Reply to referee comments

The specific comments (highlighted in blue font) are shown below with our replies (normal text).

Public justification (visible to the public if the article is accepted and published):

Please consider the last questions and corrections as suggested by the reviewers in the second round of reviews.

Additional private note (visible to authors and reviewers only):

Please consider the last questions/corrections as suggested by the reviewers.

Review report #1:

I am happy that the new SIP mechanisms were included in the study. This was a strong problem in the study and now it strengthens the results and the conclusions. I have a few more specific comments that I feel are important for this study:

- How was the number of bins for liquid droplets and ice crystals determined? The use of 7 and 10 bins appears relatively low compared to other modeling studies. What impact might this choice have on the results? could it lead to artificial spectral broadening due to diffusion? Additionally, which advection scheme was employed for the growth of drops and ice crystals?

It is true that the number of bins is relatively low compared to other modelling studies. However, unlike most other models which keep track of droplet and particle size distributions only, SALSA also keeps track of chemical composition, which increases computational costs. In the absence of liquid precipitation, our previous studies have shown that the default number of 7 and 10 bins is enough for cloud droplets and aerosol, respectively. To test the effect of the number of ice bins, we ran an additional simulation with 20 bins. Ice concentration in this simulation was practically identical with that from the previous simulations utilizing 10 bins. Also, ice size distributions have similar widths, so these settings do not have significant effect on the results.

For scalar advection, the default scheme of simple forward time stepping is used. The default scheme for condensational and depositional growth, which predicts water vapor supersaturation and calculates diffusion-limited water vapor partitioning based on the difference between ambient and equilibrium vapor pressures at droplet/particle surface. Please see the original publications for additional details. For ice, the default electrical capacitance is equal to that of a sphere. The same default value is used in SB microphysics. For SALSA, ventilation factors as well as mass and thermal accommodation coefficients have the default unit values, which is a simplification. These parameters have some effect on the ice particle growth rate, but they are not directly relevant for secondary ice production which is the dominating factor influencing cloud properties in this study.

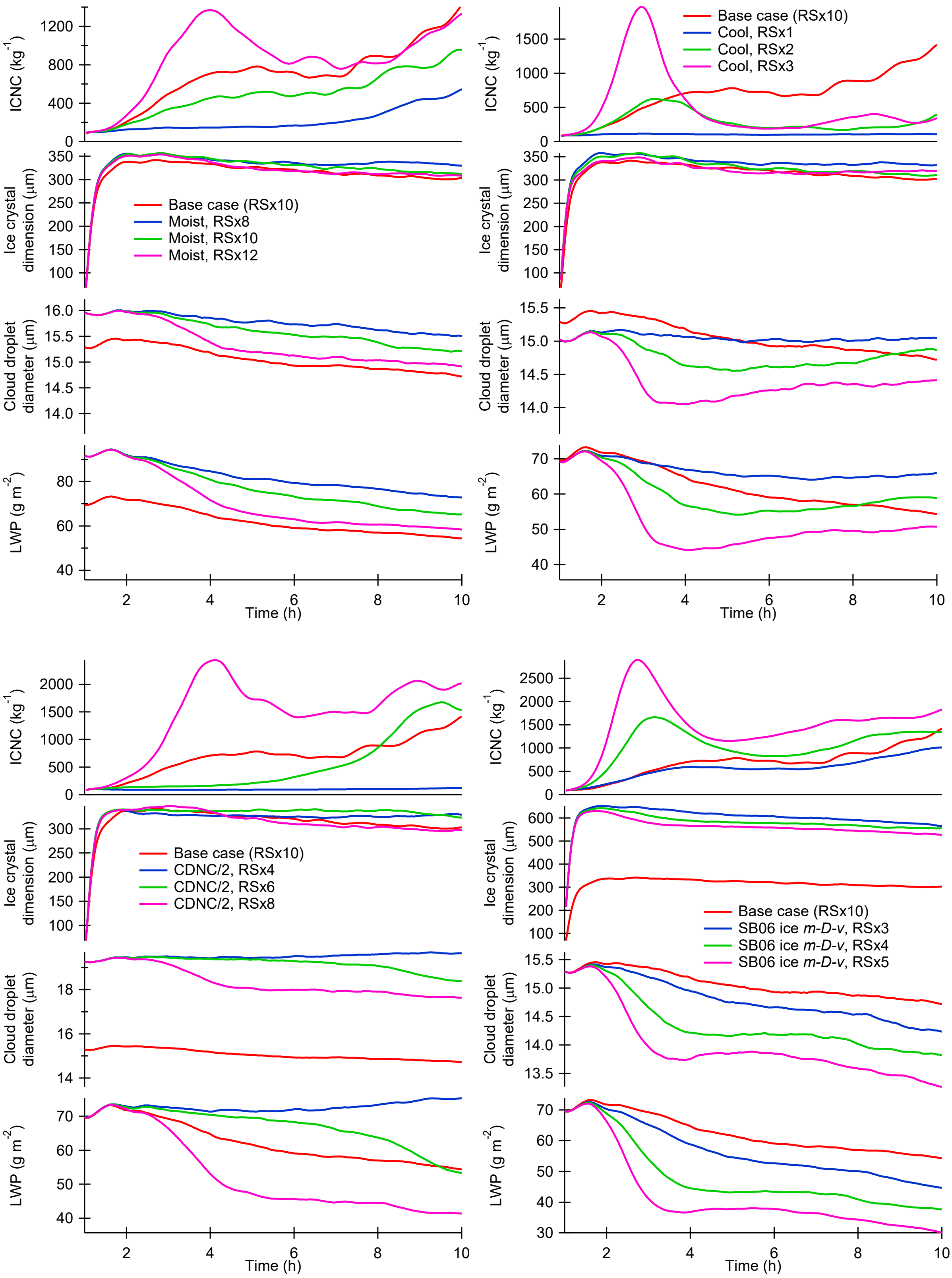
- Fig 5-6: I suggested removing some of the profiles, as many of them are very similar. Displaying eight profiles on a single plot makes the figure difficult to read. For example, why not restrict the figure to the profiles at 6:00 and 8:10?

