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Comment on acp-2022-476

Anonymous Referee #2

Referee comment on "Survival probability of new atmospheric particles: closure between theory and measurements from 1.4 to 100 nm" by Runlong Cai et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2022-476-RC2, 2022

The manuscript deals with evaluating possible approaches how to estimate particle survival property after nucleation events from measured particle size distribution dynamics. The approaches are tested by measurements in Hyytiälä and Beijing, representing growing nucleation modes after an event, and in the CLOUD chamber, representing approach to steady state dynamics. The analysis is very interesting, however, the number of studied cases is very limited in order to make the strong conclusions made, and one of the main conclusions may actually be incorrect (or at least misleading).

Major comments:

- Perhaps the main comment of the manuscript is that n_log should be used to retrieve the measured survival probability for a growing aerosol population and n (or J) for quasi steady state distributions. My intuitive claim is that the choice should instead be made based on how GR depends on size. The authors' conclusion is based on a limited number of example cases where the nucleation mode width stays roughly the same, in log-scale, while the particles grow. Wouldn't this mean that GR should be (at least roughly) linearly dependent on size, so that for example 30 nm particles should grow 10 times faster than 3 nm particles? Is this always the case in the atmosphere? What if GR is roughly independent of size? Then the linear size distribution n should stay roughly constant in width (in linear scale) and the logarithmic one n_log should become narrower (in log-scale). For example, in Hyytiälä there are commonly particle formation events, where on the contour plot the most red color appears only after some growth (for example, May 20th, 1998), indicating that the n_log value increases while the mode grows. Then, obviously, n_log cannot be the choice for experimental survival rate estimation, as the result would be more than 100%. Thus, I urge the authors to analyze some events of this type also.
- Calling 'theory' the survival rate obtained by following the peak on a contour plot and integrating the competition between growth and scavenging along this 'trajectory' is a poor choice, as it is just another approximation. Size dependent scavenging causes

apparent growth (see Leppä et al., ACP 11, p. 4939, 2011) and size dependent GR deformation of the size distribution shape, which means that the 'trajectory' obtained by following the peak of the nucleation mode (in log-space) might not represent the same aerosol particles. Please comment on this and if you agree, a change of terminology is needed.

- As GR is such an essential parameter when conssidering survival, please add figures showing the size-dependent GR (and time dependent also, if there is time-dependence) in the simulated cases. Now there is only a vague statement on page 7 (line 157) that "A growth enhancement factor for particle growth (Kuanng, 2010) was used....."
- One puzzling observation has been observed in polluted megacities such as Beijing: how can the particles survive with such high sink-values and low growth rates? The authors now claim that this proposed way of estimating survival rate, based on using n_log, resolves this issue. This is an important, intrigueging question, which is discussed here quite loosely, especially since many of the authors have another manuscript being reviewed at the same time on this specific topic (Tuovinen et al., ACPD). Much more impressive would be to use full simulations by the sectional model that the authors have in their use, with observed sink and GR values to see if the nucleated particles actually survive - tis may be, however, a topic for another publication. Now it remains a bit unclear, based on reading this manusript alone, what is really the conclusion regarding analysis of the events in Beijing.

Minor comments:

6. Equation 2 and related text: what is N actually for a continuous distribution? It is clear what it means for a monodisperse one, but if one wishes to follow survival rate for a 'real distribution', shouldn't N be then the total number concentration for some size interval?

7. Page 5, lines 123-124: It is claimed that the GSD usually remains relatively constant for atmospheric particle formation events. Is there a reference supporting this? As mentioned in comment 1, there are several events in Hyytiälä at least, where the peak value of n_log increases along with growth, indicating simultaneous narrowing of the growing mode also.

8. Page 8, line 187: Explain in detail how the growth trajectories were obtained. Are they based on peak values in log-scale? Has smoothing or fitting been used? If yes, please state the details.

9. Page 8, lines 205-206: It is stated that the used J is the daily maximum for each size bin. What does this mean?

10. page 9, line 220: The definition of equation 1 is very clear for a monodisperse growing mode, but as I explain in my comment #2, it is unclear how growth of the "same population" can be determined from a continuous evolving distribution.

11. Figures 2a and 4a, and repective simulations: Is the relatively constant width of the growing mode obtained by setting an appropriate size dependence of GR on dp see also comment 1), or is there also some numerical diffusion present?

12. Finally, if possible, the authors could discuss more what is actually a 'true' survival probability. All methods presented here are approximations, even the one that is called 'theory' in this manuscript (comment 2). Somehow, intuitively, if there is only condensational growth and scavenging, it should be the survival probability of a size interval of particles, that obviously stretches (or gets narrower) in 'length' if there is size-dependent GR. Also J, intuitively, should be one obvious candidate. This is why the results of this manuscipt are so interesting, showing that in many cases experimental n_log seems to work quite well (if the used trajectory-based analysis as a comparison is accepted as a valid one).