This manuscript present results from regional air quality model studies in order to investigate the role of constrained multi-generational aging. Several SOA formation schemes are applied, including the traditional "two product" scheme with or without "unconstrained" aging and the statistical oxidation model (SOM). The results are compared to each other and to observations. SOA constitutes a major fraction of aerosol in the atmosphere. However, current models fail to fully reproduce its concentration distributions and physical properties. One possible reason for the model-observation gap is that the model cannot capture SOA productions from multigenerational oxidations, even though many lab studies have suggested its importance. The current study evaluates the effect of multi-generational oxidations on the regional SOA simulations, clarifies drawbacks of the unconstrained aging scheme, and shows us to what extent the traditional "two-product" scheme can represent the effect of multi-generational oxidations. I would suggest publishing it after my comments below are addressed.

Major comments

The model does not take into account the influence of vapor wall-losses on SOA formation, although the influence is substantial. What is the impact of this neglect on the paper's conclusion? For example, would the similar SOA amount obtained from BaseM and SOM models still hold? Since the vapor losses on the wall compete with vapor's oxidations or/and its condensation. The inclusion of vapor losses on the wall may increase the oxidation rate and change the oxidation products' distribution, so the proportion of SOA generated from later-generation products might become larger so that the influence of multi-generation oxidation on SOA concentrations become more important than that shown in current conclusion.

Not clear to me how the authors discriminate the low NOx scenario and the high NOx scenario in the model. Is there any threshold to cut off them? Does the NOx range used for the low NOx scenario match those measured at Smoky Mountain Site? And the NOx for the high NOx scenario fit those at Urban sites?

Specific comments

Page 25840-25841. In a natural way, multi-generational VOC oxidations for SOA formation should be explicitly modeled using detailed gas-phase chemical mechanisms. And there are some studies using such type of SOA model, from the box model to the global model (e.g., Valorso et al., 2011; Lee et al., 2011; Utembe et al., 2011; Lin et al., 2012). This type of model should be discussed in the introduction part.

Page 25845, line 5. Missing a period after "(2015a)".

Page 25847, line 4-5. Are the SOA concentrations shown for Base model predicted with acid-catalyzed enhancement of isoprene SOA? If so, what would it affect the results if the enhancement was not included? Note that the BaseM model excludes this enhancement.

Page 25848, line 12. Where is the Fig. S1? I could not find it in the Supplement.

Page 25852, line 24.   Fig. 4 should be Fig.5, and Fig.5 shown in the later text should be Fig.4. The context in the paper does not match the figure shown. Switch the Fig.4 and Fig.5.

Page 15854, line 15-18. The model does not consider the SOA contributions from IVOCs, whereas some other models that managed to close model-measurement gaps include the IVOC SOA as well as the simple OH aging mechanism. Is that possible this SOA enhancement comes from IVOCs oxidation, not from the double-counting effect. i.e., the aging mechanism is added on top of existing parameterizations?

In the Supplement, Sect. Cascading Oxidation Model (COM), "It is described in Table S.2" should be Table S.3.

References

Utembe, S. R., Cooke, M. C., Archibald, A. T., Shallcross, D. E., Derwent, R. G., and Jenkin, M. E.: Simulating secondary organic aerosol in a 3-D Lagrangian chemistry transport model using the reduced Common Representative Intermediates mechanism (CRI v2-R5), Atmos. Environ., 45, 1604–1614, 2011.

Valorso, R., Aumont, B., Camredon, M., Raventos-Duran, T., Mouchel-Vallon, C., Ng, N. L., Seinfeld, J. H., Lee-Taylor, J., and Madronich, S.: Explicit modelling of SOA formation from alpha-pinene photooxidation: sensitivity to vapour pressure estimation, Atmos. Chem. Phys., 11, 6895–6910, doi:10.5194/acp-11-6895-2011, 2011.

Lee-Taylor, J., Madronich, S., Aumont, B., Baker, A., Camredon, M., Hodzic, A., Tyndall, G. S., Apel, E., and Zaveri, R. A.: Explicit modeling of organic chemistry and secondary organic aerosol partitioning for Mexico City and its outflow plume, Atmos. Chem. Phys., 11, 13219–13241, doi:10.5194/acp-11-13219-2011, 2011.

Lin, G., Penner, J. E., Sillman, S., Taraborrelli, D., and Lelieveld, J.: Global modeling of SOA formation from dicarbonyls, epoxides, organic nitrates and peroxides, Atmos. Chem. Phys., 12, 4743-4774, doi:10.5194/acp-12-4743-2012, 2012.