Response to Reviewer #1

We appreciate your time and effort in thoroughly reviewing our manuscript. We are truly grateful for your constructive comments and insightful suggestions, which encourage and help us to improve the manuscript. We have revised the manuscript carefully based on your comments. In the response below, your comments are provided in black text and our responses are provided in blue text.

Response:

GENERAL COMMENTS:

This study uses aircraft in-situ measurements from the ACE-ENA and SOCRATES field campaigns to illustrate vertical profiles of cloud microphysical and precipitation properties and their relationships with above- and below-cloud aerosols. The paper is well-written with appropriate references. There is tremendous detail in Section 2 (uncertainties in airborne observations, formulae used to calculate cloud properties, thresholds used to define in-cloud and above/below-cloud regions) to ensure the results can be reproduced. The discussion of the results is well structured, and the text is backed up with appropriate figures. The study draws proper conclusions and provides appropriate evidence. This is a comprehensive study that deals with numerous elements of aerosol-cloud-precipitation interactions – a single paper is used to show findings that could have spread across multiple studies if the individual elements were investigated further.

While the work is comprehensive, the novelty of this study comes from the fact that these in-situ observations come from regions that have not been sampled extensively by aircraft or the data examined in detail. Additionally, very distinct regions with unique cloud and aerosol characteristics are compared. In isolation, many findings might not strictly be new as they corroborate results from many previous studies that have used aircraft observations. Nevertheless, this study is an important addition to the literature because of the wide range of topics discussed and the fact that the authors contrast cloud and aerosol properties from multiple field campaigns from two different locations. The effort put into this work is commendable and the paper would be a valuable addition to the journal and the literature. Given the number of topics discussed and potential for deeper dives into each topic, I can see multiple studies coming out of further investigation into the results presented here.

Thanks for the thorough assessment of our manuscript, we have tried our best to carefully consider and address your comments and suggestions.

I have some considerations for the authors before the study is published:

1. The introduction felt a bit too broad and generic - the authors could better motivate and highlight the unique aspect of this work by guiding the reader through the distinct nature of these regions, by contrasting the existing knowledge of cloud properties from these regions - somewhat done for SOCRATES but not for ACE-ENA, highlighting the 'climatic significance' of clouds observed in these two regions – this was only done for MBL clouds in general, and the need for in situ observations from these locations.

   Is there a reason behind comparing these two specific field campaigns? Are we comparing apples to apples? - describing the cloud regime, type, or morphology in these regions could help interpret the differences in the results presented in later sections.

   We have reconstructed our discussion to review the previous works on ACE-ENA and SOCRATES in the introduction, and our results in comparison with the previous study in the summary and conclusion section. Please refer to the revised manuscript.

   Furthermore, to demonstrate the feasibility and justification of combining these two campaigns, we calculated the composite of the selected case periods during the ACE-ENA and SOCRATES using the hourly ERA5 reanalysis, as shown in Figure S1 below. The composite 850 hPa geopotential height is denoted by black contours, and the height anomaly from the 20-year climatology (2000-2020) is portrayed by the shaded area.

