# Anonymous Referee #3 (RC2)

The manuscript examines how aerosol loading and vertical transport jointly shape cloud microphysical structure in a turbulent convection chamber. The simulations are conducted using large-eddy simulations coupled with a Lagrangian super-droplet model, and the main findings focus on mean vertical profiles of liquid water content within the chamber. The results indicate that cloud water generally increases with height due to continued droplet activation and growth during ascent. However, this vertical gradient weakens substantially under polluted conditions, where enhanced competition for water vapor suppresses supersaturation variability and leads to more vertically uniform cloud water profiles. These findings underscore the role of aerosol loading in controlling vertical cloud microphysics and emphasize the coupled effects of vapor competition and turbulent vertical dynamics, with potential implications for aerosol–cloud interaction parameterizations in both laboratory and atmospheric contexts. While the topic of the manuscript is highly interesting and detailed modeling is indeed required to understand the processes governing droplet formation in cloud chambers, I have significant reservations regarding both the content and the conclusions drawn. Consequently, I cannot recommend acceptance of the manuscript in its current form. The analysis is highly technical and limited to a single experimental configuration intended to mimic a specific chamber setup. However, I do not find sufficient scientific novelty in the results when compared to previous studies using the same modeling framework or to the established understanding of how aerosol concentration controls supersaturation. In this respect, the manuscript may be more suitable for a journal with an instrumental or methodological focus, such as Atmospheric Measurement Techniques or a similar outlet.

Response: We thank the referee for the careful reading and for the clear summary of the manuscript. We also appreciate the referee's legitimate concern that the current results may appear to have insufficient scientific novelty relative to established understanding of aerosol control on supersaturation.

We agree that the qualitative damping of supersaturation (S) variability at higher CCN is well known. Our novelty is therefore not the existence of this damping, but the advances in three specific aspects, when compared to established understanding from prior chamber simulations: we show how the damping reorganizes the vertical cloud-water structure $q_c(z)$ in a turbulent, wall-forced chamber (i.e., the transition from strong increase with height to nearly uniform profiles); using the Lagrangian framework, we quantify the corresponding collapse of growth-history sensitivity across droplets originating from the same near-bottom air mass; and to address the concern that the study uses a single chamber configuration, we interpret these behaviors through a nondimensional timescale framework ($Da = \tau_m/\tau_p$) that identifies a transition from a history-sensitive to a history-insensitive regime, providing a geometry-independent process explanation.

To strengthen the atmospheric relevance (and ACP suitability), we revised Section 4 and the Concluding Remarks to explicitly connect this Da-based regime view to Lagrangian interpretations of condensational growth in turbulent shallow clouds (e.g., eddy-hopping and condensational broadening) and to clarify the distinction between chamber circulation and atmospheric updraft terminology. This interpretation is consistent with recent adiabatic cloud simulations in which the main analysis is based on a 1D turbulent-parcel framework,

supported by additional 3D LES results. These simulations show that eddy hopping effect is stronger in pristine conditions because a longer phase relaxation time allows larger supersaturation fluctuations for comparable vertical-velocity variability, and a larger peak cloud-base supersaturation activates a broader range of CCN (Grabowski et al., 2026). This framing emphasizes a nondimensional process interpretation that can be transferred beyond a specific chamber geometry (Lines 515-524, 577-604):

"From a Lagrangian perspective, we interpret our diagnostics as follows. At a given time, the super droplets within the lowest 0.2 m can be viewed as originating from a common near-bottom air mass. Turbulent motions then disperse these droplets along trajectories that differ in their net ascent and in their residence time within the near-bottom supersaturation source region. These differences produce distinct time-integrated supersaturation exposures, and therefore distinct condensational growth histories, even for droplets that start from the same near-bottom layer. In the clean (low-CCN) cases, supersaturation fluctuations are relatively large, so growth becomes strongly history dependent and the normalized radius increment, $dr$, varies substantially across trajectories. In the polluted (high-CCN) cases, supersaturation fluctuations are damped, so droplets experience more similar effective supersaturation histories and $dr$ becomes more uniform. In our simulations, this transition is accompanied by a weakening of the vertical gradient in $q_c$, consistent with reduced contrasts between strongly ascending and weakly ascending trajectories as CCN increases."

