Comment on acp-2021-861
Anonymous Referee #1

Referee comment on "Stability dependent increases in liquid water with droplet number in the Arctic" by Rebecca Jonette Murray-Watson and Edward Gryspeerdt, Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2021-861-RC1, 2021

Stability dependent increases in liquid water with droplet number in the Arctic by Murray-Watson and Gryspeerdt 2021

Under the background of global warming and Arctic amplification, the aerosol-cloud relationship is becoming increasingly important in the polar region. However, this relationship is hard to quantify in the high latitude due to a limited number of observations in the Arctic. Using MODIS and AMSR-E satellite retrievals, this work studies the effects of aerosols on liquid Arctic clouds over open ocean under different metrological conditions (specific humidity, LTS). Particularly, they focus on the relationship between cloud droplet number concentration (Nd) and liquid water path (LWP). Overall, this paper is well written and easy to follow. However, there are still some major deficiencies in the current version and need to be carefully handled. For example, it is concluded that there is a positive LWP-Nd relationship under high LTS condition. However, if we take a further look, the LWP-Nd relationship is not clear and strong enough when Nd falls into [50,200], which is very common based on the analysis in this paper. In addition, the authors did not check whether this relationship differ by season. Therefore, this paper should be accepted only if my concern has been well addressed.

Please find my specific comments as below.

Major comments:

Section 2-Materials and Methods:

1) What are the original spatial resolutions for AMSR-E and ERA5 data sets? In addition, it is highly recommended to generate a flow chart or schematic diagram to show how you filtered out cloud data to reduce retrieval bias.

2) Give the unique environment of Arctic, it is very challenging to obtain accurate cloud information over the Arctic. Therefore, there should be more discussion on uncertainties in satellite-retrieved cloud properties in the Arctic.
Reference:
A radiation closure study of Arctic stratus cloud microphysical properties using the collocated satellite-surface data and Fu-Liou radiative transfer model:
https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2016JD025255

Figure 1: I would believe that the data samples are highly variable across regions and seasons, given the filtering steps mentioned in Section 2. Can you provide a separate spatial map to show the number of samples by season?

Section 3.2: There is no explanation on how you separated the positive and negative sensitivity regions. Are there enough and comparable samples in both regions?

Line 158-162: The explanation on ocean-air temperature gradient and LTS is not clear enough. In general, smaller ocean-air temperature gradient occurs with melting ice in summer, thereby increases the atmospheric stability. In comparison, there is lower atmospheric stability in autumn due to larger ocean-air temperature difference. It is also valid for spring.

In addition, why do the positive sensitivities occur under high LTS conditions?

References:
Covariance between Arctic sea ice and clouds within atmospheric state regimes at the satellite footprint level:
https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2015JD023520

Thicker clouds and accelerated Arctic sea ice decline: The atmosphere–sea ice interactions in spring:
https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2019GL082791

Line 163-170: Have you tried to test this relationship the specific humidity in other vertical levels? Are you expecting any differences?

Line 191-193: Here, you mentioned that very low Nd conditions are relatively rare in the Arctic and therefore have little impact on the linear sensitivity. Based on Nd histogram in Figure 4, Nd between 50 and 200 (roughly) are more common. However, the LWP-Nd relationship is not clear when Nd falls into [50,200] under high LTS conditions, regardless of high or low q750. It seems to me that there is no any significant LWP-Nd relationship. How do you explain this?

Figure 4: Are these relationships different by season?

Minor comments:

Line 15: “As the LTS is projected to decrease in a future, warmer Arctic...” Change it to “As the LTS is projected to decrease in a warmer Arctic”

Line 15: “As the LTS is projected to decrease in a future, warmer Arctic, these results show that aerosol increases may produce lower cloud water paths, offsetting their shortwave cooling effect.” If this is the case, what is the overall implication to Arctic climate?

Line 22: “These smaller droplets increase cloud albedo and lead to a shortwave cooling
effect.” Are you talking about shortwave cooling effect at TOA?

Line 43-52: It is better to move this paragraph to the beginning of the Introduction section as it highlights the importance of Arctic clouds and aerosol-induced changes to cloud radiative effects.

Line 56-57: “Coopman et al. (2016) found that if meteorology is not accounted for, the magnitude of the Arctic clouds response to aerosol is artificially increased by a factor of three.” What do you mean by “artificially increased”? Please be specific.

Equation (1): I can’t understand that why the breakdown of LWP-AOD relationship by Nd is helpful. As you mentioned that aerosol retrieval is very limited in the Arctic, we will still need Nd-AOD ratio to derive LWP/AOD relationship, right?

Line 132: “This may be due to a potential negative bias in the MODIS data due to retrieval errors (Gryspeerdt et al., 2019).” A negative bias in which variable?

Line 154: “The r² values of the correlation between the sensitivity is higher” What correlations did you refer to? Please be specific.

Line 233-244 and Line 264-266: It would be important to further link the changes in LWP with Arctic sea ice to demonstrate the large-scale impact of liquid cloud on Arctic climate.

References:

Evidence of Strong Contributions From Mixed-Phase Clouds to Arctic Climate Change: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018GL081871

The climate response to increased cloud liquid water over the Arctic in CESM1: a sensitivity study of Wegener–Bergeron–Findeisen process: https://link.springer.com/article/10.1007/s00382-021-05648-5

Cloud Phase Changes Induced by CO2 Warming—a Powerful yet Poorly Constrained Cloud-Climate Feedback: https://link.springer.com/article/10.1007/s40641-015-0026-2