Response to Reviewer 1.

We greatly appreciate the careful review and constructive comments from the reviewer. We agree with the reviewer on most comments and tried very hard to address all the concerns in the responses and in the revised manuscript. A detailed description is added about the estimation of the errors caused by using first order Taylor series for the evaluation of the curvature and solution terms. We also show that the Hc parameter can be derived from first principles.

In this document, the original comments are in blue font and our responses are in italic type and black, furthermore the suggested modifications in the manuscript are in normal type and black.

The authors develop a hybrid bin microphysical parcel model to study the impact of hygroscopic seeding on the precipitation formation. Moving bins and condensational growth of droplets with solute effect are used below and close to the cloud base. Fixed bins are applied at 100 m above the cloud base, where solute effect is ignored but collision coalescence is considered. Initial background aerosol conditions and updraft profiles for control cases are obtained from two weather modification field campaigns. For comparison, three types of seeding materials with different concentrations, sizes, and hygroscopicity are used to test how hygroscopic seeding might affect the precipitation formation. Although the hybrid parcel model is suitable and the observational data is valuable, results and conclusions from different model setups (e.g., aerosol size distribution, concentration, size, compostion of background aerosol and seeding materials, vertical velocity) are not clearly described. More efforts are needed to make the manuscript clear and convincing. I suggest major revision to improve the quality of the manuscript and my comments are listed below.

1. Figure 1. Is temperature also prescribed for the parcel model? If so, the parcel model used in this study is not adiabatic, which might explain why the ratios of liquid water content are large for some cases in Figure 8a (see my comment 13).

The temperature profile is not prescribed, it is evaluated by calculating the adiabatic expansion of the parcel and the releasing latent heat of condensation. Because the calculation of the vapor uptake by the wet aerosol particles starts below the cloud base, the impact of the latent heat release of condensation is taken into consideration under the cloud base as well. If the ratio of the Q_{seed}/Q_{ctrl} *is larger than 1 the liquid water content (LWC) is super-adiabatic. In the control cases the LWC is close to the adiabatic value. Adiabatic LWC is defined as zero before the parcel reaches saturation, and the supersaturation is zero above the cloud base. At this level, the adiabatic LWC is very small around 0.1 g kg*$^{-1}$*. Therefore, even small changes in the sub-cloud aerosol conditions can result in large relative impact on the condensation. Superadiabatic LWC near the cloud base has been observed in some field projects (e.g. Blyth and Latham, 1985, Yum and Hudson, 2001).*

To clarify the content of the Figure 1. we modify the figure caption:

“Figure 1: The simulated temperature profiles and the prescribed updraft profiles in the numerical simulation for (a) the SPEC UAE cases and (b) the QCSRP cases. The background aerosol particles are BGUAE_1 and BGQNC_1, seeding materials are ICE70_2 and ICE70_4 in the figure (a) and (b), respectively. The plotted temperature profiles are calculated at the updraft profile of w_3 for each panel. The horizontal blue lines denote the altitude of the cloud base. The three horizontal black lines from bottom to top denote the level where the calculation of the diffusional growth starts (RH = 70%), the levels 100 m and 1000 m above the cloud base."

To clarify the content of the Fig. 8a, the following texts are inserted at line 335 in the original and at line 371 in the revised manuscript:

"If the ratio of the Q_{seed}/Q_{ctrl} is larger than 1, the LWC is superadiabatic, because in the control cases, the LWC is close to the adiabatic value at 100 m above the cloud base. The uptake of vapor by highly hygroscopic particles under the cloud base, especially in the case with a weak updraft, increases the LWC to above the adiabatic value. The amount of the surplus is small, so the effect is significant only when the adiabatic LWC is small (e.g., near the cloud base) and becomes negligible at a higher level above the cloud base. We hypothesize that the efficient vapor uptake by the coarse-mode hygroscopic particles can partly explain the observed superadiabatic LWC near the cloud base with weak updrafts in some field campaigns (Blyth and Latham, 1985, Yum and Hudson, 2001)."

Further explanation for the content of Fig. 8a can be found in the original version of manuscript at lines 332- 335 and at lines 369- 371 in the revised manuscript:

"The strong correlation reveals that the enhancement of the H_c parameter due to the injection of highly soluble coarse particles (in this case, the number concentration of activated particles only slightly increased) can significantly increase the water vapor uptake under the cloud base (see the intense growth rate of the drops formed on nanoparticles in Figs. 6b and d)."

