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Atmospheric Measurement Techniques Discussions

Interactive comment on "Towards an operational Ice Cloud Imager (ICI) retrieval product" *by* Patrick Eriksson et al.

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We deliberately tried to keep the manuscript as short as possible, to not let details cause distraction, but we have clearly been too brief in some parts. The other reviewers made similar remarks for some parts. We will expand the manuscript with the aim to make it more easily accessible for a broader audience.

Below we comment on your specific questions and what changes of the manuscript we will implement. Your comments are in italic, with our answers below.

line 19: I am not in the measurements field and have hard time to understand what is the receiver noise temperature and especially the very large values of 600 to 2600K. Maybe a reference could help the reader to find information on this receiver noise

temperature.

We will add a reference for receiver noise temperature. Much lower values can be achieved by cooled receivers, but cryogenic cooling represents a risk and a relatively short life-time. Hence, such techniques can not be used for operational missions.

line 29: It is actually not evident to get this document, I tried the link documentation under www.nwcsaf.org, but did not find any document related to ICI. Anyway, maybe some annexe would help the reader to understand the details of the algorithm or an academic reference.

We are deeply sorry, but the information in the reference is wrong. The mistake will be corrected.

line 10: What is the dimension (unit) of r? Specify it in the text. You could also be explicit on the solid angle by saying that the solid angle is the one of the antenna (I guess). Concerning the cartesian coordinate we have no idea on where is the origin of this cartesian system. Please specify also if the antenna pattern is taken on the ground, or change with altitude and therefore you need to know the cloud extent (information that you do not have). It is not so evident how you concretely compute IWP.

We will clarify.

line 12: dveq is the equivalent volume diameter but equivalent to what? Spherical particles? Specify it in the text.

Will be done.

line 17: the Author call Dm the mean mass size but Delanoe et al. 2014 expressed it as the volume-weighted diameter because it is the 4th moment of the size distribution over the third one. Why did you call it mean mass size? We don't see any mass weighted in the formulae!

As mass is the volume times density, the volume-weighted and mass-weighted are

equal concepts. Or consider equation 3, showing that d_{veq}^3 is directly proportional to mass. This means that d_{veq}^3 in both integrals represent the mass (factors such as density and π cancel out).

line 9: what do you mean by semi-circular?

We mean "close to circular". We will rephrase.

line 23: Last sentence "As the module likely will not be applied, no details are here given". So if you do not give any detail about the clear sky module detection of the algorithm, do we really need this paragraph?

It is described in Rydberg, 2019. We will make this clear.

line 4 (eq. 9): Could you justify why wi is written like an exponential law?

We will add a reference.

line 5: Why only observation uncertainties are taken into account in S0? Can't you add the forward model uncertainties also (due to the miss-knowledge of non retrieve parameters that play in the forward model to compute yi)?

We used the term "observation uncertainty" as the uncertainty of the observation system, thus including the forward model. We will rephrase to be clearer.

line 6: The following sentence is very hard to understand, please rephrase it. "They are not standard, but are introduced to allow tailoring of the retrieval database to the specifics of the retrievals of concern."

Will be done.

line 14 and 16 (eq. 10 and 11): Something is wrong here because $p(x'|y)$ is what we call a probability density function (PDF) in (10), we need to multiply by dx to get a probability. But in (11) $p(xi|y)$ should be a probability but the notation is almost identical to the previous equation (10), and make this 2 equation confusing. Specify somewhere

that $p(xi|y)$ is not a PDF but directly a probability to have $x = xi$.

Correct. Thanks for pointing this out. Will be fixed. (In fact, above Eq 11 it says p_n, that was meant to flag that it is a probability, but we missed to complete this). Eq 8 will also be corrected.

line 2: Why is there only one clear sky in your database? Don't you need to simulate different clear sky at least to take into account the different emissivity, surface temperature that depend of the season and location?

On the database side, the assumption is that we know the true values and there is only one clear-sky simulation to be done. However, it is critical that the database contains cases covering a distribution of emissivities, surface temperatures etc. See further comments in the reply to referee 1. We think the comments we will add in response to referee 1 will make all this clear.

line 7 (and eq. 13): We don't understand why the uncertainty on emissivity take this form, could you explain a bit or give some reference? We don't even know what is $\tau_{e,j}$?

$\tau_{e,j}$ should have been $\tau_{cs,j}$. Sorry, we missed to change this equation when changing nomenclature for expressing optical thicknesses. We will explain the expression for emissivity uncertainty.

line 9 (and eq. 13): I really don't understand why this last term of equation 13, in its present form, could model the uncertainty due to a miss-representation of the scattering in the model! Please explain why in the text or give a reference!

See answer to the next question.

line 10: Why can you assume that the modeling error (scattering) is proportional to the deviation of clear-sky reference simulation? Where does this assumption comes from? Any Reference?

As we understand it, these two questions refer to the same issue. We will add an

explanation.

