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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Precipitation enhancement in stratocumulus clouds through airbourne seeding: sensitivity analysis by UCLALES–SALSA" *by* Juha Tonttila et al.

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General comments:

This manuscript presents a numerical study investigating the hygroscopic seeding impacts on maritime stratocumulus using a LES model (UCLALES) coupled with a detailed aerosol-cloud microphysics scheme (SALSA). The seeding case simulated here was based on a well-documented field experiment. By simulating the cloud top seeding with different strategies (essentially with different seeding particle number concentrations), the authors analyzed the bulk and detailed cloud properties, compared the results against the field measurements and concluded that seeding with high concentrations of giant CCN (GCCN) can increase the cloud-based precipitation flux from 0.05

mm/h to $\sim$0.1 mm/h. The hypothetical mechanism of enhancing collision-coalescence (C-C) by introducing GCCN as the rain embryos was speculated to lead to the simulated seeding effect.

The writing and flow of this manuscript are quite good. The basic approach and analysis are sound. I also appreciate the efforts from the authors to address this controversial topic as scientific as they could. However, I do have the following serious concerns and recommendations for the authors to consider and hope to improve the scientific integrity of the manuscript and draw more robust conclusions.

1. Uncertainties associated with the simulations

It is probably well known that the evolution of a nonlinear system such as the atmosphere is very chaotic and sensitive to initial conditions and any perturbations. For a numerical model that simulates the atmosphere dynamics and relevant physics in an Eulerain framework, errors from the numeric are inevitable to propagate across the domain when sensitivity experiments are conducted (Ancell et al. 2018). It is reasonable and probably recommended to conduct ensemble simulations of the control and sensitivity experiments using perturbations in initial conditions (such random noise in thermodynamics and the back ground aerosol concentration) and some physics parameters (such as the large-scale subsidence rate) to separate the physical responses of the sensitivity experiment from the natural and numerical uncertainties. Or, the authors can apply the "piggybacking" methodology proposed by Wojciech Grabowski (Grabowski 2014; 2015 and many others) to single out the microphysical impacts in this case. Though the authors mentioned the multi-realization approach of this study, I did not see the spirit of the ensemble approach in this case.

2. Hypothesis test

I understand that the purpose of this study is not to test any of the hygroscopic seeding hypotheses as mentioned in the introduction. But when I saw the authors speculating the hypothesis of increasing C-C by introducing GCCN as rain embryos from the cloud top led to the reduced CDC as discussed in Fig. 8, I could not help suggesting the authors to spend slightly more effort to prove or disprove this point. Could it be possible that these GCCN are mixed through the cloud volume by turbulence and start to suppress background aerosol activation at cloud base (Fig 7 kind of show this in action)? The authors should be able to configure the model and test out these hypotheses, which will contribute to the field more significantly than the current form.

3. Model setup and analysis

The authors show the sensitivity of the simulated precipitation flux to the vertical resolution. How sensitive are the results to the prescribed large-scale subsidence? According to Chen et al. (2010), the simulated clouds are sensitivity to this factor.

How long did you simulate the seeding operation? That basically gives you the total seeding particles released in your model domain. By assuming a well-mixed MSc boundary layer, you can easily calculate the seeding particle concentrations from each experiment.

How do you treat the sedimentation of the GCCN particles?

In order to support the hypothesis associated with the Fig. 8, the authors should directly compare the microphysical process rates (C-C rate) from the model outputs. As what the study shows right now, we don't know what happens exactly.

The topic of this manuscript is on rain enhancement. Would it be more helpful to show the effects from seeding on ground precipitation amount and distribution?

Technical issues:

Line 20: I will replace "somewhat" with "very".

Line 21: "true effects" is not an appropriate expression.

Line 158: shown in Figure 3.

References:

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