EGUsphere, referee comment RC2

https://doi.org/10.5194/egusphere-2022-1217-RC2, 2023

Comment on egusphere-2022-1217

Anonymous Referee #2

Referee comment on "The classification of atmospheric hydrometeors and aerosols from the EarthCARE radar and lidar: the A-TC, C-TC and AC-TC products" by Abdanour Irbah et al., EGUsphere, https://doi.org/10.5194/egusphere-2022-1217

The presented manuscript from Irbah et al. introduces algorithms for the classification of atmospheric hydrometeors using the synergy of spaceborne radar and lidar measurements from the upcoming EarthCARE satellite mission. The manuscript is obviously intended to serve as a reference for the A-TC, C-TC and AC-TC products which are an integral component within the EarthCARE production model. The algorithms inherit many lessons learned from the A-Train constellation and its classification products (e.g., DARDAR-MASK) but also exploits the novelties of EarthCARE, like the HSRL and Doppler capabilities. First, the authors introduce the standalone classification algorithms A-TC and C-TC designed for ATLID and CPR and continues with the description of the synergistic classification AC-TC. Here, the ATLID and CPR measurements are merged for the first time within the production model to produce an overall target classification which is essential for downstream scene reconstructions like ACM-CAP or ACM-3D. As previous studies have shown (e.g., Cazenave et al, 2019), the target classification can have similar impacts on retrieved cloud properties compared to microphysical assumptions. A diligent introduction and discussion of the design of such target classifications is therefore appropriate.

I personally appreciated the comprehensible description of the synergistic product AC-TC, where Fig. 2 will be a helpful tool for the discussion in future studies using EarthCARE products and excels similar products in its reproducibility. The discussion of the case study and its “omniscient” evaluation convinces the reader without overselling the benefits of the instrument synergy. Overall, the science seem sound and settled and ready to be applied to measurements in the hopefully not too distant future.

While in my opinion only minor revisions are required to this manuscript, there are some critical points which I would require to be made for it be published. Just like RC1 I missed some of the traceability of AC-TC for the description of A-TC and C-TC which are too general and missing some details. As a potential future user of these products, I would probably miss some hard numbers (e.g., used thresholds) but also a quick overview if I would come across the paper in the need to understand results from EarthCARE products better. Some paragraphs are also poorly written and would benefit from a further editorial assistance from a native speaker. Specific points and instances for improvement are listed below.

References

Cazenave, Q., Ceccaldi, M., Delanoë, J., Pelon, J., Groß, S., and Heymsfield, A.: Evolution of DARDAR-CLOUD ice cloud retrievals: new parameters and impacts on the retrieved microphysical properties, Atmos. Meas. Tech., 12, 2819–2835,

https://doi.org/10.5194/amt-12-2819-2019, 2019

- The description of A-TC as well as C-TC would greatly benefit from two figures showing the mentioned “decision tree” for both products. In its current form, a reader needs to read all paragraphs to gain an overview of the approach. Similar works (e.g., Ceccaldi et al 2013 Fig. 5) became helpful references when working with data from DARDARMASK. It would eliminate some ambiguities in the text and could also increase the visibility of the manuscript when users will use them in their presentations in the future.

  A Figure similar to Fig. 5 of Ceccaldi et al. (2013) will be made for C-TC and included in the revised paper that will be resubmitted.
  For A-TC the discussion has been revised. Two new (simplified) decision trees (one for the simplified classification and one for the main classification scheme) will also be added

- For A-TC, it is not completely clear where A-PRO ends and the A-TC algorithm starts, or if it is part of it. Since the manuscript for A-PRO has not been submitted yet, it is a little bit unclear if sections 2.1-2.4 summarize steps which are already happening within APRO or which are implemented within A-TC and should be referenced with the present manuscript in the future. Are statuses -3 to -1 (detection of attenuation!) (Table 2) provided from somewhere else? This also extends to the HETEAC framework. Is the implementation described in Wandinger et al 2022 or is this happening in your manuscript? It adds to the confusion that you are both basically using the same Figure (Fig. 1 and Fig. 9 in Wandinger et al 2022) without a reference. Furthermore, Wandinger et al 2022 is also referring to Donovan et al. (2022b) for a further description of A-TC. This confusion could be settled by showing the inputs used in the “decision trees” in the previously mentioned figures.

