

We are grateful to the reviewers for the appropriate and constructive suggestions and for the proposed corrections to improve the paper. We have addressed all the issues raised and have modified the paper accordingly. We believe that, thanks to these inputs, the manuscript has definitely improved.

This is a summary of the changes we made and our responses to the reviewer #2's comments and recommendations.

Summary of the changes

(in black is the original comments of the reviewer, while our responses are highlighted in red)

Reviewer #2

Specific comments

1. The chemistry box model includes chemistry of organic species of up to 4 carbon atoms and isoprene. Since anthropogenic emissions in Beijing and a few its neighboring industrial zones are not trivial, the concentrations and emission fluxes of aromatic VOCs (e.g. toluene, benzene, xylene, etc.) are expected to be significant. These VOCs play an important role in influencing the mixing ratios of HO_x, NO_x and consequently that of ozone. The authors should include the aromatic chemistry in order to obtain simulation results that are more representative of the atmosphere in Beijing. At a minimum, a few lumped reactions representing the oxidation of aromatic compounds should be included as part of the chemical reaction scheme in the box model.

In general we agree with the referee that it will eventually be valuable to also consider the role of aromatic VOCs. However, we would have a very difficult time including it here for two reasons. One is more technical: the addition of new species and reactions to the simulations is not a simple task, even though it is a box model, since in our setup the chemical mechanism is tightly integrated with other aspects of the model (emissions, transport, deposition, and photolysis), which all need to be changed appropriately (for any newly emitted species themselves, as well as all of their oxidation intermediates) when the mechanism is altered. Second, and perhaps more important, we have begun working some with the MCM (Master Chemical Mechanism) oxidation scheme for aromatics to try to understand the general relationship to ozone production efficiency, and find that it is much more complicated than we had anticipated. In principle it is possible to set up a reduced mechanism which broadly represents aromatics, or to adopt an existing one (e.g., from regional urban airshed models). However, we have had bad experiences with making modifications in lumped mechanisms if they are not very carefully retuned to work appropriately in their applied environment each time they are modified (we have found that even seemingly trivial modifications to product yields can have substantial effects on ozone and OH; see Taraborrelli, ACP, 2009, www.atmos-chem-phys.net/9/2751/2009/). Thus, it appears that adding a few additional simplified reactions would introduce a substantial additional uncertainty, and it seems more sensible to us that this issue be approached more thoroughly in a follow-up study which focuses on developing and verifying an improved representation of aromatics for this region.

2. Photolysis reactions are important in affecting the mixing ratios of NO_x, O₃ and HO_x. In the paper, the authors arbitrarily assigned a 50% decrease to all photolysis rates based on the work of Jeong et al (2007). Considering the arbitrary nature of the value of "50%", I think that sensitivity tests on assuming different values in the decrease of photolysis rates should be carried out and results should be included in this paper.

Considering both reviewer’s comments about the photolysis rates test, a simulation with dust, but only considering the decrease of photolysis rates (DUST_J), has been added and the following modifications have been made:

Page 20154, line 6: “a simulation with dust, but only considering the decrease of photolysis rates (DUST_J),” has been inserted after “(DUST_H),”.

Page 20154, line 11: “the DUST_J simulation and” has been inserted after “is used for”.

Page 20154, line 19: “DUST_H+J” has been modified to “DUST_J”.

Page 20154, line 20: “DUST_H” has been modified to “NO_DUST”.

Page 20160, line 24: “DUST_H+J” has been modified to “DUST_J”.

Page 20160, line 26: following text has been added (after the first sentence): “It is important to note that the actual change in photolysis rates due to dust will vary from species to species, due to the wavelength-dependent effects of dust particles on the actinic flux; the approach here is only meant to establish an order-of-magnitude estimate of this effect, as an indicator of whether or not it is worth continued investigation for characterizing the effects of dust on chemistry in Beijing.”

Page 20160, line 28: “DUST_H+J and DUST_H” has been modified to “DUST_J and NO_DUST”.