2. Eq. 1 approximates the Kappa-Kohler theory. The approximation might not hold for coarse-mode aerosols. I suggest using the complete Kappa-Kohler theory for the saturation ratio over an aqueous solution droplet (Eq. 6 in Petters and Kreidenweis 2007). If not, at least justification is needed.

We agree that both the curvature and solution terms in Eq. 1.are simplified by using first order Taylor series to evaluate these terms. We justify that the approximation results in only small error. To prove this we calculate the following terms at different growth factors (GF=D_d/D_{aer}) and different aerosol sizes:

$$T_1 = \frac{1}{1+\kappa\frac{1}{GF^3-1}}\exp\left(\frac{A}{D_{aer}GF}\right)$$

$$T_2 = 1+\frac{A}{D_{aer}GF}-\frac{\kappa}{GF^3-1}$$

$$REL\_ERR = \frac{T_1-T_2}{T_1}$$

The REL_ERR (relative errors) as a function of GF at discrete aerosol sizes are plotted in Fig. R1. The smallest value of the GF is 1.5. (At the beginning of the calculation of the condensational growth, the diameter of the haze particle is assumed 1.5 times of the dry aerosol particles.) The plots reveal that the relative errors are less than 20% even in the case *of the aerosol particles with diameter of 5 μm at the initial moment, and the error decreases steeply as the GF increases. When GF is greater than 2.0, the relative error is less than 2 % independent of the aerosol size. Using Eq. 6. in Petters and Kreidenweis 2007, we need to assume that the drop is at equilibrium with its environment, i.e., the diffusional growth rate of the drop is equal to zero. The disadvantage of using Eq. 6. in Petters and Kreidenweis 2007 is that it significantly overestimates the growth rate of the water drops formed on larger hygroscopic particles (e.g. coarse particles), because in the case of the larger hygroscopic particles it takes significantly longer time than the model time step to reach the equilibrium size even in the slightly undersaturated environment (see Fig. 7a in the manuscript). The reason of this is that neglecting the temperature difference between the drops and its environment results in large error for all sizes of drops and CCN if the condensation/evaporation rate is significant (Pruppacher and Klett, 1978).*

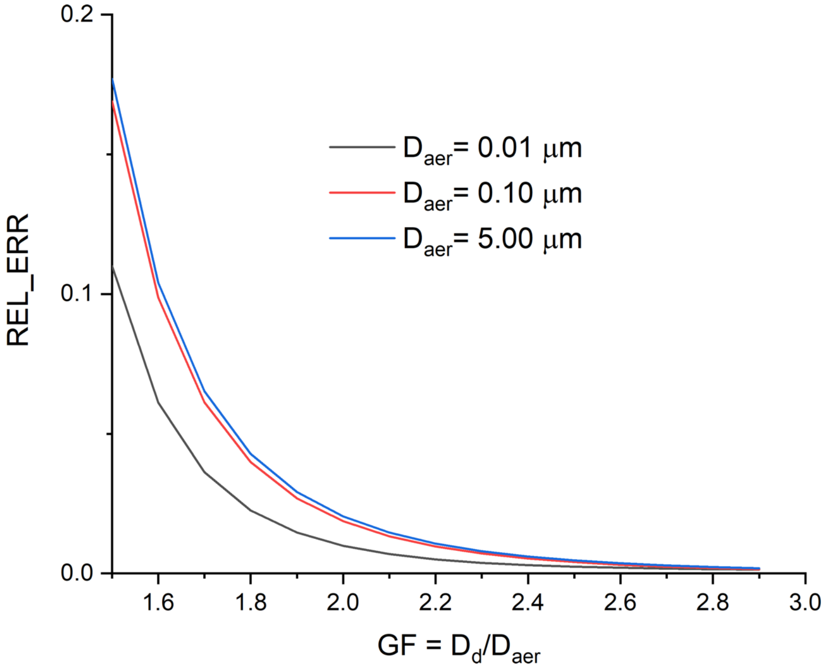

Figure R1. The relative errors between the first order Taylor series and the complete form of the curvature and solution terms as a function of growth factor for aerosol diameters of 0.01 (black), 0.1 (red) and 5 microns (blue).