  In practice, A-PRO and A-TC are indeed tightly coupled, as realized in software, A-TC is contained within the A-PRO processor. The A-TC section has been rewritten and more detail given, at the price of some redundancy between this paper and the (still in preparation for the same AMT special issue) more extensive A-PRO paper.
  The description given here is intended to be more concise than the treatment in the A-PRO paper though.
  The HETEAC paper (also submitted in the same special revue) is intended to describe the “theoretical famework” while here the aerosol type classification is a specific application of the framework.
  The suggestion to present decision trees is being adopted.

- There is also no introduction what layers are and if you derive their mean quantities like “mean beta” or “mean temperature” by yourself. Depending on the spatial and vertical extent of these layers, properties like “mean temperature” or “mean beta” could get quite arbitrary. It would be nice to add a short summary how these layers are defined and detected within A-PRO.

  A new sub-section describing the layering determination is being added.

- Further down during the evaluation of AC-TC you are referring to an “inference” technique (e.g., L386, L427, L532) to decide the likelihood for a specific class when no clear signal can be obtained. While the need for such an approach is obvious, it is never mentioned in section 4 describing the AC-TC product. This could be introduced when discussing the decision matrix in Fig. 2.

  The choices made here relate to the limitations of the radar-lidar synergy: the classes in C-TC pertaining to “in clutter” in the near-surface region and the “heavy precipitation” classes assigned when CPR is dominated by multiple scattering or attenuation, and the classes with “possible liquid” that are assigned when ATLID is extinguished.

This information about the uncertain content of regions where the instruments are not able to make a detection is encoded in the target classification, but the inferences are not built into the AC-TC decision matrix. This preserves as much information as possible without making a choice on the behalf of the user.

We have added to discussions throughout the paper to make this more clear.

L60: DARDAR-MASK also includes a radar-only and lidar-only mask before merging them.

Yes, the reviewer is correct. The sentence is modified as follow:

«The Earth-CARE synergistic product is constructed differently from DARDAR-MASK although both are basically based on the same approach. Indeed, the radar-lidar measurements are combined at each altitude grid point to create a synergistic target classification product in a single step thanks to the already existing and validated EarthCare products, A-TC and C-TC. "

L90: You could refer to the VFM product of CALIOP which also applies a layering approach.

This reference will be added.

L114: Is there a strategy to differentiate supercooled from highly oriented ice crystals (HOIC)?

No. ATLID is pointing 3 Deg off nadir. This will eliminate (90%+) of the specular reflection from HOICs.

L138: How do you define “dominant” or “low” probability? Is this further described in Wandinger et al (2022)? As this is a static information it should be possible to draw corresponding domains in the S-rho space, correct (Fig. 1)?

The dominant type is defined by that aerosol type which has the highest probability amongst the considered types and still has a probability Paer > 0.011 (the threshold is determined by the low probability configuration threshold used within this paper). Since it is a configuration parameter, it may be adapted when real EarthCARE data is available.

In case of a pixel with a ‘low probability’ assignment (i.e. the maximum value of Paer is below 0.011), the pixel is assigned to the “unknown” class.

L146: Was the term “weak targets” introduced before?

This will be added to the text.

L146: Can you provide more specific numbers to this median filter? The median filter is applied to integer masks which are by themselves layers? Please elaborate more clearly what is done here and to what effect. Should this filter not produce masks with intermediate float values? Fig 1: What are the lines? Isolines of quantiles? Some centers have 3, one has 4?