Page 20161, line 2: “OH (−54%) and O_x (−19%)” has been modified to “OH (−54%) and O_x (−18%)”.

Page 20161, line 3: “relative decrease (−0.6%)” has been modified to “relative increase (0.5%)”.

Page 20161, line 6: “(−3.5 nmol/mol)” has been modified to “(−2.8 nmol/mol)”.

Page 20161, line 11: “*B_{cp}* decreases by 12.3% and *K_{cl}* decreases by 1.17%” has been modified to “*B_{cp}* decreases by 7.5% and *K_{cl}* decreases by 10.1%”.

Page 20161, line 19: following text has been added: “In real conditions, the effects of dust on the tropospheric chemistry through the heterogeneous removals and the photolysis perturbations are combined nonlinearly. As listed in Table 7, the nonlinearly combined influences of dust on O_x and OH are somewhat smaller than the linearly summed influences: the differences in the relative influences are 9.5% for O_x 8.8% for OH, and only 1% for NO_x.”

Table 6. The differences calculated as DUST_J – NO_DUST of the daily average mixing ratios *y* and the gross chemical production rates *B_{cp}* and the gross chemical loss frequencies *K_{cl}* of O_x, NO_x and OH due to the decrease of photolysis rate coefficients for the T04 case. The relative differences calculated as (DUST_J – NO_DUST)/NO_DUST are shown in parentheses. For OH, the concentration *C* is shown instead of the mixing ratio *y*.

	<i>y</i>	<i>B_{cp}</i>	<i>K_{cl}</i>
O _x	-3.7 nmol mol ⁻¹ (-17.8%)	-0.05 nmol mol ⁻¹ s ⁻¹ (-42.3%)	-1.8×10 ⁻³ s ⁻¹ (-28.6%)
NO _x	0.3 nmol mol ⁻¹ (0.5%)	-1.5×10 ⁻⁴ nmol mol ⁻¹ s ⁻¹ (-7.5%)	-2.4×10 ⁻⁶ s ⁻¹ (-10.1%)
OH	-8.5×10 ⁴ molecules cm ⁻³ (-54.2%)	-2.2×10 ⁶ molecules cm ⁻³ s ⁻¹ (-52.3%)	1.1 s ⁻¹ (4.2%)

Fig. 10. Differences of the daily average chemical production budgets (black bars) and chemical loss frequencies (red bars) of OH, between the DUST_J and NO_DUST simulations (DUST_J–NO_DUST) in the T04 case. “Miscellaneous” (hollow bars) represents the sum of all the other source or loss terms. The reactions are listed in Table 5.

