#Reviewer 1

We sincerely appreciate the reviewer's positive feedback and useful suggestion. Based on the reviewers' suggestions, we have revised the paper. Below are our responses to each of the reviewers' comments, with the reviewers' comments in black, our responses in red, and the revised manuscript content in italicized orange font.

Then manuscript has been significantly improved. The content in Section 3 is more focused now. The new figure 3 shows clear difference in summer and winter regarding aerosol size distribution and composition. This result is better integrated in the current version than in the previous version of the manuscript. The new Table 1 also makes the comparison between this study and previous studies more straightforward. But the manuscript still needs some revision:

Reply: Thanks for reviewer's valuable comment. We have modified the Fig. S3, corrected the grammars and made some change in Section 3 in this revision.

1. In the new Figure S3, the fonts are small and not clear. Please make sure the figure is clear in the final version. There is no need to plot the figure on a scale of 2 in the vertical axis, because the AR can only get as high as 1. I think the new Figure S3 can be integrated, with the three figures for the summer plotted in one panel, and the three figures for winter plotted in another panel.

Reply: We appreciate the reviewer for this valuable suggestion. We have increased the font size and added size-resolved information in Figure S3 (now labeled as Figure S5). To avoid confusion from combining information for different supersaturation (SS) with additional size-resolved AR during different periods, we decided to plot subfigures for each SS individually.

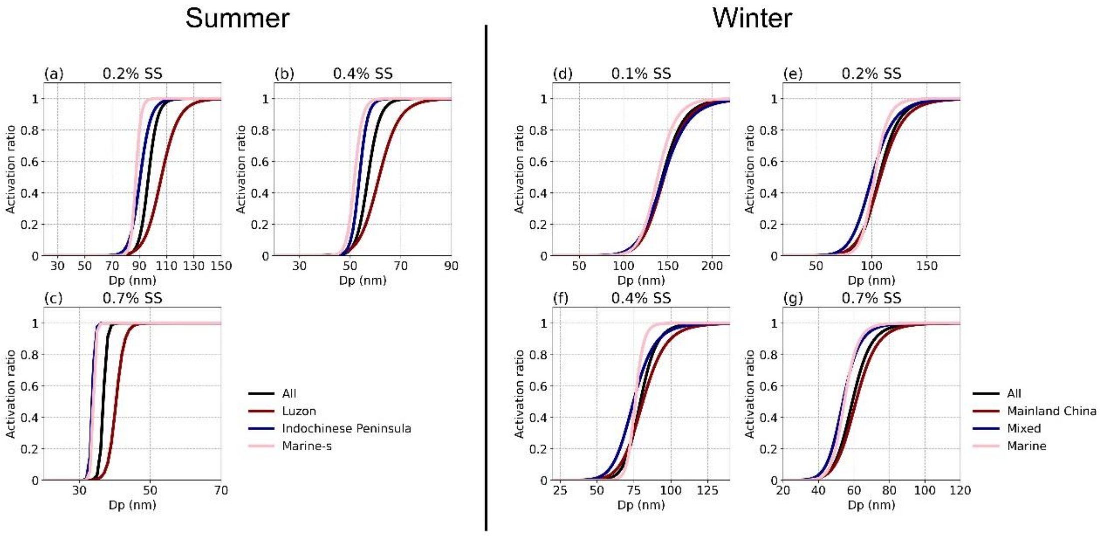


Figure S5. The average size-resolved activation ratio (AR) fitting result at 0.2% SS (a), 0.4% SS (b), and 0.7% SS (c) in different periods in summer; The average size-resolved activation ratio (AR) fitting result at 0.1% SS (d), 0.2% SS (e), 0.4% SS (f), and 0.7% SS (g) in different periods in winter.

2. The manuscript still needs to be checked for grammar errors.

Reply: We appreciate the reviewer for this valuable suggestion. We have checked our manuscript and corrected the grammar errors.

3. The writing in Section 3 is still not smooth, especially paragraphs 2-6 in Section 3.2. The content is fine. But please revise the writing so that it can read more smoothly.

Reply: We appreciate the reviewer for this valuable suggestion. We have revised the content of Section 3.2 to enhance its readability. Additionally, a native speaker reviewed the text for grammatical accuracy and helped refine the wording.

#Reviewer 2

We sincerely appreciate the reviewers for taking the time to review our manuscript and for providing valuable comments. Based on the reviewers' suggestions, we have revised the paper. Below are our responses to each of the reviewers' comments, with the reviewers' comments in black, our responses in red, and the revised manuscript content in italicized orange font.

This manuscript presents the CCN data obtained from shipborne measurement over the South China Sea. Because CCN measurement is still lacking, and especially measurement over the sea has been even rarely done, presenting CCN data measured over the sea is very valuable. However, this manuscript lacks the integrity and quality of a paper that would be worthy of being published in ACP. First, measurement setup and data analysis methods are not clearly explained. Figures and Tables are not clearly explained in captions and lack some important information. English should be greatly improved. For these reasons, I recommend resubmission of the manuscript after all my comments are addressed properly.

Reply: Thank you for the reviewer's insightful comments. In this revised version, we have added specific details about the SMCA method and included additional data to strengthen the reliability of our cluster analysis. We have also enhanced the figures and tables in accordance with the reviewer's suggestions. Furthermore, we thoroughly reviewed the manuscript and enlisted the help of a native English speaker to correct any grammatical errors and improve the overall quality of the writing.

Below are my specific comments.

Major Comments

1. Section 2.1.2: Explain clearly how size-resolved CCN and PNSD were measured simultaneously. Do the authors have an SMPS for PNSD measurement and a separate DMA that can be used to setup a DMA-CCNC system for size resolved CCN? If that is not the case, with one SMPS, how can they measure both? The authors have CCNC-200 that has two CCN measurement columns. So, it could have been possible to use one column for size resolved CCN measurement and another for regular CCN concentration measurement at several SSs. But apparently CCN concentration at a given SS was obtained from the integration of size-resolved CCN data, instead of making direct CCN measurement. I wonder why the two-column capability of CCNC-200 was not fully utilized. No clear explanation is given. Relevant to this section is the fitting results in Figure S3, which seem to show the averaged size-resolved activation ratio (AR) for the entire summer and for the entire winter periods, respectively. Since the aerosol characteristics are likely different for different air masses, the size-resolved AR should be estimated for each cluster and then calculate D50. Apparently, the authors have done that (Fig. 7). Then I wonder how the results of Figure S3 are produced. The authors should clearly explain.

Reply: Thanks for reviewer's comment. Unfortunately, we only have one SMPS and cannot afford another DMA for the size-resolved CCN measurement. Thus, we have to combine the SMPS and CCNc to simultaneously measure the PNSD and size-resolved CCN activity, following the Scanning Mobility CCN Analysis method (Moore et al., 2020). The instrument setup is illustrated in figure S2. Initially, particles were passed through a Nafion dryer to remove moisture and were then neutralized using a neutralizer. The particles were subsequently size-selected using a DMA. Afterward, the particle flow was split between a CPC for particle concentration measurement and a CCNc for

CCN measurement at a specified supersaturation. A dilution air (0.5 LPM) was added to the CPC inlet to maintain the sample flow through the DMA. The effect of the dilution air has been considered during the PNSD data processing. Therefore, we were able to measure both particle concentration and CCN concentration with a single SMPS and CCNc. We have provided additional details of this method in the manuscript (Lines 159-165):

During the SMCA measurement, the particles were first passed through a Nafion dryer to remove moisture, then neutralized using a neutralizer. After that, they were subjected to size selection with a DMA. The particles were then split between a CPC (1 L min^{-1}*) for particle concentration measurement and a CCNc (0.5 L min*$^{-1}$*) for CCN measurement at a specific supersaturation. To maintain sample flow through the DMA, dilution air (0.5 L min*$^{-1}$*) was added to the CPC inlet stream. The effect of the dilution air was accounted for in the PNSD data processing.*

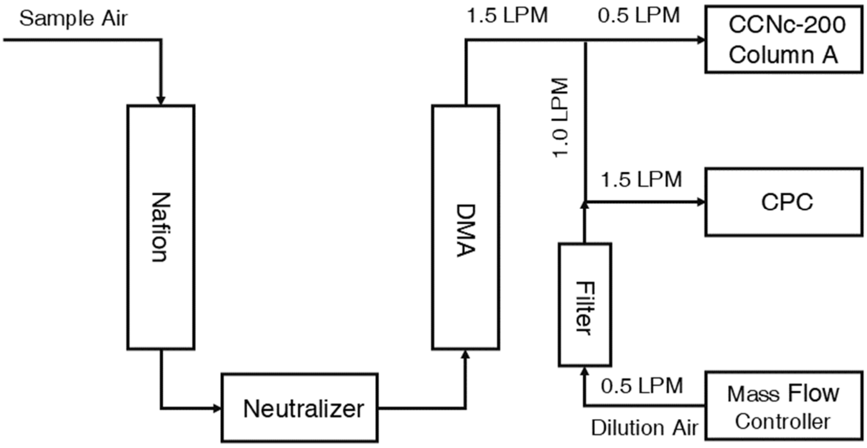


Figure S2. Instrument setup of the SMCA system.