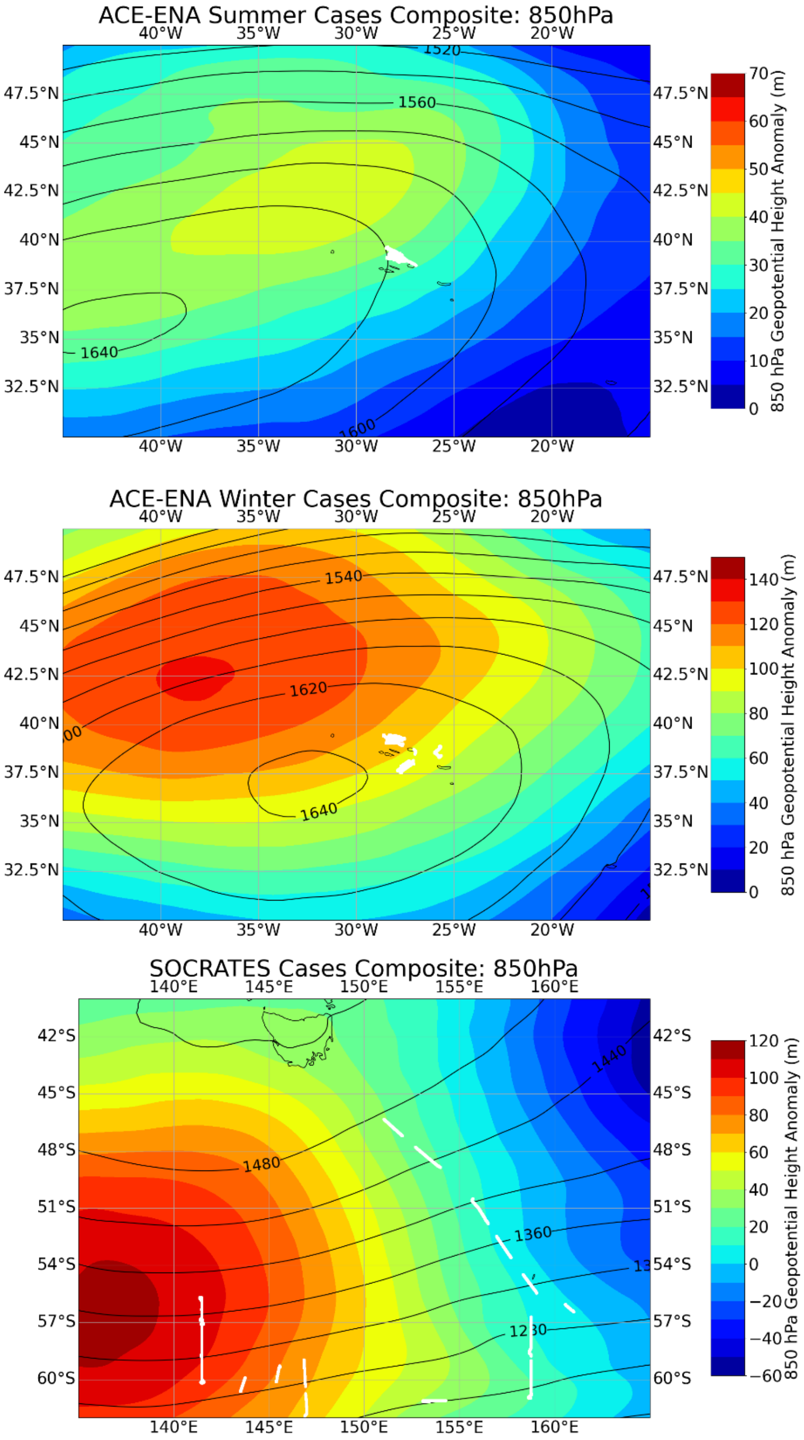
   The discussion in the introduction has been modified to better motivate our study, as follows:

‘The Eastern North Atlantic (ENA) stands as a desirable region for exploring MBL clouds in the mid-latitude, with Graciosa Island in the Azores (39.09°N, 28.03°W) representing a focal point for such studies. Located between the mid-latitude and subtropical climate zones, Graciosa is subject to the meteorological influence of both the Icelandic Low and the Azores High, and the influence of aerosols ranging from pristine marine air masses to those heavily influenced by continental emissions from North America and Northern Europe (Logan et al., 2014; Wood et al., 2015; Wang et al., 2020). Addressing the need for sustained research into the MBL clouds, the recent Aerosol and Cloud Experiments in the Eastern North Atlantic (ACE-ENA) aircraft campaign (J. Wang et al., 2022) were conducted in the summer (June and July) 2017 (ACEENA Sum) and winter (January and February) 2018 (ACEENA Win). During these two intensive operation periods (IOPs) of ACE-ENA, the research aircraft accrued abundant in-situ measurements of aerosols, clouds, and drizzle properties, providing invaluable resources for studying the ACI and ACPI processes. During the summer, the Azores is located at the eastern part of the high-pressure system, while during the winter, the center of the Azores high shifts to the eastern Atlantic and is primarily located directly over the Azores (Mechem et al., 2018; J. Wang et al., 2022). Furthermore, both summer and winter IOPs of ACE-ENA are featured with anomalous stronger high-pressure systems, compared to the 20-year climatology as shown in Figure S1. This meteorological pattern is favorable to the prevailing and persistent stratocumulus clouds observed during the ACE-ENA, especially for the winter IOP, where the enhanced large-scale subsidence would lead to a deeper stratocumulus-topped MBL (Rémillard and Tselioudis, 2015; Jensen et al., 2021). The ACE-ENA summer IOP is characterized by anomalously low MBL heights and substantial MBL decoupling (Miller et al., 2021; J. Wang et al., 2022), while the winter IOP is featured with prevalent precipitation-generated cold pools, where evaporative cooling alters the thermodynamical structure of the MBL, sustains and enhances turbulence mixing, hence contributes to dynamical perturbations that can influence the behavior of the MBL (Terai and Wood, 2013; Zuidema et al., 2017; Jenson et al., 2021; J. Wang et al., 2022). Over the recent years, many observational studies, based on the ACE-ENA data, have focused on the seasonal contrasts of the aerosol distributions and sources (Y. Wang et al., 2021b; Zawadowicz et al., 2021), the cloud and drizzle microphysics vertical distributions (Wu et al., 2020a;

Zheng et al., 2022b), as well as the impacts of MBL conditions on the cloud structure and morphology (Jensen et al., 2021). However, they seldom analyze the comprehensive interactions between aerosol, clouds and precipitation.

