This study combines ground-based observations of aerosols and satellite-based observations of clouds to evaluate cloud droplet number concentration and effective radius susceptibilities to the aerosol scattering coefficient. While it is an interesting study, I have two major points of concern:

- The study does not appear to be innovative. In fact, the authors compare their results with similar previous studies, but don't highlight enough what their analysis offers additionally in the field.
- The authors apply strict criteria in selecting their cases. As a result, however, the analysis suffers from a very small sample that leads to very high susceptibility uncertainties and a very coarse LWP binning. The latter does not produce meaningfully distinctive results (the authors should justify if this is expected), while both these shortcomings prevent them from drawing robust conclusions.

Given these points, I would recommend that this study is revised substantially, especially in the "results and discussion" part, before being reconsidered. Specifically, a larger dataset (e.g. from other ACTRIS sites), after applying similarly strict selection criteria, could increase the robustness of the results and offer more insights on the studied processes. The authors already recognize this potential in their conclusions. Given the limitations of this study, and that the increase in the dataset size is a matter of scaling, not of expanding the analysis, this should be done in the present study, and not just discussed as a future plan in the concluding remarks.

We would like to thank reviewer 2 for his/her comments and suggestions. We fully acknowledge all his/her comments and suggestions to improve the manuscript accordingly. Note that following minor refinements to the filtering pipeline since the previous version, the final dataset now comprises 201 cases (previously 188), see revised Table 2.

Major Comments

Line 22: The authors use 2 bins of LWP values to study the susceptibility of N_d and r_e to the aerosol scattering coefficient. The values they find are very similar for the two bins. Then what is the value of this distinction?

We agree that the final sample size is limited, and that splitting the dataset further reduces the number of observations available in each subset. However, liquid water path (LWP) is a key controlling variable in aerosol-cloud interaction studies. The classical Twomey and Albrecht effects are generally evaluated under approximately constant LWP conditions to reduce the influence of cloud macrophysical variability on cloud microphysical properties. Furthermore, several studies have shown that aerosol cloud susceptibilities exhibit a strong dependence on LWP. In particular, Zheng et al. (2020) demonstrated systematic variations in cloud susceptibility as a function of LWP.
For this reason, we chose to separate the dataset into LWP ranges commonly used in the literature. Although the limited sample size prevents robust statistical conclusions, this stratification allows a more meaningful comparison with previous studies and avoids mixing cloud regimes characterized by substantially different liquid water contents.

We have clarified this motivation in the revised manuscript and explicitly acknowledge the limitations associated with the reduced number of observations in each bin.

Introduction: The authors highlight the disadvantages of satellite-based retrievals being used to estimate aerosol effects on clouds, and their main advantage being global coverage (and temporal frequency for geostationary platforms). They also describe the advantages of local, detailed measurements, with their main disadvantage being locality. The approach they propose still requires station measurements (it's not satellite-based only), so the spatial limitation remains, even if expanded to other stations. How is then this study taking advantage of "the best of both worlds"? It appears that satellites are used here only to supplement the dataset with cloud properties missing from the ground-based measurements.
We thank the reviewer for this comment. We agree that our methodology does not overcome the intrinsic spatial limitation of ground-based observations, and this was not our intention when referring to the "best of both worlds".
Rather, the expression was intended to highlight the complementarity of the aerosol and cloud measurements provided by the two observing systems. Ground-based observations provide detailed and continuous aerosol characterization, including particle size distributions and optical properties, even under cloudy conditions where satellite aerosol retrievals are often unavailable or highly uncertain. Conversely, satellite observations provide cloud microphysical properties, such as droplet effective radius and droplet number concentration, from a top-down perspective that is independent of the surface aerosol measurements.
The benefit of the proposed approach is therefore not an improvement in spatial coverage, but the combination of high-quality aerosol measurements from the surface with cloud microphysical retrievals from space, allowing aerosol-cloud susceptibility estimates that would be difficult to obtain from either observing system alone.