To validate the reliability of the PNSD measurements obtained by using the instruments setup in the SMCA method, we present data from previous observations at the Heshan supersite in the Guangdong Province of China during the fall season 2019 (Cai et al., 2021). These data compare the PNSD measured by the DMA (model 3081A, TSI Inc., USA) and CPC (model 3775, TSI Inc., USA) in the SMCA method with those directly measured by an SMPS (DMA model 3081A and CPC model 3775, TSI Inc., USA). The similar PNSD measured by the two methods, along with the strong correlation in the total particle concentrations obtained (The coefficient of determination (R^2) is 0.95), indicate a high level of consistency between the results from these two-measurement method. (Fig. 1.1).

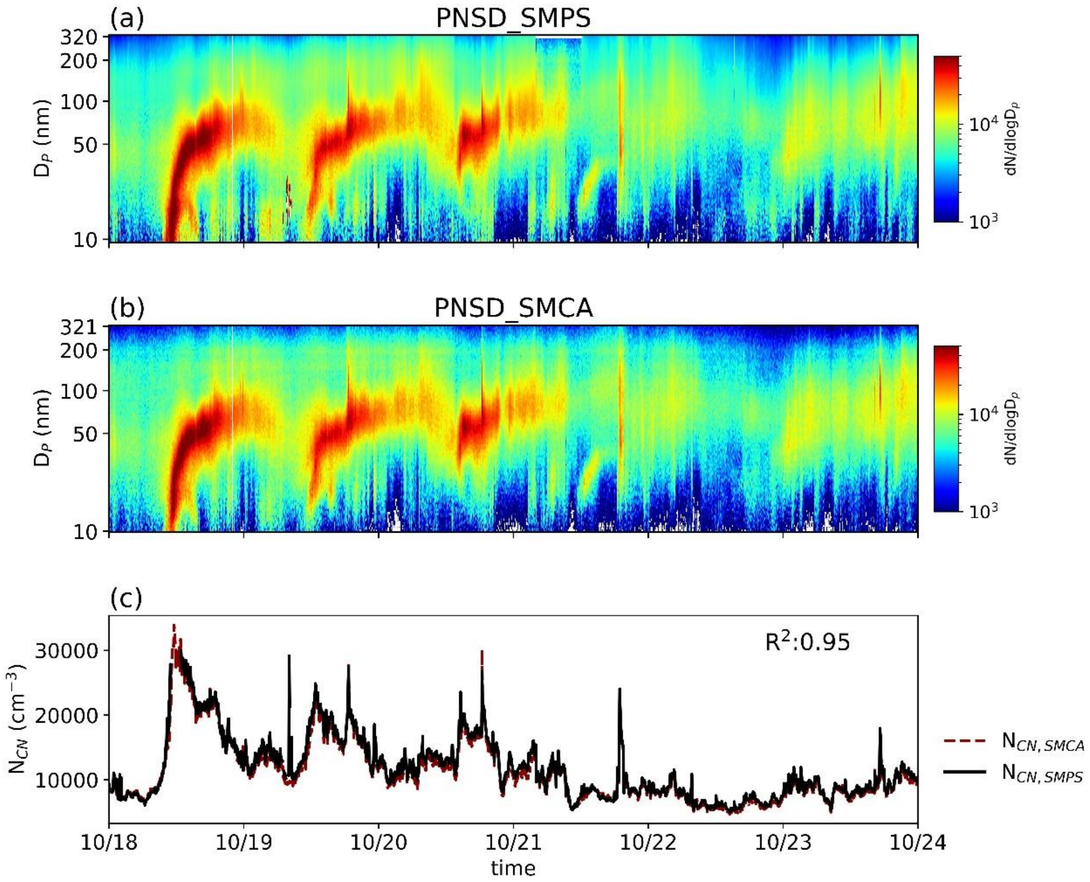


Figure 1.1. Particle number size distribution from SMPS (a), particle number size distribution from DMA and CPC in SMCA method (b), comparison of particle number concentration from SMPS (black line) and from SMCA method (red dash line).

Unfortunately, due to the malfunction of flow sensor in the column B, the data from this column was unavailable during these two measurements. We could only use the A column for observations, which prevented us from directly measuring the total N_{CCN}. In the manuscript, we have thoroughly explained the rationale behind using only one column for our analysis (Lines 158-159):

Unfortunately, due to the malfunction of flow sensor in the column B, only the data from column A is presented in this study.

The activation ratio presented in the Figure S3 originally represented the average size-resolved AR for both summer and winter. To provide a clearer depiction of the size-resolved AR curves across various periods, we have revised and redrawn the figure (now labeled as Figure S5).

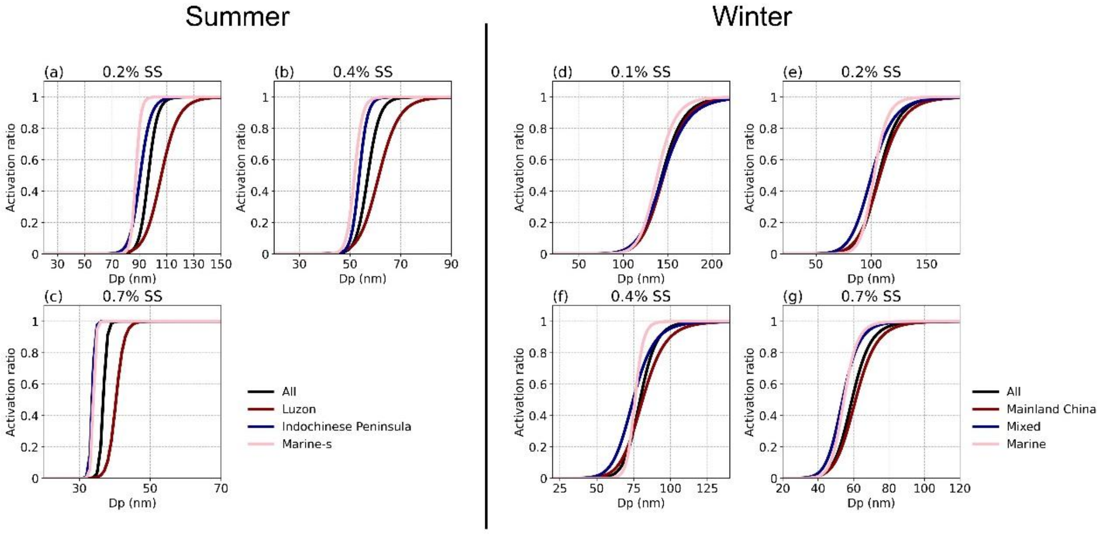


Figure S5. The average size-resolved activation ratio (AR) fitting result at different SS during various periods in summer (a, b, c) and winter (d, e, f, g).

Reference:

Moore, R. H., Nenes, A., and Medina, J.: Scanning Mobility CCN Analysis-A Method for Fast Measurements of Size-Resolved CCN Distributions and Activation Kinetics, Aerosol Sci Tech, 44, 861-871, doi: https://doi.org/10.1080/02786826.2010.498715, 2010.

