Response to Reviewer #2

We are grateful to the reviewer for comments. Please find our responses below. Reviewer's comments are in italics and our responses in normal style. Manuscript file with highlighted changes is available.

1 Major Comments

It is not clear how the multi-box simulation results can explain the CC results from the perspective of intercell mixing. Intercell mixing helps multi-box simulations to reach the convergence of mean DSD for smaller $N_{\mathrm{SD}}^{(\mathrm{bin})}$ *than in box simulations (L250, L475), but it prevents the mean precipitation in the CC simulation from reaching convergence, especially in the case of weak precipitation.*

We do not claim that intercell mixing prevents convergence in CC simulations, and we do not know why convergence is slower in CC than in box/multi-box. What we find is that mean precipitation converges when the spatial distribution of rain water converges. This might be pure coincidence, but it may also mean that mean precipitation depends on the spatial distribution of rain. If it does, it has to be due to intercell interactions. The following paragraph has been added to conclusions to convey these ideas more clearly:

" It is not clear why convergence is slower in CC than in box simulations. In CC, convergence of mean precipitation coincides with convergence of the spatial distribution of rain. This may suggest that mean precipitation is dependent on spatial distribution of droplet sizes, probably because of interaction between cells. However, in multi-box simulations we observe that intercell mixing helps reach convergence. Increasing the rate of intercell mixing in CC by using a SGS model does not help with convergence. This does not necessarily indicate that intercell mixing is not important for convergence in CC. It is possible that the increase in intercell mixing caused by the SGS model is small in relation to interecell mixing caused by resolved eddies and by sedimentation. Precipitation is sensitive to the super-droplet initialization procedure. In this study initial radii were almost evenly distributed on a logarithmic scale. If droplet radii are randomly drawn from the initial distribution, it is more difficult to reach convergence with $N_{\mathrm{SD}}^{(\mathrm{bin})}$ and using too small $N_{\mathrm{SD}}^{(\mathrm{bin})}$ induces larger errors. "

The inclusion of SGS motions of SDs enhances the mean precipitation greatly. The authors attributed this to enhanced intercell mixing. It is difficult to imagine that the enhancement of intercell mixing is generated greatly by including SGS motions of SDs since intercell mixing occurs mainly by resolved eddies and sedimentation. The strong sensitivity of SGS motions of SDs to precipitation requires a more in-depth analysis, because it has important implications in cloud models. Probably the authors need to investigate the modification of DSD and intercell mixing by SGS motions of SDs.

We did a deeper analysis of simulations with SGS motion of SDs and it revealed that SGS motion leads to a depletion of SDs (and aerosols that these SDs represent) near the surface. Random SGS velocities cause SDs to hit the surface. Depletion of aerosols results in fewer cloud droplets and more precipitation. This, and not enhanced intercell mixing, was the main reason why there was more precipitation in simulations with SGS motion. In general, simulations with more precipitation converge more easily. This (and not necessarily a positive role of SGS motion) may explain better convergence of simulations with SGS motion.

We made a new ensemble of simulations with SGS motion, in which we add SDs near the surface to counter the depletion of aerosols. Parameters of this relaxation procedure have been tuned to obtain the same aerosol concentration and number of SDs as in simulations without SGS motion. Precipitation in these new simulations is almost the same as in simulations without SGS motion. It does not necessarily mean that intercell mixing does not help with convergence in CC simulations. It is possible that it does help, but the rate of intercell mixing due to SGS motion is small compared to that caused by resolved flow and sedimentation.

I think the authors should make clear in conclusions that the CC simulation results in the dynamical simulation with the SGS motion on SDs (Fig. 15) are less affected by the non- convergence (Fig. 11).

A new set of simulations with SGS motion showed that SGS motion does not help much with convergence (see answer to the previous comment).

2 Minor Comments

1. The term 'mixing' is confusing to me; that is, mixing within a cell, which helps to produce uniform DSD within a cell, and intercell mixing.

Wherever ambiguous, we have replaced 'mixing' with 'intercell mixing'. Simulations with a model for subgrid-scale motion of SDs are now labeled 'SGS SD motion' instead of 'mixing'.

2. I hope the authors select the line color more systematically in Fig. 8, 9, and 12; i.e., from blue to red with increasing $N_{\mathrm{SD}}^{(\mathrm{bin})}$.

Colors now change gradually as in a sequential matplotlib colormap 'copper'. Color is proportional to the logarithm of $N_{\mathrm{SD}}^{(\mathrm{bin})}$.

3. L395; I do not think they are consistent. P increases monotonically in the box simulations (Fig. 3). I also cannot understand how the consistency can be explained by the convergence of $N_{\mathrm{SD}}^{(\mathrm{bin})}$.

We extend this paragraph to make it more clear why we think box and CC simulations are consistent for $N_{\mathrm{SD}}^{(\mathrm{bin})} \leq 10^3$:

"Changes of $\langle P \rangle$ for $N_{\mathrm{SD}}^{(\mathrm{bin})} \leq 10^3$ are consistent with the changes in mean DSD in box simulations (see Fig. 3 (d)). In box simulations, $N_{\mathrm{SD}}^{(\mathrm{bin})} = 10$ gives too few droplets with radii between 40 and 120 microns, but too many droplets with radii greater than $120\,\mu$m. Since surface precipitation is sensitive to the largest droplets, this is consistent with too large $\langle P \rangle$ seen in CC simulations. For $N_{\mathrm{SD}}^{(\mathrm{bin})} = 10^2$, number of the largest droplets is no longer overestimated in box simulations, but there are still too few droplets with radii between 50 and 120 microns. This is consistent with a sharp decrease of $\langle P \rangle$ between $N_{\mathrm{SD}}^{(\mathrm{bin})} = 10$ and $N_{\mathrm{SD}}^{(\mathrm{bin})} = 10^2$. In box simulations with $N_{\mathrm{SD}}^{(\mathrm{bin})} = 10^3$ the number of droplets with sizes between 50 and 120 microns is no longer underestimated, what is consistent with an increase of $\langle P \rangle$ between $N_{\mathrm{SD}}^{(\mathrm{bin})} = 10^2$ and $N_{\mathrm{SD}}^{(\mathrm{bin})} = 10^3$ in CC simulations."