We have clarified this point in the revised manuscript : *« While the combination of ground-based and satellite observations is not new, the novelty of this work lies in the framework developed to derive aerosol-cloud susceptibilities from coordinated ACTRIS aerosol measurements and geostationary satellite cloud retrievals under carefully constrained meteorological conditions. We demonstrate how cloud droplet concentration and radius susceptibilities to aerosol burden can be calculated by combining detailed in-situ aerosol observations obtained from a ground station with cloud microphysical properties retrieved from space (Lihavainen et al., 2010; Nandan et al., 2022). This approach exploits the complementarity of the two observing systems: ground-based measurements provide robust aerosol characterization under cloudy conditions, while geostationary satellite observations provide temporally resolved cloud microphysical retrievals from a top-down perspective. By linking both datasets in space and time, susceptibility estimates can be derived under well-constrained observational conditions. Moreover, by applying the methodology to a single, well-characterized site, we explore its strengths, limitations, and underlying assumptions. The broader objective is to lay the groundwork for future applications across a network of sites, rather than to draw generalized conclusions from the present analysis. Such an extension would take advantage of the advanced aerosol measurements available within ACTRIS, including aerosol chemical composition, enabling future investigations of aerosol-cloud susceptibilities as a function of aerosol type and composition.»*

Line 56: While combining station-based and satellite measurements to study aerosol effects on clouds is indeed “an alternative path” compared to the methods described before, it also has a long history. What is innovative about this study?

We thank the reviewer for this comment. Combining ground based and satellite observations to investigate aerosol and cloud interactions is not a new concept. According to reviewer 1 comment we added to the manuscript 2 figures (included just below Figure 5 and Figure 7) to compare our results with previous ones. One can see that many studies used a combination of ground based in-situ and remote sensing measurements. But none used the combination of satellite, ground based in-situ and remote sensing measurements.