"This behavior can be summarized by a timescale perspective in which $Da$ (= $\tau_m/\tau_p$) compares a chamber-scale transport time, $\tau_m$, to the phase relaxation time, $\tau_p$. As CCN loading increases, the total droplet surface area increases, $\tau_p$ shortens, and supersaturation perturbations are relaxed more rapidly toward quasi-equilibrium. The resulting reduction in supersaturation variance and narrowing of growth histories is consistent with laboratory evidence from the Pi Chamber (Chandrakar et al., 2016). Our simulations extend this picture by showing, in a fully three-dimensional Lagrangian framework, how the same mechanism links supersaturation damping to both the vertical structure of $q_c$ and the sensitivity of condensational growth to vertical history for droplets originating from the same near-bottom air mass."

"In atmospheric clouds, this timescale view is closely related to eddy-hopping and stochastic parcel frameworks for condensational broadening in shallow cumulus and stratocumulus. When Da is unity, droplets adjust slowly enough that differences in Lagrangian residence time within regions of enhanced supersaturation are efficiently translated into differences in condensational growth, favoring spectral broadening. When Da is large, supersaturation is homogenized more rapidly, so droplets following distinct trajectories can nevertheless experience similar effective supersaturation histories and grow by comparable amounts. This suggests that higher CCN loading can weaken the imprint of turbulent history on condensational broadening in cloud interiors, consistent with stochastic entraining parcel studies (e.g., Abade et al., 2018). This interpretation is also consistent with recent adiabatic cloud simulations based primarily on 1D turbulent-parcel modeling, complemented by 3D LES cloud simulations, showing that eddy hopping effect and the associated turbulence-driven condensational broadening are stronger under pristine conditions because a longer phase relaxation time allows larger supersaturation fluctuations for the same turbulent vertical-velocity variability, and a larger peak cloud-base supersaturation activates a broader range of CCN (Grabowski et al., 2026).

We note that the Da used here differs from the Da commonly adopted in entrainment-mixing studies at cloud edges, where Da often compares a microphysical adjustment time (frequently evaporation in subsaturated entrained air) to a small-scale turbulent mixing time across cloudy and environmental filaments. In that framework, large Da implies microphysics can act faster than mixing, promoting inhomogeneous mixing signatures. By contrast, our Da compares phase relaxation to a chamber-scale transport time in a near-saturated, quasi-closed environment where condensational relaxation dominates. There, a shorter $\tau_p$ strengthens the negative feedback on supersaturation perturbations, so increasing CCN primarily damps supersaturation fluctuations and homogenizes condensational growth histories in the chamber interior. In atmospheric clouds, both behaviors can coexist, with CCN damping interior supersaturation variability while entrainment at cloud edges can still drive locally inhomogeneous mixing depending on humidity deficits and mixing scales."

I also agree with the first reviewer regarding issues with terminology. Although I am not an expert in cloud chamber experiments, I find the discussion of updrafts to be potentially misleading. The manuscript explicitly states that "the positive correlation between supersaturation (S) and vertical velocity (W) in the chamber arises not from adiabatic cooling driven by the updraft itself, but rather from the mixing of air volumes with different thermodynamic properties originating from the lower and upper boundaries." Given that the dynamical processes in the chamber differ substantially from those in real atmospheric clouds, the interpretation of droplet activation in terms of updrafts at different altitudes appears questionable. If activation is primarily driven by mixing, one would expect similar effects to occur in downdrafts as well, which is not addressed in the discussion

Response: We thank the referee for this important clarification regarding terminology and the interpretation of vertical motion in the chamber. We agree that supersaturation in a convection cloud chamber is generated primarily by turbulent mixing of air masses with different thermodynamic properties, rather than by adiabatic cooling in an atmospheric-updraft sense. To avoid confusion, we revised the text to de-emphasize "updraft" terminology and to describe the flow in terms of the ascending and descending branches of the chamber circulation and their associated mixing pathways (Lines 231–233):

"indicating a relatively strong vertical increase in $q_c$ that reflects efficient droplet activation and condensational growth in the lower part of the chamber where mixing between warm, moist air from the bottom boundary and cooler air aloft generates enhanced supersaturation"

Regarding the referee's point about downdrafts, our simulations show that descending motions in the chamber interior are predominantly associated with subsaturation and therefore with low $q_c$. This is illustrated in Fig. 8 (computed from randomly sampled interior grid points away from chamber boundaries), where negative $S$ occurs preferentially for $W<0$. Physically, this arises because the descending branch carries air that has been cooled aloft and typically depleted in water vapor by prior condensation; when this air mixes with its surroundings, the resulting water-vapor mixing ratio is often insufficient to maintain saturation at the local temperature, yielding $S<0$ and favoring evaporation rather than continued activation and growth. Similar behavior has also been reported in other chamber simulations (e.g., Wang et al., 2024, Fig. 7), which show reduced $q_c$ (and smaller droplets) in descending regions. We therefore interpret activation and sustained condensational growth as occurring where mixing

produces supersaturation, whereas descending motions more often sample mixing states that yield subsaturation and reduced $q_c$. We have added a brief description of this point in the main text to more directly illustrate the W–S coupling using the S–W scatterplots (Lines 314–318):