Cai, M., Liang, B., Sun, Q., Liu, L., Yuan, B., Shao, M., Huang, S., Peng, Y., Wang, Z., Tan, H., Li, F., Xu, H., Chen, D., and Zhao, J.: The important roles of surface tension and growth rate in the contribution of new particle formation (NPF) to cloud condensation nuclei (CCN) number concentration: evidence from field measurements in southern China, Atmos. Chem. Phys., 21, 8575-8592, doi:https://doi.org/10.5194/acp-21-8575-2021, 2021.

2. Section 2.2.3: Why did the authors predict CCN concentration when direct measurement was possible with one of the two columns in CCNC-200? Anyway, later in the manuscript, this "predicted" N_{CCN} was apparently used as $N_{CCN,obs}$, when doing the CCN closure. Is this really the case? Explain clearly.

Reply: We appreciate the reviewer for this valuable suggestion. Unfortunately, flow sensor in the column B malfunctioned. We derive the total CCN concentration from the observed size-resolved AR and particle number concentration. In the revision, we recalculated total CCN concentration by integrating the size-resolved AR curves with the actual particle concentrations for improved accuracy.

$$N_{CCN}(SS) = \int_0^{\infty} AR(SS,\ D_P) N_{CN}\,(D_P) dD_p$$

where N_{CCN} (SS) is CCN concentration at a specific SS, AR (SS, D_p) is the AR on a certain diameter at a specific SS from the SMCA method and $N_{CN}(D_P)$ is the particle number density of specific diameter from SMPS measurement.

Previous researches have shown that this method (size-resolved CCN from one column in CCNc-200) provides results closely matching those obtained from direct measurement (from another column in CCNc-200), supporting its reliability (Meng et al., 2014; Lathem and Nenes, 2011). Consequently, we refer to the CCN concentration derived using this method as the observed CCN concentration. We have reintroduced the details of the calculation in the manuscript and explained the rationale for referring to the CCN concentration obtained using this method as the observed CCN concentration (Lines 222-236):

Due to the malfunction of flow sensor in the column B, the CCN concentration (N_{CCN}) can be calculated based on the size-resolved AR at a specific SS from SMCA method and observed particle number concentration. It can be calculated by the following equation (Cai et al., 2018):

$$N_{CCN}(SS) = \int_0^{\infty} AR(SS, D_P) N_{CN}(D_P) dD_p \tag{4}$$

where N_{CCN} (SS) is the CCN concentration at a specific SS, AR(SS, D_p) is the ratio of N_{CCN} at a specific SS to N_{CN} on a specific diameter from the SMCA method and $N_{CN}(D_P)$ is the particle number concentration at a specific diameter (Dp). Due to the absence of direct measurements for total N_{CCN}, we refer to the N_{CCN} derived from Eq. (4) as observed values ($N_{CCN,obs}$) in this study. Previous research has shown that this method (size-resolved CCN from one column in CCNc-200) provides results closely matching those obtained from direct measurement (from another column in CCNc-200), supporting its reliability (Meng et al., 2014; Lathem and Nenes, 2011).

The N_{CCN} (referred as $N_{CCN,sim}(SS)$) can be predicted by D_{50} from closure method and N_{CN} according to following equation:

$$N_{CCN,sim}(SS) = \int_{D_{50,sim}(SS)}^{\infty} N_{CN}(D_P) dD_p \tag{5}$$

where the $D_{50,sim}(SS)$ was calculated based on the eq. (2) and (3).

Reference:

Lathem, T. L. and Nenes, A.: Water Vapor Depletion in the DMT Continuous-Flow CCN Chamber: Effects on Supersaturation and Droplet Growth, Aerosol Sci Tech, 45, 604-615, doi: https://doi.org/10.1080/02786826.2010.551146, 2011.

Meng, J. W., Yeung, M. C., Li, Y. J., Lee, B. Y. L., and Chan, C. K.: Size-resolved cloud condensation nuclei (CCN) activity and closure analysis at the HKUST Supersite in Hong Kong, Atmos. Chem. Phys., 14, 10267-10282, doi: https://doi.org/10.5194/acp-14-10267-2014, 2014.

3. Section 2.2.4: Regarding the cluster analysis, which method is used to classify the clusters? Is it a hierarchical clustering method? If so, is it bottom-up approach or top-down approach? If not, is k-means clustering method or fuzzy c-mean clustering method used? The authors should describe the method clearly. It is implied that the authors know exactly on what day the summer monsoon started. Can this be so clearly known? If so, explain clearly how so by showing the supporting data (e.g., wind pattern change, ⋯). Unlike ground (fixed location) measurement, cluster analysis for ship measurement requires some caution since the research vessel is moving (i.e., cruising). To ensure the representativeness and suitability of the midpoint used as the starting location, the back trajectories for the ship's coordinate during the cruises and the back trajectories for the midpoint of the ship track at the same time should be close enough. The authors should confirm if this is the case by showing supporting data.

Reply: Thanks for reviewer's valuable comment. The cluster analysis was performed by TrajStat, a plug-in module of MeteoInfo, based on k-means method (http://meteothink.org/docs/trajstat/cluster_cal.html). We have described the method in the manuscript (Lines 261-263):

To clarify the sources of air masses, the cluster analysis was applied in this study, which was performed by TrajStat, a plug-in module of MeteoInfo, based on k-means method (http://meteothink.org/docs/trajstat/cluster_cal.html).

As reported by the China Meteorological Administration (Chao et al., 2022), the summer monsoon in 2021 began during the sixth pentad of May. Based on the timing of the monsoon onset and the ship's actual trajectory, we selected two representative midpoints for the backward trajectory calculations. We have updated the wording throughout our manuscript for clarity and accuracy (Line 263-267):

According to the report by the China Meteorological Administration (Chao et al., 2022), the summer monsoon in 2021 broke out during the sixth pentad of May. Therefore, based on the timing of the monsoon onset and the actual trajectory of the ship, we selected two representative midpoints of the ship track for backward trajectory calculations and cluster analysis in summer

To ensure the representativeness and suitability of the midpoint used as the starting location, we compared the backward trajectories in midpoint and actual ship location. There was a slight difference between these two type back trajectories, indicating using the midpoint as the starting location could well represent the cluster analysis for ship measurement. We have shown the result in Fig. S8.

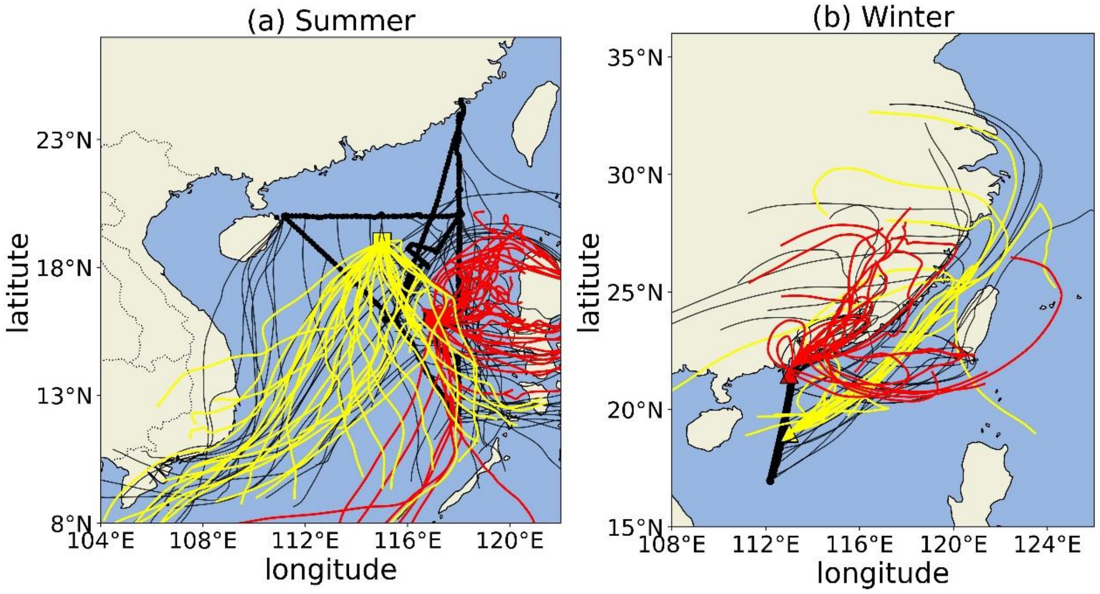


Figure. S8. The backward trajectories of two midpoints (yellow and red line) and the location of research vessel (black line) during summer cruise (a) and winter cruise (b). The time interval for backward trajectories was 12 hours during the summer. Due to the shorter duration of the winter cruise, the time interval for the winter backward trajectories was set to 6 hours to more accurately distinguish the trajectory sources between the midpoint and real location.

