Review of "Natural Marine Cloud Brightening in the Southern Ocean" by Mace et al. (acp-2022-571)

The presented study analyzes strong gradients in the cloud droplet concentration found in the Southern Ocean, using five years of satellite observations. The authors show that these stark differences in the cloud microphysical composition can be traced back to biological primary production at the Antarctic Shelf, from where airmasses with high cloud droplet concentrations are moved to the north, while low cloud droplet concentrations originate from the open sea equatorward.

Despite many technical issues and a few minor comments, I enjoyed reading this manuscript. In a concise way, the article informs about the aerosol and cloud microphysics of an important region of the Earth. Thus, I support publication in *Atmospheric Chemistry and Physics* once my concerns are addressed. However, this article is also submitted to be published as an *Atmospheric Chemistry and Physics Letter*. In the current form, I cannot support the publication in this format, as I will outline in my only major comment below, but I am willing to be convinced otherwise.

Major Comment

Does the article meet the requirements for an Atmospheric Chemistry and Physics Letter? It is stated that an *Atmospheric Chemistry and Physics Letter* must fulfill the following requirements (see www.atmospheric-chemistry-and-physics.net/about/manuscript_types/acp_letters.html):

- Important discoveries and research highlights in atmospheric chemistry and physics.
- Solutions to or progress with long-standing and important questions in atmospheric research.

In its current form, the manuscript does not give substantial hints on how these requirements are fulfilled. I understand that the Southern Ocean is one of the least understood parts of the climate system, with inherent problems in modeling it. But how does the presented study contribute to improving its understanding? What are the important discoveries made? While I admit that the presented research is very interesting, the authors should use the opportunity to frame their work and highlight the advancements made through their work.

Minor Comments

Ll. 47 – 50: What cloud process is sensible to the CCN concentration? In non-precipitating clouds, an increase in CCN will not change the precipitation efficiency. I guess the authors refer to the cloud albedo.

Ll. 56 – 58: Define what "primary production" is. This will also help to frame the importance of the work (major comment). Do ll. 79 – 84 also refer to primary production?

Ll. 105 – 108: What is the purpose of this sentence? N_d and r_e are in opposite phase, not out of phase. So there is a very tight relationship.

L. 108: Replace "cycle" with "variability"?

Fig. 2b: Add labels. The blue line represents locations with $N_d > 101$ cm^{-3} and the green line $N_d < 42$ cm^{-3}. What about adding a red line for 42 cm^{-3} < N_d < 101 cm^{-3}?

Ll. 113 – 117: The LWP changes non-monotonically with N_d. It increases with N_d for precipitation stratocumulus, but decreases for non-precipitating stratocumulus due to increasing entrainment rates (Glassmeier et al. 2021).

Ll. 131 – 134: Why is N_d only large at the ACFA and not below it?

Ll. 135 – 139: With a mean r_e of 13 µm north of the ACFA, droplet coalescence might decrease N_d. See, e.g., Freud and Rosenfeld (2012), who showed that at 14 µm surface precipitation occurs, i.e., there is probably some drizzle at a slightly smaller r_e. This should be discussed.

Ll. 275 – 278: The significantly lower adiabaticity north of the ACFA could be due to precipitation, triggering the transition of closed- to open-cell stratocumulus. Discuss the possibility of precipitation.

Ll. 297 – 300: Clouds with $r_e > 14$ µm are usually precipitating (Freud and Rosenfeld 2012). Declaring all pixels with $r_e < 50$ µm to non-precipitating clouds will cause a substantial bias. Please elaborate.

Technical Comments

L. 32: "Both" usually refers to two objects. Here, it refers to three (latitudinal, longitudinal, and temporal). Revise.

L. 45: SO for Southern Ocean is already defined. Use it.

L. 55: To what is "respectively" referring to?

L. 66: Why is "TOF" defined? It is never used.

L. 88: "ACF" is not defined. Only "ACFA".

Ll. 91, 109, 182: "N_d", not "Nd".

L. 96: See Shaw et al. (1988) for what?

Fig. 1, l. 122: Define "Chl-a".

Fig. 1: What are "MOD" and "MYD"?

Ll. 128 – 129: Switch "upper" an "lower"?

L. 189: Define G18.

L. 213: Use "PP" instead of "primary production".

L. 269: "A1", not 1.

References

Freud, E., & Rosenfeld, D. (2012). Linear relation between convective cloud drop number concentration and depth for rain initiation. *Journal of Geophysical Research: Atmospheres*, *117*(D2).

Glassmeier, F., Hoffmann, F., Johnson, J. S., Yamaguchi, T., Carslaw, K. S., & Feingold, G. (2021). Aerosol-cloud-climate cooling overestimated by ship-track data. *Science*, *371*(6528), 485-489.