

# RESPONSE TO COMMENTS

Synergistic approach of hydrometeor retrievals: considerations on radiative transfer and model uncertainties in a simulated framework

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## **AUTHORS' RESPONSE**

Thank you for your review that helps us to improve the original quality of the manuscript. Your suggestions were constructive and have been incorporated into the manuscript.

## **CHANGES IN THE MANUSCRIPT**

The modifications in the manuscript appear in blue in the track-change file so they can easily be monitored. Some modifications appear in red and are related to the other reviewer's comments. Some others appear in green that are minor corrections from the authors.

The reviewer's suggestions were included correcting some phrases and adding some details. Tables (3, 4 and 5 ; 6, 7 and 8) were merged to ease readability (now Table 3 and 4).

The y-axis of figures 2 and 3 was modified to fit the plots as suggested.

## **COMMENTS FROM REFEREE #1**

**Review of Villeneuve et al. – Synergistic approach of hydrometeor retrievals: considerations on radiative transfer and model uncertainties in a simulated framework**

The authors present a synthetic study of retrieval synergy between microwave, infrared, and sub-mm observations for constraining ice hydrometeors. This paper is well-written and

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relevant for publication in this journal. The study is well-constructed, the methodology is explained well, and reasonable conclusions are drawn about the synergistic value of these observations for frozen hydrometeors, while being clear about the caveats and shortcomings of this synthetic approach. My recommendation is for publication after some minor corrections.

Thank you for acknowledging our work. The recommended corrections were added to the manuscript as shown below.

One area where the manuscript is a little lacking regards the context of other synergistic studies in the literature. For instance, there are recent studies examining the combined use of MWI and ICI (<https://amt.copernicus.org/articles/13/4219/2020/>) and also active sensors, including using real observations (<https://amt.copernicus.org/articles/15/6777/2022/>). As their conclusions regarding the importance of particle shape and RT errors in general are similar to the ones of this study, it is perhaps worth mentioning in the discussion section or the introduction to provide some context for readers. Other studies have also probed the importance of microphysical assumptions for different wavelengths (<https://amt.copernicus.org/articles/14/5369/2021/> <https://amt.copernicus.org/articles/13/501/2020/>), again with conclusions that seem compatible with this study. There are also Bayesian-based studies on ice hydrometeor retrieval synergy (<https://amt.copernicus.org/articles/15/927/2022/>), including several others that examine radar/radiometer synergy from CloudSat and GPM. The authors' paper is more focused on eventual assimilation, but some context on retrieval focussed studies could still be helpful. The papers listed above are just from AMT, and surely there are others elsewhere.

Thank you for providing more resources on the subject. As you suggested, some context is added to the introduction section :

L35: "Several studies had already highlighted that a synergistic use of microwave or sub-millimetric radiometers and radar data was beneficial to retrieve ice hydrometeors (Pfreundschuh et al., 2020, 2022)"

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L41: "Several studies have probed the impact of different particle shapes or particle size distribution (PSD) on ice hydrometeors retrievals (e.g. Ekelund et al., 2020; Pfreundschuh et al., 2020; Geer, 2021) showing that the retrievals are sensitive to microphysical schemes"

Specific comments:

L11 – "takes advantage of both spectral range strengths" could perhaps be rewritten as "takes advantage of the strengths of both spectral ranges"

Manuscript change : from "takes advantage of both spectral range strengths" to "takes advantage of the strengths of both spectral ranges"

L13 – This last sentence is not specific enough and may need to be reworded. For instance, does "the errors" mean "the radiative transfer and numerical modelling errors"? Does "their combination" mean the combination of different sensors? It's also not clear that this is true in "all cases explored" because the graupel combined retrieval performed worse than MWI when it came to graupel.

Yes, the errors mentioned come from two sources : the radiative transfer and the numerical modeling. It has been added to the manuscript L13. The last sentence was to point out that the positive compromise created by the combination of infrared and microwave sensors remains even when considering the sources of errors. Thank you for pointing it out. I clarified it in the manuscript.

L21 – "a significant information content" is quite vague, suggest rewording

Change : this wide range of frequencies is characterised by a large diversity of information ~~a significant information content~~ on all hydrometeor phases along the vertical

L26 – Worth spelling out what all-sky means for readers

Added : All-sky observations, in contrast to clear-sky observations, gather all meteorological situations, whether it is cloudy or not.

L33 – Suggest changing "at discussing" to "to explore"

Changed "at discussing" by "to explore".

L50 – This is nitpicking, but sub-mm is greater than 300GHz, so ICI will technically measure MW and sub-mm wavelengths and L51 – Again a technicality, but there have been

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short-lived sensors measuring at sub-mm, and AWS might be launched before ICI, so this statement could be toned down.

Change about ICI : “the EPS-SG-Ice Cloud Imager (ICI) with sub-millimetric frequencies (> 300 ~~183~~ GHz) ~~which will provide observations never acquired before by spaceborne instruments~~ in addition to microwave frequencies (> 183 GHz) which gives new information on ice cloud”

Table 2 – It’s a bit confusing how “OBS FG” is shown. Does this mean OBS in rows and FG in columns? Could make this clearer.

I added arrows to point where OBS and FG are.

L113 – See tables 4 & 5, presumably?

Tables 3, 4, 5 – Would it be possible to combine into one table? This would make it easier to compare values across sensors.

Tables 3, 4 and 5 are now merged

L145 – Tables 6, 7, & 8, presumably?

Tables 6, 7, 8 – Same as above, could these be combined?

Same, tables 6, 7 and 8 are now merged.

L211 – It would be helpful to provide more detail here to explain exactly why this validation comparison is done. Right now it feels quite implicit and the reasoning is split up (L234, L355), but it would be helpful to spell out exactly why the validation was performed at the beginning of this section.

I added in the text L219: “a validation metric is needed to verify the accuracy of the chosen settings of the simulations” to justify the validation at the beginning of the section

Figures 2 & 3 – y-axis should be STD and mean?

Yes, I corrected the y-axis.

Figures 4, 6, 8 – Here the y-axis could be reasonably cut off at 100hPa, as presumably the significance differences are spurious noise above this level.

Figures 4, 6 and 8 were cut off at 100hPa as suggested.

L271 – Reword “instrumental synergy” to something like “synergy of the instruments”

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Changed from “instrumental synergy” to “synergy of the instruments”

Figures 5, 7 9 – Here the x-axis label of “abs error” was quite confusing for me. Isn’t this the difference definition given in Section 2.5? Also a typo in first panel of ‘mTR’ rather than ‘mRT’

The x-axis represents “DIFF” as defined in eq. (4), the label was adjusted. Also “mTR” has been changed to “mRT”.

L306 – Why is this given halfway through the results section? It would make much more sense at the beginning of Section 4.

Yes it makes more sense at the beginning of the section, this has been moved.

L318 – Worth mentioning that the FCI curves are again absent in Fig. 9, as stated for Fig. 7

Added L.347: “As for Snow retrievals, the curves for FCI are not displayed because this instrument is not expected to well retrieve this variable”