

The article “Effects of model spatial resolution on the interpretation of satellite NO<sub>2</sub> observations” investigates in how far the spatial (horizontal) resolution of atmospheric chemistry models (CTM) leads to biases in the simulated tropospheric NO<sub>2</sub> due to nonlinear effects in the chemistry of NO<sub>2</sub> and OH.

It presents results from simulations of NO<sub>2</sub> columns by 1d, 2d and 3d chemistry models for different horizontal resolutions and concludes with the necessary resolution for a required accuracy for selected regions.

The paper is of good quality, structured well, written very compact and the figures are supporting the results of the study (although they need to be improved and have errors in important points). The authors did a very good job in summarizing the study to the point. However, in my opinion it addresses not all the important topics and many passages are written much too short. I think the paper would improve very much if the authors spend a few words more on explaining and motivating the studies and also add a few sentences on the interpretation and discussion of the results.

The article should be considered for publishing after major revision.

1. Does the paper address relevant scientific questions within the scope of ACP? Yes
2. Does the paper present novel concepts, ideas, tools, or data? Yes
3. Are substantial conclusions reached? Yes
4. Are the scientific methods and assumptions valid and clearly outlined? Yes (and no)
5. Are the results sufficient to support the interpretations and conclusions? No
6. Is the description of experiments and calculations sufficiently complete and precise to allow their reproduction by fellow scientists (traceability of results)? No
7. Do the authors give proper credit to related work and clearly indicate their own new/original contribution? No
8. Does the title clearly reflect the contents of the paper? No
9. Does the abstract provide a concise and complete summary? No
10. Is the overall presentation well structured and clear? Yes
11. Is the language fluent and precise? Yes
12. Are mathematical formulae, symbols, abbreviations, and units correctly defined and used? No
13. Should any parts of the paper (text, formulae, figures, tables) be clarified, reduced, combined, or eliminated? Yes
14. Are the number and quality of references appropriate? No
15. Is the amount and quality of supplementary material appropriate? Yes

General comments:

1) There are few topics that need to be explained in more detail and also discussed. This will enable more readers to understand the study and its results without spending large effort and time. There is basically no connection of the different studies and their results, and how these are related to the problem of inverse modelling and the comparison with satellite observations.

Also a discussion of the results in the context of tropospheric chemistry is missing.

Only for the introduction, this aspect is provided well.

For the appendix, there is no description of the results at all, only the settings for the simulations are described.

2) For the 2D studies, area sources should be used (instead of point sources), since this will provide the realistic results important for the comparisons to measurements. The results for the point sources will be misinterpreted, since the authors write that for area sources the biases are significantly smaller.

3) One implication of the study could be that, regardless of the given resolution of the satellite observations, one should use model resolutions finer than 12 km (or even 4 km) for tropospheric NO<sub>2</sub> comparisons. Still there is also the effect of the averaging of the NO<sub>2</sub> for the satellite pixels (with different cloud coverage, albedo, etc). How do these problems for comparisons go together? And what is the meaning of accuracy in this context? I would appreciate if the authors discuss this point.

4) Then there is the point of the strength of the NO<sub>2</sub> source compared to the resolution that is important. The authors study selected regions with different source strengths, the 3D studies are performed for Los Angeles, Four Corners and other parts of the US. To make use of these studies for many scientists the authors should investigate in how far the results can be generalized (or not) for other parts of the world. What are the important parameters for the necessary resolution? The authors conclude that source strength and area are the determining parameters. If that is true, then a generalization for other regions should be easy. However, I suggest that there are a few more important parameters that are not discussed by the authors. In how far are the results depending on topography and the meteorological situation (wind direction, speed and variability)? And are there differences for different seasons, cloud coverage etc?

5) Nothing is said about the resolution in time. I heard that for CTMs the relation of the time resolution to the spatial resolution is important for a correct simulation. If this should not be the case for this study then explain why, otherwise a study on the effect of the time resolution on the results would be important.

Detailed Comments:

Titel:

Add "Tropospheric" before NO<sub>2</sub>.

The title should also make clear that the study is on "atmospheric chemistry" models (CTM), and not on models (e.g. RTM) that are used for the retrieval of the NO<sub>2</sub> observations.

And one could give the information that 1d, 2d and 3d models are used.

### Abstract:

One or two introducing sentences on a general level would be good. Especially it should be said that the study is on tropospheric chemistry and in particular NO<sub>2</sub>.

Line 4: “Here we compute the resolution-dependent bias in predicted NO<sub>2</sub> column, a quantity relevant to the interpretation of space-based observations.”

