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Atmospheric Measurement Techniques Discussions

Interactive comment on "Synergistic radar and radiometer retrievals of ice hydrometeors" *by* Simon Pfreundschuh et al.

Anonymous Referee #3

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The paper presents a methodology to assess the benefit of radar-radiometer synergies when retrieving ice particles. The topic is extremely timely (given the upcoming launch of ICI) and relevant for the cloud community. The paper is generally clear in its scope though it is indeed too long and not concise as it could be. The style must be substantially improved, the number of figures reduced, most of the OE description has been now reported in numerous papers (maybe include them in an Appendix).

There are however several major points that must be clarified. I have picked here some that must be addressed.

1) The paper is presented as an application for ICI in combination with a Cloudsat like configuration but it is not clear to me what geometry of observations the authors are thinking about. They state "As mentioned above, the same incidence angle as for the

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Discussion paper

passive radiometers is assumed also for the radar. In practice, this could be achieved by remapping the radar observations to the lines of sights of the passive beam". Are they thinking about a scanning W-band radar? or at a off-nadir pointing radar? If the former is true then they should discuss what is a realistic technological solution (and what are the consequences in terms of sensitivity) and the authors should refer to state of the art scanning W-band radar concepts (there is none at the moment!); if the latter is true they should discuss what are the consequences of such a selection (e.g. for ground clutter) and they need to convince me that what we could gain from such a configuration compensate from the loss of information introduced by pointing in such a slanted direction. There should be a certain degree of "realism" in what we are trying to simulate, especially if this was part of an ESA study. 2) "the beams of all three sensors are modeled as perfectly coincident pencil beams". Again this is quite an assumption. Non uniform beam filling will play a key factor. This is one of the many simplifications (no polarization, no multiple scattering,1D, ...) that needs to be clearly listed at the beginning of Sect.2.2.1 (some appear only at page 27). For this reason I would actually pitch more towards an airborne configuration where these simplification indeed can be realistically assumed or of a radar with a radiometric mode (where you can actually match footprints). Otherwise the (not massive) gain of having a radar-radiometer combination that you show later on can be completely washed out by the errors introduced to these assumptions. I imagine that you may also have airborne data where to test how realistic your forward model is. 3) Fig2: these PSDs look very weird to me. Why do they have the plateau at small sizes? y-axis units are obviously wrong unless you are renormalizing by some mass (but it is not explained). 4) Fig3: sorry I do not follow what is this (what is the y-axis?), and why this plot is meaningful. 5) Eq.6 clearly with values lower than 230 K it does not make any sense (negative RH, or large than 1.1???) 6) Line 210; this means that the vertical resolution changes with the surface temperature, really weird choice. 7) fIG4 : not clear to me why the scattering depression is not increasing at higher frequencies. I would expect that the optical thickness would drastically increase increasing frequency. Is this due to very large asymmetry

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parameters then? But this is not what I do see in Fig.5 (though Fig4 is of course a very idealized case) If this is the case then results will be very dependent on particle habits (which may introduce additional uncertainties in the retrieval). 8) Line 275: not clear what you mean, in Tab.4 there are 6. 9) “extends below the sensitivity limit of the passive-only observations around $10-5$ kg $m-3$” : very sloppy sentence. Passive microwave radiometer are sensitive to integrated contents! 10) Fig 6d: this retrieval looks really weird. Where are all the stripes coming from? Certainly this does not look like a cloud, or? What kind of constraint have you imposed on the cloud top? 11) “In general, the radar-only results exhibit only very weak dependency on the particle model, making the results for different particle shapes virtually indistinguishable.” Again another dangerous sentence. We know (unfortunately) that this is not true (otherwise our ice problems would be sorted). Here my guess is that you have not properly explored the backscattering variability (particularly looking at the different degree of riming). It is not clear to me whether there is enough variability in your ARTS database, I guess you are more focused at ice particles (including aggregates) but you are not considering really rimed particles. Regions where graupel is present should we avoided from the discussion of the radar-only retrieval for the simple reason that in those regions attenuation correction and multiple scattering effects make the problem very tricky. I guess that the radiometer as well is in serious trouble when entering those areas. Again I would not start tackling regions the observation system is not tailored for. 12) Fig.10 is missing!!! 13) “Since the calculation of the AVK involves the forward model Jacobian, this effect must be related to the non-linearity of the forward model” well I would avoid such very speculative statements. 14) You need to be very careful how you present the results in Fig.14. The conclusions that I can draw is the following: a CloudSat like radar is providing much more information than the ICI+MWI radiometers when characterizing ice particles (really the radiometer is providing some additional water vapour information). As a result we should invest in the former and not the latter. While I may agree with the previous statement and strongly support a CloudSat-like radar on an operational mission my feeling is that you are pitching your radiometer system at the wrong kind

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of scenes (I already see an improvement going from the first to the second scene). I would have selected completely different scenes (including high latitude clouds with mixed phase). It is to me an overkill to try to retrieve D_M of rain for these scenes from your PMW radiometer suite of sensor. If you have any skill in warm rain you should properly prove it. 15) LWP and Fig.16. I have a serious problem here. The cloud I see on the right is a liquid cloud. So how it is possible that your radiometer is doing so badly in the LWP retrieval and why the combined is so much better? I guess this must go back to understanding surface emissivity and integrated water vapour (maybe some comments there should be made to explain what kind of surface/IWP we are dealing with). You have not included radar path integrated attenuation in your retrieval (like is typically done in radar retrievals) but this could of course help in this case. 16) I do not think that for OE to work The forward model must be linear as stated at line 544. 17) Sect.4 and 5: a lot of waffling here (e.g. the three bullet conclusion, you need to be much more quantitative and linked to what you have proved; the three statements are something I could have formulated on my own without making any simulation). Again the conclusions must be related to the cloud regime you are considering (and cannot be valid for all!)

Minor comment: I would avoid the use of “ice mass density” and use “ice water content” Table 2: it would be good to see footprints as well Line 130: dBZ are the wrong units for a std of a reflectivity! Line 180: “The remaining shape of each PSD is described by the shape parameters alpha and beta, not to be confused with the parameters of the mass-size relationship shown in Tab. 1.”; very confusing. Why are you using the same letters???? Line 193:wrong units Line 199: English Line 35 page 2 (not really limited, this is a wide range!!) Line 54 page 2. maybe it is worth mentioning all the heritage coming from radar-radiometer retrievals with W-band (Ka and Ku-band) radars with PMW radiometers. Line 229: “troposphere” is too generic Line 250: rho is not defined Line 4: 272.5???? Fig 4 caption: you need to include how thick is the layer.

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