

We sincerely thank the reviewer for the careful and constructive comments. These suggestions have helped us identify several aspects of the manuscript entitled “Measurement Report: Vertical New Particle Formation characteristics observed at 356m Shenzhen Meteorological Tower” (Manuscript ID: egusphere-2026-4039) that required clarification and strengthening, particularly regarding the description of the methodology, quality assurance procedures, the interpretation of figures, and the broader applicability of the proposed observational approach. We have revised the manuscript accordingly. Our point-by-point responses are provided below.

General comments

Formatting and spacing errors throughout

There are many spacing errors throughout the manuscript, for example missing spaces after commas and full stops, and missing spaces between numbers and their units. I do not think it is useful to list the individual positions; the whole manuscript needs a careful pass.

In addition, please make unit notation consistent and SI-conform throughout (nm h^{-1} rather than nm/h , s^{-1} , $\text{m}^2 \text{s}^{-2}$, $\text{m}^2 \text{s}^{-3}$, $\text{molec cm}^{-3} \text{s}^{-1}$); at present these are mixed even within single sentences. Finally, the abbreviation of the site is used inconsistently as SZMGT, SZMG and SZMT; please pick one.

Response:

Thank you for pointing out these formatting and consistency issues. We apologize for these oversights in the original manuscript. We have carefully proofread the entire manuscript and corrected the spacing and punctuation errors. We have also standardized the notation of physical quantities and units in accordance with SI conventions, including nm h^{-1} , s^{-1} , $\text{m}^2 \text{s}^{-2}$, $\text{m}^2 \text{s}^{-3}$, and $\text{molec cm}^{-3} \text{s}^{-1}$. In addition, the abbreviation "Shenzhen Meteorological tower (SZMT)" is now used consistently throughout the manuscript to refer to the Shenzhen Meteorological Tower. These corrections have been applied to the main text, figures, captions, and tables to improve the clarity and consistency of the presentation.

Reference base is too narrow

The manuscript mainly uses Chinese references, where in many places other references would fit better. For example, in lines 65 to 67, where tower studies in Beijing, the Amazon and the Southern Great Plains are introduced, several well-fitting ATTO papers are missing. The same applies to the European long-term vertical and mountain-site work, and to the Hyytiälä and Leipzig urban datasets. Broadening the reference base would also let the authors benchmark their own numbers, which is currently not done anywhere.

Response:

Thank you for this valuable suggestion. We agree that the original manuscript did not sufficiently cover relevant international studies on NPF and its vertical characteristics. In response, we have substantially rewritten and reorganized the Introduction to provide a more comprehensive scientific background and a clearer presentation of the research motivation. The revised Introduction first highlights the importance of NPF in coastal urban environments, followed by a review of previous ground-based and vertically resolved NPF observations. We then summarize relevant studies conducted at the Shenzhen Meteorological Tower, identify the remaining knowledge gaps in the vertical evolution of NPF, and clarify the objectives and scientific significance of the present study.

Specifically, we have incorporated studies from the Amazon Tall Tower Observatory (Franco et al., 2024; Machado et al., 2024), European multi-site and long-term NPF observations (Bousiotis et al., 2021; Dada et al., 2017), and observations at different altitudes (Boulon et al., 2011). We have also added studies conducted in urban Leipzig (Brean et al., 2024; Sun et al., 2024). We have also strengthened the Discussion by including relevant studies on boundary-layer evolution and turbulent processes associated with NPF (Nilsson et al., 2001; Platis et al., 2015; Wu et al., 2021a). These additions provide a more comprehensive context for interpreting our observations and discussing the influence of boundary-layer dynamics on the vertical characteristics of NPF. These additions provide a broader scientific context for interpreting our observations and discussing the relationships among NPF, boundary-layer dynamics, and atmospheric chemical conditions.

Reference:

Boulon, J., Sellegri, K., Hervo, M., Picard, D., Pichon, J. M., Fréville, P., and Laj, P.: Investigation of nucleation events vertical extent: a long term study at two different altitude sites, *Atmos. Chem. Phys.*, 11, 5625-5639, 10.5194/acp-11-5625-2011, 2011.

Bousiotis, D., Pope, F. D., Beddows, D. C. S., Dall'Osto, M., Massling, A., Nøjgaard, J. K., Nordstrøm, C., Niemi, J. V., Portin, H., Petäjä, T., Perez, N., Alastuey, A., Querol, X., Kouvarakis, G., Mihalopoulos, N., Vratolis, S., Eleftheriadis, K., Wiedensohler, A., Weinhold, K., Merkel, M., Tuch, T., and Harrison, R. M.: A phenomenology of new particle formation (NPF) at 13 European sites, *Atmospheric Chemistry and Physics*, 21, 11905-11925, 10.5194/acp-21-11905-2021, 2021.

Brean, J., Rowell, A., Beddows, D. C. S., Weinhold, K., Mettke, P., Merkel, M., Tuch, T., Rissanen, M., Maso, M. D., Kumar, A., Barua, S., Iyer, S., Karppinen, A., Wiedensohler, A., Shi, Z., and Harrison, R. M.: Road Traffic Emissions Lead to Much Enhanced New Particle Formation through Increased Growth Rates, *Environ Sci Technol*, 58, 10664-10674, 10.1021/acs.est.3c10526, 2024.

Dada, L., Paasonen, P., Nieminen, T., Buenrostro Mazon, S., Kontkanen, J., Peräkylä, O., Lehtipalo, K., Hussein, T., Petäjä, T., Kerminen, V.-M., Bäck, J., and Kulmala, M.: Long-term analysis of clear-sky new particle formation events and nonevents in Hyytiälä, *Atmospheric Chemistry and Physics*, 17, 6227-6241, 10.5194/acp-17-6227-2017, 2017.

Franco, M. A., Valiati, R., Holanda, B. A., Meller, B. B., Kremper, L. A., Rizzo, L. V., Carbone, S., Morais, F. G., Nascimento, J. P., Andreae, M. O., Cecchini, M. A., Machado, L. A. T., Ponczek, M., Pöschl, U., Walter, D., Pöhlker, C., and Artaxo, P.: Vertically resolved aerosol variability at the Amazon Tall Tower Observatory under wet-season conditions, *Atmospheric Chemistry and Physics*, 24, 8751-8770, 10.5194/acp-24-8751-2024, 2024.

Machado, L. A. T., Unfer, G. R., Brill, S., Hildmann, S., Pöhlker, C., Cheng, Y., Williams, J., Hartwig, H., Andreae, M. O., Artaxo, P., Curtius, J., Franco, M. A., Cecchini, M. A., Edtbauer, A., Hoffmann, T., Holanda, B., Khadir, T., Krejci, R., Kremper, L. A., Liu, Y., Meller, B. B., Pöhlker, M. L., Quesada, C. A., Ringsdorf, A., Riipinen, I., Trumbore, S., Wolff, S., Lelieveld, J., and Pöschl, U.: Frequent rainfall-induced new particle formation within the canopy in the Amazon rainforest, *Nature Geoscience*, 17, 1225-1232, 10.1038/s41561-024-01585-0, 2024.

Nilsson, E. D., Rannik, Ü., Kulmala, M., Buzorius, G., and O'dowd, C. D.: Effects of continental boundary layer evolution, convection, turbulence and entrainment, on aerosol formation, *Tellus B: Chemical and Physical Meteorology*, 10.3402/tellusb.v53i4.16617, 2001.

Platis, A., Altstädter, B., Wehner, B., Wildmann, N., Lampert, A., Hermann, M., Birmili, W., and Bange, J.: An Observational Case Study on the Influence of Atmospheric Boundary-Layer Dynamics on New Particle Formation, *Boundary-Layer Meteorology*, 158, 67-92, 10.1007/s10546-015-0084-y, 2015.

Sun, J., Hermann, M., Weinhold, K., Merkel, M., Birmili, W., Yang, Y., Tuch, T., Flentje, H., Briel, B., Ries, L., Couret, C., Elsasser, M., Sohmer, R., Wirtz, K., Meinhardt, F., Schütze, M., Bath, O., Hellack, B., Kerminen, V.-M., Kulmala, M., Ma, N., and Wiedensohler, A.: Measurement report: Contribution of atmospheric new particle formation to ultrafine particle concentration, cloud condensation nuclei, and radiative forcing – results from 5-year observations in central Europe, *Atmospheric Chemistry and Physics*, 24, 10667-10687, 10.5194/acp-24-10667-2024, 2024.

Wu, H., Li, Z., Li, H., Luo, K., Wang, Y., Yan, P., Hu, F., Zhang, F., Sun, Y., Shang, D., Liang, C., Zhang, D., Wei, J., Wu, T., Jin, X., Fan, X., Cribb, M., Fischer, M. L., Kulmala, M., and Petaja, T.: The impact of the atmospheric turbulence-development tendency on new particle formation: a common finding on three continents, *Natl Sci Rev*, 8, nwaa157, 10.1093/nsr/nwaa157, 2021.

