Review of “Numerical Case Study of the Aerosol-Cloud-Interactions in Warm Boundary Layer Clouds over the Eastern North Atlantic with an Interactive Chemistry Module” by Lee et al. [Research Article, egusphere-2024-3199]

This study evaluated the simulations of three stratocumulus cloud cases in the ENA regions, each influenced by distinct weather regimes, using the WRF-Chem model. A key strength of this model is its ability to simulate aerosol-cloud interactions (ACIs) more realistically, thanks to its incorporation of aerosol chemical components and its consideration of aerosol spatiotemporal variations. The authors found that the model captured the liquid water path (LWP) and cloud fraction across the three cloud cases. They further investigated ACIs by conducting aerosol perturbation experiments, revealing a significantly positive LWP susceptibility in precipitating clouds due to precipitation suppression. They also identified some signals of negative LWP susceptibility, driven by aerosol drying effects in non-precipitating clouds, particularly at the cloud edges. Overall, the paper is well-organized and well-written, and the sensitivity experiments are thoughtfully designed. The findings regarding how LWP responds to aerosol perturbations under different weather regimes have important implications for improving stratocumulus simulations in the future. However, I have some concerns about the baseline simulation biases and their potential impact on the modeled ACIs. Addressing these issues would enhance the robustness of the study. If these concerns are resolved, I believe this paper will be suitable for publication in ACP.

**Major comments:**

1. The authors emphasize that the WRF-Chem model can potentially better represent cloud macrophysics due to its incorporation of aerosol chemical components and spatiotemporal variations. However, the model significantly underestimated LWP in all three cases, particularly the peak values, as illustrated in Figure 6. So, I am curious whether WRF-Chem can genuinely improve stratocumulus simulations through its refined representation of aerosol processes. Did the authors compare these results with those obtained using the standard WRF version? Additionally, the authors provided some potential explanations for the large LWP biases. For instance, in the 20170719 case, they suggested that these biases might stem from delayed moisture transfer from the outer domain or insufficient vertical resolution. Have higher vertical resolution simulations been tested to assess potential improvements? Also, including a precipitation evaluation in Figure 6 could help interpret the LWP and CF biases.

I think the accurate simulation of LWP in baseline simulations is the premise for the subsequent LWP susceptibility studies. If the simulated LWP in non-precipitating clouds is biased too low, the results might show a weaker negative LWP susceptibility or even no signal due to reduced cloud-top entrainment. Similarly, biases in LWP for precipitating clouds could impact the positive LWP susceptibility. If further improvements to LWP simulations are not feasible, the potential influence of these biases on the LWP susceptibility findings should be at least discussed.

2. Regarding LWP susceptibilities, I suggest that the authors expand their discussion by comparing the modeling results with observations, such as nearby ship tracks or observed LWP susceptibilities

at the ENA site. Such a comparison would help identify potential biases in the model's representation of cloud physics and enhance the broader implications of this study.

The authors investigated the variation of LWP susceptibility over time, finding positive susceptibilities during periods of no rain or light rain and negative susceptibilities during rain periods. However, previous studies (e.g., Hoffmann et al., 2024) typically observed positive susceptibilities in precipitating clouds and negative susceptibilities in non-precipitating clouds. Could the authors reconcile these seemingly contradictory findings?

3. The method used by the authors to aggregate simulation grids to calculate LWP susceptibility is not very clear. Including an illustration could help readers better understand this process. Also, it appears that the authors assumed a linear relationship between LWP and CCN in log space when calculating LWP susceptibility. However, this relationship might be non-linear or exhibit a reversed "V" shape, particularly when both precipitating and non-precipitating cases are included (e.g., Hoffmann et al., 2024). How did the authors account for the potential non-linear nature of this relationship when calculating LWP susceptibilities?

**Some technical suggestions:**

1. In many figures, the font size (including titles, axis labels, and tick labels) is too small to read. I suggest increasing the font size for better readability.
2. Please include Local Solar Time in the figures when discussing diurnal cycles to provide clearer context.
3. Please highlight raining periods in the relevant time series figures using colored boxes to make these periods easier to identify.

**Minor comments:**

L53: “Large-Eddy Simulation scale” to “large-eddy scale”

L55: I’d suggest reconsidering the phrase “accurately capturing the LWP and CF,” as the large biases shown in Figure 6 do not fully support this claim.

L158: Could you clarify whether “cloud fraction” here refers to the low-level cloud fraction or the liquid cloud fraction? What is its precise definition?

L179: Is it in-cloud LWP or aggregated into grid-mean LWP? Please clarify.

L218: Please clarify domain sizes for each domain.

L222: What is the vertical resolution near the PBL top? Using a finer resolution here will help improve the representation of entrainment processes.

L250-253: Is there any chance to validate the calculated aerosol number concentration against observations?

L302: May also check the modeled CF.

L305: It seems like simulated clouds are overly scattered. Any reasons for that?

L310: For Figure 3, I'd suggest replacing absolute temperature with potential temperature that better depicts the static stability of the lower atmosphere. Also, please mark the inversion height for better readability. Please correct typos: "(b" and "(d" to "(b)" and "(d)".

L313: Which period for the biased inversion layer height?

L314: "and shows in Figs. S1a" to "as shown in Figs. S1a"

L319: Which period?

L330: I'd expect a stronger simulated inversion for the lower simulated PBLH. But why is the inversion layer weaker compared to observations?

L351-353: Is it because winds fields are better simulated in free troposphere than in the PBL?

L385: Please add local solar time in Figure 6.

L386: Please clarify what 4 km- and domain-average mean in the main text. Also, which domain is larger?

L414: Have you checked a shorter moisture input?

L419-421: Physically speaking, is it possibly due to stronger simulated shallow convection, which penetrates stratiform decks and break them up?

L427: Please mark the time period of two systems in the figure.

L433: The underestimation of LWP and CF, right?

L434: Do you mean a weaker cloud-top entrainment due to reduced cloud-top radiative cooling, leading to a shallower PBLH?

L457: Please mark the cloud top height in the figure.

L465: "which is the assumptions" to "specifically the assumption"

L480: "the most aerosols within" to "the most aerosols are within"

L487: Revised to high Aiken-mode aerosol number concentrations.

L517: "three" to "four"

L550-551: Does it precipitate during this period?

L559: Any reasons?

L569-571: Please provide an illustration to clarify this.

L614: "motioned" to "mentioned"

L625: It seems that you are referring to the 20160701 case. Please double check.

L657: I am curious why the LWP susceptibilities are not positive during rain events, given the precipitation suppression effect of aerosols, especially since aerosol perturbations are introduced at the start of the simulations. The explanation of negative susceptibilities due to aerosol-enhanced evaporation seems more plausible if aerosols were added immediately after the rainfall events.

L669: Is it possible the thin cloud deck rather than the cloud edges? Any evidence supporting your assumption?

L704: “struggle” to “struggles”

L707-708: If so, please justify why these cases are still appropriate as baseline simulations for understanding ACIs. (or see major comment #1).

L722-723: “not only promotes evaporation but also” to “promotes evaporation, thereby leading to”

L1097: “observaed” to “observed”

L1176: “percentile” to “Percentile”

Reference:

Hoffmann, F., Glassmeier, F., & Feingold, G. (2024). The impact of aerosol on cloud water: a heuristic perspective. *Atmospheric Chemistry and Physics*, *24*(23), 13403–13412. https://doi.org/10.5194/acp-24-13403-2024