Reference:

Chao, Q., Xiao, C., Li, w., Wang, L., Sun, L., Chen, X., Chen, Y., Li, Y., Gao, G., Liu, Y., Zhang, D., Ai, W., Chen, Y., Cui, T., Dai, T., Feng, A., Guo, Y., Huang, D., Jiang, Y., Li, D., Li, M., Liu, B., Liu, Y., Lv, Z., Mei, m., Wang, Q., Wang, Y., Yin, Y., Zeng, H., Zhang, Y., Zhai, J., Zhao, L., Zhi, R., Zhong, H., Zhou, X., Zhou, X., Zhu, X., and Wu, H.: China Climate Bulletin (2022), China Meteorological Administration, https://www.cma.gov.cn/zfxxgk/gknr/qxbg/202303/t20230324_5396394.html, 2022.

4. Section 3.1: The absolute difference of N_{CCN} between the two seasons was larger at higher SS but that should be natural since N_{CCN} becomes higher at higher SS. The comparison should be relative: the ratio of $N_{CCN,\ winter}/N_{CCN,summer}$ at a given SS should be shown for such comparison. The κ values shown in Table 1 and Fig.3a do not match

for 0.4% SS (0.74 vs. ~0.60). In the text, it is 0.72. A good example of poor sincerity of this manuscript! At 0.2% SS, summer and winter κ were 0.49 and 0.31, respectively. Can they be considered "similar" as the authors stated? I do not think so. It should also be noted that the estimated κ values are for the particles of critical diameter (D50), the smallest particles that can be activated at a given SS. So, these κ values do not represent the κ values of all the particles that can be activated at a given SS. This should be stated clearly before any arguments are made on κ values.

Reply: We appreciate the reviewer for this valuable suggestion. We agree that using ratio of N_{CCN} is more appropriate in this section. As suggested, we have replaced the absolute difference in N_{CCN} between the two seasons with the ratio of $N_{CCN,winter}/N_{CCN,summer}$ at a given SS (Lines 323-326):

The ratio of N_{CCN} *between summer and winter was smaller at high SS (*$N_{CCN,winter}/N_{CCN,summer} = 0.51$ *and 0.54 at 0.4% SS and 0.7% SS, respectively) compared to low SS (*$N_{CCN,winter}/N_{CCN,summer} = 0.62$ *at 0.2% SS), likely due to the significant difference in number concentration of Aitken-mode particles between the two seasons (Fig. 3a-b).*

We apologize for the oversight. We have rechecked the data in the tables and figures throughout the manuscript to ensure their accuracy. We have revised the κ values (0.47 at 0.20% SS and 0.54 at 0.40% SS) in the text (line 330-333) and Table 1:

Besides, the hygroscopicity pattern varied between seasons: in summer, κ *increased with SS (from 0.47 to 0.54 between 0.2% SS and 0.4% SS), while in winter,* κ *decreased with SS (from 0.50 to 0.15 between 0.1% SS and 0.7% SS) (Fig. 3a-b).*

Additionally, we have revised the relevant statement (Line 330):

The aerosol hygroscopicity (κ*) was higher in summer than that in winter (Table 1).*

Moreover, we have acknowledged the limitation of κ in Lines 205-206:

Additionally, it is noting that the estimated κ *values refer to particles with the* D_{50}*, which are the smallest particles that can be activated at a given supersaturation.*

5.Section 3.2: To ensure that cluster analysis is well-conducted, I would suggest that the authors present all the back trajectories classified in each cluster in the supplement. If a back trajectory does not stay long enough within the boundary layer, it is difficult to say that it reflects the characteristics of the air masses where it passed. Therefore, it is recommended that the altitude of the back trajectory is also presented, to more clearly demonstrate the influence of the specified regions like "Mainland China", "Luzon", and "Indochinese Peninsula" on SCS. This can be confirmed by averaging the altitudes of all backward trajectories in each cluster. The authors state that low hygroscopicity of 'Mainland China' could be due to low sulfate concentration oxidized by DMS in winter than in summer. Here the comparison is between 'Mainland China' and 'Luzon,' the two terrestrial regions. So, I do not understand why DMS production is discussed here, which are definitely the source of CCN over marine regions. Explain the relevance.

Reply: Thank you for the reviewer's suggestion. We have incorporated the information on backward trajectories and clustering in Fig. S9, along with the average altitudes of each cluster presented in Fig. S10 (Lines 274-282).

We further examined the trajectories for each cluster to verify their alignment with the air mass origins they represent (Fig. S9). The results demonstrate that cluster analysis *was well-conducted. Additionally, figure S10 illustrates the average altitude variation as the age in hours increases across different periods. During summer, the altitude of the clusters remained below 880 hPa, indicating that they resided within the boundary layer (about 800 hPa). While in winter, the altitude of the clusters was higher than in summer, especially for the cluster during the mixed period (peaked at about 755 hPa). However, these clusters were generally within or close to the boundary layer. These results suggest that the back trajectories could represent the characteristics of the air masses originating from these specified regions.*

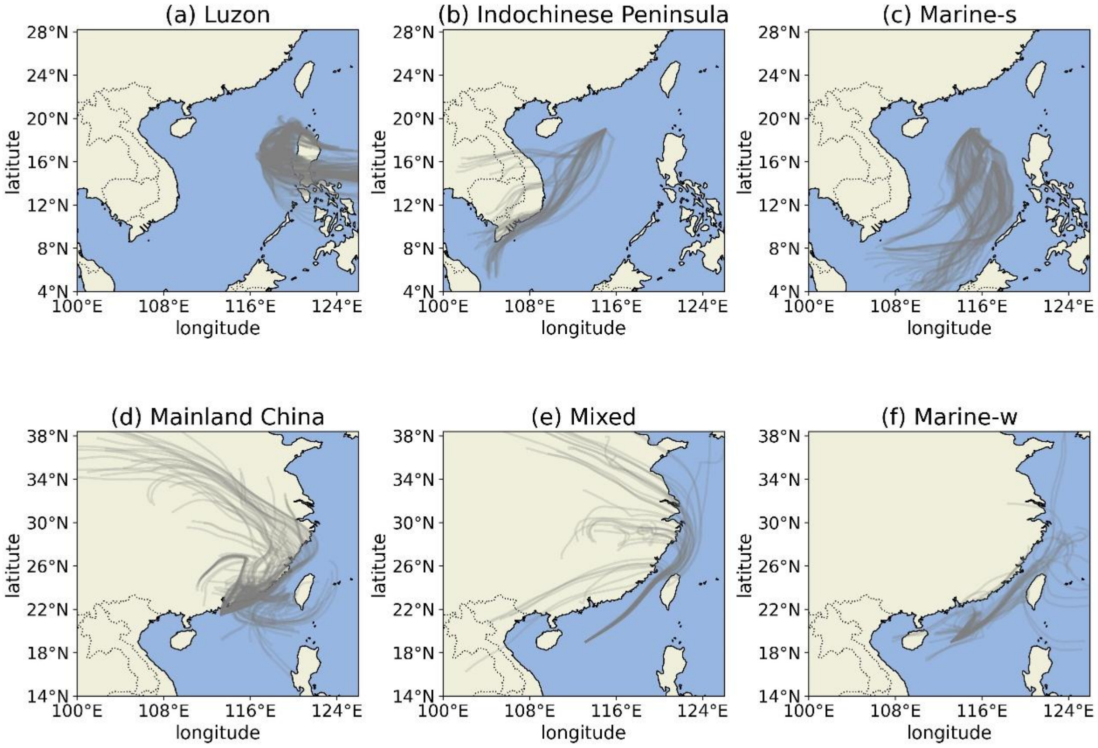


Figure S9. The backward trajectories of different clusters in summer (a)-(c) and winter (d)-(f).