Results and discussion lack references

Generally, the results and discussion part needs references. Many described facts are stated without any reference. Related to this: the manuscript goes directly from the Results to the Conclusion with no Discussion section at all. Even for a Measurement Report, the results must be placed in context. Please add a Discussion comparing the occurrence frequencies and growth rates with other vertical NPF studies and with ground-based studies.

Response:

Thank you for this constructive comment. We agree that the original manuscript lacked sufficient discussion and comparison with previous studies. In response, we have substantially revised the Results section and added a dedicated Discussion section to provide a more comprehensive interpretation of our observations within the context of existing literature.

The new Discussion is organized into three subsections. Section 4.1 discusses the relationships among boundary-layer evolution, turbulence, and vertical NPF patterns, with reference to previous studies on atmospheric mixing and particle formation (Hu et al., 2026; Nilsson et al., 2001; Platis et al., 2015; Wu et al., 2021b). Section 4.2 examines the combined influence of boundary-layer dynamics, aerosol sink conditions, and precursor-related chemical environments on the vertical occurrence of NPF (Wang et al., 2026; Yin et al., 2026; Zhang et al., 2026). Section 4.3 discusses the limitations of the observations and their implications for future vertical NPF studies.

In addition, we have expanded the comparison with previous ground-based and vertically resolved NPF observations, including studies by Boulon et al. (2011), Sun et al., (2024), and Rowell et al., (2024). We have also revised the interpretations of the observed relationships to avoid unsupported causal claims. These revisions strengthen the scientific context of our findings and provide a more balanced discussion of the factors influencing vertical NPF characteristics.

Furthermore, we have reconsidered the scope of our analysis. Given the differences in instrumental size ranges among the measurement heights, we have removed the quantitative GR analysis and the corresponding interpretations to avoid potentially unreliable cross-height comparisons. The revised manuscript therefore focuses on the vertical occurrence patterns of NPF and their relationships with boundary-layer structure, chemical conditions, and turbulence. These revisions provide a more balanced and better-supported interpretation of the observed vertical NPF characteristics.

Assertions without supporting evidence

Several passages, in particular the paragraph in lines 358 to 374, contain a large number of assertions without proof. These need either to be demonstrated with the data and figures, or supported by references. The conclusion in particular builds very strong theories on quite little data, without those results having been established in the Results section. Concrete examples of claims that are asserted but never shown: the GR-CS correlation being "stronger aloft" (line 421), for which no correlation analysis appears anywhere in the manuscript; the attribution of Type A to turbulent vertical transport and Type D to subsidence (lines 285 to 290), for which no wind, mixing-layer-height or vertical-velocity data are shown; and the entire turbulence-NPF mechanism of Section 4.1, which is argued from Figure 8 even though Figure 8 contains no turbulence data at all.

Response:

Thank you for this important comment. We agree that several interpretations in the original manuscript were insufficiently supported by observational evidence. In response, we have substantially revised the Results, Discussion, and Conclusion sections to ensure that our interpretations are consistent with the available measurements.

First, we have removed the unsupported GR–CS correlation and the related GR analysis. We have also revised the interpretation of the four vertical NPF types. We no longer directly attribute Type A events to turbulent vertical transport or Type D events to atmospheric subsidence without sufficient supporting evidence.

Second, we have incorporated additional meteorological observations, particularly planetary boundary layer height (PBLH), to investigate the relationship between boundary-layer evolution and different vertical NPF patterns. Our analysis shows that during Type B events, PBLH remained at or below the 320 m measurement level for 40.3% of the event period, suggesting that early-morning boundary-layer development may partly explain the occurrence of NPF only near the ground.

Third, we have reorganized the turbulence analysis by presenting simultaneous observations of turbulent kinetic energy (TKE), eddy dissipation rate (EDR), PBLH, and nucleation-mode particle number concentration at different heights (Fig. 9). These observations provide direct evidence of the temporal correspondence between turbulence development and changes in particle number concentrations during the selected NPF event. These observations provide direct evidence of the temporal correspondence between turbulence development and changes in particle number concentrations (PNC) during the selected NPF event. We have also incorporated relevant literature to support the discussion of possible physical processes.

Finally, we have revised the Discussion and Conclusion to avoid unsupported causal interpretations and explicitly acknowledged the limitations of the available observations. The revised manuscript emphasizes the observed relationships among boundary-layer evolution,

turbulent conditions, and vertical NPF characteristics rather than attributing these patterns to a single mechanism.

Figure captions are too sparse

The figure captions are generally very sparse. In my opinion a figure caption should be sufficient on its own to understand the figure. Please improve all captions accordingly. At minimum each caption should state the height(s) shown, the measurement period and the time convention (local time or UTC), the instrument the data come from, the quantity plotted with its units, and, for statistical plots, the number of events or days in each category.

Response:

Thank you for this helpful suggestion. We agree that the figure captions in the original manuscript were insufficiently detailed. In response, we have comprehensively revised the figure captions throughout the manuscript to improve their clarity and completeness.

Specifically, we have expanded the captions to provide information on the measurement heights, observation periods, instruments, physical quantities and their units, and time conventions. All times are now explicitly identified as local time (LT, UTC+8) where applicable. For statistical figures, we have also clarified the meaning of the boxplots and included the number of events or valid observations in each category. In addition, the descriptions of individual panels have been improved to ensure that the figures can be understood independently of the main text.

These revisions make the figures more self-contained and facilitate the interpretation and comparison of the observational results.

Color maps and figure legibility

Some of the graphics use a rainbow color map. It is well known and well established in science never to use rainbow colors, for a number of reasons. Please check all graphics for color-blind readiness. Please also regenerate every figure at higher resolution. In the current PDF, Figures 3, 4, 6, 7, 8 and 10 have axis labels, tick labels and color bars that cannot be read at normal magnification, which makes independent evaluation of the results impossible. Perceptually uniform maps such as viridis, cividis or the crameri suite would solve both problems at once.

Response:

Thank you for this helpful suggestion. We agree that the color schemes and resolution of several figures in the original manuscript affected their readability and interpretation. In response, we have comprehensively revised the figures to improve their visual quality and consistency.

Specifically, we have replaced the rainbow color maps with perceptually uniform and color-

blind-friendly color schemes. We have also regenerated the figures at higher resolution and adjusted the font sizes, axis labels, tick labels, and color bars to ensure that all information can be clearly read at normal magnification. We have standardized the figure formatting and improved the visual consistency across different panels. These revisions substantially improve the clarity and accessibility of the figures, allowing the observational results to be interpreted and compared more effectively.

Numbers in the text do not match the figures

The values stated in the text for the condensation sink do not match Figure 5 at all, and in one case the statement is the opposite of what the figure shows. This is very critical, because it contradicts several statements elsewhere in the manuscript. It is hard for me to believe how this happened.

Two further inconsistencies of the same kind need to be resolved:

Growth rate. The abstract and conclusion state that GR increases from $9 \pm 4 \text{ nm h}^{-1}$ at the surface to $14 \pm 4 \text{ nm h}^{-1}$ at 320 m (lines 19 to 20, 420, 426 to 428). Section 4.1 and Figure 9 state the opposite: GR is highest at 100 to 200 m and "within 4 nm h^{-1} " at 350 m (lines 391 to 392). The value of $14 \pm 4 \text{ nm h}^{-1}$ appears in no figure and in no part of the Results. Where does it come from, from how many events, and over which size range? Note also that even if the number were correct, the sentence at lines 420 to 421, "GR increased from 9 to 14 nm h^{-1} at 320 m, confirming turbulent mixing attenuation with height", is a non sequitur, and it directly contradicts the mechanism argued in Section 4.1.

Turbulence. The text says the dissipation rate rose from 0.01 to $0.1 \text{ m}^2 \text{ s}^{-3}$ (lines 404 to 405), but the color bar of Figure 10b appears to top out near 0.004. Which is correct?

Response:

Thank you for pointing out these inconsistencies. We apologize for the discrepancies between the numerical values reported in the original manuscript and those shown in the figures. We have carefully re-examined the relevant results and revised the analyses, figures, and descriptions accordingly.

The CS analysis has been revised using particle number size distributions measured at 5 m to maintain consistency among different NPF types. As shown in the revised Fig. 6, the median CS values for Type A and Type B events were approximately 0.013 and 0.016 s^{-1} , respectively. The corresponding descriptions have been corrected to reflect the actual distributions shown in the figure. We have also removed the GR analysis and its associated conclusions from the manuscript. The different particle size ranges covered by the instruments introduced uncertainties into the comparison of GR across measurement heights. We therefore decided to exclude these results rather than retain conclusions that could not be adequately supported by

the available measurements.

Regarding the turbulence measurements, we have corrected the reported EDR values and units. During the NPF event on 23 October 2023, EDR locally reached approximately $3\text{--}4 \times 10^{-3} \text{ m}^2 \text{ s}^{-3}$, consistent with the revised Fig. 9. The previously reported values were incorrect and have been replaced. These corrections have been incorporated into the relevant sections of the manuscript, including the Abstract, Results, Discussion, and Conclusion. We have also checked the consistency between the numerical values and their corresponding figures to avoid similar discrepancies.