"To illustrate this *W–S* coupling more directly, Figure 8 shows the scatterplot of supersaturation and vertical velocity. The scatterplots show that positive *S* values are preferentially associated with updrafts (*W*>0), whereas negative *S* occurs mainly in downdrafts (*W*<0), consistent with condensation being most effective during ascent. As aerosol concentration increases, both the positive and negative *S* tails contract toward zero, making the *W–S* relationship more symmetric and thereby weakening the *W–S* coupling. "

Some specific comments:

Lines 194–195: "The denominator is the mean of qc at both levels, where active cloud formation occurs during the quasi-equilibrium period." Is droplet activation assumed to occur only near the top and bottom of the chamber? If so, what is the physical justification for this assumption? Given the turbulent nature of the chamber, mixing should occur throughout the domain, and activation would therefore not be limited to only two vertical levels.

Response: We thank the referee for pointing out that the wording in Lines 194–195 was potentially misleading. We did not intend to imply that droplet activation is confined only to two discrete heights. The levels z=0.3 m and z=1.7 m are used only as reference heights to define a normalized metric of the vertical contrast in qc during the quasi-equilibrium period. We have revised the text accordingly by removing the phrase "where active cloud formation occurs" and clarifying that the denominator serves only as a normalization factor. The two reference heights are chosen to be symmetrically offset from the lower and upper plates (0.3 m from each boundary) to reduce sensitivity to boundary-adjacent layers (Lines 226-229):

"where the numerator is the horizontal mean $q_c$ at *z*=1.7 m minus the horizontal mean $q_c$ at *z*=0.3 m, and the denominator is the mean $q_c$ at these two reference heights during the quasi-equilibrium period, which is used to normalize the vertical-contrast metric. These heights are chosen to be symmetrically offset from the lower and upper plates (0.3 m from each boundary) to reduce sensitivity to boundary-adjacent layers."

Lines 216–218: "…the number of droplets increases, leading to stronger competition for available water vapor. As a result, each droplet grows more quickly, consuming vapor rapidly… This rapid vapor depletion suppresses the buildup of S during ascent, thereby limiting the vertical increase in qc." This description appears inconsistent. Individual droplets should grow more slowly when supersaturation is reduced, even though the total condensational growth rate (and thus qc) may increase due to a higher number of droplets. Please rephrase to clearly distinguish between individual droplet growth and bulk condensational growth.

Response: We thank the referee for pointing out this inconsistency. Our wording was incorrect: under high CCN loading, individual droplets do not grow faster because supersaturation is

reduced. Instead, the larger total droplet surface area strengthens the bulk condensational sink, so supersaturation relaxes more rapidly toward a low quasi-steady value (shorter $\tau_p$). In this sense, droplet growth equilibrates sooner and additional growth aloft is limited, which weakens the vertical increase in $q_c$. We have revised the text to clearly distinguish individual droplet growth from the bulk condensational uptake (Lines 253-256):

"As a result, supersaturation is driven rapidly toward a low quasi-steady value, so individual droplets experience weaker supersaturation and grow more slowly, but the population equilibrates sooner and exhibits limited additional growth aloft, thereby weakening the vertical increase in $q_c$."

Figure 3: How do the mean droplet size and droplet number concentration vary with height in the chamber? Is it possible that the more vertically uniform qc profiles arise from changes in supersaturation as a function of height and its interaction with the aerosol distribution? Because the chamber top is colder, condensation rates should be reduced, potentially facilitating more efficient activation and higher droplet number concentrations. As aerosol concentration increases, critical supersaturation increases and small variations in become less important, which may naturally lead to weaker vertical gradients in qc.

Response: To answer the referee's question, we draw the diagnostic figure (Figure R1) that show the vertical contrasts $\Delta N_c$ and $\Delta R_m$ defined analogously to $\Delta q_c$ and averaged over the quasi-equilibrium period (15–30 min). As shown in Fig. R1, $\Delta N_c$ decreases systematically with increasing aerosol concentration, approaching small (near-zero) values at high CCN loading, consistent with the reduced vertical contrast in $q_c$ under polluted conditions. In contrast, $\Delta R_m$ exhibits no clear monotonic dependence on aerosol concentration. These results indicate that the aerosol-dependent weakening of the vertical $q_c$ gradient is primarily associated with a reduced vertical contrast in droplet number (i.e., diminished additional activation aloft), rather than a systematic increase of droplet size aloft.