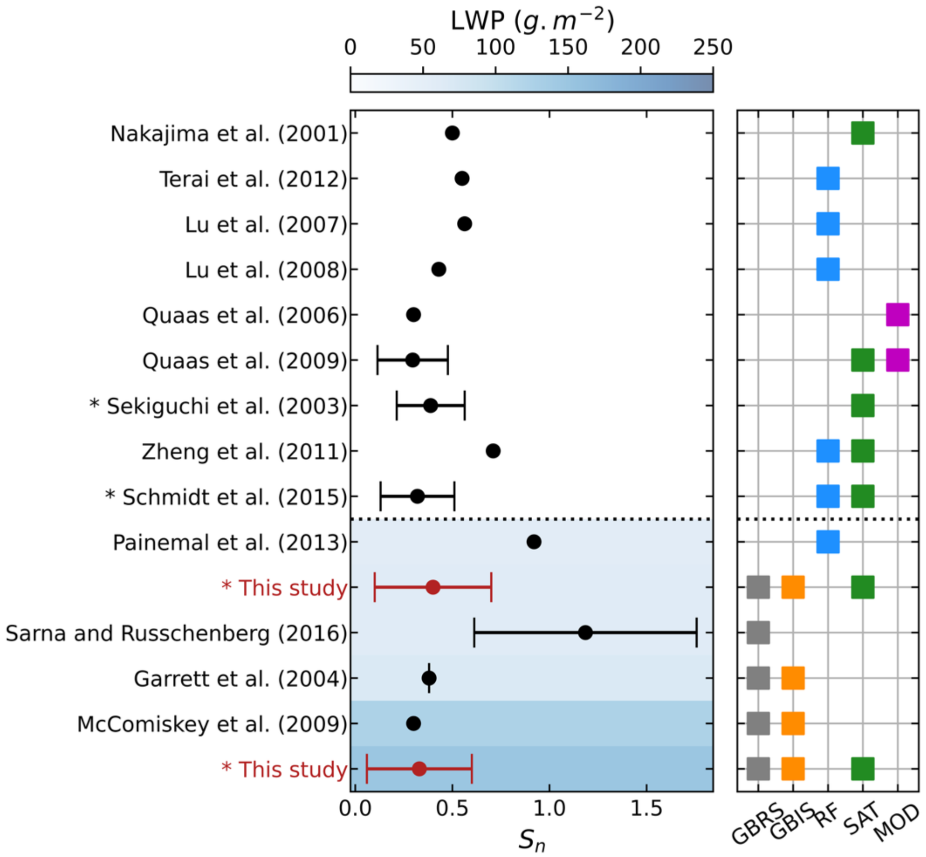
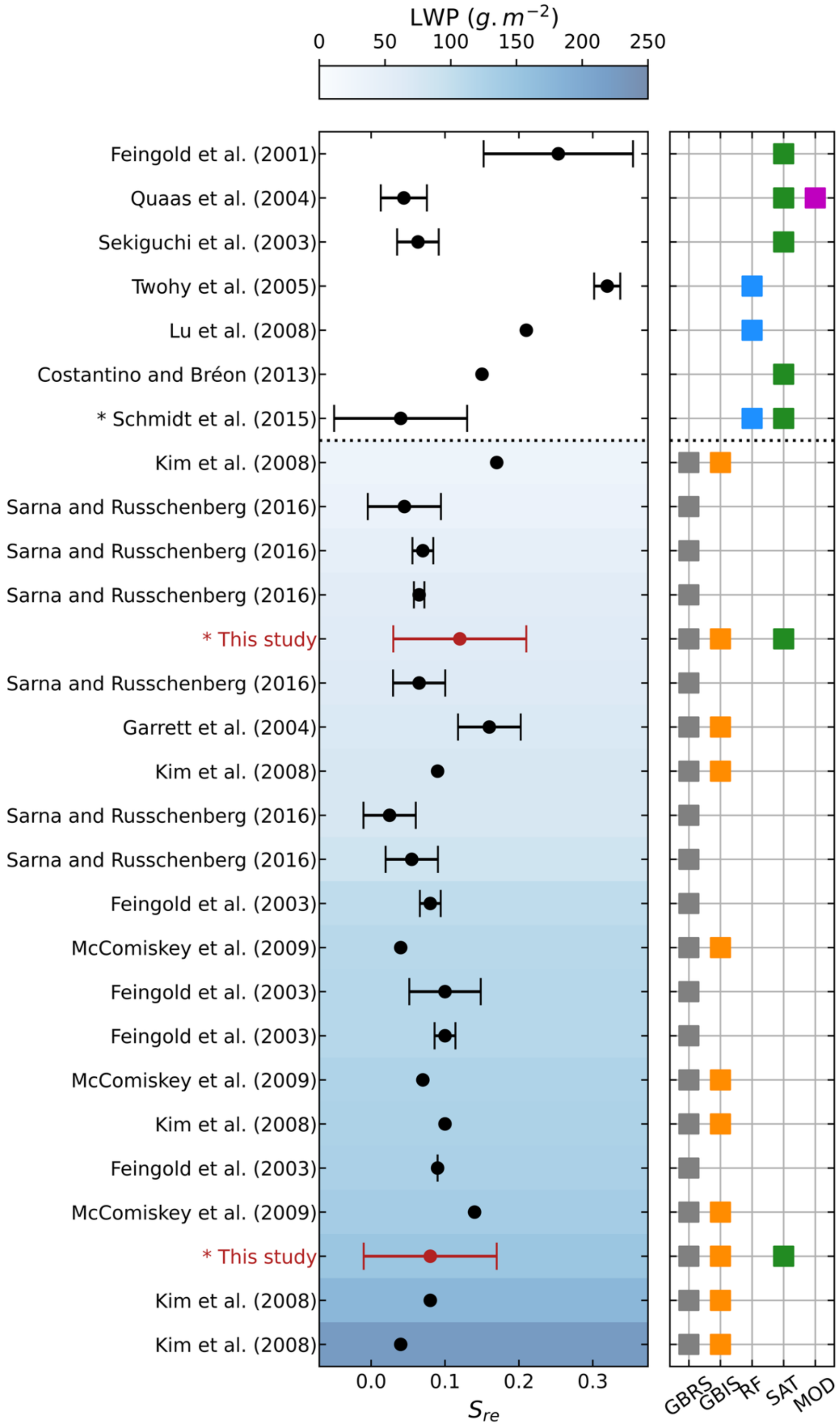


Figure R1: S_n derived from a combination of either ground-based measurements (in-situ: orange squares; remote sensing: grey squares), airborne measurements (blue squares), satellite retrievals, and/or simulation results (purple square). The white-to-blue shaded area represents the mean liquid water path (LWP) range covered across all studies. Stars indicate studies that directly reported uncertainties in their analysis, while for the remaining studies, uncertainties were recalculated using author-provided datasets for different case studies (e.g., regions or seasons) or different models. The vertical dashed line corresponds to the physical upper bound for *Sn* (all aerosol activates into a droplet). The red color corresponds to our study.



