the non-linear chemistry) for down-scaling analysis (Part 2). For long-term emission estimations, the authors could still use the hybrid inversion framework at 0.5°x0.667° resolution (together with the downscaling approaches, if resolutions higher than at 0.5°x0.667° resolution are needed). Thus, I don't think the coarse resolution regional joint inversion will be needed for any applications. At the very least, 0.5°x0.667° resolution joint inversion calculations should be performed for key experiments.

The joint inversion results, including those from the sensitivity calculations, need to be evaluated against independent in-situ measurements, in order to obtain the optimized system. For this, the authors need to use their 0.5°x0.667° resolution joint inversion system. Resolutions higher than 0.5°x0.667° would be required for reducing representation gaps, as discussed in Part 2. Nevertheless, Qu et al (2019) already demonstrated that joint inversions at 0.5°x0.667° resolution can be evaluated using in-situ surface observations. This is also essential for evaluating possible biases in both OMPS and OMI satellite observations, which can be one of the most important results from the present study.

Although the joint inversion reduced the total computational cost, its scientific benefits (required for ACP, not for GMD) are not very clear. The discussions in Sections 4.4 and 4.5 are interesting. Adding evaluations using any AOD, NH3, and relevant observations would be helpful to demonstrate the scientific value of the joint inversion.

[ A few more specific comments ]

L203 “In this study, OMPS SO2 and NO2 tropospheric VCDs are retrieved using the shape of NO2 vertical profiles from GEOS-Chem simulations (Yang et al., 2013; Yang et al., 2014), although differences of model version, simulation year, and emission inventory still exists” These profiles can be largely different. The lack of averaging kernel in the observation operator can lead to serious problems. Please justify and demonstrate its impacts. Otherwise, data assimilation adjustments can be meaningless.

L204 “Hence, the difference between the GEOS-Chem simulations and the OMPS retrievals is mostly ascribed to the uncertainty of the emissions.” This may not be true and requires further investigation.

OMI L3 data is used for validation. Without applying the averaging kernels, comparisons may not provide meaningful information. This needs to be investigated.

L325 and some other paces, “Our finding of a large reduction. . .“ The discussion about trends between the 2013 October inversion and the 2010 inventories does not make any sense.

L330 “in some model grid cells”: Please discuss the spatial pattern.

Section 4.2 does not provide very useful information and can be removed or shortened.

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