Now we show only these two profiles for SB and SALSA (current Figs 6 and 7). We have also modified the text accordingly.

- Fig 7: I would prefer to see the effect of each parameter variation individually, however, this would require presenting many additional plots, which would reduce the overall readability of the paper. Moreover, the choice of parameter values used to achieve the targeted ICNC appears somewhat arbitrary. Could the authors clarify how these choices were made? Do you expect these parameter choices to be relevant for other studies, or at least to provide useful guidance for other models?

Figures below show the effect of each parameter variation individually. Originally, the optimal RS multiplier values were determined by using simple trial and error method. These simulations aimed at reaching ice concentration of 1000 kg^{-1}, but a lower ice concentration was accepted in some cases where the higher SIP multiplier would have resulted in ice concentrations well above 1000 kg^{-1}. This is now clarified in the revised manuscript. Because the original data has been removed, we run two additional simulations for each parameter. One simulation is with lower RS multiplier and the other with a higher multiplier compared with the selected optimal multiplier (green lines – shown in the main text). In all these simulations, the lower multiplier (blue lines) produces lower ice concentrations compared with the base case (red lines), so it can be concluded that the multiplier is too low. The higher multiplier (pink likes) produces higher ice concentrations compared with the base case, so the multiplier is larger than needed. These simulations show that the optimal parameter range is narrow being in the order of +/-10%.

We expect that the parameter choices (or more specifically sensitivities) are relevant for other models using similar parameterizations. Both ambient temperature and the temperature dependency of the rime splintering parameterization are clearly important for our model, and this is likely the case with any other model using similar rime splintering parameterization. Likewise, mass-dimension-fall velocity parameterizations have a large impact on riming rate, which is the other key parameter in typical rime splintering parameterizations. These are discussed in the conclusions section, where we have clarified that the suitable combination of different parametrizations was able to initiate self-sustaining secondary ice production in this case/model at least.


ICNC (kg^{-1})
Ice crystal dimension (µm)
Cloud droplet diameter (µm)
LWP (g m^{-2})
Time (h)
Base case (RSx10)
Moist, RSx8
Moist, RSx10
Moist, RSx12
Base case (RSx10)
Cool, RSx1
Cool, RSx2
Cool, RSx3
Base case (RSx10)
CDNC/2, RSx4
CDNC/2, RSx6
CDNC/2, RSx8
Base case (RSx10)
SB06 ice *m-D-v*, RSx3
SB06 ice *m-D-v*, RSx4
SB06 ice *m-D-v*, RSx5