LWP ($g.m^{-2}$)
0
50
100
150
200
250
Feingold et al. (2001)
Quaas et al. (2004)
Sekiguchi et al. (2003)
Twohy et al. (2005)
Lu et al. (2008)
Costantino and Bréon (2013)
* Schmidt et al. (2015)
Kim et al. (2008)
Sarna and Russchenberg (2016)
Sarna and Russchenberg (2016)
Sarna and Russchenberg (2016)
* This study
Sarna and Russchenberg (2016)
Garrett et al. (2004)
Kim et al. (2008)
Sarna and Russchenberg (2016)
Sarna and Russchenberg (2016)
Feingold et al. (2003)
McComiskey et al. (2009)
Feingold et al. (2003)
Feingold et al. (2003)
McComiskey et al. (2009)
Kim et al. (2008)
Feingold et al. (2003)
McComiskey et al. (2009)
* This study
Kim et al. (2008)
Kim et al. (2008)
0.0
0.1
0.2
0.3
S_{re}
GBRS
GBIS
RF
SAT
MOD

Figure R2 : S_{re} derived from a combination of either ground-based measurements (in-situ: orange squares; remote sensing: grey squares), airborne measurements (blue squares), satellite retrievals, and/or simulation results (purple square). The white-to-blue shaded area represents the mean liquid water path (LWP) range covered across all studies. Stars indicate studies that directly reported uncertainties in their analysis, while for the remaining studies, uncertainties were recalculated using author-provided datasets for different case studies (e.g., regions or seasons) or different models. The vertical dashed line corresponds to the physical upper bound for S_{re} (all aerosol activates into a droplet). The red color corresponds to our study.

The novelty of the present work does not lie in the combination of the two observing systems itself, but rather in the specific framework developed to derive aerosol-cloud susceptibilities from coordinated ACTRIS ground-based aerosol measurements and geostationary satellite cloud retrievals. In particular, we focus on a methodology designed to link high-quality aerosol observations with cloud microphysical properties under well-defined low-cloud, thermodynamically stable conditions, while ensuring consistency between ground-based and satellite observations.

The study should therefore be viewed primarily as a proof of concept demonstrating the feasibility of this approach at a well-characterized ACTRIS site. Its broader objective is to establish a methodology that can subsequently be applied across multiple ACTRIS and other long-term observational sites to investigate aerosol-cloud interactions using harmonized datasets. One of the key advantages of such an extension is the availability of advanced aerosol observations within ACTRIS, including chemical composition measurements. With a sufficiently large sample size, these additional variables could be used to investigate aerosol-cloud susceptibilities as a function of aerosol type and chemical composition, thereby providing further insight into the role of aerosol properties in cloud formation and evolution.

We have revised the Introduction to better clarify the specific contribution and scope of this study.

Revised introduction : "*While the combination of ground-based and satellite observations is not new, the novelty of this work lies in the framework developed to derive aerosol-cloud susceptibilities from coordinated ACTRIS aerosol measurements and geostationary satellite cloud retrievals under carefully constrained meteorological conditions. We demonstrate how cloud droplet concentration and radius susceptibilities to aerosol burden can be calculated by combining detailed in-situ aerosol observations obtained from a ground station with cloud microphysical properties retrieved from space (Lihavainen et al., 2010; Nandan et al., 2022). This approach exploits the complementarity of the two observing systems: ground-based measurements provide robust aerosol characterization under cloudy conditions, while geostationary satellite observations provide temporally resolved cloud microphysical retrievals from a top-down perspective. By linking both datasets in space and time, susceptibility estimates can be derived under well-constrained observational conditions. Moreover, by applying the methodology to a single, well-characterized site, we explore its strengths, limitations, and underlying assumptions. The broader objective is to lay the groundwork for future applications across a network of sites, rather than to draw generalized conclusions from the present analysis. Such an extension would take advantage of the advanced aerosol measurements available within ACTRIS, including aerosol chemical composition, enabling future investigations of aerosol-cloud susceptibilities as a function of aerosol type and composition.*"