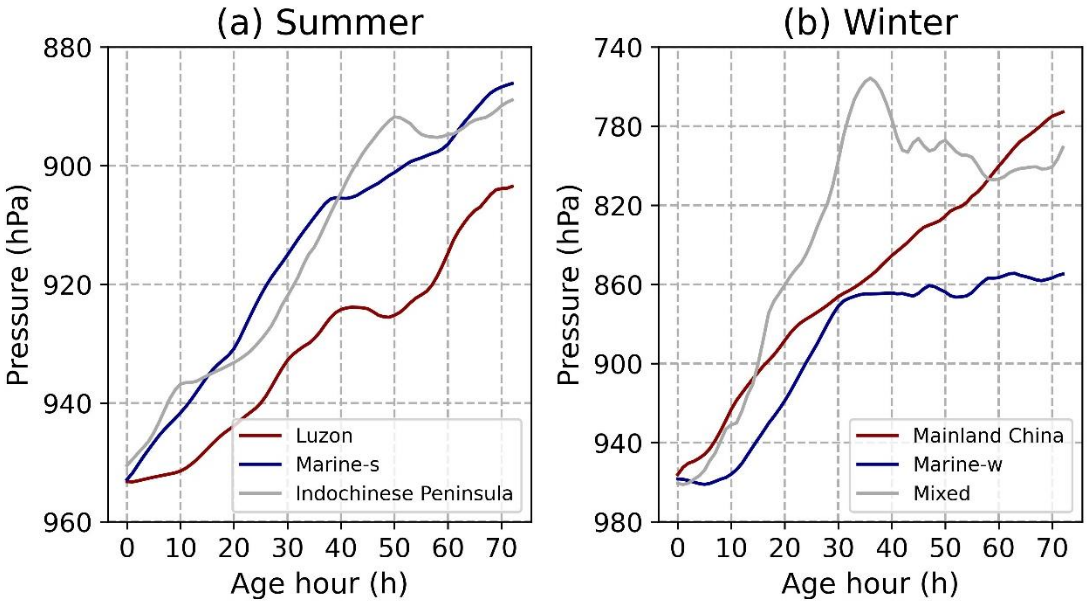


Figure S10. The average pressure variation as age hour increased in different clusters in summer (a) and winter (b).

We acknowledge that discussing the impact of DMS when comparing two periods affected by terrestrial air masses may not be suitable. We have revised the corresponding sentences and discuss the impact of DMS oxidation between summer and winter. In general, smaller particles generally exhibit lower hygroscopicity in winter (including the 'Mainland China' period) compared to summer, we speculated that sulfate from DMS oxidation likely influences the hygroscopicity of these particles. We have revised our statement accordingly (Lines 387-392):

Additionally, hygroscopicity at smaller sizes was consistently lower across all winter periods, including the "Mainland China" period, compared to summer. This phenomenon may be related to the reduced sulfate fraction in smaller sizes during winter, as sulfate production via DMS oxidation is diminished due to lower sea surface temperatures in winter (18.0 ℃) compared to summer (29.3 ℃), which in turn inhibits DMS production by phytoplankton (Bates et al., 1987).

Minor Comments

1. Line 117: "different impacts on CCN activity differently across seasons" --> "different impacts on CCN activity across the seasons"; What does "high cloud fraction" mean? Fraction of 'high cloud' or high fraction of clouds? If the former is the case, why is this relevant?

Reply: We have revised "high cloud fraction" to "fraction of high cloud." We would like to emphasize the seasonal variations in cloud properties over the SCS region, suggesting that aerosol-cloud interactions may differ across seasons. Therefore, it is crucial to conduct field campaigns on CCN activity throughout different seasons in the SCS region.

2. Line 134: "different monsoons" --> "summer and winter monsoons"

Reply: We have revised this expression.

3. Line 148: Add the information of the actual height of the sampling lines from the sea surface.

Reply: We have included information on the actual height of the sampling lines above the sea surface (Lines 148-150):

On both cruises, most of the instruments were housed in a single compartment and the sampling lines were extended from the window of the compartment to the height of the ship's bridge (~17 m above sea level) (Fig. 1a).

4. Lines 172-175: Since no result on OC/EC were discussed in the manuscript, it is inappropriate to mention OC/EC in Section 2.1.3. Likewise, the discussion of trace gases seems not to be presented in the manuscript and/or supplement. It might be worth checking.

Reply: We have removed the description of OC/EC and gas measurement.

5. Lines 181-182: Writing December 22nd as 12.22 can be confusing to readers. Unify the expression for date throughout the manuscript. Better to be December 22nd or 22 December but not 12.22.

Reply: We have changed "12.22" to "December 22nd.

6. Line 186: 'praticle' --> 'particle'

Reply: It has been revised.

7. Line 191: "AR is the size-resolved AR" --> "AR indicates the size-resolved AR value" In several occasions later in the manuscript, AR seems to indicate the bulk AR value. These should be clearly explained.

Reply: We have revised this sentence. In the updated manuscript, we calculated the size-resolved AR through SMCA method and provided an explanation. AR has been defined throughout the manuscript, with 'bulk AR' referring to the bulk activation ratio and 'size-resolved AR' referring to the size-specific activation ratio."

8. Line 210: "κ from ..." --> "κ for ...", 'Nacl' --> 'NaCl' here and for other occasions.

Reply: We have corrected these two words.

9. Line 211: κ of organic was assumed to be 0.1. Where is it from?

Reply: We have added the reference in the end of the sentence (Lines 218-219):

Besides, the κ of organic was 0.1 at this study according to Huang et al. (2022).

10. Line 217: Eq. (4) can give predicted CCN concentration under the assumption that all particles of diameter greater than D50 activate for the given SS. Where is the justification?

Reply: We have added the reference in the end of this sentence (Lines 233-234):

The N_{CCN} can be predicted by D_{50} from closure method and N_{CN} according to following equation (Jurányi et al., 2011):

11. Line 219: "number concentration under specific" --> "number density of specific"

Reply: We have revised this sentence.

12. Line 230-233: What does "have identical concentration at each size" mean? Is this intended for "fixed proportion for all sizes?" How does D50 calculated for each species? Explain clearly.

Reply: Yes, this indicates that the proportion of each component is independent of particle sizes. To avoid any confusion, we have revised the phrase "have identical concentration at each size" to "fixed proportion and hygroscopicity for all sizes". Additionally, we have explained the method for calculating D50 in the revised manuscript (Lines 246-250):

(2) External-mixed scheme: the aerosol composition from the ToF-ACSM was assumed to be size-independent and externally mixed. Four type of aerosol ($(NH_4)_2SO_4$, NH_4NO_3, NaCl and organic) are assumed to have a same proportion for all sizes. The D_{50} from each species was calculated according to their κ values mentioned in 2.2.2. N_{CCN} is calculated according to the Eq. (5) (Fig. S7b).

We also added a figure in supplement to introduce these two schemes (Fig. S7).

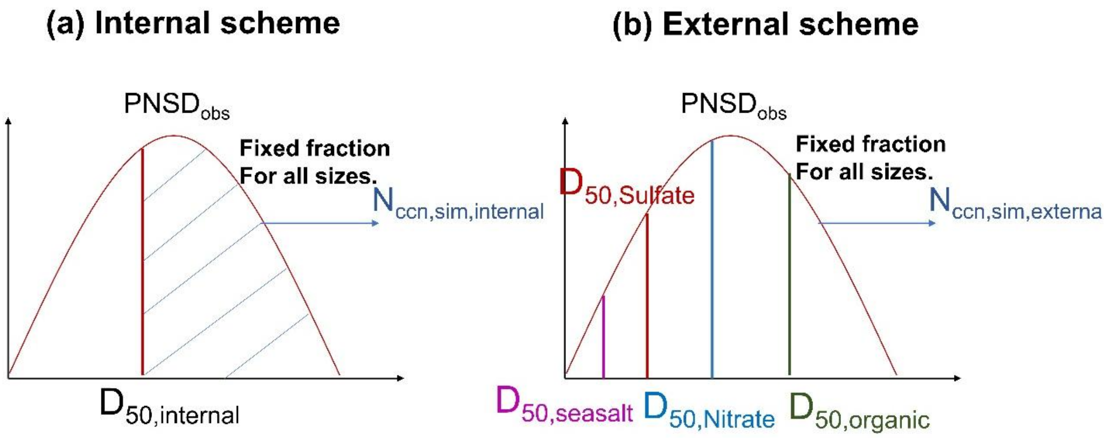


Figure S7. The internal and external simulation scheme

13. Line 236: In Eq. (6), $N_{CCN,obs}$ is not an observed value, strictly speaking. Be clear on this.

Reply: Due to the malfunction of the column B, we calculated the total CCN concentration by combining the observed size-resolved AR with the actual particulate concentrations. This method has been validated in previous studies through comparisons with directly measured CCN concentrations, demonstrating close agreement and confirming its reliability (Meng et al., 2014; Lathem and Nenes, 2011). Therefore, in this study, we refer to the CCN concentration obtained through this method as $N_{CCN, obs}$. We have included an explanation in the manuscript to clarify why we designate it as $N_{CCN,obs}$ (Lines 222-232):