320 m or 350 m?

The uppermost measurement level is given as 320 m in Section 2.2.2 and in the abstract, and as 350 m in Figure 9 and in Section 4.1 (lines 20, 26, 364, 372, 391, 420, 425). These appear to be used interchangeably. Please state unambiguously which platform was instrumented and use one height consistently, because the two are attached to contradictory GR values (see general comment 7).

Response:

Thank you for pointing out this inconsistency. The SZMT has a total height of 356 m, with observation platforms at different heights. In this study, 320 m was the highest level equipped with a particle sizing instrument during both observation periods. The references to 350 m in the original manuscript were incorrect and have been corrected to 320 m.

We have clarified the instrument deployment heights in Section 2.2 and revised the relevant figures and descriptions to consistently use 320 m as the uppermost particle measurement level. The GR analysis associated with the previously inconsistent heights has also been removed, as explained in our response to the preceding comment.

Instrument heterogeneity undermines the cross-height comparison

Figure 8 shows that the five levels of IOP2 used instruments with five different size ranges: 10 to 700 nm (320 m), 7 to 65 nm (200 m), 13 to 500 nm (150 m), 13 to 700 nm (100 m) and 10 to 532 nm (5 m). This is a fundamental problem for every quantitative comparison in the paper. Levels with a 13 nm lower cut-off cannot fully detect the nucleation mode, so NPF event identification at 100 and 150 m is not comparable with the levels that reach 7 to 10 nm, and the finding that NPF occurrence is higher at the ground may be partly or wholly an instrumental

artefact. The 200 m instrument stops at 65 nm and cannot track growth beyond that size, yet its GR is compared with levels reaching 700 nm. Since a lognormal-fit GR is strongly sensitive to the size range fitted, I recommend re-deriving all NPF statistics, CS and GR values over a common size range present at all levels (for example 13 to 65 nm), and reporting the original values only as a sensitivity test.

Response:

Thank you for raising this important concern. We agree that differences in the particle size ranges covered by the instruments could affect the comparability of measurements across different heights. To address this issue, we have standardized the particle diameter range to 13.1–107.3 nm for all particle size distribution analyses during both IOP1 and IOP2. This common range is covered by all instruments used in the study. The nucleation-mode particle number concentration (N_{nuc}) was calculated by summing the particle number concentrations in the same size channels between 13.1 and 25 nm at each measurement height. The same size channels and calculation procedure were applied throughout both observation periods, ensuring consistency in the quantitative comparison of nucleation-mode particles across different heights.

We have also removed the original GR analysis and its associated conclusions, as differences in instrumental size ranges could introduce uncertainties into the estimation of particle growth rates. The CS analysis has been revised to use only ground-level measurements at 5 m, avoiding direct comparisons between instruments with different size ranges.

We have clarified the particle size range and calculation procedures in the revised Methods section. We also acknowledge that the harmonized size range does not cover particles smaller than 13.1 nm, which limits our ability to resolve the earliest stages of particle formation. This limitation is now discussed in Section 4.3. The revised analysis provides a more consistent basis for examining the vertical occurrence patterns and temporal evolution of NPF.

Sampling line losses are not addressed

For a tower deployment with gradient sampling systems and high-altitude sampling ports (lines 124 to 126), diffusional losses in the inlet lines are a first-order effect below 20 nm and can easily reach 30 to 70 % at 10 nm depending on line length and flow. No penetration efficiency, line length, flow rate or residence time is reported anywhere. Because the core claims concern nucleation-mode particles at different heights, which presumably had different line lengths, this is essential information. Please report line lengths and flows for each level and either apply and document a diffusion loss correction or quantify the resulting uncertainty on the number concentrations and GR.

Response:

Thank you for this important comment. We apologize for the lack of clarity in the original

description of the sampling configuration, which may have caused some misunderstanding.

All SMPS instruments used in this study were deployed directly at their respective measurement heights for in situ observations. Aerosol particles were sampled locally rather than transported through long sampling lines from the upper tower levels to the ground. Therefore, the potential losses associated with several hundred meters of aerosol sampling tubing, as mentioned in the comment, do not apply to our particle measurements.

The long gradient sampling lines were used only for VOC measurements. The performance of this sampling system has been previously evaluated by Li et al. (2023), who investigated the influence of long PFA tubing on atmospheric trace gas measurements at the SZMT. Their results showed negligible concentration losses for most of the trace gases investigated, although transport delays were observed for some compounds.

We have clarified the distinction between the in situ particle measurements and the gradient VOC sampling system in the revised Instrumentation section and added the relevant reference. These clarifications better describe the actual measurement configuration and address the concern regarding long-distance aerosol sampling losses.

The CCN conclusion is not supported by any measurement

There is no CCN measurement, no hygroscopicity measurement used in the analysis, no growth-to-CCN-size calculation and no coagulation scavenging estimate. The claim that the upper tower is more effective at converting new particles into CCN (lines 25 to 27, 427 to 428) rests entirely on the disputed GR comparison. Either add further analysis of CCN or the statement should be removed from the abstract and conclusion.

Response:

Thank you for this comment. We agree that the conclusions regarding the contribution of NPF to CCN production were not sufficiently supported by the results presented in the original manuscript. We would like to clarify that a CCN counter was deployed during the measurement campaign, and CCN data were collected. However, the data quality was insufficient for reliable quantitative analysis. We therefore decided to exclude the CCN dataset from the revised manuscript rather than draw conclusions from measurements with substantial uncertainties.

Accordingly, we have removed the CCN-related analysis and the statements suggesting that the upper tower environment is more effective at converting newly formed particles into CCN. The corresponding descriptions in the Abstract, Results, and Conclusion have also been removed. The revised manuscript now focuses on the vertical characteristics of NPF and their

relationships with boundary-layer evolution, chemical conditions, and turbulence, which are better supported by the available observations.

Analyses promised in the Introduction that never appear

The Introduction (lines 86 to 93) commits to quantifying occurrence frequency, duration, nucleation rate and growth rate. In the Results, the event duration is defined in detail in Section 2.3.5 but never reported for a single event or height. Either use these or remove them from the Methods and the Introduction.

Response:

Thank you for pointing out this inconsistency. We agree that the original Introduction and Methods described several analyses that were not subsequently presented in the Results.

We have rewritten the Introduction to clarify the objectives and scope of the study. The revised manuscript focuses on the vertical occurrence patterns of NPF and their relationships with boundary-layer evolution, chemical conditions, and turbulence. The original analyses of particle formation and growth rates have been removed, along with the corresponding descriptions in the Introduction and Methods.

Regarding event duration, we have revised the Methods to clarify the purpose of identifying the start and end times of NPF events. These times were used to define the event periods for subsequent analyses, particularly the comparison between PBLH and the 320 m measurement height. We have therefore retained the event identification procedure but no longer present event duration as a separate quantitative research objective.

Boundary layer structure and the interpretation of the vertical gradients

Lines 309 to 313 state that low levels are influenced by ground emissions and higher levels by atmospheric transport. During daytime the ABL is well mixed anyway, with little variation across these heights. At night the layers can decouple, with complex effects. But what about chimneys? What about emissions from thermal industry, which create buoyancy? This definitely needs further analysis and discussion. The same applies to lines 392 to 395: the ABL normally reaches 1 to 2 km above ground, so the 356 m tower is well inside the ABL, and convection inside the ABL is generally quite homogeneous, so the air is well mixed during the day. This is the central weakness of the mechanistic argument and it should be addressed head-on rather than in passing. Concretely: no boundary layer height time series is presented anywhere, although "boundary layer development" is invoked as the explanation for GR at almost every height (lines 379 to 395), and the lidar should be able to provide the mixing layer

height directly. Adding it would let the authors show explicitly when the tower is inside a well-mixed layer, when it straddles the nocturnal stable layer and the residual layer, and whether the observed vertical gradients survive that stratification. For a coastal megacity, the sea breeze circulation is also likely to be a first-order control on which air mass is sampled at 5 m versus 320 m, and a wind sector analysis would help. The highway 800 m away and the airport 10 km away are noted at lines 109 to 113 but never revisited.

Thank you for this insightful comment. We agree that the original manuscript did not adequately consider the vertical structure of the boundary layer when interpreting the observed NPF patterns. We have therefore substantially revised the analysis and discussion of boundary-layer evolution and its relationship with NPF.

We have incorporated PBLH observations derived from aerosol lidar measurements and examined the position of the 320 m measurement level relative to the diagnosed boundary-layer height. The revised results show that during Type B events, PBLH remained at or below 320 m for 40.3% of the event-period observations, whereas PBLH exceeded 320 m for approximately 97.6–99.2% of the observations during Types A, C, and D. These differences suggest that the relatively shallow boundary layer during the early morning may partly explain why NPF was observed at 5 m but not at 320 m during Type B events. However, PBLH exceeded 320 m during more than half of the Type B observations, indicating that boundary-layer height alone cannot fully explain the contrasting NPF patterns.