I suggest rephrasing this sentence (see general comments)

Line 10: “... to 10 and 25% ... “: add accuracy

### Chapter 1 (Introduction):

Line 8: “(100s ppb)” and (100s ppt)”: please check if this is the conventional scientific writing, to me it seems not.

Line 11: “High-quality satellite based observations ...”

The term high-quality is not defined and represents an impression or opinion of the authors, which should be skipped. References not listed here (and there are a few important studies on tropospheric NO<sub>2</sub> missing) could be regarded as not “high quality”. Also it gives the bad impression of some kind of “commercial” since 2 (or 3) of 4 articles cited here are from Co-Authors of this article !

Page 4, Line 2: “... may have resolution-dependent biases”

This is a very vague formulation considering the obvious effect and also the result of this study. I suggest rephrasing this sentence.

### Chapter 2:

Page 4, line 12: “The dimensions perpendicular to the flow ...” add : (i.e. in North South direction and vertically)

Page 4, line 19: For what resolution and what distance of the source is the figure 1 ?  
Or what data is averaged here ? And would results from 2d and 3d be similar ?

Page 4, line 15 and 18: check if “1s-1” and “0 molec cm-3 s-1” are the correct values

Page 5 line 6: “NO<sub>2</sub> is numerically diluted ...” : Is this correct writing ? And if yes, I think it should be rephrased to avoid confusion. This is only distributing the large NO<sub>2</sub> over a wider area.

Page 5 line 8: Depending on the resolution, the bias averaged over this large domain seems for me not to be the important value, considering the motivation of the study. What is the maximum difference that can occur ?

Page 5 line 16: “ ... corresponding to a chemical lifetime of about three hours and maximum OH.” : Do you mean that of the three investigated source strengths, OH number density is largest for the intermediate ?

Otherwise, for the maximum in OH, the lifetime of NO<sub>2</sub> is less than 2 h, see Fig. 1

Page 5 line 17: Obviously an e-fold decay within 60 km can not be resolved by a resolution of 128 km.

Page 5 line 19: "... near the NO<sub>2</sub>-OH crossover regime,...": Is this term correct and the best choice ?

Page 5 line 21: "In a 1-D model, biases are less than 15% at model resolutions finer than 128 km and are only large (>50%) for ..."

I don't agree with this conclusion. Since the bias plotted in Fig. 3 is averaged for the whole domain, the individual biases will be much larger, also for resolutions finer than 128 km, e.g. when comparing to satellite observations.

### Chapter 3:

Page 6 line 7: "... and diffuses at 10 m<sup>2</sup> s<sup>-1</sup>." : what is meant here ?

Page 6 line 8: make clear that with "boundary" you mean the boundary of the domain and not the boundary layer

Page 6 line 15: Mention here the important fact that the bias averaged for the whole domain is plotted.

Page 6 line 19: again, these are averaged biases !

Page 7 line 7-10: see general comment, point 4

Page 7 line 11-16: this summary should be provided for the area sources, the results for the point sources are misleading.

### Chapter 4:

Header: "Resolution required to predict column NO<sub>2</sub> to 10% and 25%" : add accuracy

Page 7 line 21: "... as would be observed by a satellite based instrument ..."

Mention that the observations of tropospheric NO<sub>2</sub> have their own uncertainties (albedo, cloud coverage, aerosols, averaging over the pixel size, ...), also causing problems for such a comparison. The pixel sizes for the three instruments could be given here, not every reader will know this.

Page 8 line 7: "... simulated OH is low (<5\*10<sup>6</sup> molec cm<sup>-2</sup>) ..."

In the referred Figure 6 effective OH (molec cm<sup>-3</sup>) is shown.

### Chapter 5:

Conclusion should be rewritten considering the general comments.

Figures:

Figure 2: label x-axis with “distance (and time) from the source”

Figure 2, caption: in first sentence add that horizontal resolution in W-E direction is changed

Figures 4, 7, 8, 9: at the top of the figures, exchange “02” to “2”, “04” to 4

Figures 4, 6, 7, 8, 9: colorbar: Is it really necessary to have broken exponents, integers would be much better ! Also the units should be given near the colorbar, not in the caption.

Figure 4, caption: “The vertical layer is fixed at 1 km for all simulations shown.“ : I suppose you mean the resolution of the vertical layers ?

Figure 5 a) : unit VCD NO<sub>2</sub> (molecules cm<sup>-2</sup>) is given, but no colorbar ?

Figure 5, caption: Mention again the definition for a large source

Figure 5 e) : the caption says “point” but the text says ”12x12 km” pixel ?

Figure 6: no units on colorbars

Figure 6: mention for what altitude(s) the effective OH is given. And explain this term in the text and figure. Or if it is the OH column (like written in text) then correct.