Over the Southern Ocean (SO), the Southern Ocean Clouds Radiation Aerosol Transport Experimental Study (SOCRATES) field campaign (McFarquhar et al., 2021) was conducted during the austral summer (January and February 2018), which marks another valuable piece of the MBL cloud research. The SO, being one of the cloudiest regions globally, is predominantly influenced by naturally produced aerosols originating from oceanic sources due to its remoteness, where the anthropogenic and biomass burning aerosols exert minimal influence over the region (McCoy et al., 2021; Sanchez et al., 2021; Twohy et al., 2021; Zhang et al., 2023). The aerosol budget in this region is primarily shaped by biological aerosols, which nucleate from the oxidation products of dimethyl sulfide (DMS) emissions, as well as by sea spray aerosols. Hence, the SO provides an unparalleled natural laboratory for discerning the influence of these natural aerosol emissions on the MBL clouds under a pre-industrial natural environment. The summertime SO region, particularly near the SOCRATES focus area, is characterized by more frequently closed-cell mesoscale cellular convection structures (Danker et al., 2022; Lang et al., 2022). Furthermore, the MBL clouds over the SO predominantly consist of supercooled liquid water droplets, which coexist with mixed- and ice-phase processes (Y. Wang et al., 2021a; Xi et al., 2022), while the precipitation phases are examined to be primarily dominated by liquid hydrometeors (Tansey et al., 2022; Kang et al., 2024). The in-situ measurements collected from SOCRATES have cultivated numerous studies on aerosols, clouds, and precipitation over the SO using both in-situ measurements and model simulations (McCoy et al., 2020; Altas et al., 2021; D'Alessandro et al., 2021), and provides an opportunity to study the liquid cloud processes under a colder nature. As shown in Figure S1c, compositely speaking, the SOCRATES cloud cases used in this study are located ahead of the anomaly-stronger thermal ridge and behind the thermal trough, providing a set up favorable to the closed cellular MBL cloud structures (McCoy et al., 2017; Lang et al., 2022). While the region of selected SOCRATES cloud cases crosses a larger latitudinal zone and is under more consistent influence of mid-latitude cyclone systems than over the ACE-ENA region, the cloud sampling periods used in this study majority reside in the closed-cell MBL stratocumulus decks.

The cloud cases selected from the ACE-ENA and SOCRATES share similar cloud morphology (stratocumulus) while experiencing different aerosol sources and meteorological conditions. Using a synergistic approach to compare data from these different field campaigns can provide valuable insights to the community regarding the functioning physical processes of the interactions between aerosols, clouds, and precipitation under the influence of different MBL dynamic and thermodynamic conditions. This study targets the similarities and differences in the MBL aerosol, cloud, and drizzle properties, their distribution and evolution, and more appealingly, the ACIs and ACPIs between the two campaigns.’


ACE-ENA Summer Cases Composite: 850hPa

ACE-ENA Winter Cases Composite: 850hPa

SOCRATES Cases Composite: 850hPa

Figure S1. The selected-cases 850 hPa geopotential height composite (black contours), and the height anomaly from (shaded area) the 20-year climatology (2000-2020), for a) ACE-ENA summer, b) ACE-ENA winter, and c) SOCRATES. White dots denote the aircraft flight tracks for the selected cases.

2. The authors could better and use terminology to refer to cloud processes discussed throughout the text. Terms like “collision-coalescence”, “in-cloud coalescence”, “coalescence-scavenging” are used (often interchangeably it seems) - they can be merged or defined using more commonly used terminology.

Line 57: the authors could separate what they term the ‘coalescence-scavenging effect’ into two parts. While the drizzle drops are within the cloud layer, the process described in Line 58 can be described as the ‘collision-coalescence’ process. Once the drizzle drops are below cloud base, the process described in Line 59 can be described as the ‘precipitation scavenging’ process. Using such terminology would prevent confusion caused by using the same term for two separate processes that occur in-cloud and out-of-cloud, respectively. Please ensure consistency in using the terms as the paper currently uses “collision-coalescence process” in some spots and different terms at other spots while describing a similar process.

We have changed the term ‘in-cloud coalescence’ to ‘collision-coalescence’ throughout the paper. Additionally, we have added more explanation on ‘coalescence-scavenging’ in order to distinguish it from the precipitation of wet scavenging outside the cloud.

‘Conversely, precipitation has been shown to exert a substantial influence on the MBL aerosol and cloud condensation nuclei (CCN) budget through the coalescence-scavenging effect, as multiple aerosols combine into a single aerosol core inside the cloud droplet during collision-coalescence. As the drizzle drops descend, they are enlarged by collecting more cloud droplets within the cloud layer. However, the drizzle drops, once falling out of the cloud base, can result in net reductions in sub-cloud aerosols and CCN budgets also via the precipitation scavenging processes’.

SPECIFIC COMMENTS:

ABSTRACT:

Line 15: Could you provide quantitative estimates with the number and size used to state “larger number” and “smaller cloud droplets”?

We have added those quantities in this sentence:

‘SOCRATES clouds have a larger number (148.3 cm^{-3}) and smaller cloud droplets (8.0 μm) compared to ACE-ENA summertime (89.4 cm^{-3} and 9.0 μm) and wintertime clouds (70.6 cm^{-3} and 9.8 μm).’

