The manuscript presents a comprehensive investigation into the diurnal variation, vertical distribution, and aerosol-cloud relationships of stratocumulus clouds over Guangxi Province, China, utilizing aircraft observations. It offers insights into the impact of aerosol number concentration on cloud microphysical quantities, including cloud droplet concentration and effective diameter. The study reveals the interaction between the vertical structure of aerosols and the planetary boundary layer, highlighting the critical role of aerosols in influencing cloud microphysical characteristics. Given that China, particularly the region of Guangxi, is known for its high aerosol concentrations, this research contributes to the regional understanding of aerosol-cloud interactions, a topic that has been understudied in southern China.

The manuscript offers a detailed exploration of the diurnal variation, vertical distribution, and aerosol-cloud relationships of stratocumulus clouds over Guangxi Province, China, with a clear articulation of results and conclusions. To strengthen the manuscript, the authors should discuss the comparability of their findings with other regions globally, especially considering the unique meteorological conditions of Guangxi. At least add some discussion on this point. Enhancing the description of aircraft observation methods, including instrument calibration and data validation, is essential for credibility. Additionally, a thorough explanation of the statistical methods, including the choice of tests, significance levels, and assumptions, is necessary for the reader to replicate your results. Deepening the comparison with the existing literature\data report would provide better contextualization of the study's contributions. Further exploration of the physical mechanisms behind aerosol-cloud interactions would enrich the paper. Finally, outlining the possible implications for climate modeling, weather forecasting, and air quality management, along with suggestions for future research, would make the manuscript more impactful. Addressing these aspects will not only bolster the study's rigor but also its relevance to the broader scientific community.

Considering the above points, I recommend that the manuscript be accepted for publication in Atmospheric Chemistry and Physics (ACP) after the authors have addressed these revisions. The study's findings have the potential to significantly contribute to the field of atmospheric science, particularly in understanding the complex dynamics of aerosol-cloud interactions in regions with high aerosol loading. But overall, I cannot require a data measurement report with the same requirements as an article, therefore I recommend a minor revision.

Dear reviewer:

Thank you for your decision and constructive comments on our manuscript. We have carefully considered the suggestions, tried our best to improve and made some changes in the manuscript. We have enhanced the discussion by comparing our results with studies from other regions to highlight the unique meteorological conditions of Guangxi. We have provided a more comprehensive description of our aircraft observation methods, including instrument calibration and data validation, to bolster the credibility of our findings. We have also clarified the statistical methods used in our analysis, detailing the tests' significance levels. We have deepened the comparison with existing literature and explored the physical mechanisms underlying aerosol-cloud interactions in more detail. We believe addressing these points will significantly enhance the manuscript's rigor and relevance. We appreciate your recommendation and are committed to implementing the necessary changes. Thank you once again for your valuable insights.

The blue part has been revised according to your comments. The line numbers are in the revised manuscript; the changes are identified in red. Revision notes, point-to-point, are given as follows:

Specific comments:

1. interstitial aerosol or interstitial aerosol particles, you didn't provide any information on it, which makes it hard to understand for the reader who is not familiar with this concept, (interstitial aerosol particles: particles too small to activate to cloud droplets)

Response: Thank you for your comment. We have added an explanation of gap aerosol particles in lines 193-196 to improve the manuscript's readability.

The average vertical profiles of Na (interstitial aerosol, aerosol particles too small to activate to cloud droplets), Na (out cloud) (Fig. 1a), cloud microphysical quantities

(Fig. 1b) and meteorological elements (Fig. 1c-d) during the observation period was obtained.

2. line 245, Nc was 13~2052, should be 13-2052 cm^{-3}, please don't use '~'.

Response: Thank you for your comment. We have carefully reviewed and corrected the manuscript's formatting errors.

3. The manuscript comprehensively analyzes the vertical distribution of aerosols and cloud microphysical quantities in stratocumulus clouds over Guangxi Province, China. The findings contribute to the understanding of interactions between aerosols and clouds. However, the authors should consider providing a more detailed comparison of their results with previous studies, especially those conducted in other regions with different meteological conditions.

Response: Thank you for your comment. We have added a comparative analysis of the vertical distribution of cloud microphysical properties with other regions to highlight the unique cloud microphysical characteristics of Guangxi Province.

