4.2 Sensitivity Experiment

In the previous study, it is found that both the supercooled water content and supercooled layer thickness in the convective regions are significantly greater than those in the stratiform regions, potentially resulting in markedly different riming characteristics of ice particles compared to the stratiform regions. To better understand and explore the impact of supercooled liquid water content (SLWC) and layer thickness (SLWLT) on the riming growth of ice particles, sensitivity experiments are conducted. In the experiment, SLWC and SLWLT are set to 50% higher and 50% lower respectively. The result for region A (moderate cloud regions), B (convective regions) and C (stratiform cloud regions) is shown as Fig. 16.

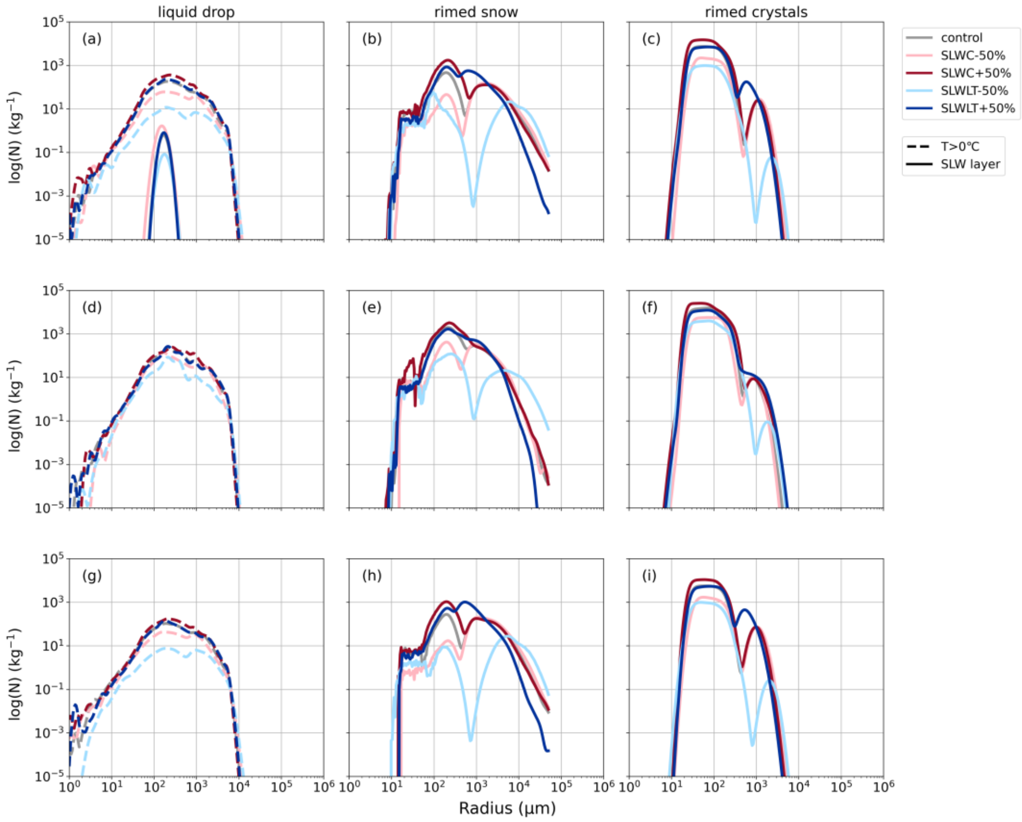

Figure 16 The liquid drop, rimed snow and rimed crystals spectra for (a)-(c) region A, (d)-(f) B and (g)-(i) C in the sensitivity experiments. Results with different control variables are represented in different colors. Dashed and solid lines indicate averages within the layer temperature above 0 ℃ and the supercooled liquid water layer (SLW layer), respectively. The vertical axis denotes the logarithm of number density, and the horizontal axis denotes particle radius.

It shows that both the increase and decrease of SLWC and the SLWLT have impacts on rimed snow and rimed crystals. When both increase, rimed snow in the 100–1000 μm range increase, while those with maximum radius larger than 1000 μm decrease in size and number concentration. The number concentration of rimed crystals also shows a slight increase. The effect of increasing SLWC is more significant than that of increasing the SLWLT, and the enhancement of rimed snow and rimed crystals is greater in region C than in region B, and greater in region B than in region A. This indicates that SR are more sensitive to such increases than CR.

Conversely, when the SLWC and the SLWLT decrease, the overall number concentrations of rimed snow and rimed ice crystals decline, while the maximum radius lager than 1000 μm increases, suggesting the presence of more large-sized rimed snow particles. This may be due to the suppression of the Hallett–Mossop secondary ice production process, especially when the supercooled layer becomes thinner.

Overall, variations in SLWC and SLWLT significantly affect the size distribution of ice-phase particles. Specifically, when both parameters increase, the spectrum of rimed snow shifts toward larger diameters, whereas decreases in either parameter lead to the opposite trend. Regarding SLWC and SLWLT, SR and CR are more sensitive to increases in the former than in the latter but are more sensitive to decreases in the latter than in the former. In addition, SR is generally more sensitive to the such variations than CR, and rimed snow is more sensitive than rimed crystals.

Figure 16 The liquid drop, rimed snow and rimed crystals spectra for (a)-(c) region A, (d)-(f) B and (g)-(i) C in the sensitivity experiments. Results with different control variables are represented in different colors. Dashed and solid lines indicate averages within the layer temperature above 0 ℃ and the supercooled liquid water layer (SLW layer), respectively. The vertical axis denotes the logarithm of number density, and the horizontal axis denotes particle radius.