More detail covering the implementation of the class filter is being added. Indeed, it is different from a “normal” median procedure in order to avoid the types of issues the reviewer raises here.

L149: A short reminder to what “high”, “low” and “medium” resolution means would be nice

This will be added to the text.

L158: What is texture in this context? Spatial structure? How is this exploited?

The word “texture” has been removed in the revised manuscript. In ground-based systems, the radar reflectivity texture (i.e., its localized (time-height) standard deviation) correlates well with the presence of insect echoes. We do not have yet such experience with spaceborne cloud radars. Thus, the reference to the radar reflectivity texture has been removed.

L164: It is the other way round, AC-TC inherits from C-TC, correct? You probably want to say here that C-TC is designed to work as standalone product.

The reviewer is correct, the wording is unfortunate and creates confusion. Here is the text added in the revised manuscript: “The EarthCARE CPR target classification (C-TC) is based on a ``decision-tree'' algorithm with fixed rules and it is designed to work as a stand-alone product. In order to facilitate its use and integration in the synergistic target classification we have adopted similar target classification definitions and names.”

L169: Is the definition of C-FMR layers analogous to the definition within A-FM? Is there a similar “simple classification” done in C-FMR as input for C-TC like within A-PRO?

In the C-FMR, we only classify CPR echoes as “no significant detection”, “clutter” and “multiple scattering”. In effect, we only classify the CPR echoes are meteorological and non-meteorological.

L198: What do you mean with “increase of Doppler velocity … (at surface level conditions)”?

The hydrometeor sedimentation Doppler velocities are first adjusted for density effects by referencing them to standard surface conditions before they are used as input to the C-TC algorithm. This sentence was added in the revised manuscript.

L205: How are the position of layers defined? Totally or also partially overlapping layers? Or is this happening along profiles?

Each atmospheric column sampled by the CPR is treated separately. We do not attempt cloud and precipitation systems classifications in terms of “cluster” overlap conditions.

L220: Awkward sentence, please rephrase.

See response for L230 below

L222, L225: What does "almost certain" and the “overlap regime” mean here? Are you somehow mixing masks here or are there fixed thresholds? In this paragraph, a figure with the actual decision tree for C-TC would be most helpful.

See response for L230 below

L230: In effect, this means that layers can be split into two different classes, correct?

The text between lines 220 and 230 (of the original manuscript) have been revised for clarity.

L241: Could you give this threshold in dB/km? dBZint depends on the resolution of the data.

We disagree. The integral of the radar reflectivity profile for values over 12 dBZ does not depend on the vertical resolution of the CPR observations.

L275: Like RC1, I cannot track the r_min_eff > 15 microns as sensitivity threshold. In contrast to RC1, I would expect r_min_eff to be even higher in reality since most dBZ_min estimates are considered without Doppler broadening (see Mech et al 2014). The mentioned -35 dBZ is also only valid for the 10 km averaged product. I would refrain from giving numbers here since this discussion is worth its own paper.

We agree with you. We have therefore decided to delete this sentence since the main information on the sensitivity of radar and lidar to particles has also already been presented in the article.

Fig. 2: Some cases should be not only unlikely but impossible. How is A-TC supercooled water and C-TC warm rain possible? When using the same temp field this case should not exist. Same is true for stratospheric clouds (A-TC) and sub-surface (C-TC). To find these combinations they should probably get their own label (hatched in Fig. 2) to find them easily as soon as EarthCARE is in operation.

We divided the impossible combinations into 2 types and tagged them:

- The first type that will be marked with an (*) corresponds to various combinations crossed out in the columns of classes A-TC 1, 2 and 3. They are due to wet bulb field issue causing a difference between the radar and the lidar: the fusion layers detected by radar are not the same for lidar

- The second type which will be marked with a (**) corresponds to impossible cases: radar seeing tropospheric targets and in clutter, and lidar detecting stratospheric features

L351: Is this fall back to the A-PRO classification also true for A-TC? It was never described there

The “simple-classification” is now discussed in this paper.