3.5.3 Database extraction and iterations: OK now I understand a bit more why there is only one clear sky in the database! You should put this paragraph before the paragraph 3.5.2!

The advice will be followed.

line 8: On figure 6 please indicate the units of the color scale

Will be done.

line 18-19: Difficult to understand the following sentence, maybe a figure could help here! "This means that line-of-sights of observations and the corresponding ones after remapping cross at the ellipsoid but deviate at altitudes inside the atmosphere."

We will rephrase.

line 19: what do you mean by unrealistically high? Give some number. (Correct the word spelling also)

We will add some number(s) and correct spelling.

line 22: why around 0.8? Don't you have an exact number or did you make some random choice around 0.8?

First, 0.8 is a "typo", should be 0.9. Let's call this an "educated guess". We will clarify that there is no reference model for land emissivity is at hand. Accordingly, this value is highly uncertain, and this is why we apply high optical thickness thresholds above land (at least 3).

line 24-25: This comparison between ATMS observations and simulations are done over which period? Does it used every observation or is there some filtering? Are you taking into account any specific antenna pattern of the ATMS instrument? How the atmospheric profile and hydrometeors are define? Are you using Cloudsat also? Are

you using the same definition for the microphysical model than for ICI? Please develop in order to help the reader to understand the limit of this statistical comparison!

Except for footprint size and time period used, all is done as for the retrieval database. We will clarify this.

line 29: Please explain how the particle orientation can explain this discrepancy?

Will be done.

line 31: What is GMI? Any reference?

GMI is introduced in the Introduction, bu the acronym will be explained again and a reference will be added.

Table 2: Could you please indicate the habit model explicitly instead of a number referring to another paper from the author.

Will be done (but will require a two-column table).

line 7-8: The degree of freedom is more commonly called DoFS ...

We will change DOF to DoF.

It was clearly a big mistake to not include a description of how we calculate the DoF. Both you and referee 1 ask for it. And by your comments we notice that we opened up for misunderstandings. In short, the DoF we display matches Rodgers' section 2.4.1. We tried to indicate this by defining the DoF as "measurements' degrees of freedom". Our comments seem to be based on the assumption that our DoF is the one described in Rodgers' 2.4.2. As this is not correct we don't go into details here.

We will describe the way we calculate DoF and clarify that it matches Rodgers 2.4.1.

line 13: Which surface parameter are you talking about, emissivity or surface temperature?

Both, and other ones. We will rewrite to something like: the various variables affecting

surface emission and reflectivity

line 6: I may have missed it somewhere but what is H?

We will change to H-polarisation.

line 8 (Fig 9): The problem with using only average is that we have no idea of the dispersion around the mean. A scatter plot presented with a 2D colorscale histogram give much more information on the overall performance of the retrieval. The author should consider this king of plot instead of presenting only the average.

The figure is based on so many retrievals that it would impossible to discern individual cases in a scatter plot, and we don't see this an option.

line 9: What do you mean by "good accuracy"? Is it in comparison to other related retrieval from other sensor?

Yes, this a vague statement. Will be rephrased.

line 14: Are the 5th and 95th percentile also averaged values?

Median. This information is found in the figure text.

line 17: This precision number for Zm and Dm are average precision, specify it somewhere!

Will be done.

line 4: Reference on ISMAR?

ISMAR is introduced and referenced in Sec 1.

line 8-9: last sentence says that ...

This section will be removed, following a recommendation of referee 1.

line 12-15: The cloudsat and caliop based algorithm like DARDAR for example, which retrieve IWC profile from the combination of both measurements, often show a layer of

supercooled water above the ice layer in the polar area. Are you planing to integrate this kind of case in your database in the futur. Is microwave sensitive to this kind of situation?

This is an interesting question, but, unfortunately, is an aspect of ICI observations that has got very little attention. To our best knowledge, nobody has studied the sensitivity of ICI to supercooled water for polar conditions. Indications to supercooled water for mid-latitude conditions are found in a manuscript in review (Pfreundschuh et al., AMTD).

This means that supercooled water probably must be considered in the generation of future retrieval databases. With the AMTD manuscript at hand, we now feel that it is motivated to suggest this. However, we want to here clarify that the generation of a complete retrieval database will be the subject of future studies, and it is today not known who will produce that database.

Another form of supercooled water is the liquid drops brought to sub-zero temperatures in updraft regions. These drops can have considerably size, and when present should impact on both ICI and CloudSat observations. We now notice that we missed to comment on this, and we will add a general comment/discussion of super-cooled water.

Best regards,

Patrick and co-authors

References:

Pfreundschuh, S., Eriksson, P., Buehler, S. A., Brath, M., Duncan, D., Larsson, R., and Ekelund, R.: Synergistic radar and radiometer retrievals of ice hydrometeors, Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2019-369, in review, 2019.

Interactive comment on Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2019-312, 2019.