Compared with aircraft observation data in other regions, the average liquid water content (LWC) in Guangxi was higher, 5.33 times that in North China, and the average cloud droplet diameter was larger, 2.58 times that in North China (Zhao et al., 2011). Compared with the Marine Stratocumulus (Lu et al., 2011; Miles et al., 2000), the Stratocumulus in Guangxi had higher cloud base height and greater cloud thickness. The cloud microphysical characteristics of the stratocumulus observed in this study are similar to those of previous observations. Compared with stratocumulus (non-precipitation warm cloud) over eastern China, the Nc, LWC and E_d of stratocumulus in Guangxi region were larger.

References:

Lu C, Liu Y, Niu S. 2011. Examination of turbulent entrainment‐mixing mechanisms using a combined approach [J]. Journal of Geophysical Research: Atmospheres, 116(D20). https://doi.org/10.1029/2011JD015944

Miles N L, Verlinde J, Clothiaux E E. 2000. Cloud droplet size distributions in low-level stratiform clouds [J]. Journal of the Atmospheric Sciences, 57(2): 295-311. https://doi.org/10.1175/1520-0469(2000)057%3C0295:CDSDIL%3E2.0.CO;2

Zhao Z, Mao J, Wang L, et al. 2011. In situ aircraft observations of one typical stratocumulus cloud process compared with the satellite measurements [J]. Acta Meteorologica Sinica, 69(03): 521-527. http://dx.doi.org/10.11676/qxxb2011.045

4. Authors should ensure a clearer accounting method or reference for definitions such as Zn, boundary layer height, FIE, etc.

Response: Thank you for your comment. We have ensured that a clear definition of Zn, boundary layer height and FIE are included in the introduction. We have incorporated the necessary information and references in the revised manuscript to address these omissions.

Define the relative heights of the cloud as Zn:

$$\mathrm{Zn} = \frac{Z - Z_{base}}{Z_{top} - Z_{base}} \qquad (4)$$

In the formula, Z_{base} is the height of the cloud base, and Z_{top} is the height of the cloud top. The cloud heights have been normalized by setting the cloud base as 0 and the cloud top as 1.

Similar to previous studies, the first indirect effect of aerosol or Twomey effect of aerosols and clouds is defined as:

$$\mathrm{FIE} = -\left(\frac{\Delta \ln E_d}{\Delta \ln \alpha}\right)_{LWC} \qquad (5)$$

In the formula, α represents the physical quantity of aerosols, which can be quantified using aerosol optical depth (Feingold et al., 2001), aerosol extinction coefficient (Feingold et al., 2003), cloud condensation nuclei concentration, and aerosol number concentration (Che et al., 2021; Zhao et al., 2012; Zhao et al., 2018). The FIE value may vary with the variables representing the aerosol amounts.

References:

Feingold G, Eberhard W L, Veron D E, et al. 2003. First measurements of the Twomey indirect effect using ground - based remote sensors [J]. Geophysical Research Letters, 30(6). https://doi.org/10.1029/2002GL016633

Feingold G, Remer L A, Ramaprasad J, et al.2001. Analysis of smoke impact on clouds in Brazilian biomass burning regions: An extension of Twomey's approach[J]. Journal of

Geophysical Research: Atmospheres, 106(D19): 22907-22922.

Che Y, Zhang J, Fang C, et al. 2021. Aerosol and cloud properties over a coastal area from aircraft observations in Zhejiang, China [J]. Atmospheric Environment, 267: 118771. https://doi.org/10.1016/j.atmosenv.2021.118771

Zhao C, Klein S A, Xie S, et al. 2012. Aerosol first indirect effects on non‐precipitating low‐level liquid cloud properties as simulated by CAM5 at ARM sites [J]. Geophysical Research Letters, 39(8). https://doi.org/10.1029/2012GL051213

Zhao C, Qiu Y, Dong X, et al. 2018. Negative aerosol‐cloud re relationship from aircraft observations over Hebei, China [J]. Earth and Space Science, 5(1): 19-29. https://doi.org/10.1002/2017EA000346

5. Line 136: In Table 1, please provide the meaning of the data in brackets.

Response: Thank you for your comment. We have added an explanation for the data in Table 1. The values of Na, Nc, LWC, and E_d in the table are all averages, with their standard deviations indicated in brackets.