Due to the malfunction of the column B, the CCN concentration (NCCN) was calculated based on size-resolved AR at a specific SS from SMCA method and observed particle number concentration. It can be calculated by the following equation (Cai et al., 2018):

$N_{CCN}(SS) = \int_0^\infty AR(SS, D_P) N_{CN}(D_P) dD_p$ *(4)*

where N_{CCN} (SS) is the CCN concentration at a specific SS, AR(SS, D_p) is the ratio of N_{CCN} at a specific SS to N_{CN} on a specific diameter from the SMCA method and $N_{CN}(D_P)$ is the particle number concentration at a specific diameter (Dp). Due to the absence of direct measurements for total N_{CCN}, we refer to the N_{CCN} derived from Eq. (4) as observed values ($N_{CCN,obs}$) in this study. Previous research has shown that this method (size-resolved CCN from one column in CCNc-200) provides results closely matching those obtained from direct measurement (from another column in CCNc-200), supporting its reliability (Meng et al., 2014; Lathem and Nenes, 2011).

14. Line 246: ‘outbreak’ --> ‘onset’

Reply: We have changed this word.

15. Lines 280-281: Aerosol number concentration is higher in summer than in winter, but mass concentration is higher in winter. Based on Figure 3, however, Aitken mode

particles are much more abundant in summer, while accumulation mode particles, which greatly affect mass concentration, are similar between summer and winter. Then, why are arosol mass concentration significantly different between summer and winter? Need more explanation.

Reply: Although the number concentration of accumulation mode appears similar between summer and winter, more particles in winter were concentrated in large sizes compared to those in summer, as shown by the particle volume size distribution (Fig. S15). And we explained it in the revision (Lines 318-321):

Although N_{CN} were higher in summer than in winter, the particle volume size distribution indicates that a higher fraction of particles was concentrated in larger size in winter, which significantly influenced mass concentration, resulting in a higher NR-PM_1 concentration (Fig. S15).

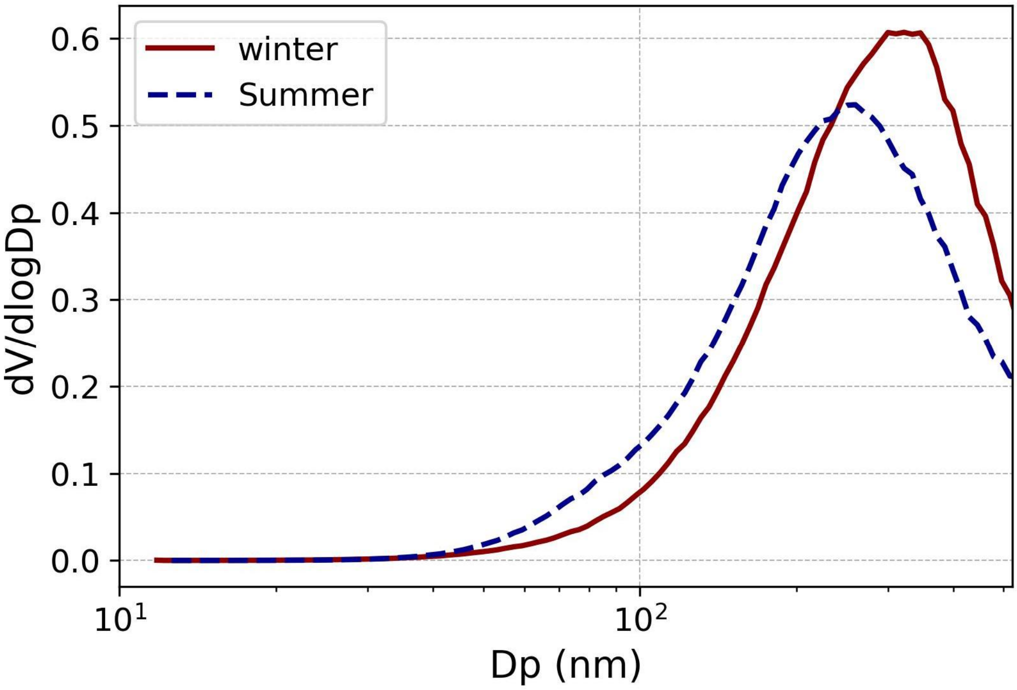


Figure S15. The average particle volume size distribution during summer and winter.

16. Line 296: Add (Cai et al., 2020) after "Guangzhou", just like in the previous sentence.

Reply: We have added the reference after "Guangzhou".

17. Line 363: "NMB always lower" --> "NMB was always lower"

Reply: We have revised this sentence.

18. Line 386: "study size-resolved" --> "study of size-resolved"

Reply: We have added "of" in this sentence.

19. Line 414-415: "higher particle fraction in the accumulation mode compared to" --> "higher fraction of the accumulation mode particles comparted to"

Reply: We have revised this sentence.

20. Line 434: In "northern SCS," what does 'northern' exactly mean? The winter cruise route shown in Fig. 1 does not seem to indicate cruising over northern part of SCS. In

the same context, what does “remote SCS” mean?

Reply: Thanks for the reviewer's comment. We adopted definitions from existing literatures to categorize the South China Sea (SCS). The region near the Chinese mainland is referred to as the northern SCS, while the area farther from the mainland, near the Palawan Islands in the Philippines and Malaysia, is classified as the remote SCS (Atwood et al., 2017; Liang et al., 2021; Zhu et al., 2012).

We have provided additional explanations in the manuscript (Lines 144-148): *Unfortunately, due to adverse weather conditions, such as strong winter monsoon winds causing poor sea conditions, and the fact that it was the first scientific deployment of the research vessel Sun Yat-sen University, the winter cruise had a shorter duration and covered a narrower spatial range, remaining only in the northern SCS (Fig. S1), compared to the summer cruise.*

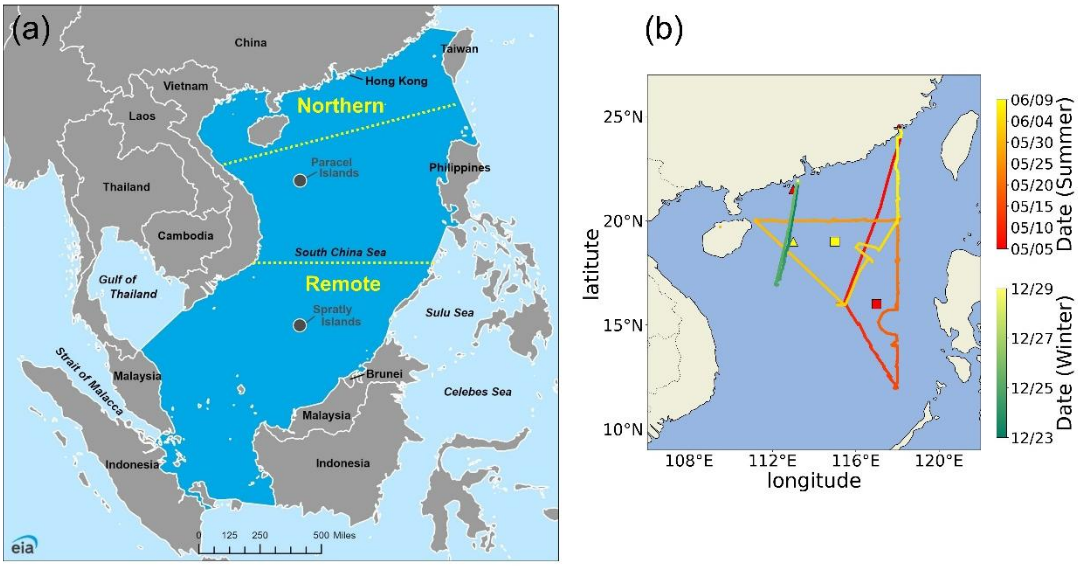


Figure S1. The definition of South China Sea from U.S. Energy Information Administration (https://www.eia.gov/international/analysis/regions-of-interest/South_China_Sea) and the yellow dash line and text were described the definition of northern and remote South China Sea according to other researches (Atwood et al., 2017; Liang et al., 2021; Zhu et al., 2012) (a); The cruises of these study (b).

