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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 #2

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With the launch of the second generation of European meteorological operational satellites (MetOp) approaching the interest in exploiting the measurements by the novel Ice Cloud Imager (ICI) is growing. While several studies already investigated the potential of these submillimeter measurements in deriving information on frozen hydrometeors alone or in conjunction with the Microwave Imager onboard of the same satellite, this manuscript addresses the synergy of ICI/MWI and a hypothetical 94 GHz cloud radar as a potential further development of space instrumentation. An optimal estimation framework for joint retrievals is developed and a comprehensive assessment of the information gain from individual (passive or radar) and combined retrievals is performed. Not surprisingly a significant benefit of the combined approach is demonstrated on the basis of two scenes simulated by a cloud resolving model. However, the effects depend

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on the parameters of interest and assumptions on particle type.

The study original and timely. It is well designed and assumptions and limitations are clearly described though some aspects on the retrieval need to be clarified (see below). In general, the paper is well written but rather lengthy and I would appreciate if the authors would follow my suggestions to shorten the paper.

MAJOR POINTS

1) A major aspect of the study concerns the representation of the particle size distribution which is retrieved by two free parameters (different from the 2 moments of the atmospheric model GEM used to provide the test scenes) and the assumptions of the particle type. The difficulty of connecting atmospheric model output to single scattering properties (which is one of the fundamental assumptions) could be better explained. The motivation why the authors choose their approach and why they test certain settings need to be discussed in the beginning. Couldn't Tab. 1 and 4 be combined and better explained which is used for which purpose? Why is cloud ice the same and GEMsnow and GEMGraupel different in both?

2) Although different parameterizations of the hydrometeor types are used to study their effects, vertical changes (development of sedimenting particles) is are not considered. Similar polarization effects are not mentioned in the discussion on particle shape. Otherwise the paper nicely discusses the different aspects but in the end I am missing a clear message on the outcome of the test (choice of particle types). What is recommended for the future?

3) Not only the two moments of the ice PSD but further variables are retrieved and their information content is nicely shown in Fig. 14. I am surprised that the he information on moisture is so low although information along three water vapor lines is provided? This should at least in the upper atmosphere provide information? Is it due to the choice of relative humidity which mainly depends on temperature? I am also skeptical about the results of Fig. 16. Basically, there should be no liquid for temperatures colder than –

40 deg C (freezing) but it even reference LWC goes up to 13 km? I would not support the statement on L568 – where is the evidence? Similar L527 – liquid water estimation within mixed phase clouds is extremely difficult and if ICI and radar could really do that together this would be worth a separate paper. To better understand the information content, I suggest to plot the profiles of cumulative degrees of freedom for the different retrievals as this could help interprete where and how the synergy works.

4) The manuscript is rather lengthy making it difficult for the reader to extract the major points. I strongly suggest a) to move part of the analysis into an appendix (, b) remove double statement (see minor comments, also the LWC plot) and c) to remove figure caption like information (for example L92 or "filled contours") from the text. The text must make sense without looking at the figure. Figure only support the statements made in the text. Lengthy descriptions such as "The plot shows.." need to be avoided.

MINOR COMMENTS:

L39: Is sensitivity really the right word? Range resolution is the main advantage – signal-to noise range depends on distance and hydrometeor distribution,

L48: MWI will also cover new spectral channels, e.g. 118 GHz

L62: "high-resolution" is always relative for a model. I would recommend avoiding this term and use Cloud resolving Model (CRM).

L68: After you mention GPM (with scanning radar) it might be good to say that you are only looking at a nadir pointing radar (curtain). The swath center cam e bit as a surprise.

L70: There has been quite some literature about combining active and passive MW using a Bayesian framework which should be acknowledged, e.g. Grecu, M., & Olson, W. S. (2006), Johnson et al. (2012) , Munchak, S. J., & Kummerow

L84: Test scenes have a grid resolution of 1 km horizontally. As this is not the true model resolution I would have recommended to coarse sample the model data (maybe

every 5th data point) and include more diverse profiles instead. This might be especially interesting for the scatter plots.

L91: Motivation lacking: “To perform RT simulations for each GEM profile the PSD needs to be diagnosed from the prognostic GEM variables, i.e. N and m..”

L92: “prognoses” means forward in time - you mean diagnosed, calculated, determined. . .

L98: I find the term “horizontal and vertical scaling” strange – why not saying PSD shape is similar but scaling in respect to diameter and number density. At least define the term clearly the first time that you use it or define a short for it.