Finally, the scatterplot of $S$–$W$ (Fig. 8) show that descending motions in the chamber interior are predominantly subsaturated, and downdraft regions are associated with lower $q_c$ and smaller droplets, consistent with other chamber simulations (e.g., Wang et al., 2024, Fig. 7). Together, these diagnostics support our interpretation that higher CCN loading damps supersaturation variability and reduces the sensitivity of activation and condensational growth to vertical history, leading to more vertically uniform qc profiles.
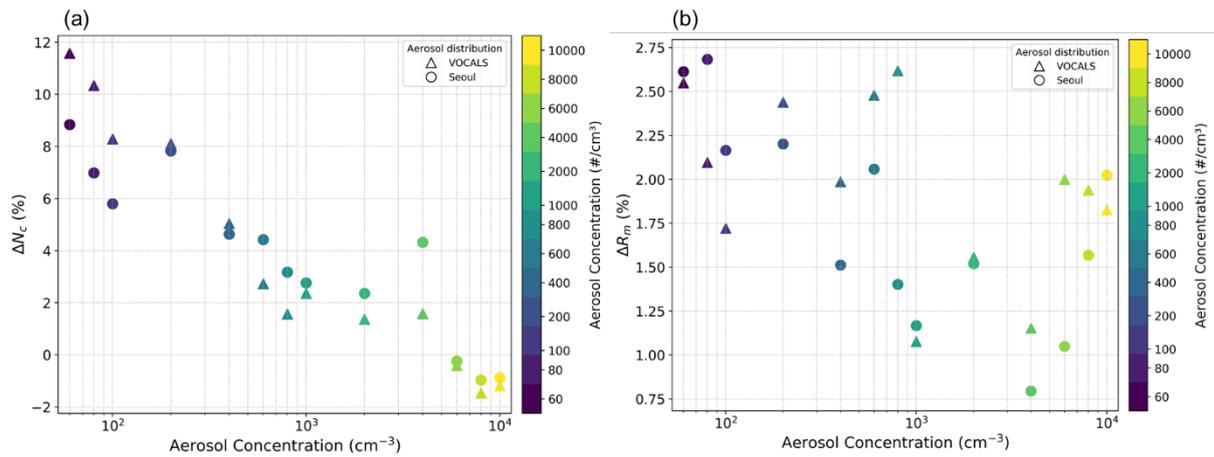
Figure R1. Vertical contrasts in droplet number concentration ($N_c$) and mean droplet size ($R_m$) as a function of aerosol concentration. Panel (a) shows $\Delta N_c$ (%) and panel (b) shows $\Delta R_m$ (%), where $\Delta X$ is defined analogously to $\Delta q_c$ as $\Delta X=(X_{1.7\,m}-X_{0.3\,m})/[0.5\,(X_{1.7\,m}+X_{0.3\,m})]\times100\%$, with $X$ denoting the horizontal-mean value at each height. All quantities are averaged over the quasi-equilibrium period (15–30 min). Triangles denote VOCALS cases and circles denote Seoul cases; marker colors indicate aerosol concentration (cm$^{-3}$).

Figure 5: The manuscript repeatedly states that supersaturation fluctuations are maintained by mixing of air parcels. However, from basic thermodynamics, mixing two supersaturated air parcels at different temperatures should still yield supersaturated air. Since all boundaries in the model domain are supersaturated with respect to water, what mechanism produces negative supersaturation values in the simulation? Additionally, what causes the strong fluctuations in mean S near the top and bottom boundaries?

Response: That is basically because of condenesational loss of water vapor. Negative supersaturation (S<0) occurs when descending air that has been cooled aloft and typically depleted in water vapor by prior condensation mixes with its surroundings; the resulting water-vapor mixing ratio can be insufficient to maintain saturation at the local temperature, yielding S<0 and favoring evaporation rather than continued activation and growth. Similar behavior has also been reported in other chamber simulations (e.g., Wang et al., 2024, Fig. 7), which show reduced $q_c$ (and smaller droplets) in downdraft regions.