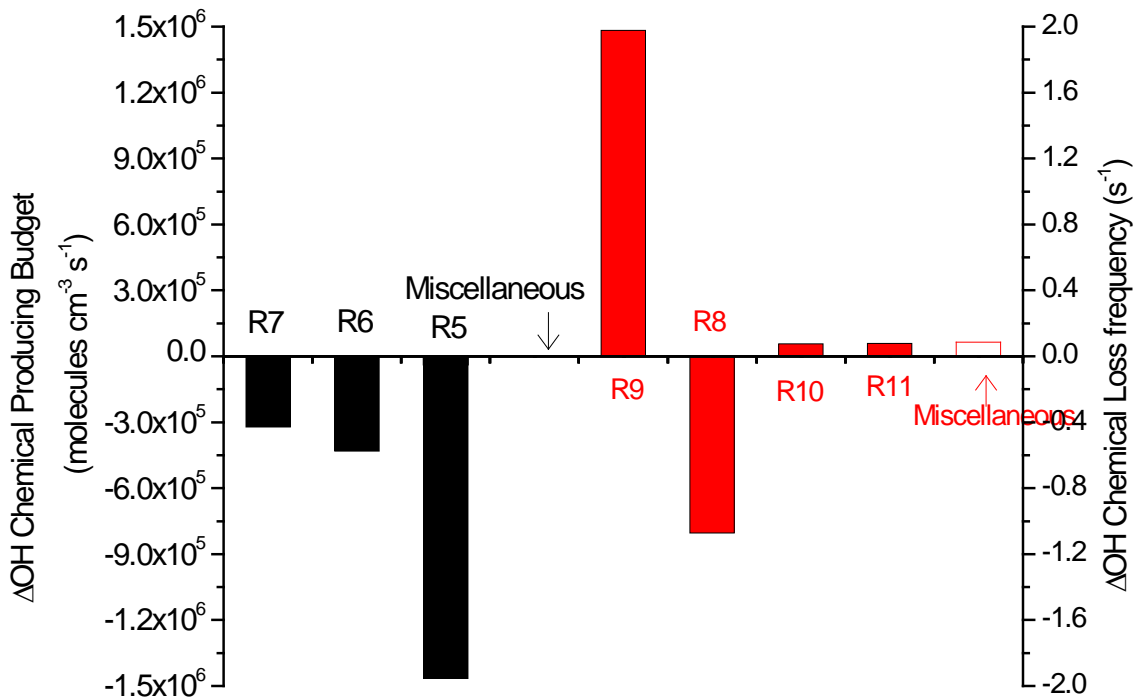


Table 7. The linearly summed influences (calculated as DUST_H – NO_DUST + DUST_J – NO_DUST) and the nonlinearly combined influences (calculated as DUST_H+J – NO_DUST) of dust on the daily average mixing ratios γ of O_x , NO_x and the daily average concentration C of OH through the heterogeneous removal reactions and the photolysis rates decrease for the T04 case. The relative influences (i.e. the influences normalized by NO_DUST) are shown in parentheses.

	$O_x \text{ nmol mol}^{-1}$	$NO_x \text{ nmol mol}^{-1}$	$OH \text{ molecules cm}^{-3}$
Linear	-15.2(-73.3%)	-5.2(-8.6%)	-1.1×10^5 (-69.9%)
Nonlinear	-13.2(-63.8%)	-5.9(-9.6%)	-9.6×10^4 (-61.1%)

3. The relative significance of the two processes resulting from the introduction of dust (i.e., heterogeneous uptake and photolysis reduction), should be studied. A set of independent runs can be carried out in order to evaluate the relative importance of different processes (i.e. dust transport, heterogeneous uptakes on dust and restrained photolysis) in affecting the mixing ratios of air pollutants. It would be more informative if authors could elaborate more in the discussion part that for the changes of mixing ratios of different gases, how much is brought in by the transport of dust and how much is due to the heterogeneous uptakes. This will help to improve the understanding of pollutant evolution due to different mechanisms.

As the referee suggests, additional budget analysis about the relative importance of different processes has been added (please see the reply to the specific comments 8 and 9 from the reviewer #1), and an additional sensitivity simulation (discussed above) now isolates the effect of the change in photolysis rates.

Minor comments

Page 20149, line 14: “Table 1” should be inserted after “12 heterogeneous removal reactions”.

“Table 1” has been added to Page 20149, line 14: “12 heterogeneous removal reactions on mineral dust (listed in Table 1)”.

Page 20151, line 3: How are “best guess” values for uptake coefficients derived? Please describe the criteria for a number to be regarded as a best guessed value.

The adoption of these “best guess” values have been discussed in Appendix A.

Page 20155, line 23: “(i.e. “ J_e/Z_{pbl} ” in Eq. 4)” should be inserted after “ B_e is the source term due to direct emission into the box”.

Page 20155, line 23: “(i.e. “ J_e/Z_{pbl} ” in Eq. 4)” has been inserted after “ B_e is the source term due to direct emission into the box”.

Page 20155, line 24: insert a space between “and” and “ K_{cl} ”.

Page 20155, line 24: a space has been inserted between “and” and “ K_{cl} ”.

Additional modifications:

Page 20158, line 12: “the relative change in C ” has been modified to “the change in C ”.

Page 20159, line 3: “ Δc_l ” has been modified to “ ΔK_{cl} ”.

The symbol “ y ” has been used for mixing ratios and the symbol “ C ” has been used for concentrations through the paper.