L103: model test – be careful also at other instances that “model” can mean too many things. Here I would say GEM test scenes.

L119: Need to clearly say that polarization effects are neglected though these can be several Kelvin, e.g. Xie et al., 2015. You ignore this effect but even consider noise reduction.

L157-159: needs to be better motived, references?

L172: I doubt that the model has constant vertical resolution. It will be better close to the surface and worse aloft. This should be mentioned than GEM is introduced.

L 174: for all hydrometeor species of the model? It would be helpful to first introduce all retrieval quantities – I was missing a motivation for the paragraph around L195. How do you define the freezing layer (and later the troposphere)? How do they vary in both test scenes? The model also likely has supercooled liquid water above the freezing layer – how is this treated?

L 198: Vertical resolution of retrieval grid: Why 4 points? The freezing layer must be very different for both cased. Maybe a sketch would be helpful as later on lines 230 the different vertical resolutions for other variables is discussed?

L281: How do I know that Large Plate is the best performing model? Which parameter, plot, table does show that?

L283-L307: Can be shortened significantly

L332: There can I see that? Give figure?

L325: The two paragraph here give similar information -> streamline

L333-344: I would put this to the appendix

L444: Here it needs to be made clearer how this goes beyond what GPM is doing.

L495: “does not say much about the general validity of the assumption”. Here you should dig in a bit more. What is the role of a priori and covariances?

L560: Rethink the bullet structure. 2. Is not an independent result. For each result refer to the part of the manuscript where you can clearly see that. Especially result 3 should be detailed – how do ICI channel advance the currently available data?

Fig. 3: Is it really worth having the slightly different size distribution shapes for frozen und liquid? Isn’t there a stronger difference between different frozen hydrometeors?

Fig. 4 and also in text: “cloud signal” say that this is dTB.

Fig. 5: Can you add freezing layer height?

Fig. 6: It would be nice to see the absolute values of IWP somewhere. Maybe you could add another time series with IWP as the sum of the different components such that the reader can see where the different categories (cloud, graupel, snow and hail) contribute most?

Fig. 7: I think it is retrieved vs. truth. The word following is not really exact. Why not put 7 and 8 together?

Fig. 9: Could go to the appendix

Fig. 10 I only see the caption???

Tab. 1. Assumed particle model information for each hydrometeor class given by GEM model. In fact it could be good to combine it

Tab.3 : I would recommend to add a first column with a spelled out name

Grecu, M., & Olson, W. S. (2006). Bayesian estimation of precipitation from satellite passive microwave observations using combined radar–radiometer retrievals. Journal of applied meteorology and climatology, 45(3), 416-433.

Johnson, B. T., Petty, G. W., & Skofronick-Jackson, G. (2012). Microwave properties of ice-phase hydrometeors for radar and radiometers: Sensitivity to model assumptions. Journal of Applied Meteorology and Climatology, 51(12), 2152-2171.

Munchak, S. J., & Kummerow, C. D. (2011). A modular optimal estimation method for combined radar–radiometer precipitation profiling. Journal of Applied Meteorology and Climatology, 50(2), 433-448.

Xie, X, S. Crewell, U. Löhnert, C. Simmer, J. Miao, Polarization Signatures and Brightness Temperatures Caused by Horizontally-Oriented Snow Particles at Microwave Bands: Effects of Atmospheric Absorption, J. Geophys. Res., doi:10.1002/2015JD023158.

GRAMMAR, TYPOS AND REFORMULATIONS

L59: "..constrain the microphysics.." better information on microphysical parameters

L82: I was expecting to see horizontal maps in Fig.2 – mention vertical profiles

L87: over the North Atlantic region

L88: not a single cloud -> cloud system

L106: cite Table2

L108: radar with similar characteristics as the CloudSat

L118: the reader does not know yet that these are double-sideband

L123: Higher freq channels were mentioned at the beginning of the section – only needed once.

L207: "..chosen as a function of temperature t "

L210: cloud water is also a liquid hydrometeor type

L213: permitted region?

L233: numerical experiment -> idealized experiment. Everything you do is numerical

L250: density rho not defined. The following paragraph until L262 can be shortened significantly.

L265: "..ice particle models for the retrieved frozen hydrometeor"

L358: retrieval error

L463: "On the other hand" only once you had "on the one hand"

L544: "..but no avail..?"

Fig 1 caption: explain m as mass density, „

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