6. In Section 3.2, the authors have provided a detailed analysis of the diurnal variation of cloud microphysical quantities, especially the effects of vertical wind direction and aerosol number concentration. It would be interesting to see if they could correlate these variations with specific meteorological conditions, such as changes in temperature and humidity.

Response: Thank you for your comment. We have rephrased the content of Section 3.2 to include a comprehensive analysis of the vertical distribution of cloud microphysical properties to meteorological factors, such as temperature, relative humidity, vertical wind speed and aerosols.

At 10:00, Nc below 900 m was less than 100 cm^{-3}, and Na in PBL was high (Fig. 2a). Although there were sufficient aerosols that can be activated into cloud condensation nuclei, RH > 60 %, the atmospheric temperature was high, which was not conducive to the activation of small-size aerosol particles (Fig. 3a). At the same time, LWC was low, and the condensed cloud droplets are difficult to grow, and the average E_d is only 8.01 μm (Fig. 3a). Between 900 m and 1500 m, there were not only sufficient cloud condensation nuclei but also sufficient water vapor and temperature conditions, which are conducive to the formation of cloud droplets. The average Nc and E_d increased to 430 cm^{-3} and 11.15 μm. Above 1500 m, although the water vapor condition was sufficient (LWC = 0.16 $g \cdot m^{-3}$), the cloud condensation nucleus was few, resulting in an average Nc value of only 35 cm^{-3}. However, sufficient LWC was conducive to the growth of cloud droplets, and E_d was significantly higher than clouds below 1500 m, with E_d ranging from 13.82 to 37.26 μm. At 1500 m, Na (interstitial aerosol) was 34 cm^{-3}, increasing to 134 cm^{-3} at 1600 m. RH remained nearly constant in this range, while LWC rose from 0.16 to 0.19 $g \cdot m^{-3}$, promoting the hygroscopic growth of aerosols. However, Nc did not show a significant increase. Thus, the temperature inversion layer (Fig. 4a) within the cloud may contribute to the rise in Na (interstitial aerosol). This increase suggests more aerosols are inactive or unable to activate within the cloud. These aerosols may result from mixing warm air from outside the cloud at the cloud base (Lu et al., 2011). Furthermore, the temperature inversion layer may hinder vertical airflow within the cloud, suppressing cloud droplet growth.

At 11:00, aerosols were transported by updrafts (Fig. 5a) to around 1500 m (near the top of PBL) and activated into cloud condensation nuclei. Below 1500 m, the average Nc value was 102 cm^{-3} (Fig. 2b), while the average LWC value was only 0.03 $g \cdot m^{-3}$ (Fig. 3b). Cloud droplets were competing for water vapor. The E_d value was only 8.20 μm, similar to the cloud microphysical characteristics near the PBL at 10:00. Between 1500 m and 3150 m, Na was less than 10 cm^{-3}, indicating insufficient CCN, and the average Nc was only 29 cm^{-3}. Compared to 10:00, the LWC was higher (mean 0.19 $g \cdot m^{-3}$), resulting in a larger E_d in the upper part of the cloud, with an average of 28.95 μm.

At 12:00, the height of PBL top rose to 1000 m, the near-surface aerosol was transported to 1200-1500 m (Fig. 2c, the mean value of Na outside the cloud was 578 cm^{-3}), the mean value of Nc reached 399 cm^{-3}, and the mean value of E_d was only 9.41 μm (Fig. 3c), higher than 11:00. Stratocumulus clouds above 1800 m had low Nc (mean 35 cm^{-3}) and large E_d (mean 26.14 μm).

At 13:00, the Nc ranged from 13 to 2052 cm^{-3} below 1200 m (Fig. 2d), which may be attributed to the uneven development of clouds within the detection range. The increase in solar radiation leads to high near-surface temperatures (Fig. 4d, $T >$ 25 °C), which enhances turbulent activity within the PBL and is favorable for cloud droplet formation. Therefore, Nc at 13:00 was larger than that at 10:00, and many cloud droplets hindered their particle size growth, with an average E_d value of 9.23 μm (Fig. 3d). From 1200 m to 1500 m, the mean values of Nc and E_d were 155 cm^{-3} and 12.29 μm. At this height, a strong temperature inversion layer appeared (Fig. 4d), and cloud droplet evaporation activity was enhanced (Li et al., 2003), resulting in a higher Na (interstitial aerosol) than Na (out cloud). For Stratocumulus clouds above 1500 m, the Nc varied little with height, and the average E_d was 21.45 μm.