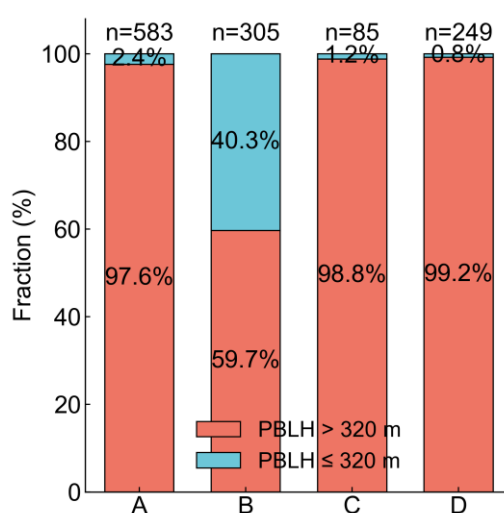


Figure. Fraction of daytime observations (08:00–18:00 LT) with the PBLH above or below the 320 m tower observation level for Types A–D. Numbers above each bar indicate the total number of available PBLH observations for each event type. The value of n above each bar represents the total number of valid PBLH observations included in the statistical analysis for that event type, rather than the number of NPF event days. PBLH was derived from MPL.

Figure 5. Fraction of daytime observations (08:00–18:00 LT) with the PBLH above or below the 320 m tower observation level for Types A–D. Numbers above each bar indicate the total number of available PBLH observations for each event type. The value of n above each bar represents the total number of valid PBLH observations included in the statistical analysis for that event type, rather than the number of NPF event days. PBLH was derived from MPL.

We have also added simultaneous observations of PBLH, TKE, EDR, and nucleation-mode particle number concentrations in the revised Fig. 9. During the NPF event on 23 October 2023, PBLH increased to approximately 1–1.4 km, placing all particle measurement heights within the diagnosed boundary layer. Nevertheless, particle number concentrations remained different among the four heights. This indicates that vertical differences in particle concentrations can persist even when the daytime boundary layer is well developed. We have therefore reconsidered our previous interpretation that turbulent mixing simply decreases with height and removed the corresponding unsupported conclusions.

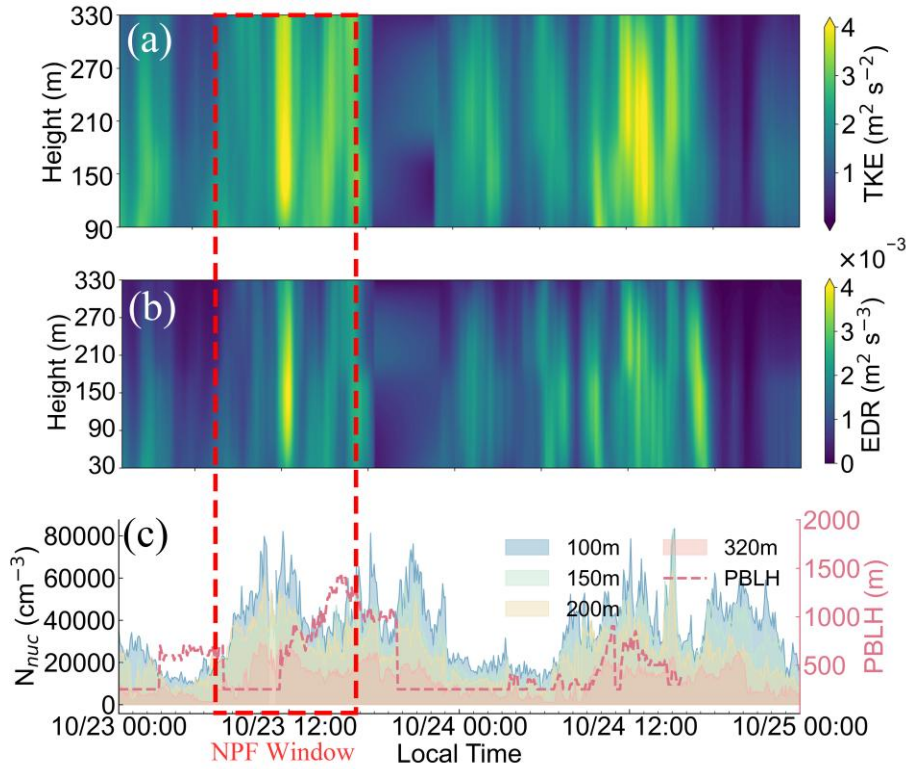


Figure. Temporal evolution of (a) TKE (b) EDR, and (c) N_{nuc} at 100, 150, 200, and 320 m, together with PBLH, from 23 to 24 October 2023. The red dashed box indicates the NPF event window on 23 October.

We recognize that sea-breeze circulation, local traffic emissions, and elevated emission sources may also contribute to the observed vertical variability. However, the available observations do not allow us to quantify their individual contributions. We have therefore avoided attributing the observed NPF patterns to specific emission sources or transport processes without

supporting evidence.

The revised Discussion (Section 4.1) now provides a more cautious interpretation of the relationship between boundary-layer evolution, turbulent mixing, and vertical NPF patterns. We have also acknowledged the limitations of the available observations in Section 4.3.

Instrument details are missing throughout

Generally, please give the manufacturer of every instrument used. This is especially important in a Measurement Report. Maybe add a full instrument table listing, for each IOP and each height: platform height, instrument make and model, size range, time resolution, inlet length and flow, and data coverage in days. This single table would resolve a large part of the confusion in Section 2.2, and it is the kind of information a Measurement Report exists to provide. A second summary table giving, per height, the number of events, mean and median GR, CS, event duration and nucleation-mode number would similarly replace much of the anecdotal narrative in Section 4.1.

Response:

Thank you for this helpful suggestion. We agree that the instrument descriptions in the original manuscript were incomplete, particularly regarding the different measurement configurations during the two observation periods.

We have rewritten the Instrumentation section to provide a clearer description of the instruments and their deployment at different heights. The revised manuscript now distinguishes the measurement configurations during IOP1 and IOP2, including the corresponding observation heights and particle size ranges. Additional information on instrument manufacturers, models, measurement specifications, and observation periods is provided in Tables S1 and S2 of the Supplement.

We have also clarified the sampling arrangements. All SMPS instruments were installed directly at their respective measurement heights for in situ aerosol observations, while the long gradient sampling lines were used only for VOC measurements. The VOC sampling system has been described in greater detail, including its six sampling heights and 18 min measurement cycle.

Regarding the suggested statistical summary, we have revised the Results section to present the occurrence of different vertical NPF types, the distributions of CS, and the temporal variations in nucleation-mode particle number concentrations. The dates of the classified events are provided in Table S3. The original GR analysis has been removed because of uncertainties in the cross-height comparison, and event duration is no longer treated as a separate research

objective.

These revisions clarify the measurement configurations and provide a more consistent presentation of the observational dataset.

Specific comments

L16. "five heights (5-350 m)" applies to IOP2 only; please make the abstract describe each IOP accurately.

Response:

Thank you for pointing this out. We have revised the Abstract to clarify the measurement configurations during the two observation periods. During IOP1, particle number size distributions were measured simultaneously at 5 and 320 m, whereas IOP2 involved multi-height measurements at 100, 150, 200, and 320 m. The original description of five measurement heights has been corrected to accurately reflect the instruments and observation heights used in each period.

L19. "at the surface" is actually 5 m. Please state the measurement height rather than "surface". The same applies at lines 26 to 27 and 420, and the ground versus 5 m distinction should be made consistently throughout, since "ground" and "surface" are also used for the separate ground-based site in IOP1.

Response:

Thank you for pointing out this ambiguity. We have revised the manuscript to clarify the distinction between ground-level and tower-level measurements. In Section 2.3, we now explicitly define the measurement at 5 m as the ground level and that at 320 m as the tower level during IOP1. In Section 2.3 shows that "IOP1 was conducted from 7 March to 18 September 2023. During this period, simultaneous PNSD measurements were performed using one SMPS at 5 m (ground level) and one Nano-SMPS at 320 m (tower level), providing coordinated observations of aerosol particle size distributions at the ground and tower levels." We have also reviewed the relevant descriptions throughout the manuscript and replaced ambiguous terms such as "at the surface" with the actual measurement heights where appropriate. These revisions ensure consistent terminology and avoid confusion regarding the observation heights.

L19-20, L26-27. The value of $14 \pm 4 \text{ nm h}^{-1}$ is unsupported and contradicts Section 4.1. See general comment 7.

Response:

Thank you for pointing out this inconsistency. As explained in our response to General Comment 7, we have removed the GR analysis from the revised manuscript because the original results did not provide a sufficiently reliable basis for comparing particle growth rates across different heights. The previously reported value of $14 \pm 4 \text{ nm h}^{-1}$ and the corresponding interpretations have therefore been removed from the Abstract, Results, Discussion, and Conclusion. The revised manuscript focuses on the vertical occurrence patterns of NPF and their relationships with boundary-layer evolution, chemical conditions, and turbulence.

L21. The CS values contradict Figure 5. See general comment 7.