Lines 180-181: It is not clear how the space- and ground-based data were collocated spatially (nearest neighbor? something else?) and temporally. It takes ~12 minutes for SEVIRI to scan the Earth's disk from south to north. This means that the scanning time at the latitude of the ATOLL observatory occurs ~9 minutes after the nominal CLAAS-3 acquisition time. Did the authors correct for this time difference when collocating the data temporally?
We thank the reviewer for their comment. We considered the nearest pixel to collocate CLAAS-3 with the ground-based station (without any interpolation).

We propose to **specify this in the text by adding**: "*Spatial collocation between CLAAS-3 and the ground-based station was performed using a nearest-neighbour approach, i.e., the CLAAS-3 pixel closest to the ATOLL station location was selected, without any spatial interpolation.*"

We did not take the acquisition time into consideration. Even if we had, another issue would arise from the fact that the pixel resolution does not match the spatial extent of the ground station: the cloud measurements are averaged over the entire pixel, which does not correspond to the exact location of the ATOLL station, and therefore we could not draw firm conclusions about the exact collocation regardless. The clouds we consider — low-level, stable clouds — are unlikely to change drastically from one time step to the next, so the 9-minute difference likely has limited impact. In addition, for methodological consistency and ease of application, we find it simpler to keep the time provided by CLAAS-3. Finally, we do not have precise information on the exact acquisition time of the measurements. Nevertheless, it is important to note that we temporally and spatially averaged the ground-based measurements on the resolution from the satellite observations as mentioned in line 195-198 in the manuscript.

We propose to add to the text: "*It is also worth noting that SEVIRI requires approximately 12 minutes to scan the Earth's full disk from south to north, meaning that the temporal resolution, in addition to the coarse spatial resolution, may introduce further uncertainty. This effect, however, may be partially mitigated by the temporal averaging of ground-based measurements over the 15-minute CLAAS-3 resolution. Spatial collocation between CLAAS-3 and the ground-based station was performed using a nearest-neighbor approach, i.e., the CLAAS-3 pixel closest to the ATOLL station location was selected, without any spatial interpolation.*"

Section 4.1: The authors compare their findings with those from previous studies. They should also include here possible explanations of the differences found, and highlight the value that this study adds to the field. Section 4.2: Similarly to my previous comment, part of the discussion regarding explanation of differences when comparing with other studies is missing.
We thank the reviewer for this suggestion. We have expanded the discussion to compare our results and those reported in previous studies using Figure R1 and Figure R2. An important distinction is that previous studies generally did not explicitly constrain the atmospheric thermodynamic stability, whereas our analysis is restricted to stable meteorological conditions. Consequently, part of the observed differences may reflect variations in cloud dynamics rather than differences in aerosol properties alone. This effect is likely to be particularly important for studies based on airborne observations, which often sample cloud fields at relatively small spatial scales where vertical velocity can vary rapidly. Such dynamical variability may contribute to the higher (S_{re}) and (S_n) values reported. By minimizing the influence of meteorological variability through the selection of stable conditions, our methodology aims to

provide susceptibility estimates that are more representative of the aerosol contribution to aerosol-cloud interactions independently from the cloud dynamics.

Revised text for S_n: *"These results are comparable in magnitude, though somewhat lower, than those reported in the literature (Figure 5). At least 9 studies reported in Fig. 5 do not provide LWP range using a combination of either airborne measurement, satellite and simulation (Nakajima et al., 2001; Terai et al., 2012; Lu et al., 2008, 2009; Quaas et al., 2006, 2009; Sekiguchi et al., 2003; Zheng et al., 2011, Schmidt et al., 2015). They reported Sn values from 0.078 to 0.787. Sarna and Russchenberg (2016), using ground-based remote sensing retrievals of droplet number concentration and integrated attenuated backscatter, found S_n values between 0.78 and 1.59 (above the upper S_n physical bound) for two case studies with LWP between 30 and 90 g m^{-2}. Furthermore, Painemal et al. (2013) reported a Sn of 0.92 in a range of LWP centred at 55 g m^{-2} using onboard in-situ instruments. In a larger statistical analysis, McComiskey et al. (2009) reported substantially lower S_n values, ranging from 0.51 to 0.64 for LWP between 107 and 143 g m^{-2}, using MWRP-derived n_d and aerosol light scattering from a nephelometer."*

