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Discussions
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Interactive comment on "Improved rain-rate and drop-size retrievals from airborne and spaceborne Doppler radar" *by* Shannon L. Mason et al.

Anonymous Referee #2

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This paper uses airborne radar data from the TC4 field experiment to evaluate 94 GHz Doppler radar retrievals of rainfall. Several versions of retreiveal are compared using reflectivity (Z), Doppler (D), and Path Integrated Attenuation (PIA), then only Z-D, and also Z-PIA. Taking Z-D-PIA is truth the authors explore the information available in each of the other two methods. Z-PIA generally performs well but for the lightest rain V-D performs better. The full retrieval Z-D-PIA has some skill in determining drop number concentrations. These observations will be available from EarthCARE and will help with further constrain light rainfall beyond what CloudSat can do.

The paper is well written with no observable flaws in the analysis. My specific comments below are minor. I have some recommendations regarding references. The uncertainties assumed in the optimal estimation need to be justified. I think using an a-priori in this retrieval is unjustified but others would disagree with me so I won't fight

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the point.

I recommend returning to the authors for minor revisions.

Line 1: remove second ‘of’

Page 1, line 18: also A. Behrangi, 2012

Page 8, line 19: Lebsock et al., 2013 is a better reference than Lebsock et al., 2011

Line 20: Stephens et al. only references intensity. Cite Abel and Boutle, 2012 for the DSD.

Page 2: line 5. I would mention the GPM DPR before bringing up cloudsat. It has increased sensitivity (12 dbz) vs PR (17 dbz).

Page 2: Lines 14-16. CloudSat actually does not use the SRT (as in the Meneghini 1983 definition) method in its operation products. Instead a look-up-table of normalize surface cross section as a function of wind speed and SST from ECMWF analysis. But Lebsock et al. (2011) do use the SRT for cloud/precipitation water path estimates from CloudSat. The SRT can provide a superior estimate when the length scale of precipitation is short. In the next release of cloudsat precipitation products (release 05) cloudsat will use a hybrid method combining the LUT and SRT techniques each used where appropriate.

Page 2, line 30: although these approaches have been challenged in practice due to the spectral dependence of the non-uniform-beam-filling and multiple scattering affecting the two frequencies.

Page 3: Lines 27/28: should be Lebsock et al., 2011

Equation 1: What is the structure of J_c? What is the structure of B? This is where all the magic happens. Also it’s really hard to justify a prior in this retrieval. Why do you feel that you need one? And how do you justify it? The prior variance had better be large. Rodgers was doing sounding where you might actually have a moderately

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reasonable prior constraint. This approach shouldn't A prior of 0.1 mm/hr is going to make it hard to retrieve 10 mm/hr.

Page 6, Line 28. I think the assumption is a necessary one but I think that the justification has less to do with rain rate and more to do rain type. For broad areas of stratiform precipitation I would suppose the invariance is most appropriate but that for any type of convection (light or heavy rain) I'm not so sure.

Page 7, Line 10: This value of k is not consistent with your retrieved rain rate DSD in that bin though is it? I'm not that concerned about this but if I'm correct you should make a note of it.

Page 8, Line 5: add citation for the models that use for attenuation. There are many.

Page 8, Line 15: I'm really skeptical of this Matrosov approach. It really depends strongly on steady state rainfall. How often does this happen? In practice in CloudSat data I see that the stuff that really fully attenuates the radar is the convection, where I just wouldn't trust this assumption.

Table 2: a little discussion about where these numbers come from is required. 0.3 dB would be a very good estimate of PIA. From the SRT method the instrument noise alone is probably close to this value. Is the 3 dBZ including the uncertainty in your DSD – Z relationship? Another thing to consider is whether this 3 dBZ uncertainty should be constant with height. In reality uncertainty should grow with depth into the column (e.g. Lebsock and L'Ecuyer, 2011) because any errors you make in your forward modeled attenuation in the range volumes up high is compounded as you descend into the rain column. This becomes an issue when the PIA is order 20 dB like the cases you explore later in the paper.

Fig 5a and elsewhere: I can't understand why the Zv retrieval is not matching the radar reflectivity. Doesn't Zv mean that both radar reflectivity and mean Doppler are used to constrain the solution. It looks like only Doppler is used in these plots.

Conclusions: The idea that mean Doppler will help with light rainfall retrievals over land is good but I worry that you often won't know whether you are looking at light rainfall or heavier rainfall that appears light because it is attenuated. This process will need to be automated in a retrieval algorithm and it doesn't' seem straightforward. Also, the signal in the Doppler is not all that large relative to the uncertainties that are expected.

Conclusions: Won't Doppler be affected by Multiple scattering for EarthCARE? I haven't done any calculations of this but I wonder how this might complicate things.

Refs

A. Behrangi, M. Lebsock, S. Wong, B. Lambrigtsen, 2012: On the quantification of oceanic rainfall using space-born sensors, J. Geophys. Res., 117(D20), D20105.

Lebsock, M., H. Morrison, and A. Gettelman (2013), Microphysical implications of cloud-precipitation covariance derived from satellite remote sensing, J. Geophys. Res. Atmos., 118, doi:10.1002/jgrd.50347.

Abel, S. J. and Boutle, I. A. (2012), An improved representation of the raindrop size distribution for single-moment microphysics schemes. Q.J.R. Meteorol. Soc., 138: 2151–2162. doi:10.1002/qj.1949

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