SECTION 1:

Line 34: The authors mention ‘cloud-top longwave radiative cooling’ here which is very important and should be mentioned but it is not discussed later. In contrast, there is an excellent discussion of cloud top entrainment mixing and droplet evaporation near cloud top later, but it is not introduced here. The authors could better motivate their results by introducing cloud processes in Section 1 if they are discussed later.

We have added the discussion on the cloud-top longwave radiative cooling and entrainment mixing in the introduction as follows:

‘Precipitation, particularly in the form of drizzle, is common in MBL clouds (Wood et al., 2015; Wu et al., 2020), and the turbulence forced by stratocumulus cloud-top radiative cooling can increase the cloud liquid water path, and contributing to drizzle production (Ghate et al., 2019, 2021). The drizzle formation and growth processes are deeply entwined with the MBL aerosols and dynamics. Aerosols have been found to suppress the precipitation frequency and strength by constantly buffering cloud droplet number concentrations via activation, hence increasing cloud precipitation susceptibility (Feingold and Seibert, 2009; Lu et al., 2009; Sorooshian et al., 2009; Duong et al., 2011). Furthermore, the assessments of precipitation susceptibility are examined to be under the influences of methodology (Terai et al., 2012), cloud morphology (Sorooshian et al., 2009; Jung et al., 2016), ambient aerosol concentrations (Duong et al., 2011; Jung et al., 2016; Gupta et al., 2022), and cloud thickness (Terai et al., 2012; Jung et al., 2016; Gupta et al., 2022). The in-cloud turbulence and wind shear can effectively enhance collision-coalescence efficiency, stimulating drizzle formation and growth, and consequently leading to enhanced precipitation (Chen et al., 2011; Wu et al., 2017). Cloud-top entrainment of dryer and warmer air can potentially deplete small cloud droplets and shrink large droplets via evaporation, thereby impacting cloud top microphysical processes depending on the homogeneous or inhomogeneous mixing regimes (Lehmann et al., 2009; Jia et al., 2019).’

Line 42: This statement is only true under conditions of comparable cloud water content. Please update accordingly and provide appropriate references.

We have changed this statement to:

‘…the aerosol-cloud interaction (ACI), can be typically viewed as decreased cloud droplet effective radii (r_c) and increased number concentrations (N_c) with more aerosol intrusion, under conditions of comparable cloud water content (Feingold and McComiskey, 2016).’

Line 44: Instead of listing references at the end of the sentence, a reader would benefit much more if references for specific elements followed the corresponding text. For example, “…investigated by different observational platforms, such as aircraft (Diamond et al., 2018; Painemal et al., 2020), model simulations (Hill et al. 2009)…”. Please directly state some of the “different maritime regions”. Something like “….over different maritime regions like the southeast Pacific (Painemal and Zuidema, 2011), northeast Pacific (Braun et al., 2018), southeast Atlantic (Diamond et al., 2018), and eastern North Atlantic (Zheng et al., 2022a).”

We have changed this discussion accordingly:

‘The ACIs have been extensively investigated by different observational platforms, such as aircraft (Hill et al., 2009; Diamond et al., 2018; Gupta et al., 2022), ground-based and satellite observations (Painemal et al., 2020; Zheng et al., 2022a), and model simulations (Wang et al., 2020) over different maritime regions like the southeast Pacific (Painemal and Zuidema, 2011), northeast Pacific (Braun et al., 2018), southeast Atlantic (Gupta et al., 2022), and eastern North Atlantic (Zheng et al., 2022a).’

Line 53: More recent studies of precipitation susceptibility (e.g., Gupta et al., 2022; Jung et al., 2016; Terai et al., 2012) have been built upon the studies cited here. To my knowledge, Feingold and Seibert (2009) introduced the term precipitation susceptibility and the study should be cited here. I see the authors briefly compared their results with some of these previous studies (good to see) - but the studies should be cited in the introductory text. Also suggest discussing the different issues with estimating/interpreting S_o based on results from previous studies.

The suggested references (Gupta et al., 2022; Jung et al., 2016; Terai et al., 2012) are added to the text.

‘The assessments of S_o are examined to be under the influences of methodology (Terai et al., 2012), cloud morphology (Sorooshian et al., 2009; Jung et al., 2016), ambient aerosol concentrations (Duong et al., 2011; Jung et al., 2016; Gupta et al., 2022), and cloud thickness (Terai et al., 2012; Jung et al., 2016; Gupta et al., 2022).’

Line 75: Please also provide the months for the ACE-ENA IOPs along with the years.

This information is added:

‘…the recent Aerosol and Cloud Experiments in the Eastern North Atlantic (ACE-ENA) aircraft campaign (J. Wang et al., 2022) were conducted in the summer (June and July) 2017 (ACEENA Sum) and winter (January and February) 2018 (ACEENA Win).’

Line 80: Please provide the duration for the SOCRATES austral summer IOP.

