Review - First Nationwide Analysis of Riming Using Vertical Observations from the Operational German C-Band Radar Network

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Summary & recommendation

The manuscript describes a novel method to detect riming events using the German weather radar network. A rime fraction retrieval originally developed for Ka-band cloud radars is transferred to routinely performed vertical measurements by the C-band weather radars, so called “birdbath” scans. This allows the authors to analyze riming events nationwide in wintertime, stratiform clouds.

The proposed approach and the obtained results are sound, and fit well within the AMT scope. The paper is well structured and easy to read. I do not have major concerns, but some choices / analysis steps are not clear to me especially regarding the “mockup” that the authors use to validate the retrieval (see general comments). This should be addressed in the revision. Further, I would recommend to make the motivation (and the conclusions) less Germany-focused. This would make the manuscript more interesting for an international audience given the method can be applied/adapted to other radar networks.

General comments

- While the introduction does a good job introducing the readers to the content of the manuscript, I am missing the “bigger picture motivation”. There is also a strong focus on Germany. This makes the study less accessible/interesting for international readers. I would suggest to start with a more general paragraph on why riming is important and why large-scale monitoring is crucial to study spatial variability. And afterwards go into your dataset (German radar network), but mention that this could be applied to other radar networks.

- I don’t understand certain choices regarding your mockup retrieval. To act as a validation for your method, the mockup should be as close as possible to the C-band data. However you only resample the Ka-band cloud radar data to the C-band spatial and temporal resolution if I understood correctly. The blind range of 600 m is not included in the mockup and neither the lower. I am wondering why as I would assume both could be implemented rather easily and make the validation more sound. If you want to show the contribution of the lower temporal resolution vs. sensitivity and blind range, why not include two mock-up version? Then you can show the discussion in L265-271 also visually, e.g. by

including both mockups in Fig. 7 as an example. In addition, I would argue calling the resamples Ka-band data “C-band mockup” is misleading as readers might expect you performed some kind of frequency correction.

- References are missing at several location (seems to be a bibtex issue since there are (?) instead). Please make sure to double check all references. I will list all occurrences that I notices in technical corrections.

Specific comments

- L55-60 (there is an issue, these are more than 5 lines): How is the separation of rain and ice part done? Do you mean liquid and ice instead of rain and ice? Is this done via cloudnet? What about mixed-phase regions, which are important especially in the context of riming? Please include more details and/or a reference and discuss uncertainties of the used approach.
- L55-60: I don’t understand why you stress “unique” relation. What do you mean by unique?
- Figure 1: the yellow x might be hardly visible if this plot is smaller in the final paper. I suggest to make the symbols all a bit larger. Also please mention in the figure description that the station abbreviations are included in the brackets. This might be missed at first glance, which is confusing later.
- L96: “liquid layers in ice clouds” is an oxymoron, no? → Write mixed-phase clouds or ice-containing clouds
- L99-101: But ERA5 is available for the station locations, right? Could DWD automate the download and store alongside the radar data? I’m asking, because right now it sounds like the problem is with ERA5. But I assume you want to stress that Cloudnet like data storage would be ideal? Maybe rephrase this section to get your point across better.
- L111: So, are you applying relations developed for X-band to the C-band data (since everything is in the Rayleigh regime for both)? If yes, please state this explicitly.
- L124: I understand that you need height dependent thresholds, but I have some difficulty with the site dependence. Won’t that impact your statistics? Especially if there were any offsets between sites? How different would your results be if you use universal height dependent thresholds for all sites? Based on which timespans are the thresholds defined? Or is there a threshold for each birdbath scan? Please include a few more details and a discussion how much the choices in setting the thresholds impacts your results.
- L134: how many riming events do you miss due to the 600 m minimum? I suggest to use your mock-up with and without a 600 minimum to quantify.

- L139: What about mixed-phase regions of the cloud? Do you mean ice-containing?
- L145: Your riming detection only works for FR>0.6 if I am not mistaken. I would therefore argue that you can't say riming is rare, only that strong riming cases are rare.
- L155: "from manual analysis" I'm inclined to trust you, but this might be nice to include in an appendix to ensure reproducibility.
- L162: Can it happen that a riming event is detected as a melting layer? If riming occurs, I would also expect an increase in v, faster falling particles below and slower falling particles above the event.
- L165: You write that this makes it less likely that riming is misinterpreted as the melting layer, but what about larger-scale riming events?
- Figure 3: Looking at this I'm wondering. What if you have a melting layer and re-freezing below (probably very rare, but might occur)?
- Figure 3: This shows one case / site. What about a comparison with more data? For example, you could compare this detection using the mock-up data to the Cloudnet melting layer detection?
- L191: for what amount of data did you do the mentioned systematic tests?
- Figure 4c. I suggest to make this subfigure more intuitive to read by using different colors. For example, you could use similar colors for the true positives & the false negatives and similar colors for the false positives & true negatives. And maybe label this also accordingly, so that it's clear at first glance which are the "correctly identified" pixel and which are "wrong".
- L213-214: I don't understand what you mean with this sentence. Do you mean by the 2 min km filtering you remove 17 riming cases?
- Figure 6: Mention that this shows example sites in the figure description. Also please state clearly in the text why you focus on winter. Possibly where you introduce the convection filtering.
- Figure 8: I recommend to include RMSE.
- L241: different results for some months → is this random or is there some seasonality?
- L250: why are you only using the Lindenberg Ka band to compare. Isn't there also a cloud radar in Munich that is close to the Isen DWD radar? I just quickly looked at the cloudnet stations in Germany, so I could be mistaken. If there are other "close-by" cloud radars, I think it would be highly valuable to do the comparison for a second site.
- L272: You only detect riming for stratiform situation if I understood correctly. Do you still compare to all surface precipitation? How much precipitation from convective cases do you have in winter for your dataset? Please discuss. Also, does this include rain and snow?

- Figure 10: what do the different circle sizes mean? Please include a legend
- Figure 13: Please include the amount of data per temperature bin in theses figures to give context how reliable the data is. Also, it would be great to include a measure / statistic test if the distributions are significantly different for different subregions or stations or not.
- L311: But you only showed a weak correlation, right? Please include this here.
- L313: this should be stressed earlier in the text. Also, please include for example percentages how large (or rather small) the contribution of convective data in winter is compared to stratiform.
- L346: I recommend to remind the reader what a birdbath scan is. This will make the text more accessible for people only reading the conclusions.
- L374: Include a reference for this statement (I'm assuming the Kneifel & Moisseev paper or whoever they cite).
- L365-366: what is hindering the integration to Cloudnet? Are you in contact with ACTRIS and DWD?
- L373: Why the focus on Europe? Could the method be applied to international radar networks?
- Data availability: Will you provide the code? Maybe a python tool? This looks like a nice retrieval that could be applied or adapted to radar networks in other countries.

Technical corrections

- L71: reference missing
- L91 (and later): remove the brackets around the year in the reference → citep instead of (citet).
- L140: reference missing
- L201: Figure 5b is mentioned before Figure 5a → please flip
- Figure 4: please use color-blind friendly color maps.
- L236 (and likely earlier): Usually, Figure is written out at the beginning of a sentence and abbreviated to Fig. otherwise.
- L 270-275 (again way more lines than 5): the equations: I don't think all parameters are described.
- L369: reference missing