Response:

Thank you for pointing out this inconsistency. As explained in our response to General Comment 7, we have revised the CS analysis and corrected the inconsistent numerical values. In the revised manuscript, CS was calculated using ground-level particle number size distributions measured at 5 m. The median CS values for Type A and Type B events were approximately 0.013 and 0.016 s^{-1} , respectively, as shown in the revised Fig. 6. The incorrect CS values and related interpretations in the original Abstract have been removed, and the corresponding descriptions in the Results have been updated to agree with the revised figure.

L55. Carnerero et al. (2018) is cited but does not appear in the reference list.

Response:

Thank you for pointing out this inconsistency. The citation to Carnerero et al. (2018) was included in the original manuscript but was not relevant to the revised discussion. We have therefore removed this citation during the revision of the Introduction. The corresponding references have also been reviewed to ensure consistency between the text and the reference list.

L65-67. Many well-fitting ATTO papers are missing here. See general comment 2.

Thank you for this suggestion. As noted in our response to General Comment 2, we have substantially rewritten the Introduction and expanded the discussion of previous international studies. In particular, we have added relevant studies from the Amazon Tall Tower Observatory

(Andreae et al., 2015; Franco et al., 2024; Machado et al., 2024; Wang et al., 2016) . These studies provide important insights into the vertical variability of aerosol properties and the occurrence of NPF at different heights. The corresponding discussion has been incorporated into the revised Introduction (Lines 73–79), providing a broader context for our multi-height observations at the Shenzhen Meteorological Tower.

Reference:

Andreae, M. O., Acevedo, O. C., Araùjo, A., Artaxo, P., Barbosa, C. G. G., Barbosa, H. M. J., Brito, J., Carbone, S., Chi, X., Cintra, B. B. L., da Silva, N. F., Dias, N. L., Dias-Júnior, C. Q., Ditas, F., Ditz, R., Godoi, A. F. L., Godoi, R. H. M., Heimann, M., Hoffmann, T., Kesselmeier, J., Könemann, T., Krüger, M. L., Lavric, J. V., Manzi, A. O., Lopes, A. P., Martins, D. L., Mikhailov, E. F., Moran-Zuloaga, D., Nelson, B. W., Nölscher, A. C., Santos Nogueira, D., Piedade, M. T. F., Pöhlker, C., Pöschl, U., Quesada, C. A., Rizzo, L. V., Ro, C. U., Ruckteschler, N., Sá, L. D. A., de Oliveira Sá, M., Sales, C. B., dos Santos, R. M. N., Saturno, J., Schöngart, J., Sörgel, M., de Souza, C. M., de Souza, R. A. F., Su, H., Targhetta, N., Tóta, J., Trebs, I., Trumbore, S., van Eijck, A., Walter, D., Wang, Z., Weber, B., Williams, J., Winderlich, J., Wittmann, F., Wolff, S., and Yáñez-Serrano, A. M.: The Amazon Tall Tower Observatory (ATTO): overview of pilot measurements on ecosystem ecology, meteorology, trace gases, and aerosols, *Atmospheric Chemistry and Physics*, 15, 10723-10776, 10.5194/acp-15-10723-2015, 2015.

Franco, M. A., Valiati, R., Holanda, B. A., Meller, B. B., Kremper, L. A., Rizzo, L. V., Carbone, S., Morais, F. G., Nascimento, J. P., Andreae, M. O., Cecchini, M. A., Machado, L. A. T., Ponczek, M., Pöschl, U., Walter, D., Pöhlker, C., and Artaxo, P.: Vertically resolved aerosol variability at the Amazon Tall Tower Observatory under wet-season conditions, *Atmospheric Chemistry and Physics*, 24, 8751-8770, 10.5194/acp-24-8751-2024, 2024.

Machado, L. A. T., Unfer, G. R., Brill, S., Hildmann, S., Pöhlker, C., Cheng, Y., Williams, J., Hartwig, H., Andreae, M. O., Artaxo, P., Curtius, J., Franco, M. A., Cecchini, M. A., Edtbauer, A., Hoffmann, T., Holanda, B., Khadir, T., Krejci, R., Kremper, L. A., Liu, Y., Meller, B. B., Pöhlker, M. L., Quesada, C. A., Ringsdorf, A., Riipinen, I., Trumbore, S., Wolff, S., Lelieveld, J., and Pöschl, U.: Frequent rainfall-induced new particle formation within the canopy in the Amazon rainforest, *Nature Geoscience*, 17, 1225-1232, 10.1038/s41561-024-01585-0, 2024.

Wang, J., Krejci, R., Giangrande, S., Kuang, C., Barbosa, H. M. J., Brito, J., Carbone, S., Chi, X., Comstock, J., Ditas, F., Lavric, J., Manninen, H. E., Mei, F., Moran-Zuloaga, D., Pöhlker, C., Pöhlker, M. L., Saturno, J., Schmid, B., Souza, R. A. F., Springston, S. R., Tomlinson, J. M., Toto, T., Walter, D., Wimmer, D., Smith, J. N., Kulmala, M., Machado, L. A. T., Artaxo, P., Andreae, M. O., Petäjä, T., and Martin, S. T.: Amazon boundary layer aerosol concentration sustained by vertical transport during rainfall, *Nature*, 539, 416-419, 10.1038/nature19819,

2016.

L74 and L100. The word "tower" is missing: "the tallest meteorological in Asia". Note also that line 74 says "among the tallest" while line 100 says "the tallest"; please use one claim consistently.

Response:

Thank you for pointing out this inconsistency. We have corrected the grammatical errors and revised the description of the Shenzhen Meteorological Tower (SZMT) to ensure consistency throughout the manuscript. In the revised Introduction, the tower is described as "among the tallest meteorological observation towers in Asia", while the Measurement Site section specifies its actual height of 356 m. The unsupported claim that it is "the tallest" has been removed.

L113-114. There seems to be a leftover half-sentence from the writing phase. In this context it would also be useful to give the size of the urban area.

Response:

Thank you for pointing this out. We have removed the incomplete sentence and revised the description of the measurement site in Section 2.1. The revised text now provides a clearer description of the surrounding environment, including the drinking-water source protection area near the Shiyan Reservoir and the potential influence of nearby traffic and airport emissions. We have focused the site description on the local environmental characteristics most relevant to the measurements conducted at the tower.

L117-118. This sentence fits better in the paragraph before.

Response:

Thank you for this suggestion. We have reorganized Sections 2.1 and 2.2 to improve the flow of the manuscript. The description of the tower height and observation platforms has been moved to Section 2.1 (Measurement site), while Section 2.2 (Instrumentation) now focuses on the measurement instruments and their configurations.

L119. "...monitored continuously by a Meteorological by a Vaisala..." seems strange. As written, a wind sensor is said to measure the particle number size distribution. Please rewrite and state which instrument covered 1.8 to 500 nm and at which height. Note also that a 1.8 nm lower limit is not achievable with the stated model 3776 CPC, whose nominal d50 is about 2.5 nm;

please clarify.

Response: Thank you for pointing out this error. We apologize for the incorrect description of the measurement instruments in the original manuscript. The sentence mistakenly combined the descriptions of the particle sizing instruments and meteorological sensors, and has been rewritten in Section 2.2.

We have clarified that PNSDs were measured using SMPS and Nano-SMPS systems rather than meteorological sensors. During IOP1, an SMPS was deployed at 5 m and a Nano-SMPS at 320 m. The previously reported particle size range of 1.8–500 nm was incorrect and has been removed. We have revised the instrument specifications and adopted a common particle diameter range of 13.1–107.3 nm for the analyses throughout both observation periods. The revised manuscript now clearly distinguishes the particle sizing instruments from the meteorological instruments and their respective measurement functions.

L120. BNU is not explained.

Thank you for pointing this out. BNU refers to Beijing Normal University, which provided the SMPS system used during IOP1. We have clarified this in the revised Instrumentation section by spelling out the full name of the institution and specifying the corresponding instrument deployment.

L124. Was the PSL calibration really done every 5 minutes? I assume the 5 minutes refers to the scan cycle; please rewrite. In addition, a sizing uncertainty of $\pm 1\%$ is optimistic for a nano-DMA; please state how it was determined and give the sizing uncertainty at 10 nm specifically.

Response:

Thank you for pointing out this ambiguity. We apologize for the incorrect description in the original manuscript. The 5 min interval referred to the SMPS measurement cycle rather than the frequency of calibration using PSL particles. We have corrected this description in the revised manuscript.

We also agree that the previously reported sizing uncertainty of $\pm 1\%$ was not sufficiently justified, particularly for the Nano-SMPS. We have therefore removed this statement from the revised manuscript. Furthermore, a common particle diameter range of 13.1–107.3 nm was adopted for all particle size distribution analyses, meaning that particles at 10 nm were excluded from the quantitative comparisons. We have clarified the measurement and data processing procedures to avoid overstating the instrumental accuracy.

L126-127. For the Vocus PTR, please state at which heights it sampled, with what time

resolution, how the gradient sampling was sequenced and what calibration was applied. None of this is given, yet Section 3.2 and the whole OOM calculation depend on these data.