At 14:00, the Nc range below 1500 m was 11 to 1109 cm^{-3} (Fig. 2e), with the highest PBL top height at 1500 m, which diluted the Na (out of the cloud) within the PBL, resulting in a decrease in the maximum Nc ($Nc = 1109$ cm^{-3}). The average LWC was 0.29 $g \cdot m^{-3}$ (Fig. 3e), higher than at 13:00, providing moisture conditions for cloud droplet growth, while the upward airflow was strong (Fig. 5b). Consequently, the average E_d was 13.75 μm. A temperature inversion layer was present at 2500 m (Fig. 4e), hindering aerosol diffusion and enhancing the evaporation of cloud droplets near the cloud top, leading to a peak in Na (interstitial aerosol) at that height.

At 15:00, the Nc and Na (interstitial aerosol) between 1600 m and 2000 m were higher than those at 14:00 with average values of 720 cm^{-3} and 249 cm^{-3} (Fig. 2f). Due to the increase in Nc, the average E_d was only 13.72 μm (Fig. 3f). The increase in Na (out cloud) above 2000 m provided CCN, resulting in an average Nc of 146 cm^{-3}. Although the moisture conditions were sufficient, with an average LWC of 0.23 $g \cdot m^{-3}$, which was higher than the 0.05 $g \cdot m^{-3}$ recorded at 14:00 (Fig. 3f), and RH was 52% (Fig. 4f), the average E_d decreased to 16.73 μm. This decrease was due to the competition for moisture among cloud droplets, which led to an increase in small particle-size cloud droplets.

At 16:00, Nc and Na (interstitial aerosol) below 2000 m were relatively large, 458 and 468 cm^{-3}, respectively (Fig. 2g). The temperature inversion layer at the top of PBL hinders the condensation growth of cloud droplets. The average E_d was only

11.00 μm (Fig. 3g). Similar to the observations at 15:00, Na (out cloud) and Na (interstitial aerosol) near 3000 m were higher. The low temperature (T = 7.75 °C) and high humidity (RH = 70 %) of the cloud environment (Fig. 4g) were conducive to the activation of aerosol. The maximum value of Nc reached 395 cm^{-3}. However, the average of E_d was only 17.13 μm due to water vapor contention between cloud droplets.

At 17:00, the height of PBL decreased to 730 m. Aerosols were transported above the PBL (Fig. 2h), providing CCN above 2000 m. Nc remained constant with an average of 134 cm^{-3} (Fig. 2h), while E_d averaged 17.12 μm (Fig. 3h). Under the cooling of the atmosphere and the cooling of the cloud tops at sunset, the Ed near the cloud tops is greater than 30 μm. The temperature inversion layer of 1600-2000 m (Fig. 4h) enhanced cloud droplet growth and hindered aerosol diffusion, causing the Na (interstitial aerosol) to be higher than the Na out cloud.

At 18:00, the height of PBL decreased to 500 m, resulting in the accumulation of aerosols between 900 m and 1400 m (Fig. 2i), which led to the formation of small particle-size cloud droplets, with an average Nc of 273 cm^{-3} and an average E_d of 16.67 μm (Fig. 3i). The atmospheric temperature above 1400 m was high (Fig. 4i), and cloud droplet evaporation caused Na (interstitial aerosol) to be close to or greater than Na (out cloud).

At 20:00, there were upward flows between 1000 and 1500 m (Fig. 5d). The abundance of CCN and low temperature (Fig. 4j) promoted the formation and growth of cloud droplets. The average Nc was 194 cm^{-3} (Fig. 2j), higher than the Nc observed from 10:00 to 13:00. LWC and Ed gradually increased with height (Fig 3j). LWC rose from 0.02 $g \cdot m^{-3}$ to 0.64 $g \cdot m^{-3}$. Ed increased from 7.52 μm to 29.59 μm.