Sentences were added at the line 88 in the original and at lines 90 - 93 in the revised manuscript:

“Both the curvature and solution terms (e.g. in Petters and Kreidenweis 2007) are approximated by the first order Taylor series in Eq. 1. The error caused by this approximation steeply decreases with the increase of the drop size. It is less than 20 % if the drop diameter is equal to the 1.5 times of the aerosol diameter, and less than 2 % if the ratio of the drop diameter and the aerosol diameter is greater than 2, even in the case of aerosol diameter of 5 μm.”

3. Eq. 3 and Eq.6. The “new” parameters are confusing, e.g., it looks like that doubling the hygroscopicity parameter is equivalent to half coarse particles, which is not true. In my point

of view, “Hc” is not a general parameter that can be used for future applications, because it is not derived from the first principle. I suggest the authors add more justifications and discussions of why and the benefit to introduce this new parameter.

We intend to introduce a dimensionless, bulk parameter that can be used to describe the impact of the coarse particles on the broadening of the drop spectrum and can be easily derived from both observational data and output of the numerical simulation. We agree that, in general, changes in H_c *by doubling the hygroscopicity of the coarse particles is not necessarily equivalent to the effect by reducing the concentration by half. However, we justify in the following that this parameter can be used to estimate the role of the coarse particles in the broadening of the DSD near the cloud base.*

Let’s start with the equation that describes the diffusional growth of water drops.

$$\frac{dm_d}{dt} = 2\pi D_d \frac{\left[S - 1 - \frac{4\sigma_{wa}}{R_v T \rho_w D_d} + \kappa \frac{m_a}{m_d - m_a} \frac{\rho_w}{\rho_a}\right] f_v}{\frac{L_v}{k_a^*}\left(\frac{L_v}{R_v T} - 1\right) + \frac{R_v}{e_{sat,w} D_v^*}}$$

For the diffusional growth of the drop formed on coarse particles, we assume that the solute term is dominant in the numerator of the above equation. Near the cloud base this is an acceptable approximation because of the large size of the coarse particles and the high concentration of the soluble components inside the droplets.

Neglecting the terms about the supersaturation and Kelvin effect, we get the following differential equation which is easy to solve analytically:

$$\frac{dm_d}{dt} \approx C \cdot \kappa \cdot m_d^{-2/3}$$

The solution of this equation is:

$$m_d = \left(m_{d,0}^{5/2} + C \cdot \kappa \cdot t\right)^{2/5} \approx \left(C \cdot \kappa \cdot t\right)^{2/5}$$

From this we can evaluate the reflectivity assuming monodisperse size distribution for coarse particles:

$$Z \approx N m_d^2 \approx N\left(C \cdot \kappa \cdot t\right)^{4/5} \approx N\kappa \cdot t$$

Because the lg(Z) is plotted in Fig. 3a, we can take the logarithmic of the above equation.

$$\lg(Z) \approx \lg(N\kappa t)$$

The impact of the coarse particles is normalized with the number concentration of the activated aerosol particles from the observations. The numerical simulation shows that the *efficiency of precipitation is negatively correlated to the number concentration of the activated aerosol particles. We can modify the equation above by taking into consideration of the number concentration of the activated aerosol particles (n_{act})*

$$\lg(Z) \approx \lg\left(\frac{N\kappa t}{n_{act}}\right) + \lg(n_{act}) = \lg(H_c) + \lg(n_{act}) + \lg(t)$$

The relation between the H_c parameter and reflectivity can be presented more clearly if we change the x axis scale from linear to logarithmic in Fig. 3a (see Fig. R2). The plot can be interpreted as follows: If the value of H_c is small, the role of the coarse particle comparing to that of all CCN particles is small in the formation of the larger drops. If the H_c is above the threshold value of about 10^{-4} , the logarithm of reflectivity is approximately a linear function of the logarithm of the H_c parameter. This relation reveals that the approximations we used are reasonable.