This information is added:

‘…the Southern Ocean Clouds Radiation Aerosol Transport Experimental Study (SOCRATES) field campaign (McFarquhar et al., 2021) was conducted during the austral summer (January and February 2018),’

SECTION 2:

I want to commend the authors for the discussion in this section. However, the section does lack some context about the cloud sampling locations. A map of the sampling locations/flights tracks or a list of the range of latitude-longitude coordinates where clouds were sampled during the IOPs would be very useful.

Thanks for your recognition.

We have added Figure S1 to illustrate the meteorological patterns of the study domains, and the sampling locations of the selected cases are indicated by the white dots in Figure S1.

Line 106: I believe by “resolutions” you actually mean - “the size bins of the probe were 1 to 3 um wide”?

The description is changed as follows:

‘The Fast Cloud Droplet Probe (FCDP) onboard aircraft during ACE-ENA can detect droplets with diameter (D_p) ranging from 1.5 μm to 50 μm, with the size bins of the probe between 1 and 3 μm (Glienke and Mei, 2020). While the SOCRATES used a similar CDP to measure droplets from 2 μm to 50 μm at a 2 μm probe size bin width.’

Line 111: Can you provide a reference for the phase classification product? If not, a short description of the methodology for it would be useful.

This information is added:

‘…the University of Washington Ice–Liquid Discriminator product, which is a Machine-learning-based single-particle phase classification of the 2DS images (Atlas et al., 2021)’

Line 128: Can cite Hansen and Travis, 1974 where the term “effective radius” and the associated formula were introduced.

We have added this reference to the revised manuscript.

Line 160: Do your results depend on the selection of the value of 200 m to determine the distance for above-cloud aerosols that are important for the analysis? Gupta et al. (2021) conducted a sensitivity test to determine if their analysis of cloud microphysical properties was affected by this number for distance from above-cloud aerosols. A comment on the sensitivity of the results on this value would be useful.

We have added the discussion as follows:

‘The above-cloud aerosols and CCN are selected between the cloud top and 200 m above. Note that the selection criteria of 200 m above the cloud top would inevitably induce uncertainty in the cloud top ACI assessment, depending on the vertical trend of the individual aerosol profile. Over the Southeast Atlantic, Gupta et al. (2021) conducted an analysis focusing particularly on the differing impacts when biomass burning aerosols are in contact with marine stratocumulus cloud tops, using 100 m above as the demarcation, versus when they are separated by various distances, and found that significant differences were observed in cloud microphysics, owing to different droplet evaporation and nucleation, compared to separated profiles. That result is in agreement with the modeling sensitivity study over the Eastern North Atlantic by Wang et al. (2020), who found that aerosol plumes can exert impacts on the cloud-top microphysics only when they are in close contact with the cloud layer. In most cases, the ACE-ENA feature is a rather stable or slightly decreasing profile within a couple hundred meters above the cloud top, while the long-range transports, particularly during summertime, will induce an elevated aerosol layer in higher altitudes that is not in contact with the cloud layer. While the frequent new particle formation events during SOCRATES will significantly alter the free-troposphere Aitken mode aerosol budget, they would need to further subside down to impact the cloud (McCoy et al., 2021; Zhang et al., 2023). Therefore, the 200 m criteria used in this study are in the reconciliation of getting the close-to-cloud aerosol plumes and enough sample size for statistical analysis.’

SECTION 3:

Line 192: These aerosol concentrations for SOCRATES seem high for the Southern Ocean, which was typically viewed to be a pristine environment. The authors refer to previous studies from SOCRATES to explain the aerosol size distribution or composition, do these studies have similar aerosol concentrations?

We have added the discussion as follows:

‘Previously, McCoy et al. (2021) reported average values of 680.69 cm^{-3}, 546.28 cm^{-3} and 465.05 cm^{-3} for mid-troposphere, above and below cloud for the multiple SOCRATES cases, respectively. While for the individual cases the above cloud aerosols vary from a couple hundred to over a thousand (McCoy et al., 2021; Zhang et a., 2023). These aerosols are predominantly produced from the oxidation of biogenic gases, notably the dimethyl sulfide (DMS) emitted by marine biological productivity (Sanchez et al., 2018; McCoy et al., 2020). The rising air currents in MBL transport these particles into the free troposphere (FT) with dominant aerosol population over the SO (McCoy et al., 2021; Sanchez et al., 2021). And hence, it reinforces the notion that the SO represents a pre-industrial marine environment where the influence of anthropogenic and biomass-burning aerosols is mostly negligible (McCoy et al., 2020, 2021).’

Line 213: Do you mean that the ‘sub-cloud Nacc values’ are more than double the ‘above-cloud Nacc values’? Suggest rewording this sentence.

We have reworded this sentence as:

‘Notice that the sub-cloud N_{Acc} values from three IOPs are more than double of the above-cloud N_{Acc} values, and most of the sub-cloud accumulation mode aerosol can be activated to become CCN at SS of 0.35%.’