7. Section 3.2, Figure 6 shows the diurnal variation of cloud and aerosol number concentration spectra at different altitudes. However, the explanation of this content in the manuscript is relatively brief. It is recommended that the authors provide additional explanations better to understand the characteristics and causes of these changes.

Response: Thank you for your comment. We have added the characteristics of spectral distribution changes over time and analyzed the temporal variations in the boundary layer and the effects of meteorological factors on cloud droplet and aerosol spectra.

From 10:00 to 13:00, the interstitial aerosol particle size in the cloud's lower layer was concentrated below 0.4 μm. In comparison, the cloud droplet diameter was primarily concentrated below 20 μm, with few large particle-size cloud droplets (Fig. 6a, 6d). In the middle cloud layer, Na across all particle size ranges had decreased to below 1000 $cm^{-3}\cdot\mu m^{-1}$. Nc for particles smaller than 20 μm has decreased, while Nc for particles larger than 20 μm exceeded 0.1 $cm^{-3}\cdot\mu m^{-1}$ (Fig. 6b, 6e). Na in the upper cloud layer was minimal compared to the middle and lower layers. Sufficient water vapor (LWC = 0.14 $g\cdot m^{-3}$, Fig.3a-c) and low temperature (T = 11.72 °C, Fig.4a-c) promote the growth of cloud droplets, resulting in fewer Nc for particles larger than 20 μm in the upper layer (Fig. 6c, 6f) compared to the middle layer.

From 14:00 to 16:00, aerosols diffused upward with the increase in PBL, leading to a decrease in Na in the cloud's lower layer (Fig. 6a, 6d). The upward transport of aerosols caused the upper-level Na of the cloud to be higher than that observed from 10:00 to 13:00. This change increased the Nc of droplets with diameters greater than 20 μm (Fig. 6b-c, 6e-f). Newly formed cloud droplets competed for water vapor. Nc of droplets larger than 30 μm decreased, while Nc of smaller droplets increased.

From 17:00 to 20:00, the height of PBL decreased. Na increased, and Nc of large droplets decreased. Aerosols retained at the top of PBL provided CCN for the cloud's middle and upper layers (Fig. 6b-c, 6e-f). During this period, Nc was higher than observed from 10:00 to 13:00. The increase in Nc may be attributed to the rise in Nc of droplets smaller than 20 μm.

Reference:

Li Z, Li R, Li B. 2003. Analyses on Vertical Microphysical Characteristics of Autumn Stratiform Cloud in Lanzhou Region [J]. Plateau Meteorology, 22(6): 583-589. http://dx.chinadoi.cn/10.3321/j.issn:1000-0534.2003.06.008

8. In Section 3.3, the study first mentions the influence of air mass sources on cloud microphysical properties. Then, it selects two examples to analyze the interaction

between aerosols and clouds in detail. How is the source of the air mass determined? Is there any relationship between the selection of individual cases and the air mass source? Why were October 29 and November 2 chosen?

Response: Thank you for your comment. The sources of aerosols were analyzed using the Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) by the National Oceanic and Atmospheric Administration. We found that below 3000 m, air masses that have passed over land tend to bring higher aerosol number concentrations to Guangxi compared to those that have passed over the ocean. This provides sufficient condensation nuclei for cloud formation. Additionally, the aerosol size distribution from land is broader than that of marine aerosols, and aerosols with a diameter greater than 1 μm are more easily influenced by continental air masses (Liu et al., 2024). Larger diameter cloud condensation nuclei are also generally more likely to activate than smaller diameter nuclei. October 29 and November 2 are the two most representative cases from this observation. The cloud thickness observed on these two dates is similar, with cloud base heights below the boundary layer height and cloud top heights exceeding 3000 m. The clouds' macro characteristics are similar, indicating that the processes of formation and development for both cases were similar. This reduces the interference from other factors and more intuitively reflects the impact of different concentrations of aerosols on cloud microphysical properties. Polluted air masses from the continent influenced October 29. November 2 experienced clean weather under the influence of maritime air masses, allowing for a clear demonstration of the microphysical characteristics of clouds under these two different air mass conditions. The aerosol number concentration near the surface for both cases ranged from tens to two thousand, ensuring a more rigorous validation of the relationship between aerosols and clouds in Guangxi by the Twomey effect.