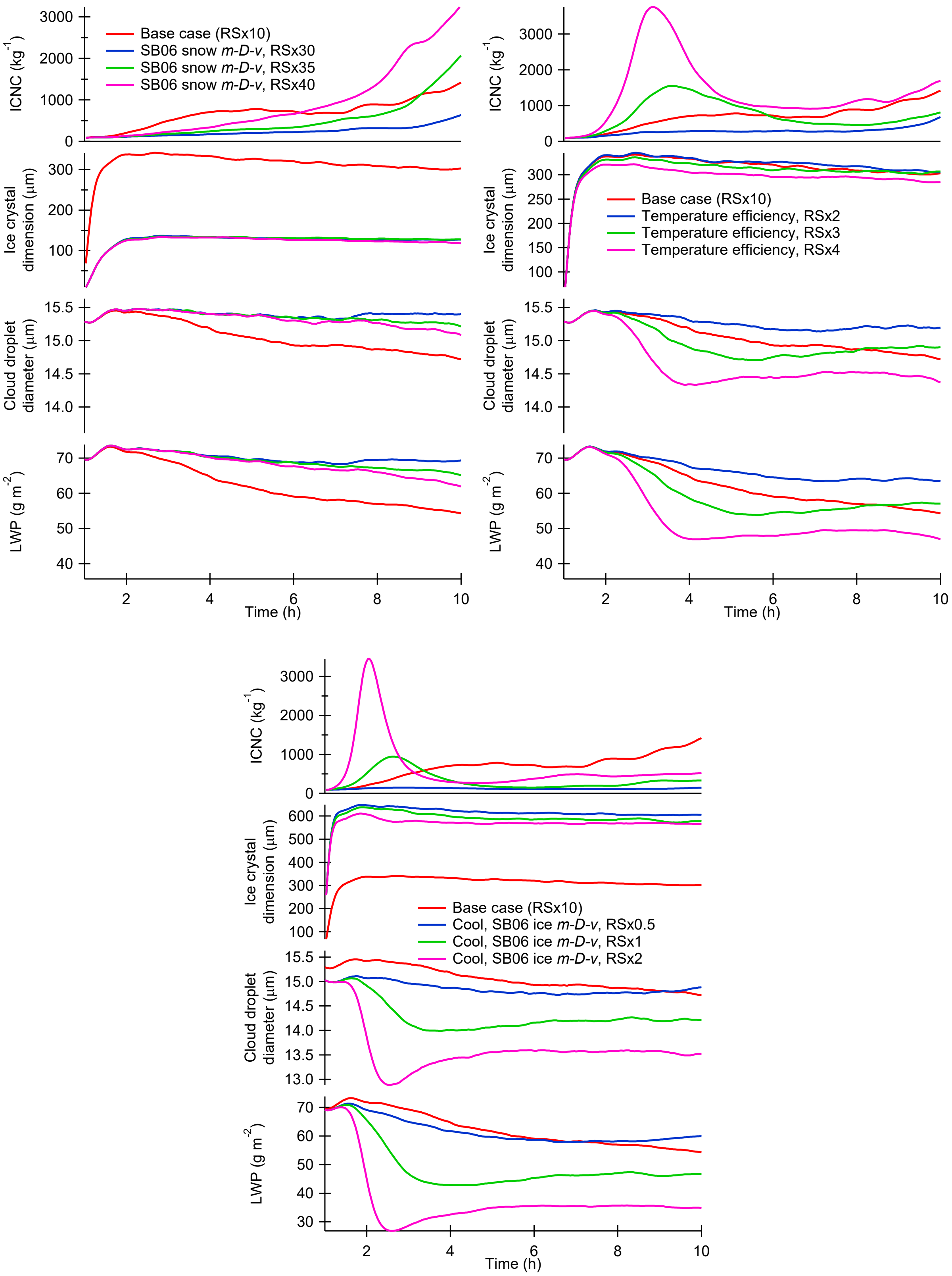


Figure 1: Sensitivity tests based on the observed variability of moisture (Moist), temperature (Cool) and cloud droplet number concentration (CDNC/2), mass-dimension-velocity (*m-D-v*) parametrizations from Seifert and Beheng (2006) (SB06 ice and snow *m-D-v*), and temperature efficiency (*f(T)* in main text Eq. 1). The last test is with cool profiles and SB06 ice *m-D-v* parametrization. INP concentration is 100 kg^{-1} in all simulations. The base case simulation is

based on default model settings where RS SIP rate is multiplied by ten. RS SIP rates for the other simulations are multiplied by different factors so that the mid value (green lines – shown in the main text) produces ice concentration close to the target ice concentration of 1000 kg^{-1}. The other two simulations use lower and higher RS SIP rate multipliers.

Changes to the manuscript (line numbers in the revised manuscript):

Line 319: ~~Therefore, it is not surprising that~~ Because the profiles are fairly similar for simulations with INP concentrations of 1, 10 and 100 kg^{-1} and SIP rate multiplied by a factor of 10, we show only the first one in addition to the simulation with INP concentration of 1000 kg^{-1} without SIP.

Figures 6 and 7 show only four simulations. Figure captions: ~~different~~ selected simulations.

Line 341: We ~~use the same approach as above~~ used simple trial and error method to determine a multiplier for the SIP rate so that the simulated ice concentration reaches the observed ice concentration of about 1000 kg^{-1}, but a lower ice concentration was accepted in some cases where the higher SIP multiplier would have resulted in ice concentrations well above 1000 kg^{-1}.

Line 410: ~~Suitable~~ At least in this case, suitable combination of those ~~can easily~~ was able to initiate self-sustaining secondary ice production ~~even~~ without using any artificial multiplier for the rime splintering rate.

Review report #2:

-both 'parametrizations' and 'parameterisation' appear in the text. Lack of consistency

Line 409: “Parameterization” is now replaced with “parametrization”.

-line 392: With the artificially increased the rime splintering SIP rate (remove 'the')

Done.

-line 406: 'different parameterisations' instead of 'different parameterisation'

Done (now “parametrizations”).