Line 268: “These results have further improved the understanding of the aerosol first indirect effect”. This statement is a bit overreaching. There are many studies that have shown similar results. I suggest rewording to “These results are consistent with the understanding of the aerosol first indirect effect”

We totally agree. We have reworded this statement to ‘These results have further confirmed and reassured our understanding of the aerosol first indirect effect’

Line 271: It is interesting that the average Nc for ACE-ENA winter is greater than both the sub-cloud Nacc and Nccn. Do you have any comments on why this is the case? Has this been observed elsewhere? Are the values of Nc influenced by above-cloud aerosols or sub-cloud Na?

We have added a brief discussion on this:

‘Note that the $N_{CCN0.35\%}$ and N_c values are lower than N_c values during the ACE-ENA winter IOP, which is also confirmed in previous studies (J. Wang et al., 2022; Wang et al., 2023), which is also confirmed in previous studies (J. Wang et al., 2022; Wang et al., 2023). This interesting phenomenon can potentially be attributed to a combination of factors including lower MBL aerosol sources, stronger in-cloud coalescence-scavenging depletion of sub-cloud aerosols, and the aircraft snapshots capturing the equilibrium states of aerosols and cloud due to enhanced aerosol activations induced by stronger updrafts during the ACE-ENA winter (J. Wang et al., 2022). This thereby compels further investigation into the potential impacts of precipitation on the MBL CCN budget.’

Line 310: This is an excellent discussion of entrainment mixing and its competing influence on droplet size/liquid water content and likely highlights two different modes of cloud top mixing – homogeneous and inhomogeneous mixing that depend on the entrainment rate (Lehmann et al., 2009; Lu et al., 2011) – do the authors have any comments based on their calculated entrainment rates? The authors could cite examples of previous studies that show similar vertical profiles of cloud properties where the effects of entrainment mixing on cloud microphysical properties were evident.

We have added the discussion as follows:

‘For the three IOPs, the N_c and LWC_c exhibited a stable trend from the cloud base, followed by a noticeable decrease near the cloud top mixing zone, while the changes in r_c trend were not as dramatic as the others. Such characteristics of the cloud microphysics vertical profiles indicate the signal of inhomogeneous mixing, which occurs when dry and warm air mixes unevenly and not rapidly with the cloud air, hence partially evaporating the cloud droplets (Lehmann et al., 2009; Lu et al., 2011). The results are consistent with findings in stratocumulus clouds over multiple field campaigns (Brenguier et al., 2011; Jia et al., 2019) and with the findings in Sanchez et al. (2020) for five stratocumulus cases during the SOCRATES. However, further quantification of the entrainment-mixing mechanisms requires high-frequency eddy dissipation and accurate examination of the mixing time scale (Lehmann et al., 2009; Lu et al., 2011), which is of interest for future study.’

Line 370: The skewness of a distribution can actually be calculated as a statistical parameter rather than having a visual comparison. I leave it to the authors to decide if they would like to add this parameter to the study.

We have calculated the skewness values for the cloud DSDs and include them in the discussion: ‘For the four cloud portions from cloud base to cloud top, the skewness of summertime (wintertime) cloud DSDs are 0.627 (0.271), 0.358 (0.175), 0.098 (-0.063), and -0.362 (-0.554), respectively.’

SECTION 4:

Line 434: This statement would be more accurate if the Liquid Water Path (LWP; vertical integral of the LWC) values were compared across campaigns rather than the mean LWC. Suggest adding LWP values or rewording the sentence.

We have changed this statement to:

‘Furthermore, the similarity in the vertical integral of LWC_c (as shown in Fig. 3c) provides comparable liquid water between three IOPs’

Line 468: Do you want to mention some of these aircraft campaigns - VOCALS, ORACLES, ACTIVATE, etc.?

We have expanded the discussion here:

‘However, a more comprehensive investigation into the cloud microphysical responses to CCN intrusions under a larger range of various water supply conditions, and further untangling the ACI from the meteorological influences, will require additional aircraft cases from more field campaigns, for instance the VAMOS Ocean-Cloud-Atmosphere-Land Study (VOCALS), the Cloud System Evolution over the Trades (CSET), the ObseRvations of CLouds above Aerosols and their intEractionS (ORACLES), and the Aerosol Cloud meTeorology Interactions oVer the western ATlantic Experiment (ACTIVATE).’

Line 475: These are some very interesting results. While the $\mathrm{ACI}_{\mathrm{r,CT}}$ values are close to what one might expect (droplets are too large near cloud top for above-cloud aerosols to exert a significant influence on r near cloud top), it is interesting to note the $\mathrm{ACI}_{\mathrm{N,\,CT}}$ values reported here. Do the authors have any explanation or hypotheses for what causes these values to not be closer to 0 like $\mathrm{ACI}_{\mathrm{r,\,CT}}$?