Reference:

Atwood, S. A., Reid, J. S., Kreidenweis, S. M., Blake, D. R., Jonsson, H. H., Lagrosas, N. D., Xian, P., Reid, E. A., Sessions, W. R., and Simpas, J. B.: Size-resolved aerosol and cloud condensation nuclei (CCN) properties in the remote marine South China Sea – Part 1: Observations and source classification, Atmos. Chem. Phys., 17, 1105-1123, doi:https://doi.org/10.5194/acp-17-1105-2017, 2017.

Liang, B., Cai, M., Sun, Q., Zhou, S., and Zhao, J.: Source apportionment of marine atmospheric aerosols in northern South China Sea during summertime 2018, Environmental Pollution, 289, 117948, doi:https://doi.org/10.1016/j.envpol.2021.117948, 2021.

Zhu, W., Zhong, K., Li, Y., Xu, Q., and Fang, D.: Characteristics of hydrocarbon accumulation and exploration potential of the northern South China Sea deepwater basins, Chinese Science Bulletin, 57, 3121-3129, doi:https://doi.org/10.1007/s11434-011-4940-y, 2012.

21. Table 1: Show D_{50} values at least for this study. Is AR a bulk AR value? Explain in the caption. Why 'Northern' for winter cruises? There are several CCN measurement studies over the Yellow Sea, which would represent influence of northern part of continental China and therefore can provide good contrasting results.

Reply: We have included information on D_{50} from this study. In addition, we have clarified in the table that the AR refers to bulk AR.

Table 1. The number concentration of particle and cloud condensation nuclei at different supersaturation (SS), the hygroscopicity and bulk activation ratio (AR), and activation diameter (D_{50}) at different SS in different studies.

The winter cruise was conducted only in the northern SCS, and the specific definition of the northern South China Sea in this study is provided in Fig. S1.

Finally, we compared the result in Yellow Sea and our study in Line 326-329:

Compared to the observation in the Yellow Sea, a region similarly influenced by terrestrial air masses from mainland China, the N_{CCN} were lower in winter, while in summer, the N_{CCN} were more comparable to those observed in the Yellow Sea (4821 cm^{-3} at 0.63% SS) (Park et al., 2018).

Table 1. The number concentration of particle and cloud condensation nuclei at different supersaturation (SS), the hygroscopicity and bulk activation ratio (AR), and activation diameter (D_{50}) at different SS in different studies.

Location	period	N_{CN} (cm^{-3})	N_{CCN} (cm^{-3})	Hygroscopicity (κ)	Bulk AR	D_{50} (nm)	Reference
South China Sea	2021.05.05-2021.06.09	6966±9249	2640±3639 (0.20% SS) 4392±6415 (0.40% SS) 5215±6862 (0.70% SS)	0.47±0.21 (0.20% SS) 0.54±0.21 (0.40% SS)	0.37±0.16 (0.20% SS) 0.63±0.17 (0.40% SS) 0.87±0.17 (0.70% SS)	96±19 (0.20% SS) 57±9 (0.40% SS)	This study
Northern South China Sea	2021.12.19-2021.12.29	4988±3474	1086±691 (0.10% SS) 1625±1110 (0.20% SS) 2218±1503 (0.40% SS) 2797±1883 (0.70% SS)	0.50±0.21 (0.10% SS) 0.31±0.10 (0.20% SS) 0.19±0.05 (0.40% SS) 0.15±0.05 (0.70% SS)	0.23±0.09 (0.10% SS) 0.33±0.12 (0.20% SS) 0.44±0.13 (0.40% SS) 0.55±0.14 (0.70% SS)	145±18 (0.10% SS) 107±13 (0.20% SS) 79±7 (0.40 % SS) 59±6 (0.70% SS)	This study
Northern South China Sea	2018.08.06-2018.08.27	3463	1544 (0.34% SS)	0.38±0.09 (0.18% SS) 0.40±0.08 (0.34% SS) 0.38±0.08 (0.59% SS)	/	/	Cai et al., 2020

Remote South China Sea	2012.09.14-2012.09.26	503±455	450±388 (0.14% SS) 675±516 (0.38% SS) 698±555 (0.53% SS) 724±512 (0.71% SS)	0.54±0.14 (0.14% SS) 0.50±0.21 (0.38% SS)	0.47±0.16 (0.14% SS) 0.72±0.17 (0.38% SS) 0.79±0.15 (0.53% SS) 0.85±0.13 (0.71% SS)	/	Atwood et al., 2017
Western North Pacific	2015.03.04-2015.03.26	/	/	0.75±0.21 (0.11% SS) 0.51±0.16 (0.24% SS) 0.45±0.16 (0.60% SS)	0.40±0.22 (0.11% SS) 0.50±0.22 (0.24% SS) 0.70±0.23 (0.60% SS)	/	Kawana et al., 2020
Guangzhou	2014.11-2014.12	/	3103±1913 (0.10% SS) 5095±2972 (0.20% SS) 6524±3783 (0.40% SS) 7913±4234 (0.70% SS)	0.37±0.11 (0.10% SS) 0.29±0.09 (0.20% SS) 0.18±0.07 (0.40% SS) 0.15±0.06 (0.70% SS)	0.26±0.10 (0.10% SS) 0.41±0.14 (0.20% SS) 0.53±0.15 (0.40% SS) 0.64±0.13 (0.70% SS)	156 ± 19 (0.1% SS) 107 ± 17 (0.2% SS) 78 ± 15 (0.4% SS) 58 ± 11 (0.7% SS)	Cai et al., 2018
Yellow Sea	2017.04-2017.05	7622±4038	4821±1763 (0.63% SS)	/	/	/	Park et al., 2018

22. Table 2: Add AR values in a separate column and widen the column to show data in one line.

Reply: We have added AR values in Table 2 and adjusted the width of columns.

Table 2. The number concentration of particle, cloud condensation nuclei, and bulk activation ratio in different periods.

	Summer			Winter		
Cluster	Indochinese Peninsula	Luzon	Marine	Mainland China	Marine	Mixed
N_{CCN} (cm^{-3})						
0.1% SS	\	\	\	1359±669	439±223	945±400
0.2% SS	1200±787	4066±4748	1135±800	2058±1095	614±318	1460±514
0.4% SS	1650±1187	7804±8608	1812±1052	2792±1478	830±424	1801±640
0.7% SS	2239±1367	10480±9741	2515±1523	3514±1841	1024±463	2101±757
N_{CN} (cm^{-3})						
Total	2699±2147	14674±13844	3033±2366	6875±3263	1728±465	2918±1204
Nucleation	111±206	1543±3341	238±426	893±925	214±281	141±191
Aikten	1156±1261	8653±8815	1668±1526	3089±2017	732±337	806±427
Accumulation	1434±1444	3764±4157	1121±929	2923±2440	781±313	1975±831
Bulk AR						
0.1% SS	\	\	\	0.21±0.07	0.26±0.10	0.32±0.04
0.2% SS	0.49±0.13	0.31±0.17	0.40±0.13	0.30±0.09	0.36±0.14	0.51±0.05
0.4% SS	0.73±0.09	0.55±0.18	0.68±0.14	0.40±0.10	0.49±0.16	0.63±0.06
0.7% SS	0.98±0.15	0.76±0.16	0.90±0.13	0.50±0.09	0.61±0.18	0.73±0.06

23. Figure 1: Add important place names and mark the mid-points of back trajectories in (a). Provide full explanation in the caption.

