Atmos. Meas. Tech. Discuss., 5, C4068–C4073, 2013
www.atmos-meas-tech-discuss.net/5/C4068/2013/

Atmospheric Measurement Techniques Discussions

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

J. Rémillard et al.

jasmine.remillard@mail.mcgill.ca

Received and published: 12 March 2013

Reply to Reviewer 2

General Comments:

The authors present an update to traditional radar-radiometer methods (e.g. Frisch et al. 1995, 1998, 2002) for the retrieval of microphysical properties in non-drizzling marine stratocumulus cases using additional constraints provided by a 1D microphysical model. Principally, the idea to include a microphysical model to constrain the retrieval presents an innovative way to at least partially overcome the rather large uncertainties

given the uncertainties that occur when relating radar reflectivity to the microphysical properties of clouds (i.e. LWC, N, effective radius. . .).

Generally, I think the authors must mention (especially in the title and the abstract) more the rather limited range of applicability of their method to non-drizzling stratocumulus clouds. What percentage of clouds observed at the Azores site are actually non-drizzling? And which published retrievals so far deal with drizzle? (i.e. Frisch et al. 1995 (JAS), O'Connor et al. 2005 (JAM), Löhnert et al. 2008 (JTECH). . .)

Authors Answer:
In the Azores, most stratocumulus clouds are drizzling. Retrievals dealing with drizzle either do so under the cloud base (e.g. O'Connor et al. 2005), or ignore the cloud contributions (e.g. Frisch et al. 1995). Löhnert et al. 2008 retrieve only the LWC profile, without differentiating cloud and drizzle, beyond using 3 categories based on drizzle strength.

Specific Points:

1.) Page 7511, lines 6–10: *Please explain the underlying assumptions for the effective radius formula and indicate the uncertainties to be expected from the NFOV measurements /retrieval.*

Authors Answer: As pointed out by another reviewer, this formula is actually for the cloud-top effective radius. As described by Wood and Hartmann, it takes into account the expected increase in LWC with height.

2.) Page 7515, lines 2–6: *Please quote the exact equation used from Korolev and Mazin 2003. Is S_{qs} at all dependent on the solute of the droplet?*

Authors Answer: Equation 12 is Eq. 16 in Korolev and Mazin, with different symbols used. The solute of the droplet is never considered in their paper, since their equation corresponds to the droplets with radius larger than about 1 µm. The solute is affecting the formation of droplets, at the very beginning of their life and where the quasi-steady

AMTD
5, C4068–C4073, 2013

state assumption would not be valid.

3.) Page 7515, lines 13–14: *The causality of the sentence is not clear to me.*

Authors Answer: That sentence will be removed, as it seems to be rather confusing. It was just a side note, used to point out that Eq. 13 shows a relation between the gradient of reflectivity and the LWC (through the $N_{cld}r_0^3$ in the denominator). However, that relation is complicated by the exponential, which does not have the exact argument needed for LWC.

4.) Page 7515, line 19: *Mention explicitly the remaining two unknowns.*

Authors Answer: The revised version will mention them ($N_{cld}(z)$ and $\langle N_{cld}^{1/2} \rangle$).

5.) Page 7516, top: *How is the minimization carried out? Explain how the $N_{cld}(z)$ profile is actually derived.*

Authors Answer: The minimization can be explained in the revised version. The value of the right-hand side is computed using a set of values for the unknown ($\langle N_{cld}^{1/2} \rangle$). This set covers the range of values expected climatologically, and a bit more (corresponding to values of N_{cld} between 20 and 2000 cm^{-3}). Over the main range (for marine cases, N_{cld} between 50 and 600 cm^{-3}), it uses an increment of $\sqrt{10}$ between values, while increasingly larger increments are used outside it. The value from the set that provides the minimum result is kept. Using this value in Eq. 14 directly retrieves the $N_{cld}(z)$ profile.