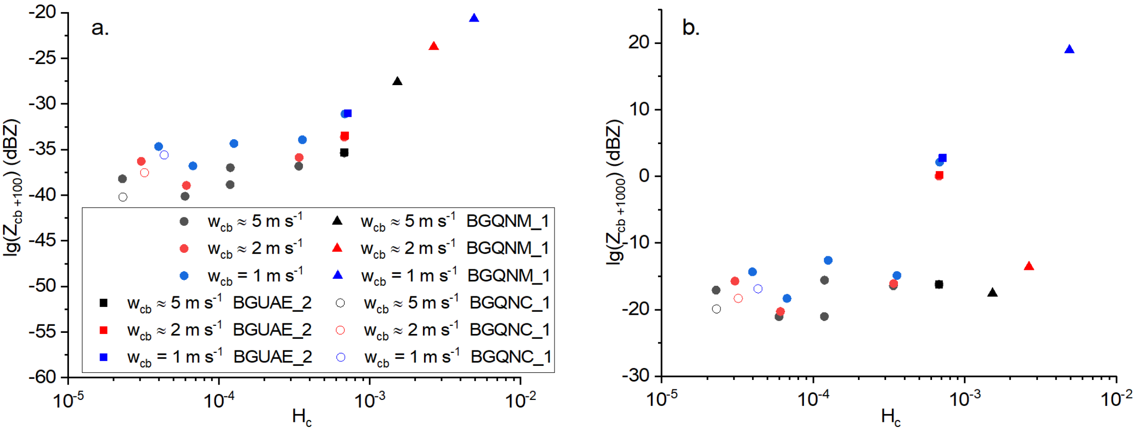

Figure R2. Same as Fig. 3 in the original manuscript but using the logarithmic scale in the horizontal axis for Hc.

To clarify this point, we modify the text at line 187 in the original and at line 204 in the revised manuscript:

“If the value of H_c is small, the impact of the coarse particles comparing to all of CCN particles is small in the precipitation formation. This can be interpreted as – is such case – coarse particles contribute insignificantly to the evolution of the DSD when compared to the fine particles. If H_c is above of the threshold of about 10^{-4}, the logarithm of the reflectivity is approximately a linear function of the H_c parameter logarithm.”

4. Line 164. “kappa = 20 is the hygroscopicity of dry nanoparticles”. Any reference to support such high value of hygroscopicity? I cannot find it in Tai et al., 2017.

Based on the published data, we found that the vapor uptake of the NaCl-TiO$_2$ nanoparticles becomes efficient at a low relative humidity of 50 – 60 %, while the NaCl particles start to deliquesce above 70%. The hygroscopicity of the nanoparticles is not constant, the observations show that it depends on the size of drops formed on them, and it is rather difficult to measure its value. The observations only reveal that about 5 to 10 times more mass of vapor is uptaken by the nano particles in the undersaturated environment if the diffusional growth of the drops occur in a sub-saturated environment within a reasonable *time (Bermeo et al, 2020). In the numerical studies, arbitrary values as high as 20 (e.g. Lompar et al, 2018) were used for the hygroscopicity. Contrary to the above cited research, we considered the dependence of the hygroscopicity on the GF (see Eq. 5 in the manuscript). Using this equation, the hygroscopicity is less sensitive to the initial value, and it is more sensitive to X. If X = 1 and GF = 5, the hygroscopicity of the nano particles is less than twice of the hygorscopicity of the salt if* κ_0 *is equal to or less than 20.*

We clarify this point in the manuscript. Explanation is added at line 166 in the original and at line 173 in the revised manuscript:

“There are no available observation data to calibrate the value of κ_0. In the numerical studies, arbitrary values as high as 20 (e.g. Lompar et al, 2018) were used for the hygroscopicity of the nanoparticles. Contrary to the above cited research, the dependence of hygroscopicity on the GF is considered in this study. If X is set to 0.1 (NANO_2) and 1.0 (NANO_1), the nanoparticles uptake about 5 and 2 times, respectively, more vapor than the salt particles (NANO_5) during the air parcel ascends from the levels of the RH = 70% to the cloud base. This enhancement of the vapor uptake agrees well with the laboratory observation data which shows that about 5 to 10 times more mass of vapor is taken up by the nanoparticles in the sub-saturated environment within a reasonable time (Bermeo et al, 2020).”

ref:

Bermeo, M., Hadri, N. E., Ravaux, F., Zaki, A., Zou, L., Jouiad M., 2020: Adsorption Capacities of Hygroscopic Materials Based on NaCl-TiO 2 and NaCl-SiO 2 Core/Shell Particles. Journal of Nanotechnology **2020,** *2020* , 1-16. https://doi.org/10.1155/2020/3683629

Lompar, M., Ćurić, M., Romanic, D., Zou, L., Liang, H., 2018: Precipitation enhancement by cloud seeding using the shell structured TiO2/NaCl aerosol as revealed by new model for cloud seeding experiments. Atmos. Res. 212, 202-212

5. Lines 187-189: “The monotonic increase of the reflectivity with increasing Hc…” This statement is not convincing. To support this argument, the authors need to do sensitivity studies by just changing the hygroscopicity of the coarse particles but keep other variables (e.g., droplet size distribution, aerosol number concentration, and vertical velocity) the same.