Response:

Thank you for this comment. We have expanded the description of the Vocus PTR-TOF measurements in Section 2.2. VOCs were measured sequentially at six heights (5, 40, 70, 120, 220, and 335 m) using a vertical gradient sampling system. Each height was sampled for 3 min, resulting in a complete vertical profile every 18 min. The sampling configuration is also illustrated in Fig. S1. The instrument was calibrated using certified gas standards, with background measurements performed using a platinum catalyst, following the procedure described by Li et al. (2023). These details have now been included in the revised manuscript to clarify the sampling configuration, temporal resolution, and calibration method.

L131. "serving as the reference instrument" - what serves as the reference instrument? And what does THU mean? The intercomparison as described is also far too brief to establish comparability between the levels.

Response:

Thank you for pointing out this ambiguity. THU refers to Tsinghua University, whose research team joined the measurement campaign during the latter part of IOP1. The original description of the instrument intercomparison was unclear and did not provide sufficient information to establish comparability between the instruments. We have therefore removed the ambiguous reference-instrument statement and the insufficiently documented intercomparison from the revised manuscript. Instead, we have clarified the instrumental configurations and measurement heights for both IOPs in Sections 2.2 and 2.3. For the quantitative comparison of particle size distributions, a common diameter range of 13.1–107.3 nm was adopted across the measurement heights.

L134. What is a Bi SMPS? please give manufacturer and model for every instrument, and replace descriptions such as "conventional particle size range" (100 m) with actual size ranges.

Figure 2. Why are the levels 200 m and 150 m named without instruments?

Response:

Thank you for these suggestions. We have revised the instrumentation description to clarify that Bi SMPS refers to a bipolar scanning mobility particle sizing (Bi-SMPS) system. The instrument configurations for IOP2 have been specified, including two Bi-SMPS systems at 100 and 320 m, an SMPS at 150 m, and a Nano-SMPS at 200 m. Their corresponding particle diameter ranges are 11.5–469.5, 10.2–389.1, 10.3–107.3, and 10.2–570 nm, respectively. The instruments deployed at 100, 150, and 200 m were manufactured by TSI, while the system at

320 m was developed by Tsinghua University. Detailed information on the manufacturers, instrument models, and measurement specifications is provided in Table S2 of the Supplement. We have also revised Figure 2 to explicitly identify the instruments installed at 150 and 200 m, rather than displaying only their measurement heights.

L152. PNSD is the particle NUMBER size distribution.

Response:

Thank you for pointing this out. We have corrected the terminology to "particle number size distribution (PNSD)" in the revised manuscript and ensured that this definition is used consistently throughout the text.

L190. "particle swarm" sounds strange in my opinion.

Response:

Thank you for this comment. We agree that the term "particle swarm" is inappropriate in this context. As part of the manuscript revision, we have removed the original growth rate calculation section, including this expression, and revised the terminology throughout the manuscript to improve clarity and consistency.

L195. How long are 12 data points? At 5 min resolution this is one hour, but it should be stated explicitly.

Response:

Thank you for pointing this out. The temporal resolution of the PNSD measurements was 5 min, and therefore 12 consecutive data points correspond to approximately 1 h. We have clarified this in Section 2.4.1 of the revised manuscript to make the NPF event identification procedure more transparent.

L204-205. For the wind lidar, please state the lowest usable range gate. Figure 10 shows data from 100 m, which is plausible, but the blind zone should be given.

Response:

Thank you for this suggestion. The Doppler wind lidar was installed at ground level, with its lowest usable range gate located at 30 m above ground level. Measurements below this height

were unavailable due to the instrument's near-field blind zone. However, the turbulent kinetic energy (TKE) analysis in this study was conducted using wind measurements from 90 m and above. We have clarified both the instrument's lowest usable measurement height and the minimum height used for the TKE analysis in Section 2.2 of the revised manuscript.

L206-207. "...and data with a single wind speed profile missing rate exceeding 20 %..." - this sentence is not clear to me.

Response:

Thank you for pointing out this unclear description. The 20% threshold refers to the proportion of missing wind speed measurements within an individual vertical profile, rather than the proportion of missing profiles over time. We have clarified the quality control procedure in Section 2.4.3. Specifically, vertical wind profiles with more than 20% missing measurements between 90 and 500 m were excluded from the turbulence analysis.

L210. "The above quality control process was repeated three times" - why three, and what changed between the iterations?

Response:

Thank you for pointing out this ambiguity. We agree that the original statement regarding three repetitions of the quality control procedure was unclear and insufficiently justified. We have removed this statement from the revised manuscript and reorganized the turbulence analysis methodology in Section 2.4.3 to focus on the calculation of turbulent kinetic energy and the energy dissipation rate.

L250-253. "indicating that the ground atmosphere is more conducive to the occurrence of NPF" is a strong causal claim from a 26 % versus 18 % difference. please either test it properly or soften the wording.

Response:

Thank you for this comment. We agree that the difference in NPF occurrence frequency alone is insufficient to establish that near-surface atmospheric conditions are more favorable for NPF. We have therefore removed this unsupported interpretation and revised Section 3.1 to focus on the observed vertical differences in NPF occurrence. In the revised analysis, 27 NPF events were identified at 5 m and 24 at 320 m during IOP1. We now emphasize the differences in NPF occurrence patterns between the two heights without attributing them to specific atmospheric

conditions solely based on event frequency.

L255. "It is not difficult to see that" and similar rhetorical constructions should be removed throughout.

Response:

Thank you for this suggestion. We agree that rhetorical expressions such as "It is not difficult to see that" are inappropriate for scientific writing. We have removed this expression and revised the Results section to present the observational findings in a more objective and concise manner. Similar subjective and informal expressions have also been addressed during the manuscript revision.

L256-258. In my opinion this phrase does not make sense. It would benefit from a clearer formulation. What are "micro-particles", and why are they concentrated around the tower?

Response:

Thank you for pointing out this unclear expression. We agree that the term "micro-particles" was inappropriate and that the original statement regarding particle accumulation at the tower level was not sufficiently supported by the observations. We have removed this statement and substantially revised Section 3.1 to focus on the observed differences in NPF occurrence between 5 and 320 m. The revised manuscript uses more precise terminology, such as "nucleation-mode particles" and "newly formed particles", and avoids unsupported interpretations of particle accumulation and transport.

Figure 3. Please state the heights of the two panels. The description is very sparse, and it might help to add meteorological data as context.

Response:

Thank you for this suggestion. We have reorganized the Results section and replaced the original Fig. 3 with representative particle number size distributions for the four vertical NPF types. These observations were obtained simultaneously at 5 and 320 m, and the measurement heights are now explicitly identified in the revised figure caption. To provide additional meteorological context, we have included a statistical comparison of temperature, relative humidity, wind speed, and PBLH among the different NPF types in Fig. 4. The relationship between PBLH and the 320 m observation level is further examined in Fig. 5. These revisions provide a clearer presentation of the vertical NPF patterns and their associated meteorological

conditions.

L267. The first sentence needs rephrasing, as it can be misunderstood. The type definitions also need to be precise: what does "tower" mean here, at which height, and what happens on days when only some tower levels show NPF?

Response:

Thank you for this comment. We have clarified the definitions of the four vertical NPF types in Section 3.1. The classification was applied only to IOP1, during which simultaneous PNSD measurements were available at 5 m (ground level) and 320 m (tower level). Type A represents NPF at both heights, Type B represents NPF only at 5 m, Type C represents NPF only at 320 m, and Type D represents decreasing mode diameter events at both heights. We have also removed the statement implying that simultaneous NPF at 5 and 320 m necessarily indicates particle formation throughout the intervening atmospheric layer.

During IOP2, PNSDs were measured at four heights (100, 150, 200, and 320 m), and no event-type classification was applied. Instead, we focused on a representative event on 23 October 2023, during which NPF was observed at all four heights. This distinction has been clarified in the revised manuscript to avoid confusion between the event classification used in IOP1 and the multi-height case analysis conducted during IOP2.

NPF types. How were the four types of NPF chosen? What were the thresholds, or was the classification made optically?

Response:

Thank you for this comment. We have clarified the NPF event identification and classification procedures in Section 2.4.1. NPF events were identified through visual inspection of the time-resolved particle number size distributions, based on the appearance of nucleation-mode particles and their subsequent growth. No fixed numerical concentration threshold was applied to distinguish the four vertical event types.

During IOP1, events were further classified according to the observations at 5 and 320 m. Type A represents NPF at both heights, Type B represents NPF only at 5 m, Type C represents NPF only at 320 m, and Type D represents decreasing mode diameter events at both heights. These four categories were mutually exclusive, and each classified event was assigned to only one type. We have revised the Methods section to make these criteria explicit.

Figure 4. The axis labels are impossible to read, even in the PDF. Rainbow color is used again. The colors also appear burned out in parts, so the color scale needs recalculation. The description is sparse.