6.) Page 7518, last paragraph: *a consistency check the authors could carry out would be to integrate the retrieved LWC over the depth of the cloud and compare this to the LWP measured by the microwave radiometer.*

Authors Answer: The reviewer has an interesting point. This check has been carried out successfully, although not discussed in the paper. The two quantities indeed compare very well. For the two considered cases, a linear regression performed on

AMTD

5, C4068–C4073, 2013

a scatterplot of the two quantities return a r^2 coefficient near 0.98, and a slope approaching 1. The slight discrepancy (with the measured LWP having a tendency to be just above the retrieved LWP) can be explained by the lack of retrieval at the cloud base, and the neglecting of drizzle contribution.

7.) *The discussion on page 7519 contains uncertainty estimates due to retrieval and measurements uncertainties. The authors should discriminate better between these two, especially when comparing the Frisch method and the method presented in their study. E.g. temperature, pressure and LWP uncertainties may be regarded as measurement uncertainties, which propagate through the retrieval equations. On the one hand, it is important to compare both retrieval results on the basis of measurement uncertainties. On the other hand, the variation of the lognormal width gives a sensitivity of the results to an assumption within the retrieval. The method presented here also uses many assumptions (e.g. eq. (8) or (12)) related to the pure evaporation growth regarding a rising parcel, respectively the steady state super-saturation approximation. Parameters and approximations used, respectively made in these equations should also be tested towards the sensitivity of the retrieval results if the comparison with the varying logarithmic width are to be fair.*

Authors Answer: The reviewer raises a valid point. This discussion will be revised to ensure consistency and fairness in the comparison. Testing is underway to estimate the error related to the retrieval main assumptions.

8.) *Table A1 should contain all symbols and parameters contained in the paper (e.g.* r_0, N_{cld}, N_{norm}*...)*

Authors Answer: The other symbols and parameters will be included in the revised paper.

9.) Fig. 2 / Fig. 5: *The authors should explain the occasional occurrence of* N_{cld} *values larger than 600* cm^{-3}*. Why do these cases look "binned" to certain, exact values?*

AMTD

5, C4068–C4073, 2013

Authors Answer: The "binned" aspect comes from the minimization process, which will be further explained in the revised version (see comment 5 above). 600 cm^{-3} is the limit considered reasonable climatologically for the Azores. Above that number, the increment between values increases.

10.) Fig. 3 / Fig. 6: *A plot including the effective radius uncertainty would also be conclusive. I would find the errors in sub-plot (c) easier to interpret if they were given in %. Why does the method presented here give a minimum (optical depth), respectively maximum (effective radius) w.r.t. the Frisch method that is varied within the sensible logarithmic width range?*

Authors Answer: A plot of the effective radius uncertainty can be added. The uncertainties can also be given in % instead, although it will appear to inflate those for small values. From the equations (4), (7), (16), and (17), it can be seen that an increase in logarithmic width causes an increase in optical thickness (respectively a decrease in effective radius) in the Frisch method. Since our retrieved width is in the smaller end of the range considered in the Frisch method (and climatologically), it is reflected as a minimum optical depth and maximum effective radius.

11.) *It would be nice if some of these questions could be covered in the Summary /Outlook: What are the next steps in remote sensing of strato-cumulus clouds? Do the authors plan on including drizzle, use a more sophisticated model, and apply the retrieval to continental clouds? Have they thought about further evaluation of their method, e.g. the ARM program?*

Authors Answer: The revised version will cover these questions, in paragraphs added at the end. Here are some brief answers: work in underway to remove the drizzle contribution from the radar measurements to be able to apply the method to more cases; continental clouds from the SGP are being considered; the possibility to evaluate the method using an ARM campaign with radar and in situ measurements is being investigated.

AMTD

5, C4068–C4073, 2013

Further "Minor Point":

1.) *The paper is written and structured in a clear way. However, the figures are too small in this pdf version and thus difficult to read.*

Authors Answer: The figures are small in this version. They actually all have the same width, as they all have the same time span. This will be considered for the revised version.

Interactive comment on Atmos. Meas. Tech. Discuss., 5, 7507, 2012.