Revised text for S_{re}: *"Figure 7 presents previously reported values of S_{re} derived from a combination of ground-based observations (in situ: orange squares; remote sensing: grey squares), airborne measurements (blue squares), satellite retrievals, and/or numerical simulations (purple square). The results from this study (red symbol) are comparable in magnitude to those reported in the literature. Higher S_{re} values (0.15–0.33) are generally found in studies where the LWP range was not constrained (Feingold et al., 2001; Twohy et al., 2005; Lu et al., 2008; Costantino and Bréon, 2013). Feingold et al. (2001) and Twohy et al. (2005) reported the highest retrieved S_{re} values, ranging from 0.12–0.38 and 0.307–0.332, respectively. The elevated S_{re} values reported by Feingold et al. (2001) may be attributed to smoke-affected conditions over Brazil, whereas those reported by Twohy et al. (2005) may reflect the limited sample size (only 16 observations) and the use of aerosol number concentration measurements rather than aerosol optical properties. For low LWP conditions (below 100 g m^{-2}), Sarna and Russchenberg (2016) reported S_{re} values ranging from 0.00 to 0.09, in good agreement with our findings. In contrast, Garrett et al. (2004) retrieved a higher S_{re} value of 0.17 over the Arctic, suggesting that aerosol–cloud interactions may vary depending on the environmental conditions in which the observations are made. For higher LWP conditions (above 150 g m^{-2}), reported S_{re} values typically range between 0.02 and 0.17 (Feingold et al., 2003; Kim et al., 2008; McComiskey et al., 2009), which encompasses the values obtained in the present study. Interestingly, based on cloud-radar estimates of r_e and Raman lidar aerosol extinction, Feingold (2003) derived S_{re} values of 0.03–0.16 from seven cases observed at the DOE ARM Southern Great Plains site in Oklahoma. Using the same methodology at the same site, Kim et al. (2008) reported comparable S_{re} values (0.04–0.17) from a much larger, three-year dataset of continental stratus clouds. This close agreement suggests that, when the retrieval methodology and observational setting are consistent, the number of observations alone may not substantially influence the retrieved S_{re} values. »*

Line 326 (see also my comment on line 22): The authors attribute the only 2 LWP bins that they use to the small size of their sample. In fact, it is not clear what the LWP binning offers here: results are very similar in both bins, for both n_d and r_e.

As this issue was also raised by Reviewer 1, we have addressed it in the same way. We agree that the final sample size is limited, and that splitting the dataset further reduces the number of observations available in each subset. However, liquid water path (LWP) is a key controlling variable in aerosol-cloud interaction studies. The classical Twomey and Albrecht effects are generally evaluated under approximately constant LWP conditions to reduce the influence of cloud macrophysical variability on cloud microphysical properties. Furthermore, several studies have shown that aerosol cloud susceptibilities exhibit a strong dependence on LWP. In particular, Zheng et al. (2020) demonstrated systematic variations in cloud susceptibility as a function of LWP.

For this reason, we chose to separate the dataset into LWP ranges commonly used in the literature. Although the limited sample size prevents robust statistical conclusions, this stratification allows a more meaningful comparison with previous studies and avoids mixing cloud regimes characterized by substantially different liquid water contents.

