Interactive comment on "Aerosol–cloud interactions studied with the chemistry-climate model EMAC"

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Response to reviewer 1

We thank the reviewer for the constructive and valuable comments, and will revise and improve the manuscript soon as your comments.

In response to the comments:

This manuscript tests the sensitivity of the simulated clouds to the treatments of solutes in droplet nucleation and to the treatment of cloud macrophysics as well. While most of the presentation is clear, the sensitivity to the treatment of solutes is surprisingly large, which calls for further investigation into why.

General Comments

It can be shown that if κ =B and the treatment of the Kelvin term is the same then the two treatments of the solute effect and critical supersaturation are nearly identical, so the differences in the results with STAND and HYB arise mostly to differences in the values of κ and B (and perhaps the Kelvin terms) for the two treatments. While the values of κ are provided for each component, the values of B are not.

→Both STN and HYB are based on Köhler theory but with two different ways to represent the solute effects using the osmotic coefficient model and κ- Köhler theory. The values of B and relevant parameters were provided for each component and

compared to κ values in Table S.1 (Supplement). This table will be included in the revised version of the manuscript.

More discussion in the text regarding Table 3 is needed, particularly for the limiting case of saturated conditions, when the fractions and the exponentials can be expanded into linear terms to show that the expressions are equivalent if $\kappa = B$ *and the treatments of the Kelvin effect are the same.*

→ **We will discuss Table 3 in greater detail with expanded linear terms of the critical supersaturation.**

Also, the treatments Kelvin effect should be compared to determine to what extent differences in the treatment are driving differences in the global simulations. Please repeat experiments using the same treatments of κ *and B and the same treatments of the Kelvin effect. This is needed to determine whether the surprisingly large sensitivity of column droplet number is due to the formulation of activation or just the parameter values.*

→ **Thank you for your suggestion. We will provide more details about differences derived from the solute effect and the Kelvin effect separately. As requested, we will perform additional experiments to clarify the effect of the Kelvin effect and different solute effects.**

The parameter D is never identified in Table 3 as the critical diameter for activation. Better to use the same parameter (radius or diameter) for the expressions for both treatments, and provide an expression for the critical size (which is the same for both treatments?). The current presentation sounds like ac is prescribed rather than being dependent on the dry particle size.

→ **We apologize for the unidentified parameter D. The parameter D is the diameter of dry particle size as you suspected. We will rephrase some of expressions in Table 3 with the same parameter (i.e., radius) in both schemes.**

Also, the first line in the Table 3 key says SC is the critical saturation (sc = SC + 1) in STN and is comparable to SCk (=sck -1) in HYB. It should say SC is the critical supersaturation (sc =SC +1) in STN and is comparable to SCk (=sck -1) in HYB.

→ Thank you for your correction. Yes, you are right. We will correct it in the revised manuscript.

Section 3.4. I question the value of the synthesis in this section. The manuscript has clearly demonstrated surprisingly large sensitivity of droplet nucleation to the treatment of the solute effect and perhaps also the Kelvin term. This sensitivity drives differences in LWP and other cloud variables that produce large impacts on the cloud radiative forcing. Since simulated cloud radiative forcing, a critical climate variable, also depends on choice of parameter values that also influence the cloud radiative forcing and since we have good measurements of cloud radiative forcing, any climate model contemplated for applications to coupled simulations would have its parameter values adjusted to improve the agreement with the observed cloud radiative forcing. So I think the evaluation has been carried too far. If the model with the STD treatment of nucleation had been better tuned to produce a more realistic cloud radiative forcing, the impacts of the different treatments could just have easily made the cloud radiative forcing worse. The important point is that the treatment a big difference, and the challenge is to understand why. I would like to see more effort devoted to that task.

→ We apologize that the section 3.4 referring to the evaluation of the cloud droplet nucleation scheme with the observation and some parts of conclusions are too far from the purpose of this study. The simulations of cloud properties have been carried out with identical conditions except for the calculations of critical supersaturation in the ARG scheme as a sensitivity test. The simulated climate values result from the propagated impacts of different cloud properties. We will exclude the section 3.4 and modify conclusions in the revised manuscript. We will put more effort to explain the large differences with specific steps and more detailed description according to your comment.

Page 21997, lines 4-6. If find this sensitivity to solute effect difficult to accept. Please compare maximum supersaturations, compare κ *and B, and compare surface tension for the*

different simulations. If the CCN concentrations (at a given supersaturation, not at Smax) differ greatly that can influence the maximum supersaturation and hence the AF.

-> Thanks for your valuable suggestion. We will discuss in more detail the sensitivity with additional comparisons, following your suggestion.

Technical comments

Thank you very much for your technical comments. We will revise the manuscript based on all your corrections. The revised manuscript will also answer your questions and comments.