The strong oscillations in the mean $S$ profile near the top and bottom plates are the same issue raised by Anonymous Referee #2 and are discussed in the revised manuscript (Lines 301–309):

"Before interpreting this relationship, we address a potential concern raised by the mean supersaturation profiles in Figure 5a,b, which exhibit oscillations near the lower and upper rigid boundaries. Two factors likely contribute to these near-wall oscillations. First, resolved transport and mixing are inefficient near rigid boundaries in ILES, which can allow sharp gradients to persist. Second, supersaturation is a diagnosed quantity, so small grid-scale perturbations in temperature and water vapor can translate into comparatively large fluctuations in S because of the nonlinear saturation relationship and advection–condensation coupling (Grabowski and Smolarkiewicz, 1990). Importantly, the $W$–$S$ correlations reported

in Figure 7 are computed over the interior region away from the plates, and the aerosol-dependent trends in Figure 7 remain unchanged when the boundary-adjacent layers are included (not shown). With this in mind, we interpret the aerosol dependence of W–S coupling as follows."

We attribute these near-wall oscillations primarily to the ILES configuration, where resolved transport and mixing are inefficient near rigid boundaries, and to the fact that supersaturation is a diagnosed nonlinear quantity. So small grid-scale perturbations in temperature and water vapor can translate into comparatively large fluctuations in $S$ via advection–condensation coupling (Grabowski and Smolarkiewicz, 1990). Importantly, the $W$–$S$ correlations in the main analysis are computed over the interior region excluding boundary-adjacent layers, and a sensitivity test including the boundary layers (and the full domain) shows that while the absolute correlation magnitude is reduced, the aerosol-dependent trends remain unchanged (Fig. R2). While Fig. 5 shows intermittent oscillations with both positive and negative S near the boundaries, the tendency for predominantly positive supersaturation in the near-bottom boundary layer is a robust feature also reported in one-dimensional turbulence model (Chandrakar et al., 2020). This supports our interpretation of the lower layer as a potential activation region. We have added this clarification and the supporting citations in the discussion of Fig. 5 in the revised manuscript (Lines 259-263):

"Notably, the near-bottom layer exhibits predominantly positive mean supersaturation, although both positive and negative values occur intermittently. This behavior is consistent with moist Rayleigh–Bénard convection results from a one-dimensional turbulence (ODT) framework (Chandrakar et al., 2020), supporting the role of the lower boundary layer as a plausible activation region"
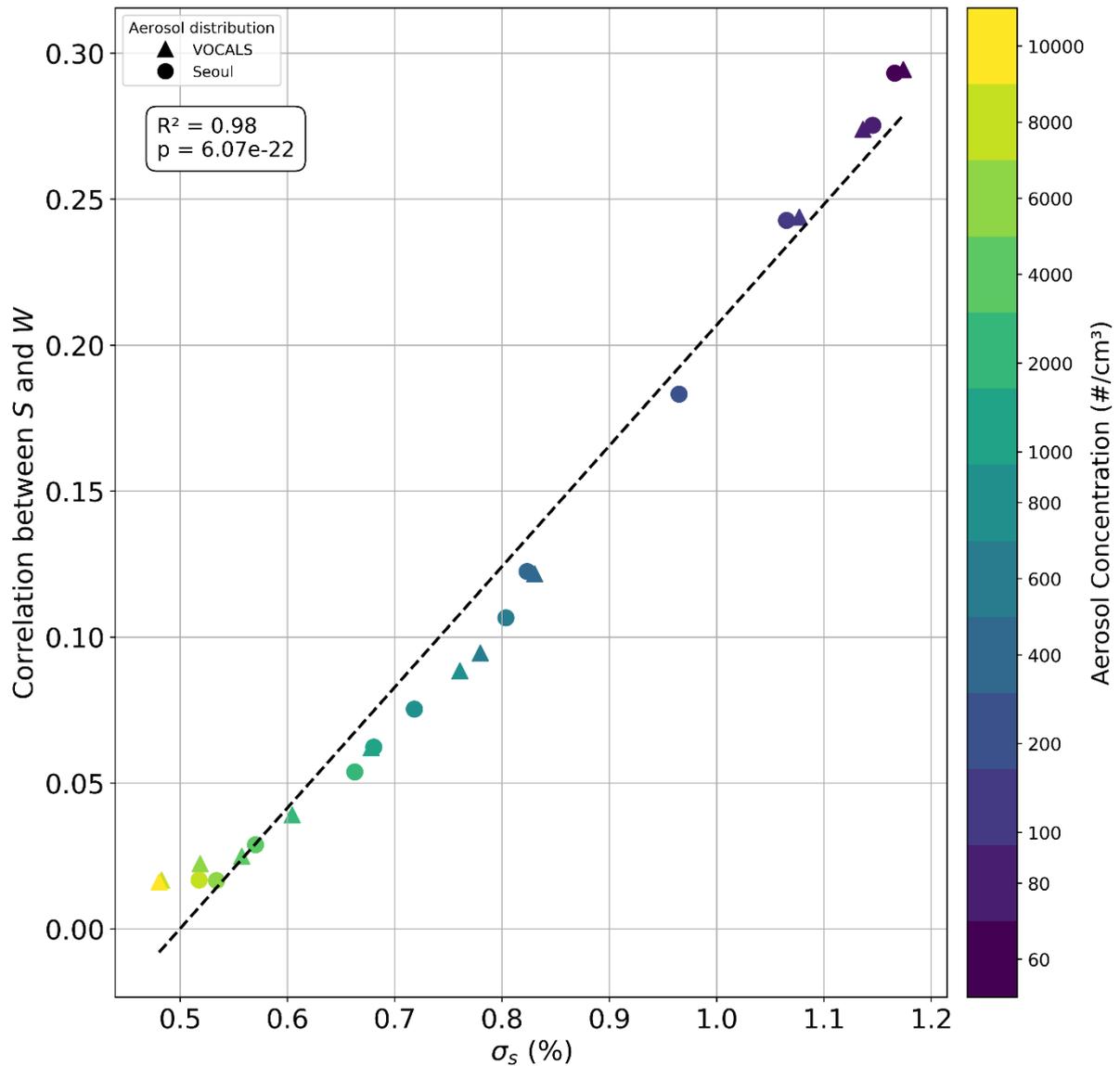
Figure R2. Scatter plot showing the relationship between the domain-averaged supersaturation standard deviation ($\sigma_S$) and the correlation coefficient between supersaturation ($S$) and vertical velocity ($W$). Both $\sigma_S$ and corr($S, W$) are calculated using all grid points in the domain, without excluding the uppermost and lowermost boundary layers for VOCALS (triangles) and Seoul (circles) aerosol cases. Each point represents the averaged value for the quasi-equilibrium period (15–30 minutes).

