

## ***Interactive comment on “Multi-model ensemble simulations of tropospheric NO<sub>2</sub> compared with GOME retrievals for the year 2000” by T. P. C. van Noije et al.***

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Received and published: 27 June 2006

We thank Referee #1 for reviewing our manuscript.

Response to specific comments:

p. 2982: This is a good point and we thank the reviewer for making this comment. To collocate the model output with the GOME measurements we do not use any model information for cloud cover and cloud optical properties. The sampling is done by including only model data at the scenes that have actually been included in the BIRA/KNMI retrieval. We have adapted the text to clarify this issue.

p. 2983: As is clear from our explanation above, the same scenes are selected for

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all models. The point made by the reviewer that for "the climate models (ensemble B) it probably makes no sense to select specific days of a month" is addressed in Section 5.3. The results presented there demonstrate that by sampling the model data we do account for sampling biases in the retrievals due to correlations on seasonal time scales between local cloud cover and tropospheric NO<sub>2</sub> columns. Only for the models of ensemble A, the sampling also accounts for day-to-day fluctuations related to meteorological conditions (as shown in Figure 7).

p. 2984: Given our explanation to the reviewer's first point referring to p. 2982, we do not use monthly mean cloud cover. Regarding the reviewer's question "how are data sampled from monthly means?", we refer to the formulas and the accompanying definitions. As stated there, first the operator M "assigns the monthly mean values to the daily fields" (the resulting fields are still defined on a daily basis, but show no variations within a month); then the sampling operator S "selects the scenes that have actually been retrieved".

p. 2986, l. 10/14: The idea of this paragraph is to first give a qualitative description of the spatial patterns observed in the retrievals. This justifies our use of "relatively high" versus "relatively low". A more quantitative analysis is given in Section 5.2 where number are quoted for various regions.

p. 2986, l. 22: Again, we do not want to include too many details at this stage of our discussion of the patterns simulated by the models. Table A2 contains all the information the reader needs to know which are the "higher-resolution models".

p. 2987: Note that we actually state that the CH<sub>4</sub> lifetime in the models varies between 7 and 12 years (not days!). The CH<sub>4</sub> lifetime is determined predominantly by reaction with tropospheric OH, however there are also losses via oxidation in the stratosphere and by soil uptake. For these two minor loss processes, we assumed IPCC TAR values. The range of 7-12 years refers to the lifetime with respect to all sinks. As stated, in the setup used for these simulations, the methane mixing ratio is fixed throughout the

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model domain (see also Stevenson et al., 2006 for more details on all these points). Tropospheric OH is a free variable, so there is no conflict in having a range of CH<sub>4</sub> lifetimes and prescribed CH<sub>4</sub> concentrations; the range simply reflects the range of model OH. In the revised document we have clarified that removal of CH<sub>4</sub> by OH is diagnosed even though CH<sub>4</sub> was fixed, and that this is used to calculate the lifetime.

p. 2988: In the text, we state that "The differences in model performance are caused by a complex interplay of various aspects of the chemistry and dynamics of the models." Several possible explanations are given, including differences in the (heterogeneous) chemistry scheme used in the different models and in the parametrization of vertical mixing processes. We have indicated that "vertical mixing is important for two competing reasons. On the one hand, the lifetime of NO<sub>x</sub> increases with height ... On the other hand, the daytime NO<sub>2</sub>/NO ratio typically decreases by an order of magnitude from the surface to the upper troposphere." The latter effect seems to be the more important, because it is consistent with the relatively low NO<sub>2</sub> columns simulated in LMDz-INCA, which has too vigorous vertical mixing, and the relatively high columns in NCAR and MOZ2-GFDL models, which tend to cap pollutants in the boundary layer. Please note this would only imply that there is a negative correlation between the strength of the vertical mixing and the simulated NO<sub>2</sub> columns. However, it does not imply that other factor such as the OH level and details of the chemistry, which also affect the NO<sub>x</sub> lifetime, are less important.

p. 2992: We have split this sentence into two and clarified the text.

p. 2997: In Section 4 it is explained that the "corrected" annual mean is constructed "by first calculating the monthly mean and then averaging the monthly means". From this and the fact that in this sentence we explicitly refer to this section it should be clear that "the number of days per month" is nothing but the total number of days in a month.

p. 3000: Given the short lifetime of NO<sub>x</sub> and the relatively small amplitude of the seasonal cycle (compared to annual mean), the impact of a seasonal cycle in emissions

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to first order is only a simple scaling of the NO<sub>2</sub> columns. Estimation of the impact of a diurnal cycle in emissions is more complicated, because the diurnal cycle can be relatively strong for some emission categories (compared to the daily mean) while there is no separation of time scales. We have indicated in the text that this is the reason for analyzing the impact of a diurnal cycle in emissions in more detail.

p. 3003: Southern needs a capital when it is part of a name, but it is not necessary when it just means "the south part of". We consistently write "eastern United States", "eastern China", "southern Congo" and "southern Sudan" throughout the paper.

p. 3016: As explained in Section 3, where we refer to Table 1, the numbers include the emissions from international shipping, but not from aircraft. For clarity, we have changed "Anthropogenic NO<sub>x</sub> emissions" to "Anthropogenic surface NO<sub>x</sub> emissions".

p. 3035: Figure 2 shows the results "obtained directly from the daily model columns", which means that no averaging kernels are applied. Figure 8 (left) shows the corresponding results "calculated by application of the averaging kernels". Figure 8 (right) shows the difference between Figure 8 (left) and Figure 2. We have reformulated the caption to Figure 8 as well as the accompanying text in Section 5.4.

p. 3036: This is a good point. However, it should be realized that as stated in Section 4 we smooth the data from 0.5x0.5 to 5x5 using a moving average. This means that the field still shows variations on a scale of 0.5x0.5 degrees. The region defined in South Africa covers an area of 5x5 degrees, which is an order of magnitude larger in both directions. The results for this region are therefore robust, independent of the interpolation method.

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Interactive comment on Atmos. Chem. Phys. Discuss., 6, 2965, 2006.

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