9. Figure 10 illustrates the correlation between aerosol number concentration and effective droplet diameter; however, there is currently insufficient detail regarding the basis for the calculations. Additionally, the meaning of the function presented in the figure has not been explained. It is recommended that the authors provide supplementary data and detailed explanations to help readers better understand the

information conveyed by this figure and the significance of the research.

Response: The equation in the panel represents a fitted curve for the data, indicating the relationship between Na and E_d. The relationship between Na and E_d can be expressed as $E_d = Na^{FIE}$. Within different ranges of LWC, FIE is consistently less than 0, indicating that the relationship between aerosol and cloud in the Guangxi region conforms to the Twomey effect. The R^2 value reflects the strength of the relationship between the fitted curve and the actual data. We conducted a significance test on the fitting results, setting the significance level α at 0.05 and obtained a P-value < 0.05. We have added the necessary information in lines 406-411.

10. The manuscript would benefit from a more explicit conclusion section that summarizes the key findings, their implications, and potential areas for future research.

Response: Thank you for your comment. We have summarized the conclusions and added potential areas for future research. Below are the revised conclusions.

This study provides the vertical profiles of stratocumulus microphysical quantities, number concentration spectrum and meteorological parameters over Guangxi in autumn using the aircraft observation data of 9 sorties. The temporal variations of cloud microphysical characteristics at different altitudes are described, and the effects of air mass source on cloud microphysical quantities are discussed. The results are as follows.

(1) Below 1500 m in Guangxi, Na and Nc gradually decreased with the increase in altitude. Aerosols were mainly concentrated under PBL. Nc was large, with an average of 407 cm^{-3}. Between 1500 m and 3300 m, the value of Na remained low, with Nc staying below 200 cm^{-3} and not changing with height. With the increase in height, E_d first increased, then remained constant, and finally increased again. The E_d at the cloud top was 2.75 times that at the cloud base. The inversion layer at the top of PBL hindered the increase in the cloud droplet particle size. Compared with other regions in China, LWC was high, with an average value of 0.22 $g \cdot m^{-3}$, and LWC variation was independent of height.

(2) The vertical distribution of microphysical quantities of stratocumulus in autumn in this region had noticeable temporal variation, mainly influenced by the temporal variation of the vertical distribution of aerosols. From 10:00 to 13:00, aerosols were primarily concentrated at low altitudes, which led to smaller particle-size cloud droplets in the lower cloud layer (Nc = 313 cm^{-3}, E_d = 10.78 μm). From 14:00 to 16:00, due to the combined effects of the lifting of the top of the PBL and updrafts, the low-level aerosols were diluted, leading to a decrease in the number of cloud droplets in the lower layer (Nc = 184 cm^{-3}). From 17:00 to 20:00, the descending motion and downdrafts of the PBL increased the number of small cloud droplets in the lower layer (E_d = 12.15 μm). From 10:00 to 13:00, Nc in the middle and upper clouds was low, while the particle size was large. From 14:00 to 20:00, the upward transport of aerosols near the surface and the formation of a high concentration aerosol layer (600-1300 m) increased the number of small particle-size cloud droplets in the middle and upper clouds.

(3) The air mass source and PBL influenced the distribution characteristics of cloud microphysical quantities by influencing Na. Nc under the influence of the land air mass was 5.06 times that of the ocean air mass, while E_d under the influence was 1.62 times that of the land air mass. When there was a high number concentration of aerosols below PBL, the cloud droplet number concentration spectrum was unimodal, and the cloud droplet size was concentrated below 20 μm. Above PBL, the cloud droplet number concentration spectrum was bimodal, and the number of large particle-size cloud droplets (cloud droplet diameter > 30 μm) was more than that in PBL. The relationship between aerosol and cloud in the Guangxi region was consistent with the Twomey effect. E_d and Na were negatively correlated in different LWC ranges, and FIE ranged from -0.07 to -0.58.

In conclusion, our findings highlight the significant influence of aerosol concentrations and air mass origins on the microphysical properties of stratocumulus clouds over Guangxi. The observed temporal and vertical variations in cloud microphysics underscore the complexity of aerosol-cloud interactions in this region. Future research should cover a comprehensive time frame, including nighttime observations, to provide a complete vertical structure of these clouds, the effects of different aerosol types, and their impact on regional climate patterns.