Lines 231–232: "In contrast, because our size distribution spans multiple modes, $\bar{s}$ does not collapse exactly to one number but instead asymptotes to a narrow range just above the largest-mode critical S ($\sim 0.02\%$)." This explanation is difficult to justify physically. The close correspondence between $\bar{s}$ and the largest-mode critical supersaturation may be coincidental rather than mechanistically constrained.

Response: We realize that "the largest aerosol mode" was not clearly understood. What we intended to say is that the minimum critical supersaturation is designated to the largest particles in the aerosol distribution. We have revised the text to state this explicitly and removed "largest aerosol mode." We also clarify that as aerosol loading increases, $\bar{S}$ approaches this minimum $S_{crit}$, so particles near this threshold can alternate between weak activation and deactivation as $S$ fluctuates around the threshold (Lines 270-279):

"The minimum critical supersaturation ($S_{crit}$) in the prescribed aerosol spectrum is approximately 0.02%, designated to the largest aerosol particles in the size distribution. As aerosol loading increases, $\bar{S}$ steadily falls toward this value, often converging near 0.02% (see Fig. 6). This behavior is qualitatively consistent with Yang et al. (2025), who found that mean supersaturation approached the critical value for their monodisperse aerosol. In our polydisperse case, $\bar{S}$ does not collapse to a single value, but instead converges to a narrow range near the minimum $S_{crit}$ set by the largest particles. When $\bar{S}$ is near this threshold, particles with $S_{crit}$ close to $\bar{S}$ can repeatedly transition between weak activation and deactivation as turbulent $S$ fluctuations move conditions slightly above or below their critical value, which effectively buffers $\bar{S}$. This buffering helps explain why, beyond a certain aerosol concentration, the domain-mean $q_c$ no longer increases (Fig. 2): enhanced vapor competition limits additional net activation and condensational growth despite further increases in aerosol loading."

Lines 234–236: Can this hypothesis be tested by explicitly accounting for water uptake in the aerosol phase? What role does water availability from the chamber walls play, and could it contribute to the apparent stagnation behavior?

