**Atmospheric
Chemistry
and Physics
Discussions**

Interactive comment on "A statistical-numerical aerosol parameterization scheme" *by* J.-P. Chen et al.

Anonymous Referee #1

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This manuscript describes a statistical parameterization scheme SNAP for modal aerosol models with the intention to improve the accuracy of approximate analytical solutions of the size distribution evolution. While the scientific approach presented is interesting and potentially useful, the manuscript is a very laborious to read and, because of this, I worry that it may lose some of its target audience. I give some suggestions below how the readability could be (at least partially) improved, but I encourage the authors to give this a serious thought themselves as well.

My second major comment is that the manuscript would be much better suited to ACP's sister journal Geoscientific Model Development, and if it is possible without an additional review round, I strongly recommend it to be transferred to GMD.

Specific comments:

1) The manuscript is very heavy on the mathematical equations. Consider whether you could move some of the mathematical details to appendices.

2) The terminology used is often quite technical (e.g., 'offline spectral integration', 'evolution tendency is solved by in-line numerical integration') which makes the text hard to follow at times. Try and be more concrete, this will help the readers that are not directly familiar with this terminology. In addition, in many places it would helpful to focus better on the specific topic at hand, rather than discussing several related points simultaneously.

3) Introduction: It takes a quite a bit of work for anyone without extensive hands-on experience with modal models to understand what this study aims at and why it is important. In this light, I recommend the authors to cut the majority of the general aerosol and aerosol model description on pages 12034 and 12035, and concentrate in more detail to the specific problem that they are addressing in this manuscript, i.e. simplification of the distribution evolution integrals to obtain analytical solutions. E.g., why are these analytical solutions needed and what makes obtaining them so difficult (e.g. compared to bin schemes); a general overview of previous attempts to solve this problem (also beyond BS95; some of material from section 2.2 could be moved here) and what can be considered the current state-of-the-art method; how this method improves upon the previous methods, etc.

4) P. 12038: I would also cut the discussion on the similarities and differences to the earlier Chen and Liu (2004) study, as it is not directly relevant here.

5) Intro: The introduction misses lots of references e.g. to models that are discussed.

6) P. 12035, l. 14-16: there are many bin models that activate only a fraction of particles in the bin; several techniques to do this as accurately as possible have been developed.

7) P. 12306, l. 15-17: The modal models have in-built problems with step-function type

processes such as activation. It is therefore misleading that imply that a continuous size spectrum in the modal model would automatically treat this process more accurately than a sectional scheme.

8) The gamma distribution on p. 12040 is not further discussed in the manuscript and can be moved to an appendix.

9) It might be helpful to summarize briefly and using clear terminology the essence of the four method already in section 2.2. E.g. (1) SNAP-A: assume a constant particle size —, (2) SNAP-B: transform growth kernel by —, etc.

10) Why is SNAP-A included when it is quite clear from the start that this is not a good approximation for non-monodisperse modes (it is later called 'no-skill reference')? If you decide to leave SNAP-A, consider if you can condense some of the text in 2.2.1 and remove the equations which are not of direct relevance to what is done later in the study. This goes with the description of all the methods as well.

11) P. 12045-12046: Indicate in text whether you are talking about Figure 2a or 2b.

12) Section 2.2.2: It is confusing that sedimentation velocity is discussed as an example here but no such examples are given for the other methods. Remove it, or alternatively choose a simple process that you can work through with all the four methods (this would illustrate the differences between the approaches in a concrete way).

13) Eq. 23: what does 'modal-value approximation' mean? Is it the same as eq. 11? If so, call it by the same name; if not, change the notation to something less confusing.

14) Is Eq. (32) used for both f terms in equation (25)? If not, won't this be inconsistent?

15) Figure 4 & P. 12502: Visually it is close to impossible to see whether SNAP-D (or any of the other methods) performs better - contrary to what is claimed in the text. What are the error values for I2 and I3 with the other methods (now one cannot judge whether SNAP-D performs better)?

16) P. 12053, last line: Vapour density at the surface is not size independent (Kelvin term)! I also disagree with the statement later in the text that the Kelvin effect is often ignored in aerosol models. What is this claim based on?

17) P. 12058, l. 20: 'selected amount of data' what is this selection based on?

18) Throughout the text: change appendices A and B to Table A1 and Table A2.

19) Section 3.4. is quite confusingly formulated. Condense the text and focus on the aspects directly relevant to this study. Regarding nucleation, there is clear consensus (e.g. based on the CLOUD experiments, which are the best nucleation experiments to date; see Kirkby et al., 2011) that binary nucleation alone does not explain observed nucleation rates. Regarding Kelvin effect: this effect causes the small particles to absorb less water but is negligible for larger particles; indicate the size of particles in Fig. 8 in the text; what is 'r_0'?

20) P. 12062 bottom -12063 top: are you all the time verifying the sectional model here? "âĂŤfound similar results.' what are these results (the readers shouldn't need to go back to the earlier study).

21) Figure 9: The text is not entirely fair and seems to favour SNAP. E.g. at 6 h, SNAP does not capture the smallest particles better than the other two methods. "at somewhat larger sizes to the left of the modal size.' what does this mean?

22) End of section 4.1: Give values also for the intra-modal coagulation test.

23) Section 4.2 incorporates SNAP into regional models only in terms of some specific processes while (apparently) simulating the rest of the processes with the old formulation. I do not see the point of such a comparison and would remove this section. However, if the editor disagrees, see also the following comments.

24) Figure 11: would be clearer to show the following two panels: baseline and difference to baseline.

25) P. 12064, bottom: it is clear that the modal model with 6 tracers is faster than the bin scheme with 12 tracers; however, do you need 12 bins to obtain this good a solution or could the number of bins be reduced without losing accuracy?

Typos: - p. 12037, l. 19: 'gas'???