We have added a brief explanation to this:

‘Compared to the $ACI_{N,CB}$ and $ACI_{r,CB}$, the $ACI_{N,CT}$ and $ACI_{r,CT}$ are much weaker, especially for $ACI_{r,CT}$, as the near cloud top droplets are too large for above-cloud aerosols to exert a significant influence on r_c (Diamond et al., 2018; Gupta et al., 2022). While the weaker cloud top N_c dependence on the $N_{CCN,0.35\%}$ could be due to the legacy of the sub-cloud CCN impacts on N_c being conveyed to the cloud top. This occurs because FT aerosols and CCN can be entrained down to the MBL before and during the cloud process, as observed in the assessment of inter-cloud cases. These weaker relationships support the notion that though the aerosols entrained into the upper-cloud region can affect the cloud microphysics to a certain degree, the effects are less pronounced than those from the sub-cloud aerosols (Diamond et al., 2018, Wang et al., 2020) because the MBL cloud N_c and

r_c variations are dominated by the condensational growth process, collision-coalescence process, and cloud top entrainment mixing near the cloud top.'

Line 480: I think the authors should also mention cloud top entrainment mixing over here.

We have changed this statement to:

'…the MBL cloud N_c and r_c variations are dominated by the condensational growth process, collision-coalescence process, and cloud top entrainment mixing near the cloud top.'

Line 484: As mentioned earlier, would be good to also cite Feingold and Seibert, 2009 when defining S_o, which to my knowledge was the first study to define the term.

This reference is added.

Line 491: The authors should provide the correlation coefficient values for the S_o calculations and contrast these with previous studies. At least two recent studies did this – Jung et al. 2016 and Gupta et al. 2022.

Line 501: "…due to decreasing So within the thicker cloud (Terai et al., 2012)". This is oversimplifying the problem. The value of S_o depends not only on cloud thickness but also on the calculation methodology as shown by Terai et al, the cloud type – cumulus versus stratocumulus (Sorooshian et al., 2009; Jung et al., 2016) and the above- and below-cloud aerosol concentration (Duong et al., 2011; Jung et al., 2016; Gupta et al., 2022). Having more information on cloud type/morphology in the introduction would give context to these S_o values and other results in the study.

Response to comments on L491 & L501:

We have added the suggested reference in the introduction, and the following discussion in the Section 4.2 (precipitation susceptibility):

‘The S_0 values are 0.979, 1.229, and 1.638, with the absolute values of correlation coefficients being 0.33, 0.29, and 0.45 for SOCRATES, ACE-ENA summer and winter, respectively. These correlation coefficient values fall within the reasonable range found in previous studies on precipitation susceptibility in MBL stratus and stratocumulus clouds (Jung et al., 2016; Gupta et al., 2022), and indicate statistically significant dependences of R_{CB} on N_c. Previous study by Terai et al. (2012) found that the S_o values decrease with the increasing cloud thickness over the southeast Pacific, and Jung et al. (2016) found that the S_o is more pronounced within the medium-deep clouds with thickness ~300-400 m in the MBL stratocumulus over the eastern Pacific. While Gupta et al. (2022) found that the S_o values are generally higher under low ambient N_a condition in the southeastern Atlantic MBL. In this study, R_{CB} for the ACE-ENA winter is more susceptible to the layer-mean N_c than the ACE-ENA summer and SOCRATES, which can be partially attributed to the existence of more large drizzle drops (as shown in Fig. 4d) near the cloud base. As previously discussed, the ACE-ENA winter feature with enhanced collision-coalescence and the drizzle-recirculating processes, especially under low N_c conditions with more larger drizzle drops, leading to the increase of S_o values. In comparison, the higher ambient aerosol and CCN concentrations during SOCRATES lead to relatively narrower drizzle DSDs and may induce effective aerosol buffering effects, where the warm-rain processes in cloud are already fairly suppressed, hence diminishing the sensitivity of R_{CB} to N_c (Stevens and Feingold, 2009; Fan et al., 2020; Gupta et al., 2022).’

Line 531: What are the units of the CCN loss rate? Here, the values are reported with units of “cm^{-3}” which does not include a unit of time, this is likely an error?

We have corrected the unit to $\mathrm{cm}^{-3}\mathrm{h}^{-1}$, thanks for catching this.

SECTION 5:

Line 568: The differences can also be attributed to the different size distributions which are then due to the sources discussed in the following sentences. That would then nicely lead to the discussion of aerosol modes toward the end of the paragraph.

Line 569: I don’t think using the words ‘pristine natural environment’ is appropriate when the previous sentence claimed the aerosol concentrations are highest for SOCRATES.

Response to comments on L568 & L569:

We have reworded the following discussion as:

‘The differences can be attributed to the differences in aerosol size distributions between ACE-ENA and SOCRATES, which are largely due to the aerosol sources in those regions. The SOCRATES features the pre-industrial natural environment enriched by aerosols from marine biological productivity and without the contamination of anthropogenic aerosols…’

Line 580: Can you also list the percentage increase in r from cloud base to top since these campaigns had different cloud thickness values?

We have changed this statement to:

‘…the r_c growths (and percentage increases), from cloud base to top, being 4.03 μm (0.66%), 4.78 μm (0.68%), and 5.85 μm (0.79%) for SOCRATES, ACE-ENA summer, and winter, respectively.’

