Review of "Lagrangian condensation microphysics with Twomey CCN activation" by Grabowski et al.

The manuscript presents a new approach for the treatment of aerosol activation in Lagrangian Cloud Models (LCMs), a novel and promising approach for the simulation of cloud microphysics based on individually simulated super-droplets (SDs). The novelty (and advantage) of the new activation approach is that SDs are only introduced if the supersaturation exceeds a certain threshold. This is fundamentally different from previous activation approaches, in which SDs needed to be simulated even before activation. As pointed out in the manuscript, this new approach is not suited for simulating cloud-processing of aerosols. Applications in which cloud-processing of aerosols is of minor interest, however, benefit from reduced computing time as well as a smaller memory demand. Furthermore, the authors introduce further improvements necessary for the correct determination of supersaturations in LCMs: a velocity interpolation scheme which conserves the incompressibility of the flow as well as a technique to cope with spurious supersaturations. Since these latter refinements do not require the proposed aerosol activation scheme, they are a recommendable addition to all current LCMs.

All in all, this manuscript is well written, presents novel and useful methods, and is of interest to the entire LCM community. Accordingly, I recommend publishing this paper in Geoscientific Model Development. However, I would like the authors to address some minor comments, which will only increase the value of this already nice manuscript.

Minor Comments

- p. 2, l. 25: Please define "multiplicity". It might be understandable but there are also synonyms used in the literature (e.g., weighting factor).
- p. 4, Eq. (4): There is a "+" missing between "r_i" and "r_0".
- sec. 2.3: Although the Twomey activation approach is new to warm-cloud LCMs, there is already an analog in ice-cloud LCMs. Sölch and Kärcher (2010) describe how they introduce new SIPs (simulation ice particles – the ice-cloud equivalent to SDs) to the model domain based on an underlying nucleation scheme, which exhibits many similarities to Twomey activation. Additionally, Unterstrasser and Sölch (2014) describe how a stochastic representation of that nucleation scheme can improve the model's statistics. I think these publications should be mentioned and discussed in the manuscript.
- p. 6, ll. 11 – 12: Is the sentence "Without … past." true if entrainment/mixing is considered? The diluted number mixing ratio cannot reveal the previous maximum supersaturation. (Although the Twomey activation scheme will still be applicable.)
- p. 7, ll. 12 – 14: I agree with the sentence "This is … to another". However, the same multiplicity for all SDs might be disadvantageous for the initiation of collision and coalescence (see Unterstrasser et al., 2017).
- sec. 2.4: The suggested interpolation scheme should be used in all LCMs. However, there is one suggestion: Please add two plots to Fig. 4, which show the results for 100 SDs per grid cell, which is the typically applied SD concentration in current LCM simulations. This plot will be of great value to judge if there is a big impact of thoughtlessly applied tri-linear velocity interpolation in the published literature.

(Although I assume that there will be no impact visible due to the LCM's inherent fluctuations (now with a much higher standard deviation of around 10 %).)

- p. 10, l. 29: Why is the calculation limited to cloudy regions ($q_l > 0.01$ g kg^{-1})? Shouldn't the results be independent of the region within the model domain?
- p. 14, ll. 19 – 21: Please give more details (or a reference) how the water condensation is split into 10 substeps. Based on the given text, I cannot imagine how this procedure is applied.
- sec. 3.2: Please add some details on the number of SDs initialized in each grid box or the maximum number of SDs per grid box created by the Twomey activation scheme. These details follow later (p. 17, l. 6) but I expected them to be in the setup section.
- Fig. 9/10: How do you define activated particles? Using the Twomey activation scheme, this is a straightforward task. But how do you proceed in the UWLCM?
- Fig. 9/10: Could you please comment a little more on the strong oscillations in the $\sigma(r_{act})^{com}$ plots? It seems that those time series jump between two solutions.
- p. 21, ll. 8 – 14: I agree that using the Twomey activation scheme will reduce the number of SDs in the model domain and, hence, computing time and memory demand. However, these considerations deserve some more thoughts. Models are usually parallelized using a 2D domain decomposition applied to the Eulerian fields but also the SDs. Accordingly, if there is a cloud in just in one subdomain, massive load imbalance will occur slowing down the whole computation. To benefit most of the new Twomey activation scheme, new parallelization strategies for the treatment of SDs need to be developed, e.g., a uniform distribution of SDs over all cores independent of their physical location in the model domain to avoid load imbalance issues.

Technical Comments

- p. 1, l. 18 (and several other places): The abbreviation SD has never been introduced.
- p. 2, l. 5 (and several other places): There is an unnecessary space between the bracketed citations and the following punctuation mark. Probably a LaTeX issue.
- p. 2, l. 30: I would cite Twomey's (1959) paper right here.
- p. 6, l. 5: A. Jaruga's PhD dissertation does not appear in the references section.
- p. 6, l. 17: The paper by Grabowsky and Abade (2017) has been cited several times in the unabbreviated form before the abbreviation GA17 is introduced.

References

Sölch, I., and Kärcher, B. (2010). A large-eddy model for cirrus clouds with explicit aerosol and ice microphysics and Lagrangian ice particle tracking, Q. J. Royal Meteorol. Soc., 136, 2074-2093.

Unterstrasser, S., and Sölch, I. (2014): Optimisation of the simulation particle number in a Lagrangian ice microphysical model, Geosci. Model Dev., 7, 695-709.

Unterstrasser, S., Hoffmann, F., and Lerch, M.: Collection/aggregation algorithms in Lagrangian cloud microphysical models: rigorous evaluation in box model simulations, Geosci. Model Dev., 10, 1521-1548.