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Interactive comment on “Vertical Dependence of Horizontal Variation of Cloud Microphysics: Observations from the ACE-ENA field campaign and implications for warm rain simulation in climate models” *by* Zhibo Zhang et al.

Anonymous Referee #1

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This is an interesting and well written paper which discusses the variability of cloud water content, droplet number, and correlation between the two in stratiform clouds. The key findings seem to be the positive correlation between the water content and drop number, and the vertical dependence of this correlation, increasing towards cloud top. The consequences of these results for autoconversion parametrizations is discussed, showing that including the correlation is crucially important for getting the enhancement factor correct, although neglecting variation in drop number entirely is a surprisingly good estimate. I recommend publication after addressing some minor comments I’ve

listed below.

Minor comments

1. L45 and elsewhere - does the vertical dependence of EF really need to be accounted for, or would it suffice to simply get it right at cloud top? If the model is correctly representing the domination of accretion throughout the remainder of the cloud (e.g. as in Wood et al (2005b)), then autoconversion and the EF applied to it shouldn’t matter so much here.

2. L103 - it would be worth noting here or later that some CMIP6 models (e.g. Walters et al, 2019, GMD) have adopted variable enhancement factors (better options!) based on the recent work cited, so it’s not quite as bad as presented.

3. L157 - you could also note here that this suggests an equal amount of time should be dedicated to EFs for accretion, something which certainly isn’t the case in the literature!

4. L271-273 - are your statistics for variance and correlation then only calculated in regions where qc>0.01g/m3, i.e. over the cloudy portion of the leg which may be <10km, or are they calculated over the entire >10km leg and include points where qc<0.01g/m3 (i.e. the zeros). As this is an important distinction, as it significantly affects the results (as shown in Witte et al, 2019, JAS) and also important for model developers to know to implement correctly in their microphysical parametrization (i.e. does the scheme work on in-cloud quantities or grid-box mean quantities).

5. Section 4.1 - how much do you think the results are affected by the non-stationarity of the cloud being sampled. i.e. for a model parametrization, you are interested in the variability at different heights within the cloud at the same time. But what you are sampling is the variability at different heights in the cloud at different times, up to several hours apart. The cloud is clearly evolving in this time, and how much might that evolution be affecting the results. For example, just looking at the variability in reflectivity in Figure 1 suggests there may be external factors affecting the cloud amount and drop

number, and currently this variability is being attributed to the height at which the flight leg during that period happened to be at.

6. Section 4.2 - do you have any hypothesis or theory why qc and Nc are positively correlated? Is there a physical mechanism for the correlation, or just something that happened to be the case for this study? One could imagine that areas with lower Nc will precipitate easier, thus lowering qc?

7. L491 - as with the comment above, do you think this really is a fortunate cancellation, or is there some underlying physical mechanism?

Typos

L41 - should say "effect that tends to make".

L60 - should probably say "e.g. Morrison and Gettleman" as theirs isn't the first or only scheme out there.

L538 - this should say "Eq is significantly larger than E" I think.

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