Lines 255 and 576: How does in-cloud coalescence cause an increase in the size of sub-cloud aerosols? In-cloud coalescence would increase the size of a cloud drop as it accumulates water by colliding and coalescing with other droplets. Once this drop evaporates in the sub-cloud to expose the residual aerosol, the aerosol/CCN core size should be the same unless the CCN is modified during droplet growth. Is this related to the condensation of sulfuric gas onto aerosol cores as described in Line 245? If so, is there a way to verify this based on these observations? If not, this should be stated as a hypothesis rather than a conclusion?

We have added the discussion as follows:

‘Coalescence scavenging refers to the process in which cloud or drizzle droplets, containing aerosol particles, merge with each other. Upon the collision-coalescence of cloud droplets, the dissolved aerosol masses within the cloud droplets also collide and merge into a larger aerosol core, leading to larger aerosol particles upon droplet evaporation. The sub-cloud aerosols are then replenished into the cloud layer, experiencing growth within the cloud through cloud and drizzle droplet collision-coalescence, and subsequently falling and evaporating outside the cloud again. Eventually, the residual aerosols undergoing this cloud-processing cycle will gradually decrease in number concentration and increase in size (Flossmann et al., 1985; Feingold et al., 1996; Hudson and Noble, 2020; Hoffmann and Feingold, 2023).'

Lines 591-597: I don't fully understand or agree with the conclusion drawn here. The studies that the authors cited here/earlier (among many others) have calculated f_{ad} using in-situ aircraft data from other locations and shown that assuming $f_{ad} = 0.8$ could lead to errors in satellite estimates of droplet concentration. While the calculation of f_{ad} and stating the regional values is important, these f_{ad} values do not "shed light on the further understanding of the satellite retrievals, particularly the satellite-based aerosol-cloud interaction assessment". The authors can state the f_{ad} values and perhaps add a comment on the need to use these values when calculating droplet concentration for these regions using satellite retrievals, but I suggest removing lines 594-597.

We have eased our tone and modified our discussion to:

'While satellite retrievals of droplet number concentration heavily rely on the adiabatic cloud assumption and are usually given as a constant of $f_{ad} = 0.8$, the in-situ observational evidence found in this study further confirms the unrealistic nature of this assumption. It will be of interest to utilize multiple aircraft measurements (campaigns) to explore the variability of MBL cloud and drizzle microphysical properties over different marine regions. This can help examine potential predictors for f_{ad}, which will aid in satellite-based retrievals and aerosol-cloud interaction assessments (Painemal and Zuidema, 2011; Grosvenor et al., 2018; Painemal et al., 2021).'

Line 614: I don't understand what is meant by "the aircraft assessment provides more connected circumstances between the aerosols and cloud layer."

We have changed this statement to:

'…the aircraft assessment of ACI is based on measurements where the aerosols are in direct contact with the cloud layer.'

TECHNICAL CORRECTIONS/CLARIFICATIONS:

Line 12: Could use the term "aerosol-cloud-precipitation" given the terminology in the title? Also, change to "interactions" given the verb "are" in the next sentence?

We have changed this sentence as suggested.

Line 94: "aerosol, cloud, and drizzle"?

We have changed this statement to:

'This study targets the similarities and differences in the MBL aerosol, cloud, drizzle properties, their distribution and evolution, and more appealingly, the ACIs and ACPIs between the two campaigns.'

Line 105: "onboard the aircraft"?

We have changed this sentence as suggested.

Line 110: "large, ice particles"? Large ice particles would be a lot larger than 200 um.

We have changed this statement to:

'The 2DS in-situ measurements will be used as additional screening to eliminate the ice particles with diameters larger than 200 μm.'

Line 286: "To ensure the representativeness of the vertical profiles"?

We have changed this sentence as suggested.

Line 443: The sentence should probably end with "during the winter".

We have changed this sentence as suggested:

'…indicating that N_c is more sensitive to the sub-cloud $N_{CCN,0.35\%}$ during the winter.'

Line 582: Do you mean "The mean cloud-top entrainment rates (we) are a function of cloud top virtual potential temperature and vertical velocity and their values are…."

We have changed this sentence to:

'Given the valid cloud top virtual potential temperature and vertical velocity measurements for the selected cloud cases, the averaged w_e values are 0.570±0.834 cm s^{-1}, 0.581±0.560 cm s^{-1}, and 0.960±1.127 cm s^{-1} for SOCRATES, ACE-ENA summer and winter, respectively.'

Figure 1: Please mention which statistical metrics are provided in the legends. Suggest adding that to the figure caption.

We have added the following to the caption:

'The statistical metrics in the legends denote the mean and standard deviation values for all samples in three IOPs.'

Figure 2: The caption lists the incorrect size range for the inner plots. Should be "Aitken mode size distribution (Dp = 0.01 to 0.06 μm)"

The caption is corrected, thanks for catching.

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