Furthermore, we performed gamma distribution fitting on the total number concentration spectra to derive the spectral parameters, and the fitting results from the two sets of sensitivity experiments (SLWC and SLWLT) are presented in Figures and 18, respectively.

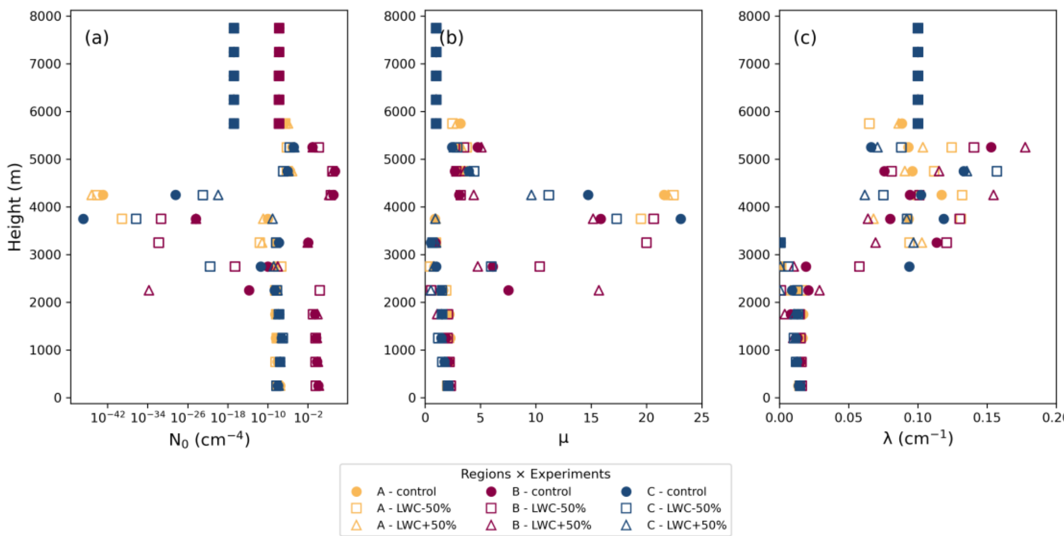

Figure 17. Vertical profiles of the fitted spectral parameters — N_0 (a), μ (b), and λ (c) — after varying SLWC. Different experiments are represented by distinct marker shapes, while different regions are distinguished by color.

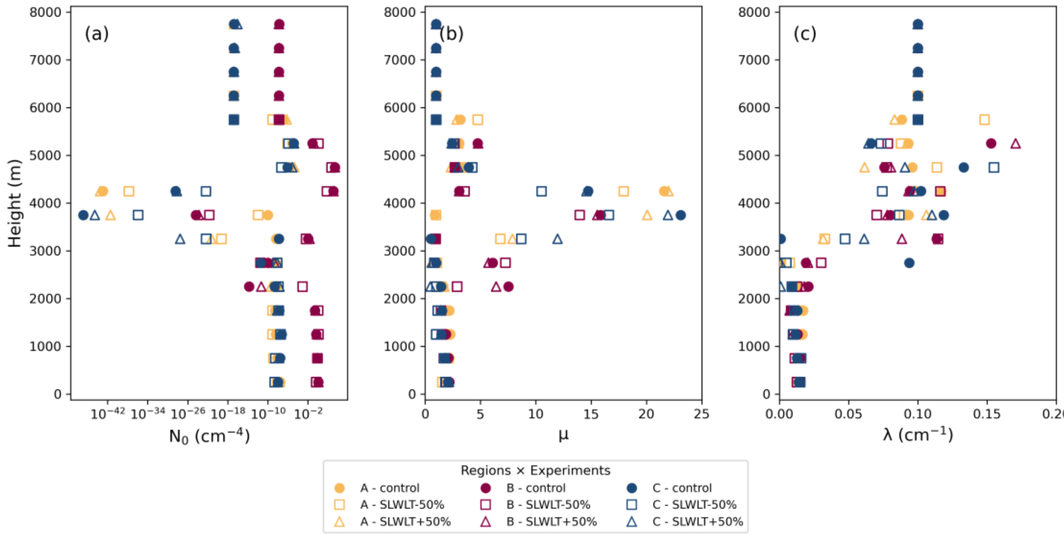

Figure 18. Same as Figure 17, but for variations in SLWLT.

For the control experiment, N_0, μ, and λ remain nearly constant above 5500 m. Between 2000 m and 5500 m, $N0$ shows considerable variability, while below 2000 m it increases again. In contrast, μ and λ vary inversely with N_0. Compared with the stratiform region C, the convective region B generally exhibits larger N_0 values, while μ and λ are comparable but become smaller than those in region C at altitudes between 3000 and 5000 m. These findings are consistent with the observed spectral distribution trends. However, the slight increase in N_0 between 4000 m and 5500 m relative to higher altitudes, as well as the numerical discrepancies among the three spectral parameters, are likely attributed to fitting uncertainties — for instance, particle size spectra at some heights deviate from the ideal gamma distribution.

Across different sensitivity experiments, variations in SLWC and SLWLT primarily affect the spectral parameters within the 2000–5500 m layer. The three parameters exhibit a stronger response to decreases than to increases in both SLWC and SLWLT, with N_0 being particularly sensitive to SLWC changes. Moreover, the SR shows greater sensitivity than the CR.