We have clarified this motivation in the revised manuscript and explicitly acknowledge the limitations associated with the reduced number of observations in each bin. **Revised text :** *"In this section, the cloud droplet number and effective radius susceptibilities to aerosol loadings will be estimated. Although dividing the dataset into liquid water path (LWP) classes reduces the number of observations available in each subset, this stratification is essential in aerosol-cloud interaction studies. LWP is a key controlling variable, and the classical Twomey and Albrecht effects are generally evaluated under approximately constant LWP conditions to minimize the influence of cloud macrophysical variability on cloud microphysical properties. Moreover, several studies have shown that aerosol-cloud susceptibilities strongly depend on LWP. In particular, Zheng et al. (2020) reported systematic variations in cloud susceptibility across different LWP regimes. Consequently, separating the analysis by LWP provides a more physically meaningful interpretation of the retrieved susceptibilities, despite the reduction in sample size."*

Minor comments

Line 79: it is mentioned that the instruments are positioned "at least one meter above the rooftop", but what is their height relative to the ground?

The station is located at 60 m above sea level as stated in the station description. The site altitude is around 41 m altitude. Therefore, the altitude of the inlet is 19 m above the ground level. The altitude above sea level was replaced by the altitude above ground level.

Line 104: Is there a reference for the neural network mentioned here?

We thank the reviewer for pointing this out. We have now added the appropriate references describing the retrieval methodology used by the RPG-HATPRO G5. The neural network approach implemented for the retrieval of atmospheric temperature and humidity profiles is described by Rose et al. (2005), while additional details on the retrieval accuracy and methodology can be found in Crewell and Löhnert (2007) and Löhnert and Crewell (2003). These references have been added to the revised manuscript.

Crewell, S., & Löhnert, U. (2007). *Accuracy of boundary layer temperature profiles retrieved with multifrequency, multiangle microwave radiometry.* **IEEE Transactions on Geoscience and Remote Sensing, 45**(7), 2195–2201.

Löhnert, U., & Crewell, S. (2003). *Accuracy of cloud liquid water path from ground-based microwave radiometry: Part I. Dependency on cloud model statistics.* **Radio Science, 38**(3), 8041. https://doi.org/10.1029/2002RS002654

Rose, T., Crewell, S., Löhnert, U., & Simmer, C. (2005). *A network suitable microwave radiometer for operational monitoring of the cloudy atmosphere.* **Atmospheric Research, 75**(3), 183–200. https://doi.org/10.1016/j.atmosres.2004.12.005

Line 110: “and 0.4 g m^{-3} RMS.” Consider adding “for liquid water content” for clarity. Please also add a reference for these numbers.

We thank the reviewer for pointing this out. The accuracy values originally reported were taken from the instrument manufacturer's manual. Following the reviewer's suggestion, we have replaced this citation with a peer-reviewed reference (Walbröl et al., 2022), which reports retrieval uncertainties evaluated against radiosonde observations. We also realized that the value of 0.4 g m^{-3} was not attributed to any parameter. It actually corresponds to the uncertainty in absolute humidity retrievals. Since LWC is not directly retrieved by the microwave radiometer but is derived from the retrieved liquid water path using an adiabatic-cloud model, its uncertainty depends on the assumptions of the adiabatic retrieval and cannot be represented by a single instrumental RMSE. The manuscript has **therefore been revised accordingly and now reads**: "*The profile accuracies are typically on the order of 0.7–1.8 K RMS for temperature and 0.45–0.6 g m^{-3} RMS for absolute humidity, depending on altitude (Walbröl et al., 2022).*"

Line 155: “… is also retrieved from the cloud optical depth, r_e considering …”. I assume the authors mean “… is also retrieved from the cloud optical depth **and** r_e considering …” ?
This has been corrected accordingly in the new version of the manuscript.

Table 1 contains useful information but is not mentioned anywhere in the text.
We apologize for this mistake. This is now done in the introduction of section 3. : *“In this study, we leverage a comprehensive dataset, summarized in Table 1, combining in-situ and remote sensing observations from both ground-based and satellite platforms to investigate aerosol-cloud interactions (see section 4) over the 2020–2024 period.”*

Lines 197-198 should read “to determine the height of the boundary layer (e.g. Sinclair et al., 2022)”.
That is now corrected.

Line 328: “A similar tendency appears to be present here”. I don’t think this claim can be made here, even if the authors are cautious to state that “the large uncertainties prevent this behaviour from being statistically confirmed”. Please consider removing it.
This sentence is now removed.

Line 331 should read “… how cloud droplet concentration and **effective** radius susceptibilities …”
That is now corrected.