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Interactive comment on "Radar-radiometer retrievals of cloud number concentration and dispersion parameter in marine stratocumulus" *by* J. Rémillard et al.

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Reply to Reviewer 1

Specific Comments:

7508/24 *Please clarify what you mean by cloud scale when referring to Sc or St. Also, the reference to 'smaller' is made without clear indication of what is being compared.*

Authors Answer: The revised version will state 'small' instead of 'smaller', and specify that 'cloud-scale' means spatial scales of tens of meters and temporal scales of a few minutes or less.

7509/8 *What is the meaning of 'multi-synergistic'?*

Authors Answer: This should have read simply 'synergistic'.

7513/6 *This seems to be a misreading of the Miles et al. paper or ambiguity in the definition of the dispersion parameter referred to. In Fig. 5 of Miles et al. the dispersion is clearly seen as increasing with height.*

Authors Answer: The reviewer is right to point out that the name 'dispersion parameter' is rather ambiguous. In this paper, it always refers to the logarithmic width of a lognormal PSD (or to a function of only that parameter). On the other hand, Miles et al. defined various dispersion and width parameters for their paper. For instance, the observed width of the distribution is defined as the "standard deviation about the mean diameter ($\sigma_{v,obs}$)", while the logarithmic width of the lognormal distribution (σ_{log}) gets related to $\sigma_{v,obs}$ through the median diameter of the lognormal distribution ($D_{n,log}$) in their Eq. 7c (or through the observed mean diameter ($D_{m,obs}$) using their Eq. 7b). Therefore, although they report an increasing $\sigma_{v,obs}$ with height, its ratio with $D_{m,obs}$ (named the "spectral dispersion") appears somewhat constant with height (see their Fig. 5, and associated discussion). From their Eqs 7b and 7c, that ratio is a function of σ_{log} only. Thus, by extension, the σ_{log} (or σ in this paper) appears constant with height in the observations.

7513/9–12 *If sigma is constant with height and variations in N are small, the LWC would have to be nearly constant. Something wrong here.*

Authors Answer: The cloud PSD has three parameters (N_{cld}, σ, r_0). Most changes with height in LWC are usually accounted for by one of those parameters. Empirically-obtained LWC–Z power-law relations have an average slope only slightly larger than 0.5 (e.g., Sauvageot and Omar 1987; Liao and Sassen 1994; Fox and Illingworth 1997), leading to a relationship close to Eq. (5). Here, Eq. (5) has been obtained by eliminating

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r_0 from Eqs (3) and (4), implying that the main parameter responsible for the variability of Z with the LWC is r_0 and not the two remaining PSD parameters. If N_{cld} was the main parameter, the empirical slope of the LWC–Z relation should be closer to 1, and if σ was the main parameter, a slope close to 4 would be expected.

7513/16 *The intention in weighting by Zˆ0.5 seems to be to introduce some measure of mass (LWC). Why? What is the consequence of doing this? How well does it work when the PSD varies? Even though this is adapted from Frisch et al., the impact of this step on the application here developed deserves some examination.*

Authors Answer: This choice of weighting function came naturally from Eq. (5), to keep in the integral only the observable quantities.

7513/17 *Why is this step called a retrieval and not just a rearrangement of the equation to solve for N.*

Authors Answer: The reviewer brings an interesting point. Although Eq. (7) comes from a simple rearrangement of Eq. (6), the left-hand-side variable can be retrieved directly from the observations. So, this will be reformulated to emphasize this duality.

7514/eq. 10 *Isn't this equation valid only if sigma is invariant with height?*

Authors Answer: In Eq. (10), the rate of change with height of the amplitude of the backscatter energy at a given range gate is introduced as proportional to $6r^5\frac{\mathrm{d}r}{\mathrm{d}z}$, taking the PSD parameters at a given gate.