We did not intend to emphasize the separate impact of the hygroscopicity and number concentration, we intended to consider the impact of the coarse particles relative to all CCN.

We modified the text at line 204 in the revised manuscript:

“If the value of H_c is small, the impact of the coarse particles comparing to all CCN particles is small in the precipitation formation. This can be interpreted as – in such case –coarse particles contribute insignificantly to the evolution of the DSD when compared to the fine particles. If H_c is above a threshold of about 10^{-4}, the logarithm of the reflectivity is approximately a linear function of the H_c parameter logarithm.”

6. Figure 4a. Sub-micrometer droplets (r<1 um) exist at 100 m above the cloud base, but they do not exist at 1000 m above the cloud base. Please explain why? Are they all activated as cloud droplets?

The smallest drop size plotted in the figure is larger than critical drop radii for the drops formed on the fine aerosol particles (0.13 µm and 0.06 µm for the updrafts of 1 ms^{-1} and 5 ms^{-1}, respectively). So all drops in the plotted size range grow through the vapor condensation above this level.

Sentences to clarify this point are inserted to the text at line 204 in the original and at line 224 in the revised manuscript:

"Figure 4a shows the DSDs at 100 m and 1 km above the cloud base. Note that the critical droplet radii for both updrafts (0.13 µm and 0.06 µm for the updrafts of 1 ms^{-1} and 5 ms^{-1}, respectively) are smaller than the minimum droplet size plotted in the figure, the concentration of the drops larger than the critical size actually remain constant during the ascent of the parcel. "

7. Figure 4c. Droplet radius for r0=5 um is already over 10 um at the beginning of the simulation. How do you calculate the initial droplet radius at the beginning of the simulation?

The plots in Fig. 4c start at the altitude of 3800 m, and the calculation of the diffusional growth of water drops starts at 3300 m (see Fig. 1c). The reason that we plot only a subrange of the whole simulated range, is that we intend to take a close look near the cloud base.

A sentence is added to the figure caption to clarify this:

"Note, the plots in Fig. 4c start at the altitude of 3800 m, and the calculation of the diffusional growth of the water drops starts at 3300 m (see Fig. 1c)."

To avoid the division by zero in the solution term in Eq. 1, the integration of the equation starts with the haze particle having 1.5 times diameter of the dry aerosol particle. A sentence is added to clarify this at line 88 in the original and at line 93 in the revised manuscript:

"To avoid the division by zero at the evaluation of the solution term in eq 1. at the beginning of the calculation of the condensational growth, the diameter of the haze particle is assumed 1.5 times of the dry aerosol particle."

8. Line 206. "Figure 4c shows the evolution of drop sizes with different initial dry radii." I'm confused. Are monodisperse aerosols used for Figure 4c and 4d?

Sorry for the confusion. No, we did not use monodisperse aerosols for these plots. We intend to plot the evolution of the water drops at discrete sizes which represent the spectrum of the aerosol particles.

A sentence is added to clarify this at line 207 in the original and at line 230 in the revised manuscript.

"Figure 4c shows the evolution of drop sizes with different initial dry radii. These discrete initial radii are chosen to represent the diffusional growth of drops formed on aerosol particles with different sizes and hygroscopicities."

9. Lines 258-261. "the broadening effect is found to be negatively associated with the concentration of the background coarse particles…" Text here might mislead the reader that seeding is more efficient when the concentration of the background coarse particles is less. It is unfair to make comparisons between BGQNC_1 and BGQNM_1 because they have different aerosol size distributions, number concentrations, and compositions.

That was what we intended to conclude based on the aerosol backgrounds assessed. The main purpose of this research is to study the efficiency of the seeding in different environmental conditions, which means different background aerosol size distributions and chemical compositions as well. See the purpose of the research at line 63.

Numbers of papers have been published on how natural precipitation formation depends on the number concentration and/or the size distribution of the background aerosol particles (typical examples are the papers comparing the precipitation formation in polluted and clean air mass).