Response: Thank you for these suggestions. We have revised the original Fig. 4, which is now presented as Fig. 3 in the revised manuscript. The updated figure shows representative particle number size distributions for the four vertical NPF types at 5 and 320 m. We have improved the readability by enlarging the axis labels, tick labels, and colorbar annotations. The original rainbow color scheme has been replaced with a perceptually uniform colormap, and the color scale has been adjusted to reduce saturation in regions with high particle number concentrations. We have also expanded the figure caption to clarify the measurement heights and the characteristics of each event type.

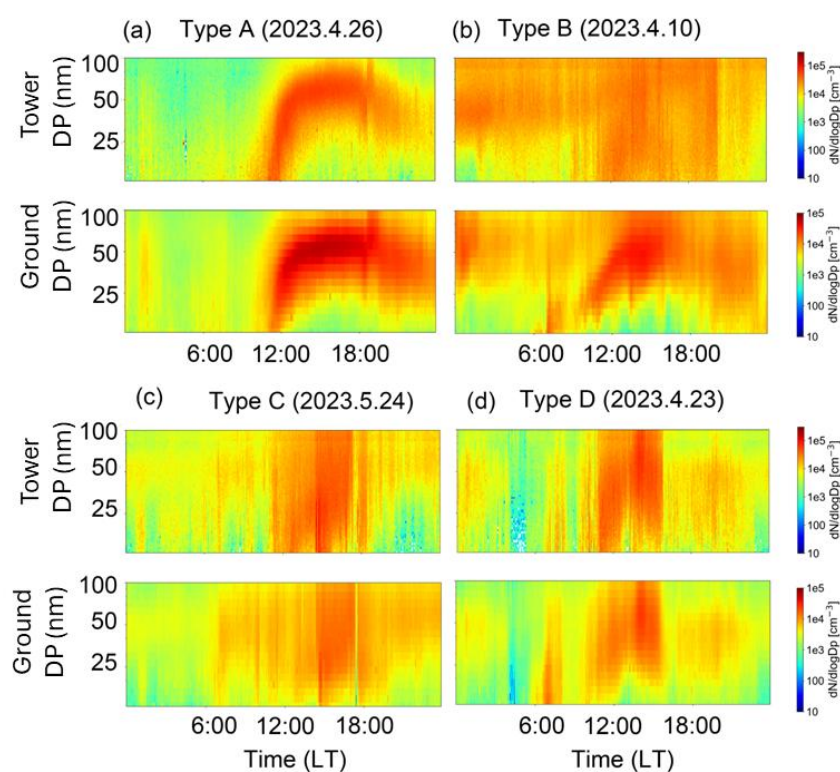


Figure 5. See general comment 7, the values in the text and the figure do not match, and in the case of Type N the direction is reversed. In addition, the caption says "mean CS level" but the plot shows medians and quartiles; the number of days per category should be given; and the claim of "significant differences" at line 272 requires an actual statistical test. It should also be stated whether Figure 5 shows ground CS, tower CS or a mixture, and over what time window, since the physically meaningful quantity is normally the pre-event morning CS.

Response:

Thank you for these detailed comments. We have revised the CS analysis and corrected the inconsistencies between the text and the figure. In the revised manuscript, the CS distributions are presented in Fig. 6. The median values for Type A and Type B events were approximately 0.013 and 0.016 s⁻¹, respectively. The description of Type N has also been corrected to agree with the revised figure.

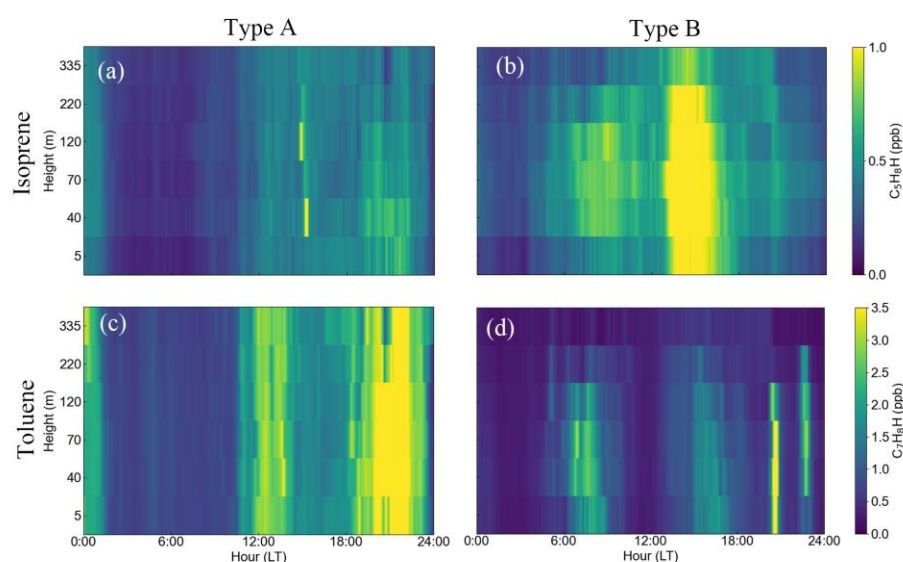
CS was calculated exclusively from the particle number size distributions measured at 5 m. For each observation day, the 24 h mean CS was calculated, and these daily mean values were grouped according to the event classification. The boxplots therefore represent the distributions of daily mean CS, with the horizontal lines indicating the medians and the boxes representing the interquartile ranges. We have clarified this statistical approach in the revised manuscript. We agree that pre-event morning CS would be more directly relevant to investigating the conditions preceding NPF onset. Our analysis of 24 h mean CS is intended to provide a descriptive comparison of the overall aerosol sink conditions associated with different event types, rather than to identify the conditions that triggered NPF. We have therefore avoided causal interpretations and removed the original claim of statistically significant differences, for which no formal statistical test was performed.

Figure 6. The graphic seems to use some kind of interpolation between the levels; this has to be removed. Rainbow color again. The legends and labels are too small to read. It needs a better caption. The title also reads "ethvl alcohol"; it should be "ethanol". And since only a single day (7 April 2023) is shown, please state whether it is representative and add a campaign-averaged version.

Response:

Thank you for these detailed suggestions. We have substantially revised the original Fig. 6, which is now presented as Fig. 7 in the revised manuscript.

The revised figure displays VOC concentrations at six actual measurement heights (5, 40, 70, 120, 220, and 335 m). To address the concern regarding vertical interpolation, we have removed interpolation and smoothing along the height dimension. The six measurement heights are now displayed separately, without estimating concentrations at unmeasured altitudes. Linear interpolation and smoothing were applied only along the temporal dimension at each measurement height to improve the visualization of diurnal variations.



We have also improved the graphical presentation by adopting the perceptually uniform viridis colormap, adjusting the colorbar ranges, and increasing the font sizes of the axis labels, tick labels, and colorbar annotations. The figure caption has been revised to provide clearer information on the measured species, sampling heights, and event types. The original spelling error in the ethanol label has also been addressed. In the revised figure, we focus on isoprene and toluene as representative biogenic and anthropogenic VOCs, respectively, while additional VOC species are presented in Figs. S2 and S3.

Regarding the representativeness of the observations, we agree that a single-day case is insufficient to characterize the differences between NPF types. We have therefore replaced the original single-day figure with a comparison of the available VOC observations during Type A and Type B events. The revised Fig. 7 presents the mean diurnal variations for two Type A events and the corresponding diurnal variations for one Type B event. We acknowledge that the limited number of events does not allow a robust campaign-wide statistical characterization. Accordingly, these results are interpreted as illustrative differences in the vertical chemical environments associated with the two NPF types rather than as representative characteristics of the entire observation period.

Figure 7. The panel labels a to d are missing. Panel d (lower right) has two identical line types. The graphic is of very poor quality and looks AI-generated. I cannot read the labels. All four panels need readable axis labels with units, and the legend times (08:00 to 16:00) should state whether these are single-day or campaign-mean profiles.

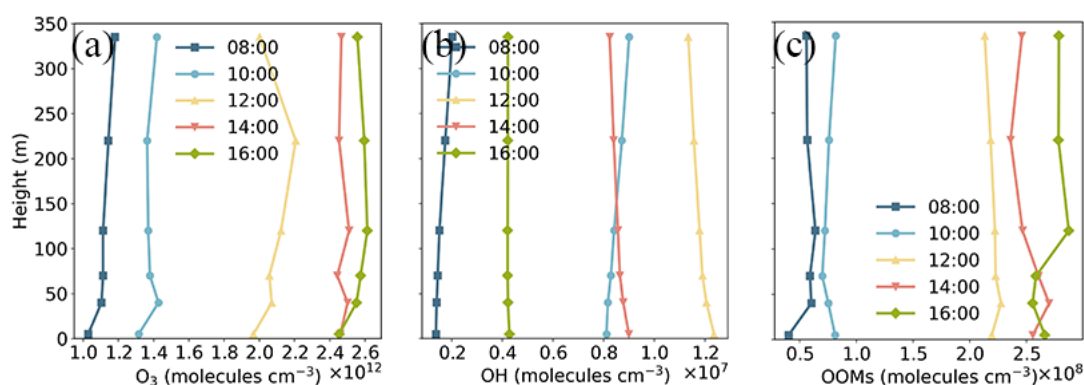
Response:

Thank you for these detailed comments. We have substantially revised the original Fig. 7, which is now presented as Fig. 8 in the revised manuscript. The figure has been reorganized into three

panels showing the vertical profiles of O₃, OH, and estimated OOMs, respectively. The original fourth panel has been removed, thereby eliminating the ambiguity associated with the duplicated line styles.

