Reviewer's Comment

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The manuscript presents a study on cloud condensation nuclei (CCN) activity in the South China Sea (SCS), examining seasonal variations and anthropogenic influences through two shipborne campaigns in the summer and winter of 2021. The researchers measured aerosol chemical composition, particle number size distribution (PNSD), and CCN, revealing significant seasonal differences in aerosol properties and the impact of anthropogenic emissions on CCN activity. Despite these insights, the manuscript appears hastily written, lacking novelty, and presents vague data and discussions that are difficult to interpret. Furthermore, the manuscript fails to clearly differentiate these campaigns from previously reported measurements in the SCS, reducing its contribution to the existing body of knowledge.

The manuscript is challenging to follow, primarily describing a lengthy dataset with confusing correlations and writing that diminish readability. The main scientific conclusions are unclear, and the text is overly lengthy, obscuring the scientific merits of the data analysis. It is recommended that the authors focus on a few key scientific findings in their revision. Based on the given title, the manuscript should focus solely on reporting the measurements from the cruise campaigns. However, it also delves into scientific analysis, giving the impression that the authors aim to publish their analytical findings under the guise of reporting measurements. This approach detracts from the clarity and purpose of the study, as the title suggests a primary emphasis on measurement data rather than comprehensive scientific interpretation. In its current form, the manuscript is not suitable for publication in ACP.

Major comments:

Regarding the main scientific findings presented in the manuscript, the discussion does not adequately support these claims. The authors assert that they represent the seasonal variation of aerosol-CCN activity; however, this is not convincingly demonstrated. The winter observations span only 10 days and, unlike the summer campaign, do not spatially cover the entire region. Furthermore, there is no discussion about the potential bias introduced by the limited sampling, which could significantly affect the derived results. Addressing this gap is crucial for validating the study's conclusions.

While the title effectively highlights the focus on seasonal variations in CCN activity in the South China Sea (SCS), the Introduction needs further development for full contextualization. It should provide detailed background on the SCS's unique meteorological and environmental characteristics, such as meteorology and anthropogenic influences, to explain its significance for aerosol studies. Explicitly identifying specific research gaps will underscore the necessity of the study. Additionally, clearly stating the objectives of study and hypotheses will provide a precise research roadmap. Integrating a comprehensive review of recent, relevant literature will position the research within the broader scientific context, highlighting its novelty and relevance. Does author think that focusing solely on regional measurements can effectively reduce uncertainties related to aerosol-cloud interactions and radiative forcing? Emphasizing the potential significance and broader impact of the findings, such as advancements in scientific understanding and improvements in climate modeling, will underline the study's importance. Addressing these aspects will enhance the clarity, relevance, and impact of the Introduction, setting a solid foundation for the manuscript.

Although the methodology section comprehensively details the measurements and data analysis, some critical information is missing.

Firstly, the authors need to provide a rationale for selecting the specific periods in summer and winter for the cruise measurements. The inconsistency in measurement periods between summer and winter requires clarification, along with the reasoning behind the chosen cruise routes. This scientific justification is crucial for understanding the relevance to the study's objectives.

Additionally, I recommend incorporating the detailed data quality control procedures (currently in Text S1) into the methodology section, as this is crucial for a measurement report. The authors should clarify why wind direction data from other platforms was not utilized for quality control during winter, particularly in the absence of onboard wind measurements, and explain how ship emissions were prevented from being considered in the measurements. Additionally, the justification for the wind direction ranges used to filter out ship emissions during the summer campaign needs to be provided. Including wind rose plots, similar to those in Hung et al. (2018), would enhance this section. The current data filtering approach, adopted from previous studies, lacks sufficient justification, especially given the differences in cruise measurements and periods. The choice of wind direction ranges and data filtering criteria needs a more logical and scientific basis specific to this study. Furthermore, the rationale for calibrating the ACSM only at the start and end of the cruise, particularly for the longer summer campaign, requires clarification. Additionally, please provide an abbreviation for SMCA. Moreover, The authors mentioned removing abnormal measurement spikes ($> \pm 3\sigma$), attributing them to potential ship emissions. This approach appears arbitrary without concrete reasoning. Providing chemical analyses of particles in these spikes would help determine if they match expected ship exhaust compositions. Additionally, correlating these spikes with wind direction data and specifying their duration, frequency, and handling (whether removed or averaged out) is essential.

Regarding the back trajectory analysis, there is confusion, particularly in winter. Unlike in summer, distinguishing terrestrial and mixed air masses in winter is challenging despite notable differences in particle concentrations and chemical compositions. The short winter cruise period and limited sampling frequency complicate the analysis. To improve clarity, a cluster analysis of back trajectories is recommended to identify distinct air mass origins and pathways, as suggested by Patel et al., 2021, ERC. Including pathway altitudes would enhance understanding of air mass transport. The authors should justify the 48-hour period for back trajectory calculations and consider whether extending this period would provide more comprehensive information. Conducting cluster analysis for distinct source region identification is strongly encouraged.

In several instances, the authors present global statements based on regional studies without clarifying that the findings are specific to particular regions. For example, the statement in lines 71-72: "Ajith et al. (2022) showed that 64% of particles…" does not universally apply, as the referenced study is not global. It is essential to specify the region where the study was conducted to ensure the accuracy and relevance of the statement. Additionally, numerous instances in the manuscript show incorrect citation of equation and figure numbers, which need to be addressed for clarity and precision.

The manuscript lacks a scientific discussion on how the significantly different chemical compositions in terrestrial and mixed air masses during winter, characterized by high inorganic and low organic concentrations, impact hygroscopicity and CCN activity. It is highly recommended to create a plot showing the contributions of inorganic and organic components for various air masses, further dividing them into specific species (refer to Patel et al., 2021). This approach will provide more comprehensive insights than species plots alone.

Lastly, the discussion on D50 and PNSD for AR and N_CCN calculations lacks clarity and coherence. Begin by clearly explaining the D50 and PNSD methods used for calculating AR and N_CCN, detailing how D50 depends on PNSD. Discuss the variations between these parameters comprehensively. Instead of using a single approach, employ varies methods to calculate hygroscopicity based on D50, based on the chemical composition, considering both internal and external mixtures. Calculate N_CCN and AR accordingly and compare these with observations. Refer to previous studies on CCN closure analysis to provide a clear understanding of whether particle concentrations or chemical composition have a greater impact on CCN activity.