Response: We tested this hypothesis by separating liquid water into "cloud" water (our operational definition, r>1μm) and total liquid water (all particles), and defining a haze-water reservoir $q_{c,haze} \equiv q_{c,total} - q_{c,cloud}$. We find that $q_{c,haze}$ increases systematically with aerosol concentration (Fig. R3), indicating that under polluted conditions an increasing fraction of condensate resides in sub-micron, near-threshold particles rather than in fully activated cloud droplets. This supports our interpretation that near-threshold activation–deactivation (haze–droplet interaction) might contribute to the apparent stagnation of $q_{c,cloud}$ at high aerosol loading. We also note that, at a given aerosol number concentration, VOCALS cases tend to exhibit larger $q_{c,haze}$ than Seoul cases, consistent with its size spectrum containing a larger fraction of large dry aerosol particles (Fig. 1) that can hold more water below the r>1μm cloud threshold.
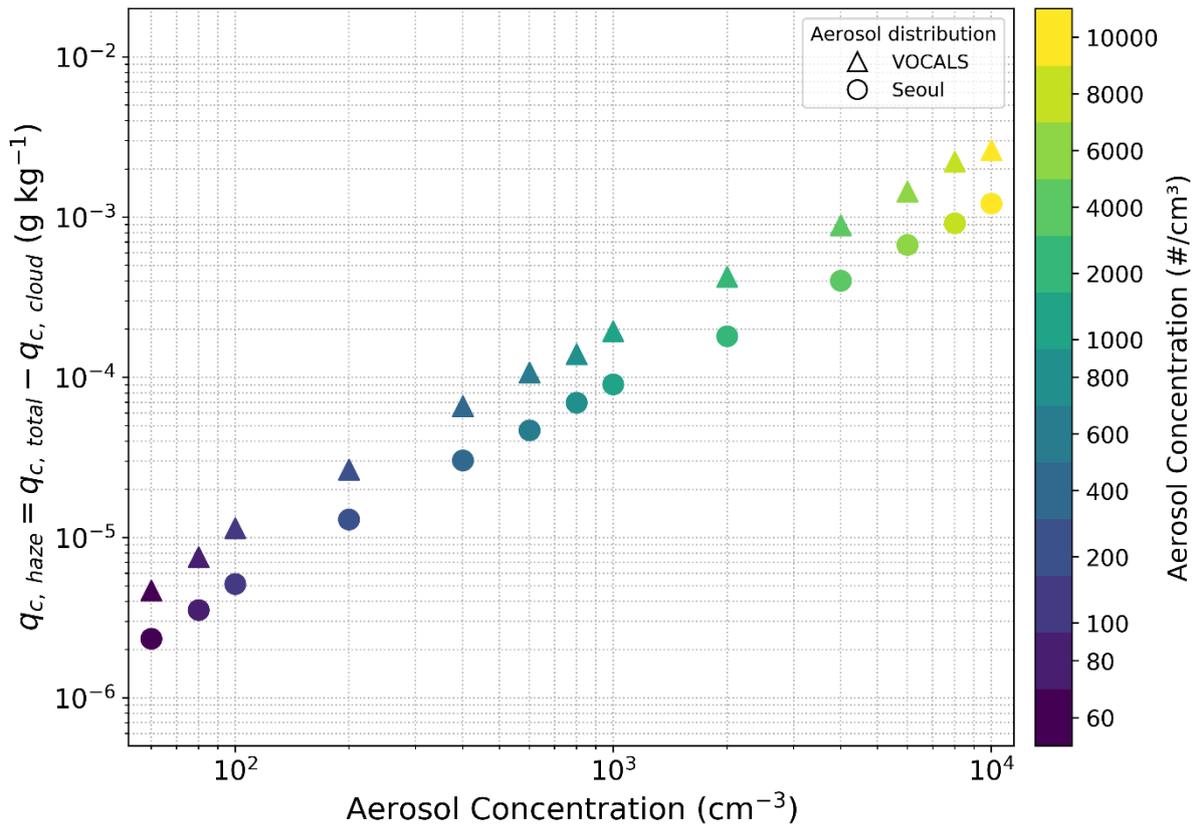
Figure R3. Aerosol-loading dependence of the "haze water" proxy $q_{c,haze} \equiv q_{c,total} - q_{c,cloud}$. Here, $q_{c,cloud}$ is defined using the paper's cloud criterion (liquid water from particles with r>1 μm), while $q_{c,total}$ includes all liquid water (r>0 μm). Markers denote aerosol size distributions (VOCALS: triangles; Seoul: circles), and colors indicate the prescribed aerosol concentration (cm$^{-3}$); both axes are shown on logarithmic scales. Each point represents the averaged value for the quasi-equilibrium period (15–30 minutes).

