Authors' response to the review comments #2

Title: OMI NO_2 column densities over North American urban cities: The effect of satellite footprint resolution

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First of all, the authors express their appreciation to the two reviewers and the editor. We believe that their comments are very productive and substantially contributed to improving the manuscript. We provide replies for the reviewer's two main comments: (1) Why this draft is suited to the GMD's general goal, and (2) why findings and approaches in this draft are valuable for the future scientific model development. We also try to clarify the use of Averaging Kernel (AK) in the draft. Reviews' comments are shown in italics.

(1) The journal choice

"I consider this study out-of-scope for the aforementioned journal, as the authors have merely used the CMAQ model in their study; the study does not include any aspects of model development."

We believe that the evaluation of a model is a crucial part of model development. Without proper evaluation with observational evidences, the model's capability to represent the natural phenomena will be seriously limited. The main goal of this study is to discuss how a geoscientific model should be evaluated when its evaluation has likely been systematic biased due to data resolution.

In this draft, we have demonstrated that a direct comparison of the modeled and satellite NO_2 vertical column density (VCD) over urban cities might have serious systematic bias due to differences in the data geospatial resolutions between the model and observation (e.g. satellite). Subsequently we have described an approach to reduce this systematic bias. We have submitted this draft to the *Geoscientific Model Development* because our study addresses the scientific fairness in model evaluation between different geospatial data sets.

Furthermore, the comparison of modeled and satellite NO_2 VCDs is usually used to improve model's emission input (e.g. NO_x emission) which is one of the most important elements for better atmospheric chemistry modeling system.

(2) Scientific importance and implication

"The study lacks scientific novelty. Regarding the second point, the fact that measurements of trop. NO2 over urban areas are not able to capture the high pollution maxima over the emission hot spot due to the spatial smoothing caused by the coarse satellite ground pixel is trivial and has been reported on previously."

The reviewer commented that this draft is trivial since the underestimation of satellite NO_2 VCD observations over urban cities due to its coarse spatial resolution has already been reported. However, this comment seriously misinterprets our work. The draft did not only report these biases, but also tried to quantify the magnitude of the biases, and tried to suggest approaches to overcome those systematic biases.

In addition, we do not agree with the notion that quantification of such biases as was suggested by this draft is trivial or negligible. The draft has demonstrated that the theoretical systematic biases from OMI could be as large as 100% over urban cities just by the geometric effect of coarse satellite footprint pixels. Considering the economic cost and impact on the public health, the estimation suggested from this study has a serious implication in the interpretation of current anthropogenic emission inventory, and should be further considered in the policy decision-making of emission regulation.

For more detailed technical point of view, this study is a first approach to use a (mass) conservative spatial regridding method with satellite data in a footprint pixel level (e.g. level2), using the polygon clipping algorithms. Although the smoothing effect due to satellite resolution is already reported, there have been few approaches to adjust the impact of satellite resolution effect; Hilboll et al. (2013) might be the one to name. In accordance with the authors' knowledge, no approach has been tried with pixel level mass conservation in the top-down approach.

The key idea in this approach is to handle geospatial data as "polygon with area" instead of "pixels", as described in Kim et al., (2013) or in the response to the review #1. The mass conservative spatial regridding capability will be essential in the development of fine-scaling modeling approaches. We believe that this technique can provide a useful tool to handle multi-scale model or geospatial data together; It can be useful for the comparison between model and satellites, or inter-comparison between various satellite platforms.

"The fact that the agreement between modelled and measured pixels improves when AK information is applied to the model fields is also trivial; in fact, any quantitative comparison between model and measurements has to use AK information, as neglecting to do so leads to a comparison of apples and oranges."

Moreover, we would like to clarify the use of the Averaging Kernel (AK) information. We do not claim that the use of the AK information in the comparison of modeled and space-borne NO_2 VCD is one of our achievements in this study. We just used the AK information because its use is a necessary step to prepare the satellite data for a fair comparison as the reviewer commented. We described through a step-by-step data comparisons (e.g. raw data case, using AK case, using downscaling (DS) case, and using both AK and DS case), to demonstrate that the impact of the DS method is comparable to the impact of AK use in the model-satellite comparison. If one thinks the use of the AK is mandatary for satellite-model comparison, we suggest that the impact of satellite footprint pixel resolution also should be considered to understand the fine scale phenomena such as urban NO_2 plumes.

Thanks again for the reviewer's comment.

Hilboll, A., Richter, A., & Burrows, J. P. (2013). Long-term changes of tropospheric NO2 over megacities derived from multiple satellite instruments. *Atmospheric Chemistry and Physics*, *13*(8), 4145–4169. doi:10.5194/acp-13-4145-2013

Kim, H., Ngan, F., Lee, P., & Tong, D. (2013). *Development of IDL-based geospatial data processing framework for meteorology and air quality modeling*. Retrieved from http://aqrp.ceer.utexas.edu/projectinfoFY12_13%5C12-TN2%5C12-TN2 Final Report.pdf