The importance of this comparison study is also supported by the conclusion of the field experiment (Wehbe et al, 2021):

„Similarly, the modelling work of Segal et al. (2004) indicates a decrease in seeding effects in the presence of large background CCN due to their efficient collision. Hence, given the comparable sizes between the existing GCCN over the UAE and typical seeding particles, it is unclear if hygroscopic seeding can be effective in these clouds. Modelling studies are needed to investigate whether the concentration and hygroscopicity of the background GCCN are high enough to cause a natural competition effect. Furthermore, modelling studies can help assess the effectiveness of perhaps larger seeding particle sizes (10–15 µm) in augmenting this potentially active natural competition effect and/or in initiating C-C."

ref:

Segal, Y., Khain, A., Pinsky, M., and Rosenfeld, D.: Effects of hygroscopic seeding on raindrop formation as seen from simulations using a 2000-bin spectral cloud parcel model, Atmospheric Research, 71, 3-34, 2004.

Wehbe, Y., Tessendorf, S. A., Weeks, C., Bruintjes, R., Xue, L., Rasmussen R. M., Lawson, P., Woods, S., and Temimi, M. 2021: Analysis of aerosol-cloud interactions and their implications for precipitation formation using aircraft observations over the United Arab Emirates, Atmospheric Chemistry and Physics, https://doi.org/10.5194/acp-21-12543-2021

To emphasize our aim in this study more clearly, we modify the text in the paragraph about the purpose of this research at line 65:

(i) “Understanding the mechanisms of the spectral broadening induced by characteristics of both background aerosols and hygroscopic seeding materials. A large number of numerical experiments are performed to examine the dependence of seeding efficiency on the type of seeding materials, on the cloud dynamics, and on the characteristics of background aerosols. The assessment of the broadening of drop spectra at different CCN concentrations and different characteristics of the coarse particles may advance the designation of the optimal environmental conditions for the hygroscopic seeding. We hypothesize that the competition for the available vapor near the cloud base between the drops formed on fine-mode (r < 0.1 μm) and coarse-mode particles (r > 1 μm) impacts the precipitation formation. “

10. Figure 8. What are the reasons for the cases with high ratio of liquid water contents (up to 1.6)? I would expect the liquid water content at 100 m above cloud base is similar (close to adiabatic value) for different cases, as shown in Figure 4b.

If the ratio of the Q_{seed}/Q_{ctrl} *is larger than 1 the liquid water content (LWC) is super-adiabatic. In the control cases the LWC is close to the adiabatic value. (At this level, the adiabatic LWC is very small around 0.1 g* kg^{-1}*.) Therefore even small changes in the sub-cloud aerosol conditions can result in large relative impact on the condensation. Super-adiabatic LWC near the cloud base has been observed in some field projects (e.g. Blyth and Latham, 1985, Yum and Hudson, 2001).*

To clarify the content of Fig 8a, the texts are inserted at line 335 in the original and at line 371 in the revised manuscript:

“If the ratio of the Q_{seed}/Q_{ctrl} is larger than 1 the LWC is superadiabatic, because in the control cases, the LWC is close to the adiabatic value at 100 m above the cloud base. The uptake of vapor by highly hygroscopic particles under the cloud base, especially in the case with a weak updraft, increases the LWC to above the adiabatic value. The amount of the surplus is small, so the effect is significant only when the adiabatic LWC is small (e.g., near the cloud base) and becomes negligible at a higher level above the cloud base. We hypothesize that the efficient vapor uptake by the coarse-mode hygroscopic particles can partly explain the observed superadiabatic LWC near the cloud base with weak updrafts in some field campaigns (Blyth and Latham, 1985, Yum and Hudson, 2001).”

Further explanation for the content of Fig. 8a can be found in the original version of manuscript at lines 332- 335 and at lines 369- 371 in the revised manuscript:

"The strong correlation reveals that the enhancement of the H_c parameter due to the injection of highly soluble coarse particles (in this case, the number concentration of activated particles only slightly increased) can significantly increase the water vapor uptake under the cloud base (see the intense growth rate of the drops formed on nanoparticles in Figs. 6b and d)."

Minor comments:

1. Line 105: Add more descriptions of bin method, e.g., gridded uniformly in radius, or mass.

A sentence is added and modified at line 104 in the original version of manuscript and at line 111 in the revised manuscript about the moving bin method:

"The initial size distributions of the aerosol particles in different categories are divided into 70 mass bins ranging from radius of 0.016 µm to 46.6 µm with bin mass increment factor of the square root of 2."

The sentence at line 105 in the original version of manuscript and at line 112 in the revised manuscript is modified as follows:

In the case of the fixed bin scheme, 48 mass doubling bins are defined over the radius range from 0.1 µm to 5.0 mm.