Fig. 3, Caption: Describe panel c, d, e, separately. Labels would also improve the figure.

This figure is being re-worked.

L437: How do you infer an 99% detection of total ice water content from Table 5? I only see lower numbers.

This should have read “around 99%”; the value in the Table is 98.7%.

L459: Same is true here. To what cost does this inference come with respect to false positives? While the number looks impressive, the false positive rate enhancement is important here.

The false positives due to these inferences are now shown (dark blue) in Figures 5, 6 & 7 updates and discussed especially in the case of liquid cloud, where the most false positives occur. The false positives due to inferring precipitation in the surface clutter and convective cores are near-negligible, at least in the test scenes.

The overestimation of the volume fraction of these classes due to misclassification and inferences can be quantified (and now added to the figures); but the significance of any false positives depends on how these inferences are used. As an example: within the ACM-CAP (see Mason's paper et al., also submitted in the same special revue) retrieval the liquid water content retrieved within rain, rimed snow and convective cores is represented with a very simplified vertical distribution that is not intended to recover the small-scale features of liquid clouds, and where the prior can be set very low. When the CPR attenuation and MSI solar radiance measurements justify higher liquid water contents, they can be retrieved—but this can only be done where the target classification allows. In other words, the problem is asymmetric: the error in the retrieval due to not inferring the presence of liquid cloud will be as large as the liquid water content not detected, but the error due to retrieving liquid cloud inferred where none in fact exists will generally be very small due to the low a-priori value. While this is borne out in the test scenes, this assumption will need to be continually assessed in the context of the ACM-CAP retrieval.

A lot of this relates to the retrieval rather than the target classification, but we have expanded on this discussion.

Technical corrections:

L29: "important to an understanding the climate" -> "important to understand the climate" Done

L53: "detected through the profile of the atmosphere" -> "detected throughout the atmospheric profile" Done

L94: "described here is described in" -> "is described in" Done

L203: Repeated sentence. Done, sentence deleted

L220: Awkward sentence, please rephrase. Done

L227 "classify liquid clouds are warm" -> "classify liquid clouds as warm" Done

L256: "points" -> "pixel" (?) Done

L261: "defined different vertical grids" -> "defined on different vertical grids" Done

L278. Awkward wording, please rephrase. The whole paragraph is a little bit hard to read.

Done, sentence changed as follow: "The detection of liquid cloud is challenging for CPR but possible depending on the sensitivity and the presence of drizzle"

L286: "detecting liquid cloud presence" -> "to detect the presence of liquid clouds" Done with L278

L321: Awkward wording: "is considered detected" … "has issue with clutter" … "it is assumed detected" Done: sentences changed to "The ground or "sub-surface" classification is assigned when radar or lidar can see it. It is also assigned when the radar sees the ground and the lidar signal is attenuated or has data issues (missing data)"

L327: Very unclear sentence.

Done. Sentences reformulated as follow:

“Concerning the radar surface clutter region, it essentially relies on a specific processing of the radar reflectivity signal coming from zones assumed to be close to the ground. The C-TC classes resulting from this processing will be taken as such for this region.”

L335: “developed to help develop” -> “designed to help develop” Done with “… produced to facilitate the development and testing of …”

L336: The term “PDGS” was never mentioned before? Done by adding “Payload Data Ground Segment (PGGS)”

L369: “structures resolved resemble” -> “resolved structures resemble” Done

L374: “which has the great advantage of including inside A-TC at all resolutions and C-TC”

-> “which incorporates A-TC and C-TC at all resolutions”

Done by changing the sentence with ” which incorporates A-TC at all resolutions and C-TC” since only A-TC is built with many resolution not C-TC

L483: “aerosls” -> “aerosols”, please rephrase sentence. Done

Fig. 7, Caption: “liquid cloud” -> “rain” (?) Done