Lines 264–265: "Downward motions near the upper boundary carry cooler and drier air down into the chamber, generating negative S perturbations." According to the model setup, the upper boundary is at 100% relative humidity. If mixing is the dominant process affecting temperature and moisture, why do negative supersaturation values form?

Response: Although the upper boundary is prescribed at RH = 100%, that air is saturated at a colder temperature and therefore has a low absolute water-vapor mixing ratio. When this cold, low-$q_v$ air is transported downward and mixed into the warmer chamber interior, the local saturation mixing ratio increases rapidly with temperature, while $q_v$ remains almost the same. As a result, the mixed air is often unable to maintain saturation at the local temperature and becomes subsaturated (S < 0). This is consistent with our diagnostics (Fig. 8), which show that negative S occurs preferentially in descending motions (W < 0), and with prior chamber studies reporting negatively skewed S and the most negative S in downdrafts (e.g., Anderson et al., 2021). We revised the text to clarify that negative S is associated with the warming and mixing of cold saturated air from aloft into a warmer environment, rather than implying that the upper boundary itself is "dry." (Lines 322-325):

"Conversely, downward motions transport air that is saturated at the cold upper boundary (low absolute $q_v$) into the warmer chamber interior; as this air warms and mixes, saturation vapor mixing ratio increases faster than $q_v$, so the local relative humidity decreases and subsaturation ($S < 0$) can occur. This behavior is consistent with observations from laboratory chamber experiments, which report the most negative $S$ in downdrafts (Anderson et al., 2021)."

Figure 10 and related analysis: The main message of this figure is unclear. Please explain more explicitly how this analysis supports the manuscript's conclusions. Why is the analysis restricted to particles initially located near the bottom of the chamber rather than applied to all particles?

Response: The goal of Figure 11 (formerly Fig. 10) and related analysis is to define a simple Lagrangian metric that quantifies each droplet's recent vertical-history (predominantly ascending vs. mixed ascent–descent) and to show that this metric clearly separates distinct transport pathways in the chamber. This supports our main conclusion that vertical-history can strongly differentiate growth in clean cases, but that this sensitivity diminishes at high aerosol loading when supersaturation rapidly relaxes toward a quasi-steady value ($\tau_p \ll \tau_m$).

We restrict the analysis to SDs sampled from the same near-base source layer (z = 0–0.2 m) at the start of each 20 s tracking window so that all trajectories begin from a comparable origin region. This reduces a major confounding factor: if SDs from the full depth were included, differences in growth and height would largely reflect where droplets happened to be at the start (e.g., proximity to the lower vs. upper boundary and the associated S environment) rather than differences produced by turbulent transport and supersaturation history along the trajectories.

Lines 363–364: "Suggesting that condensational growth becomes increasingly decoupled from vertical motion due to limited S variability under polluted conditions." Or simply because there is more particles to use the same amount of water that is limited by the transport rate from the walls, and that's why the relative growth is less.

Response: We agree with the referee that moisture availability in the chamber is ultimately controlled by the rate at which water vapor is supplied from the boundaries and transported into the interior, so that increasing the number of particles can reduce the per-particle growth simply by partitioning a finite vapor supply among more droplets. In our framework, this effect is expressed through the same source–sink balance that determines the quasi-steady supersaturation: higher aerosol loading increases the total droplet surface area and strengthens the condensational sink (shorter $\tau_p$), so supersaturation is rapidly buffered near a low quasi-steady value with reduced variability. As a result, condensational growth becomes less sensitive to vertical-motion-induced supersaturation fluctuations, which is what we referred to as "decoupling." We have revised the sentence to make this source–sink (transport-limited source and sink-enhanced relaxation) interpretation explicit (Lines 434-437):

"Suggesting that condensational growth becomes less sensitive to vertical motion because $S$ is rapidly buffered near a low quasi-steady value set by the balance between the boundary-forced

vapor supply (transport) and the enhanced condensational sink at high aerosol loading (short $\tau_p$).”

References

Chandrakar, K. K., Cantrell, W., Krueger, S., Shaw, R. A., and Wunsch, S.: Supersaturation fluctuations in moist turbulent Rayleigh–Bénard convection: a two-scalar transport problem, J. Fluid Mech., 884, A19, https://doi.org/10.1017/jfm.2019.895, 2020.

Grabowski, W. W., Chandrakar, K. K., and Morrison, H.: Broadening of adiabatic droplet spectra through eddy hopping: Polluted versus pristine environments, J. Atmos. Sci., in review, 2026.