Reply: We have added the important place names and mark the mid-points of back trajectories in Fig.1.

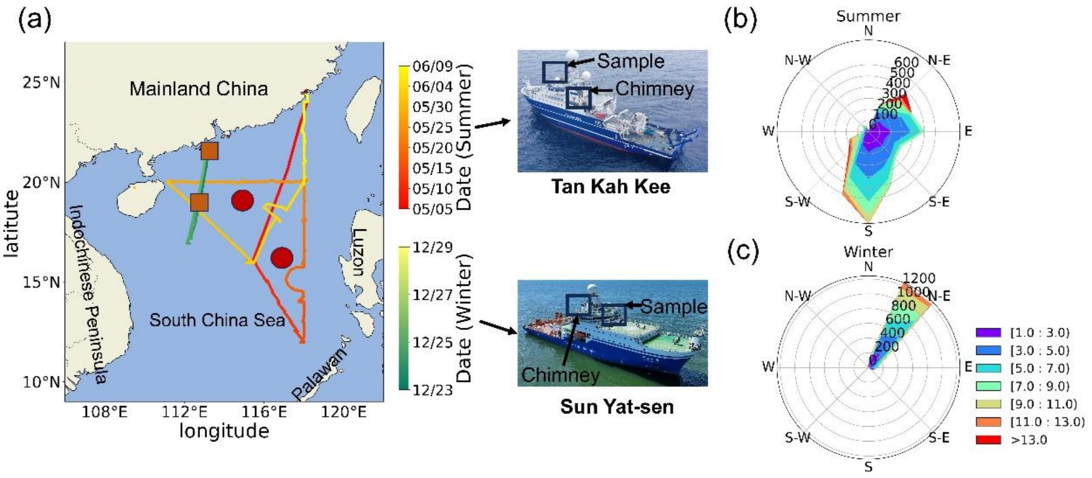
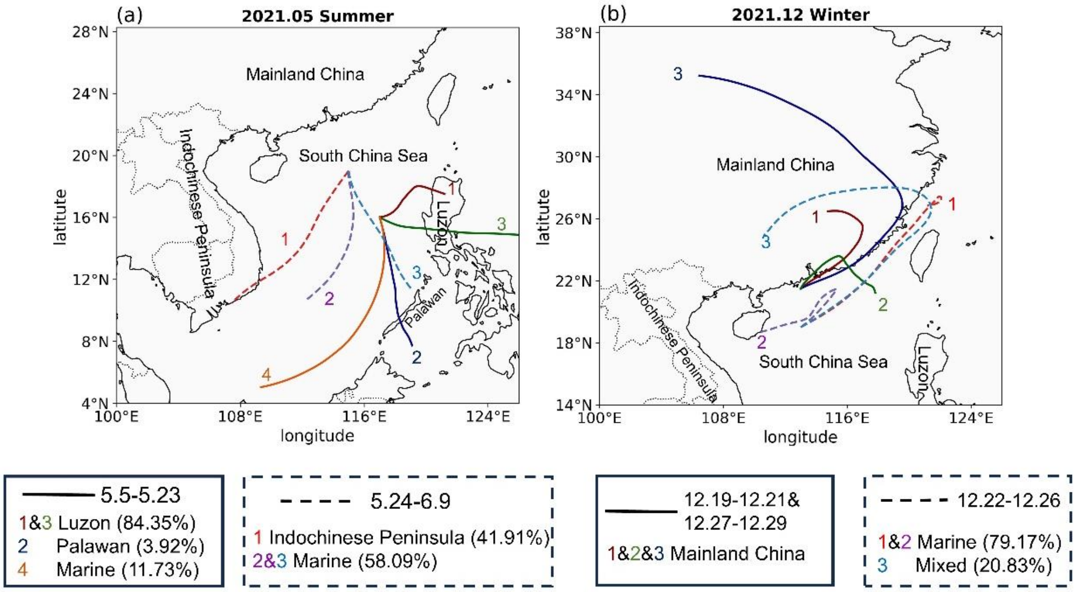


Figure 1. The cruises of two shipborne observations, and the location of sample line and chimney of Tan Kah Kee, and Sun Yat-sen scientific vessel (a); Wind rose of the wind direction and wind speed in summer and winter cruises; The radius represents the frequency of wind direction occurrences, and the shaded areas indicate wind speed (b) and (c). The red circles are the midpoints of the ship trajectory selected for backward trajectory and cluster analysis in summer and the orange squares are the midpoints of the ship trajectory selected for backward trajectory and cluster analysis in winter.

24. Figure 4: Show important place names.

Reply: We have added the important place names in Fig.4.



25. Figure 7: Why are there no κ plots for Indochinese Peninsula and Marine for 0.7% SS? Explain in the main text.

Reply: During these periods, the number concentration of particles smaller than 50 nm was relatively low (lower than 10 cm^{-3}). For the 0.7% SS settings, the D_{50} fell within a small diameter range with low particle concentration, which would increase uncertainty in the corresponding κ values. We have clarified the reason for presenting only the κ value at 0.7% SS during the "Luzon" period in the main text. Additionally, we included Fig. S6 to illustrate the specific situation where we did not consider the fitting results at 0.7% supersaturation (Lines 207–210).

During part of the summer measurement period, the D_{50} at 0.7% supersaturation ranged between 30 and 40 nm. However, due to lower concentrations during these times, instrument noise introduced greater measurement uncertainty, as demonstrated in Fig. S6. Consequently, the average D_{50} and κ at 0.7% SS are not included in Table 1.

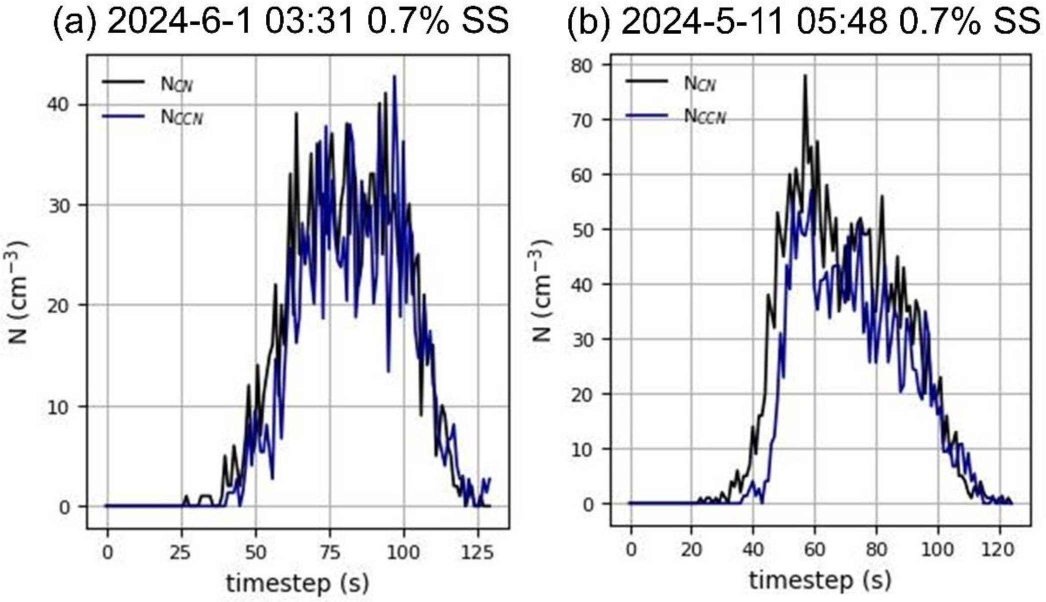


Figure S6. An example of N_{CN} and N_{CCN} timeseries during the Indochinese Peninsula (a) and Luzon periods (b).

We also added the reason why we only presented data during "Luzon" period in Lines 352-356:

Notably, we were able to obtain an accurate D_{50} at 0.7% supersaturation only during the "Luzon" period in summer. Due to the relatively lower hygroscopicity compared to other summer periods, the corresponding D_{50} at 0.7% SS ranged between 40 and 60 nm, with relatively high concentration of CN and CCN (Fig. S6), allowing for a more precise measurement of D_{50}. As a result, the κ at 0.7% SS shown in Fig. 7 was specific to the Luzon period in summer.