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Comment on acp-2021-861

Anonymous Referee #2

Referee comment on "Stability-dependent increases in liquid water with droplet number in the Arctic" by Rebecca J. Murray-Watson and Edward Gryspeerdt, Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2021-861-RC2, 2021

Review of "Stability dependent increases in liquid water with droplet number in the Arctic" by R. Murray-Watson and E. Gryspeerdt

Overview

This paper uses satellite retrievals and reanalysis data to investigate the effects of aerosol on Arctic liquid clouds. The authors observe a positive response in LWP to Nd in high latitudes, which contrasts with previous studies that show a weak correlation between the two. The paper is well motivated, with a clearly identified gap in current knowledge and comparison to results from similar studies throughout. The authors did a good job of linking statistics of Nd, LTS, q750, and LWP to physical processes such as precipitation suppression, droplet evaporation, and cloud-top entrainment. While I do not think any further analysis is required, additional analysis could be useful to better understand the indirect effects in this region and some of the discussion could be improved.

Main Comments

- My primary comment is on the choice of meteorological factors considered in this study. While the authors did a good job of justifying the use of LTS, free tropospheric moisture, and MCAO as meteorological indices by referencing their use in previous studies, I think more discussion of other potential meteorological influences on the LWP-Nd relationship would be beneficial. In the results, LTS is shown to be the most significant of the chosen metrics in predicting whether the LWP-Nd relationship is positive or negative. However, the r^2 is still fairly low at 0.39. What other factors, especially those mostly independent of LTS, could be influencing the LWP-Nd relationship, and could there be a better predictor than LTS?
- Figure 4 shows the most interesting results of this study. I spent quite a bit of time

contemplating this figure and I think the discussion of the figure could be improved. First, the authors may want to point out explicitly that LWP begins to decrease with Nd at high Nd, high LTS, and low q750. To a lesser extent, the low LTS & low q750 panel shows the same thing as high LTS & low q750, namely, an initial increase in LWP with Nd followed by a decrease in LWP. The big difference is that at high LTS the peak in LWP is around 100/cm3 whereas at low LTS the peak in LWP is at 20/cm3. This difference leads to the interesting patterns in panel h. So, the question to me seems to be why precipitation suppression (which is driving an increase in LWP) at low LTS ends so early. Is it because at low LTS precipitation is weaker for a given Nd? Or is it that the drying effects of mixing are much stronger for low LTS and so precipitation suppression is less evident? The latter seems more likely. As written now, there is no discussion of precipitation in explaining panels g and h.

- Finally, the authors discuss moisture inversions frequently, but I'm not convinced that they need to be invoked in order to explain anything in this study. For example, moisture inversions are discussed in lines 209-211. But can't the clouds in the Arctic have higher LWP at low LTS for the same reasons as discussed in lines 203-206? And generally, I'd think that more moisture above cloud top should reduce evaporation, regardless of whether it is in the form of an inversion or not.

Minor Comments

- Line 12: LTS isn't necessarily the driving force behind spatial variations in LWP response, just the strongest of the metrics studied here. I'm uncomfortable with "driving force" given that the R2 value was somewhat low even for LTS.
- Line 23: Smaller droplets lead to *smaller* coalescence rates.
- Line 25: See also Williams and Igel (2021) who argue that smaller droplets radiatively cool cloud top more quickly, generating turbulence, etc. as already stated.
- Section 2: Can the authors mention somewhere that they're using sunlit times only?
- Line 130: Caption for Fig 1 states panel (b) is JJA not all seasons. Figure 1: Panel (b) says "AMSR-E all seasons" but caption reads "AMSR-E June, July, and August". Please double check everything for consistency.
- Line 172: I'm not sure what was meant by this sentence. The "small influence" seems at odds with "a strong response".
- Lines 219-220: Not sure what is meant by the background Nd state.
- Section 5: The authors might remind readers that they've only analyzed liquid clouds and not mixed-phase clouds.