We have added clear panel labels (a–c), improved the resolution of the figure, and enlarged the axis labels, tick labels, and legends to ensure readability. The concentration units have also been clarified, and the profiles at different times are distinguished by colors and markers.

We have further clarified that the profiles were obtained during a single Type A NPF event on 7 April 2023, rather than representing campaign-averaged conditions. This information is now explicitly stated in the figure caption. Accordingly, the results are presented as a case study illustrating the possible vertical evolution of oxidants and estimated OOMs, without assuming that the observed patterns are representative of all NPF events.



L327-343. This paragraph partly does not represent the data shown in the graphics, and it discusses facts which have not been proven, especially lines 341 to 343. Specifically, the OOM generation rate at 16:00 was higher than stated (see the graphic), which contradicts lines 329 to 330

Response:

Thank you for this valuable comment. We agree that the original description of the temporal variation in OOM generation rates was not fully consistent with the results shown in the figure. In particular, the OOM generation rate at 16:00 remained relatively high, whereas it was previously described as decreasing. We have corrected this description in the revised manuscript to better represent the observed variations.

We have also revised the interpretation of the OOM generation rates. The original manuscript over-interpreted the vertical distribution of OOMs by attributing the observed patterns to atmospheric transport and diffusion processes. Since the estimated OOM generation rates only represent the potential chemical production associated with VOC oxidation and oxidant levels,

they cannot directly demonstrate vertical transport or mixing processes. The revised manuscript therefore focuses on the temporal and vertical variations of estimated OOM generation rates and avoids unsupported mechanistic conclusions.

The calculation method for OOM generation rates has also been clarified in the revised Methods section. The OOM generation rate was estimated based on the oxidation of VOC precursors by OH and O₃, following previous studies. The corresponding equations, parameters, and assumptions have been added to improve the reproducibility of the analysis.

L358-374. This paragraph contains a lot of assertions without proof. It needs either proof with data and graphics, or references. The specific problem is that the mechanism is argued from Figure 8, which shows only PNSD and contains no turbulence data at all; the turbulence data appear only in Figure 10, for a different subset of days and only for 100 to 300 m.

Response:

Thank you for this important comment. We agree that the original discussion contained interpretations of turbulent transport that were not adequately supported by the presented data. In particular, particle number size distributions alone cannot provide direct evidence of turbulence-driven vertical transport.

We have substantially revised the Results and Discussion sections to address this concern. During IOP2, simultaneous measurements of particle number size distributions, turbulence, and planetary boundary layer height were available. The revised Fig. 9 presents the temporal evolution of turbulent kinetic energy (TKE), energy dissipation rate (EDR), PBLH, and nucleation-mode particle number concentrations at different heights during the NPF event on 23 October 2023.

During this event, enhanced nucleation-mode particle concentrations at multiple heights coincided with increasing TKE, EDR, and boundary-layer development. These observations provide evidence of a temporal association between turbulent conditions and the vertical evolution of NPF. We have also expanded the Discussion with relevant references on turbulence and boundary-layer mixing.

Importantly, we have revised the mechanistic interpretations to distinguish the observed associations from possible explanations. We acknowledge that the simultaneous enhancement of turbulence and particle concentrations does not establish turbulent transport as the direct cause of the observed vertical particle distributions. The revised discussion therefore presents turbulent mixing as a potential contributing process rather than a demonstrated mechanism.

L388-389. This sentence makes no sense to me.

Response:

Thank you for pointing out this unclear statement. We agree that the original interpretation was not sufficiently supported by the observations. In particular, the relatively high particle growth rate at 200 m does not demonstrate that turbulent mixing continuously promotes boundary-layer development or creates favorable conditions for particle growth.

We have removed this statement and the associated growth rate analysis from the revised manuscript. Instead, Section 3.4 now focuses on the simultaneous observations of particle number size distributions, TKE, EDR, and PBLH during a representative NPF event on 23 October 2023. The revised discussion emphasizes the observed temporal relationships between turbulence, boundary-layer development, and particle number concentrations, without attributing these variations to an unverified causal mechanism.

L392-395. See general comment 13: the tower is well inside the ABL, which is generally well mixed during the day, so the proposed attenuation-with-height argument needs to be reconsidered.

Response:

Thank you for pointing out this unclear statement. We agree that the original interpretation was not sufficiently supported by the observations. In particular, the relatively high particle growth rate at 200 m does not demonstrate that turbulent mixing continuously promotes boundary-layer development or creates favorable conditions for particle growth.

We have removed this statement and the associated growth rate analysis from the revised manuscript. Instead, Section 3.4 now focuses on the simultaneous observations of particle number size distributions, turbulent kinetic energy (TKE), energy dissipation rate (EDR), and planetary boundary layer height (PBLH) during a representative NPF event on 23 October 2023. The revised discussion emphasizes the observed temporal relationships between turbulence, boundary-layer development, and particle number concentrations, without attributing these variations to an unverified causal mechanism.

Figure 8. It needs a better caption. The y-axis labels and titles are missing. Rainbow color again. From which time period are the data, and is the time axis UTC or local time?

Response:

Thank you for these suggestions. After reassessing the relevance of the original Fig. 8, we

decided to remove it from the revised manuscript, as it provided limited additional insight into the main objectives of this study. We have streamlined the Results section to focus on the simultaneous observations of particle number size distributions, boundary-layer evolution, and turbulence, which are more directly relevant to understanding the vertical characteristics of NPF.

Figure 9. The x axis is labelled "GR(m/h)"; it should be nm h^{-1} . The y axis is a discontinuous linear height axis that makes the 350 m bars look detached from the rest. A horizontal bar chart is also not the natural representation of a vertical profile; consider a profile plot with error bars, or a boxplot per height.

Response:

Thank you for these suggestions. We agree that the original Fig. 9 contained errors in the growth rate units and limitations in its graphical presentation. After reassessing the growth rate analysis and its relevance to the main objectives of this study, we decided to remove the original Fig. 9 and the associated GR analysis from the revised manuscript. The revised Results section now focuses on the simultaneous observations of particle number size distributions, boundary-layer evolution, and turbulence, which provide more direct evidence for examining the vertical characteristics of NPF.

L403. Figure 13 does not exist. Presumably Figure 10 is meant.

Response:

Thank you for pointing out this error. We apologize for the incorrect figure reference. The original reference to Fig. 13 should have been Fig. 10. Following the reorganization of the Results section, the corresponding figure has been revised and renumbered as Fig. 9. We have corrected the figure reference in the text and checked the consistency of figure numbering throughout the revised manuscript.

L416-428 (Conclusion). The conclusion builds very strong theories on quite little data, without those results having been proven in the Results section. It needs a full rewrite once the numerical inconsistencies are resolved, and it should state the limitations of the study and what the results imply for models, which the Introduction promises at lines 96 to 97 but the Conclusion never delivers.

Response:

Thank you for this important comment. We agree that the original Conclusion contained several

interpretations that were not sufficiently supported by the observations. We have therefore substantially rewritten and shortened this section to focus on the main findings supported by the revised Results.

The revised Conclusion highlights the four vertical NPF patterns identified during IOP1, the differences in boundary-layer and chemical conditions among event types, and the simultaneous variations in nucleation-mode particle concentrations, turbulence, and PBLH during IOP2. Unsupported interpretations regarding particle growth rates, turbulent transport mechanisms, and CCN production have been removed.

We have also explicitly acknowledged the limitations of the study, particularly the restricted vertical and temporal coverage of the measurements and the absence of direct vertical particle flux observations. Finally, we have clarified the implications for atmospheric modeling by emphasizing the importance of representing vertical variability in NPF, while avoiding claims of model improvement or validation that are not supported by the present data.

Technical and editorial

Spacing errors throughout: after commas and full stops, and between numbers and units. Please make a full pass over the manuscript.

Response:

Thank you for pointing out these formatting issues. We have carefully proofread the revised manuscript and corrected spacing errors throughout the text, including those following commas and full stops and those between numerical values and units. We have also standardized the formatting of numerical ranges, scientific notation, figure captions, and measurement units to improve the overall consistency and readability of the manuscript.

Once an abbreviation such as NPF has been established, it is not necessary to state it in full again (general comment).

Response:

Thank you for this suggestion. We have reviewed the use of abbreviations throughout the revised manuscript and removed unnecessary repeated definitions. Abbreviations are now defined at their first occurrence and used consistently thereafter. Definitions in the Abstract and main text are retained separately where appropriate to ensure that the Abstract remains self-contained.

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