Atmos. Chem. Phys. Discuss.,
https://doi.org/10.5194/acp-2019-1167-RC1, 2020

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.

Anonymous Referee #1

Received and published: 21 April 2020

Review of "Precipitation enhancement in stratocumulus clouds through airbourne seeding: sensitivity analysis by UCLALES–SALSA" by Tonttila et al.

In this study the authors use a large eddy model with a detailed bin-microphysics scheme that represents CCN and hydrometeors to investigate the impact of cloud-seeding on a precipitating marine stratocumulus cloud (MSC). The setup of the model and analysis is closely tied to a field campaign during which salt particles were released into marine stratocumulus clouds; these results are presented in Jung et al. 2015 (hereafter J15). The cloud seeding simulations performed by the authors show that the CDNC is strongly impacted with subsequent impacts on warm-rain processes and pre-

cipitation rates. Greater concentrations of seeded particles result in lower CDNC and enhanced precipitation. The authors attribute this to enhanced collision-coalescence efficiency. The model setup and experimental setup is appropriate but I believe in order for publication additional analysis and discussion is required.

Major comments:

There is a lack of a quantitative comparison to results from the observations in J15. '..a remarkable resemblance' (line 227) does not provide enough evidence to support the claim that the 'model simulations skillfully reproduced the seeding effects... as compared with J15' (line 255). Please can you include values in the manuscript or data in the figures to show this comparison.

Other than hydrometeors there is no discussion of the impact to other aspects of the cloud properties. In particular I am surprised that the liquid water content was not presented, as this provides an easy diagnostic to compare to J15 (table 3). There is also no discussion on the radiative impact, nor the temporal evolution of the cloud. For instance, why are there seemingly two peaks in the precipitation rate (Figure 6) at 1 hour and 2 hours? What is the temporal evolution of the CDNC? How long would we expect to see an effect last for? What happens to the sub-cloud fluxes of moisture and buoyancy? What happens to cloud-top entrainment? Do any of these thermodynamic responses counteract or enhance the microphysical effect?

The discussion section needs to be expanded. There is no discussion on uncertainties that may arise due to the model microphysics. Are there any? As the authors point out the results may be impacted due to variations in the meteorology – there are many studies focusing on MSCs that could be used to provide examples of how the results may be affected. For example, the cloud dynamics are highly sensitive to the buoyancy profile – too strong surface fluxes or cloud-top entrainment rate may make your cloud more or less susceptible to changes in CDNC. Could this be a possible reason you don't see the same 'seeding efficacy' as J15? I believe the authors should spend

more time discussing this. Finally, have there been any other cloud-seeding modelling studies? How do the conclusions and results compare? Can this study be compared with other MSC modelling studies focusing on aerosol-cloud-interactions?

Minor comments:

Title. I believe airbourne should be spelled airborne.

Line 63 (Model description): how is mixing of air parcels represented? e.g., homogeneous or inhomogeneous?

Line 118: The 8.5K inversion strength appears a lot stronger than in J15. Is this correct? What impact does this have on the simulations?

Line 120: Why were fluxes and subsidence prescribed according to Ackermann 2009? Were values for the campaign not available? Are they appropriate for the time and place of the campaign? Please include these values in the manuscript. Also, I presume being prescribed they are not interactive. Please clarify this in the text.

Line 113 (Initial conditions): Was there any vertical damping applied within the domain? Please clarify in text.

Line 140: What is the objective of using a domain-wide injection? This isn't realistic so there must be a reason for it?

Line 143: vertical cross-section?

Line 162: What are the total masses released for each of the three experiments and how does this compare with the campaign?

Line 167: What is the simulated precipitation rate that is 'rather low'?

Line 167: J15 table 3 states a pre-seeding precipitation rate at the cloud base of 0.04 mm/hr - why was 0.05 used to constrain the control case?

Line 168: On seeding efficacy.. this sounds like this should be a metric for dP/dM

(change in precip per mass of seeded salt) and is something I was expecting to be quantitatively evaluated later in the manuscript. Is this possible? It could provide a good way to compare different models or observations. . .

Line 184: It is stated that '10m vertical resolution has been shown to be inadequate to fully represent the effects of entrainment mixing' yet the 10m vertical resolution is used. Is entrainment not an important process? Did you see differences in entrainment rate between the two simulations? Were there any changes to other BL processes?

Line 189: What is the cloud base height?

Line 195: What is the injected mass?

Line 199: Can you provide an estimate of how quickly the particles are activated?

Line 204: Can you please provide a value for how long 'not long' is?

Line 206: Could you provide a description for seeding efficacy?

Line 207: Please change 'concentration' to 'concentration of seeding particles'.

Line 208: Is this simply the mean of the Seed2 profile in figure 7? Please could you clarify in the text.

Line 210: is this statement just for MSCs or for all cloud types?

Line 214: A crux of the argument for dismissing water-vapour competition (between ambient and seeded particles) is based on the RH yet this is not shown, nor are values provided. Please include this. Also, do other modelling studies see the same response? For example, MSC modelling studies with above-cloud plumes (such as in the SE Atlantic) are potentially analogous to this seeding experiment..

Line 217: The competition between activation of ambient and seeding particles is discussed, but what about competition between ambient droplet growth and activation of seeding particles at cloud top? Does this enhance or suppress the width of the DSD?

Line 219 / Figure 8: Why does the cloud base and cloud top height change with increasing seeding mass?

Line 219: How much of the decrease in CDNC is attributed to increased removal via precipitation?

Line 224 to 230: Referring back to a previous comment please make this comparison to DSDs in J15 quantitative, including the terminology (e.g., '..bear a remarkable resemblance to..'). Including the DSDs from J15 onto the figure 9 would provide a very good comparison.

Line 234: Saying 5 hours is confusing – change to 1 hour after emission or something to that effect..

Line 249: 'In successful cases' do you not see this in all three cases?

Line 249: 'sustained effect up to 2-3 hours' without extending the simulation length you can't really give a maximum timescale. Please clarify.

Line 250: 'peak enhancement.... within 1-1.5 hours' Seed1 and Seed2 appear to reach a maximum enhancement at $\sim$ 2hours. Please clarify.

Line 253: 'on the high end of the diluted plume concentration...' i don't think this was ever discussed before - what were the estimated concentrations in J15?

Line 255: 'The model simulations skillfully reproduced..' What measure of skill was used? Perhaps replace skilfully with qualitatively unless the quantitative comparison is provided in section 4.2.

Line 268: Are there other processes that could produce the required concentration?

Discussion section: Are the results and conclusions applicable to different locations? MSCs have a very strong diurnal cycle – what would happen if the seeding took place at a different time when the MSC may be more sensitive to the perturbation?

Throughout figures: 'function of time' please clarify what time this refers to - since injection I presume?

Figures 7,8,9,10. The manuscript refers to concentrations in units of cm-3 and diameters in um - but these figures are in m-3 and m. Please update figure axes units so that they are consistent with the usage in the manuscript.

References:

Jung, E., Albrecht, B. A., Jonsson, H. H., Chen, Y.-C., Seinfeld, J. H., Sorooshian, A., Metcalf, A. R., Song, S., Fang, M., Russell, L. M.: Precipitation effects of giant cloud condensation nuclei artificially introduced into stratocumulus clouds. Atmos. Chem. Phys., 15, 5645-5658, doi:10.5194/acp-15-5645-2015, 2015.

Interactive comment on Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2019-1167, 2020.