7515/8 *On what horizontal scales can the Korelev-Mazin assumption be applied? Are the results here obtained consistent with the assumption of the Korelev-Mazin theory?*

Authors Answer: Korolev and Mazin argued in their paper that the averaging of in situ measurements, to find supersaturation, should be done over scales larger than a characteristic spatial scale l_p (their Eq. (39)). In stratocumulus, this scale is in the order of 1 m, which is smaller than a radar volume. Overall, the results appear consistent with their theory. Although not shown in the paper, the relaxation time described in Korolev

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and Mazin (Eq. (17) or (18)) was computed, and it was found to be small enough (typically between 1 and 2 s, which is similar to what they had found) to assume that their quasi-steady state theory could be applied within a radar volume.

7517/1–16 *This paragraph seems to be running about in circles about drizzle presence with the lack of radar echo below cloud base as the only criterion being applied . How about the magnitudes of Z?*

Authors Answer: The reviewer brings an important point. The goal for this section was simply to demonstrate the potential of the technique. It was beyond the scope of the paper to actually isolate the cloud contribution in the measurements. Thus, simple arguments are made to justify the choice of these two cases. The absence of significant drizzle is more fully described at the beginning of each subsection. In a revised version, all criteria will be briefly mentioned in that paragraph too. The other criteria are the increase of Z with height, and the low values of LWP. The actual magnitudes of Z are not used, as Liu et al. demonstrated that such a criterion is highly variable and subjective. Also, Kollias et al. showed that drizzle particles are present even at really low values of Z. Still, the fact that Z remains below -20 dBZ indicates a fairly limited production of drizzle particles.

(cont'd) What explains the large range of values derived for Ncld both in the vertical and in the horizontal? No clear correlation is evident in the results between Ncld and updraft, so are we to assume that the the variations in N are the result of local variations in CCN? Is that a reasonable result? How does this variability in Ncld square with the statement on 7513/11–12?

Authors Answer: Although it was beyond the scope of the paper to fully analyze the results, the reviewer's concerns are relevant. This will be addressed in the revised version. First, the strong vertical variations near the top comes from the weighting done there after the retrievals, to account for mixing which has caused a drop in Z (p. 7516/ l. 6–9). Line plots will be added to show the time series of the mean and standard deviation of N_{cld}. These show that the variability in height is small (typically $< 30\,\%$ of the mean value), while the variations in time are relatively smooth. The correlation of N_{cld} and w_{air} was investigated. Effectively, they were only weakly positively correlated. Looking at the results of Pinsky et al. 2012, the correlation between the updraft and the fraction of activated aerosols is not expected to be very strong. Also, Martucci and O'Dowd found similar variabilities in their retrieved N_{cld}, for which they discuss the in-cloud dynamics to partly explain the variability origin.

(cont'd) Mixing seems to have been assumed to have no role in the cloud structure. If so, please state the limitations of that assumption. Again, there is a need to provide some explanation for both the observed and retrieved variations in all scales in terms of the model assumption.

Authors Answer: Mixing close to the cloud top is considered to occur through the entrainment of dry air, as depicted by a decrease in the reflectivity values with height. It is taken into account when retrieving $N_{cld}(z)$ in those areas. Mixing of diluted and undiluted parcels near the cloud base is not considered, as there is no retrievals obtained directly at the cloud base. Finally, although not explicitly mentioned in the paper, mixing inside the cloud is considered. In fact, it is required to explain the vertical variability of the number concentration and the subadiabaticity. Still, in the presence of entrainment and mixing in stratocumulus, Korolev and Mazin argued that the supersaturation will recover to its quasi-steady value, if the averaging scale is greater than about 1 m, which is the case in this study.

(cont'd) If condensation and evaporation are assumed to form a reversible process cycle here, what accounts for the variations in LWP for regions with similar cloud depths?

Authors Answer: Different mixing/turbulence near the edges and humidity conditions also affect the LWP. Mixing within the cloud also occurs.

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