2. Line 155: Please add more descriptions of the seeding materials (nanoparticles, ICE70, and NCM).

We add more information about the nano particles at line 173 in the revised manuscript:

See our responses to point 4.

Sentence at line 167 in the original version of manuscript and at line 181 in the revised manuscript is inserted for the ICE70 particles:

"This type of burning flares produce both fine- and coarse-mode hygroscopic particles, but the concentration of the fine particles is about two-order of magnitude higher than that of the coarse particles (Bruintjes et al., 2012)."

To our knowledge there is no publication about the NCM seeding materials. Sentence at line 171-172 in the original version of manuscript and at lines 187-189 in the revised manuscript is modified to add more information about the NCM particles:

"The NCM seeding material (Table 4 and Fig. 2c) is released from hygroscopic flares and was recently developed by the National Center of Meteorology in UAE. Comparing to the ICE70 particles, the size distributions of the NCM particles are narrower, it consists of only fine particles. "

ref:

Bruintjes, R.T., Salazar, V., Semeniuk, T. A., Buseck, P., Breed, D.W., and Gunkelman, J., 2012: Evaluation of Hygroscopic Cloud Seeding Flares. Journal of Weather Modification. Vol. 44 No. 1

3. Figure 1. Solid circles are cases for BGUAE_1? It is not clear in the Figure and captions.

We think you probably mean Figure 3.

The solid circles represent all of the six other background cases (BGUEA_1, BGUAE_3, BGUAE_4, BGUAE_5, BGUAE_6 and BGQNC_2 with three corresponding updraft profiles). Because we changed the x axis to the logarithm scale, the dots belong to the case BGUAE_4 cannot be plotted ($H_c = 0$ in this case). A sentence is added to the figure caption and one sentence is inserted in the text to clarify this.

The figure caption is modified:
"Figure 3: Reflectivity calculated from the modelled DSD (a) 100 m and (b) 1000 m above the cloud base for non-seeded control cases. Symbols with different colours represent different updraft velocities at the cloud base as indicated by the key. Three different background aerosol size distributions are presented by solid triangles, squares, and open circles, respectively (see the legend in panel a.). The solid circles represent all of the six other background conditions (BGUEA_1, BGUAE_3, BGUAE_5, BGUAE_6 and BGQNC_2 with three corresponding updraft profiles except for BGUAE_4 case where H_c is zero)."

The following sentence is inserted at the line 193 in the original version of manuscript and at line 210 in the revised manuscript:
"(all the other background cases are not distinguished from each other by using different symbols, and they are denoted by closed circle)"

4. Line 184. "27 control cases are simulated. Figure 3a…" Not all 27 control cases are shown in Figure 3a. Add more discussions of which cases are plotted in Fig. 3.

All cases are plotted, but some points are overlapped. If you zoom in, you can count almost all 27 cases, but one. Explanation is added in the figure caption (see our response above). Because we changed the scale to logarithmic in Figs. 3a and b, the BGUAE_4 case cannot be plotted because the H_c is zero in this case.

5. Figure 4a and others (e.g., Figure 5). The y label should be "dN/dlog(r)". "d" is missing.

Thanks, the labels are modified.

The following references are added to the manuscript:

Blyth, A.M., Latham, J., 1985. An airborne study of vertical structure and microphysical variability within a small cumulus. Q. J. R. Meteorol. Soc. 111, 773–792.

Yum, S.S., Hudson, J.G., 2001. Cloud microphysical relationships in warm clouds. Atmos. Res. 57, 81– 104.

Yum, S.S., Hudson, J.G., 2005: Adiabatic predictions and observations of cloud droplet spectral broadness. Atmos. Res. 73, 203– 223.

Bermeo, M., Hadri, N. E., Ravaux, F., Zaki, A., Zou, L., Jouiad M., 2020: Adsorption Capacities of Hygroscopic Materials Based on NaCl-TiO 2 and NaCl-SiO 2 Core/Shell Particles. Journal of Nanotechnology **2020,** *2020* , 1-16. https://doi.org/10.1155/2020/3683629

Lompar, M., Ćurić, M., Romanic, D., Zou, L., Liang, H., 2018: Precipitation enhancement by cloud seeding using the shell structured TiO2/NaCl aerosol as revealed by new model for cloud seeding experiments. Atmos. Res. 212, 202-212