Response to Associate Editor and Reviewers

July 21, 2025

Manuscript egusphere-2025-1914 "First insights into deep convection by the Doppler velocity measurements of the EarthCARE's Cloud Profiling Radar"

1 Reviewer 1 Comments:

This article describes an analysis of convective events as observed by the radar of the ESA/JAXA EarthCARE mission. This radar uses a novel technology in space, which is its Doppler capability. The authors do a great job of

1. illustrating the quality of the EarthCARE observations and
2. tying radar observations to underlying atmospheric dynamics.

The Authors' expertise allows them to juggle between data products and select the most appropriate to analyze various aspects of convection. The task at hand is challenging because vigorous convection often means significant attenuation, large velocities that are aliased, multiple-scattering etc., especially at millimeter wavelengths like the one of EarthCARE's radar.

We thank the reviewer for their careful reading of the manuscript and for the thoughtful and constructive comments, which helped us improve the clarity and focus of the paper.

I suggest major revisions of the article before it can be published. This is motivated by the fact that

- the article is quite long (Section 2 should be subdivided and unnecessary material should be left out).
- there is some work needed in terms of editing to avoid distracting the reader from the main message of your article (such distractions are unfortunate because you obviously did a lot of good work!).

For instance Lines 204-224 are really well written. Could you maintain that standard throughout the article, or have that co-author re-read the article?

We will work on improving Section 2 by splitting it into subsections and removing sentences that are not essential to understanding the topic. In addition, to reduce the overall length of the manuscript, all co-authors will re-read the text to improve its focus and avoid unnecessary digressions.

While I appreciate your use of radar and GEO data, I would recommend also using reanalysis data from ECMWF. In particular, it would be interesting to see if the height of the 0C isotherm is consistent with the melting layer that you observe, and if the ERA5 vertical wind has any updraft.

In convective scenes, due to attenuation and multiple scattering, it is not possible to clearly identify the melting layer. Therefore, the 0°C isotherm from ECMWF was used as a proxy to define the level below which Doppler velocities can reasonably be assumed to be dominated by sedimentation. We believe a comparison with ERA5 data would not be particularly meaningful for the following reasons:

- The spatial resolution of reanalysis data is too coarse compared to EarthCARE observations.

- A key strength of the EarthCARE mission is its ability to investigate atmospheric dynamics at very high spatial resolution, capturing processes that were previously unresolved by both satellite and ground-based instruments.

- In convective systems, updrafts are expected to occur on sub-kilometer scales. While dealiasing Doppler measurements at this resolution is indeed challenging, ERA5 simply cannot resolve such fine-scale dynamics.

Also, I would suggest combining Fig. 7 and 8: they are great but having to flip back and forth between them was yet another distraction from the precious scientific content of your article.

Thank you also for the suggestion to merge figures; unfortunately, Fig. 8 has already three panels and, if merged with Fig. 7, it won't fit in a single page.

Lastly, this is just a convention, but could you please consider showing downward motion as negative velocities? That prevents mental exercises to interpret the Doppler observations.

As is conventional for spaceborne radar measurements, positive Doppler velocity indicates particles falling toward the ground. For this reason, we have chosen to retain the current color scale convention.

All the grammar errors have been corrected in the revised version of the manuscript as suggested in the document attached to the comment.

From the attached document (questions and comments answered already above are omitted):

- Please explain how Doppler radar allows to answer the scientific question of paragraph1, before you describe EarthCARE. Doppler radars, in principle, are able to measure the vertical air motion within clouds, thus giving an insight to understand convective dynamics and convective mass flux. This statement has been added in the abstract of the revised version of the paper.

- While you are reviewing all the spaceborne radar missions, why not mention RAINCUBE's Ka-band radar? It did observe quite a lot of convection. The RAINCUBE mission has been added to the list of previous radar mission, observing convective events.

- You should consider citing the seminal articles from the European and Japanese teams that describe the Doppler radar of Earthcare (Kumagai et al., Illingworth et al.) References added in the revised version of the paper. Thank you for the suggestion.

- Section 2 is way too long for a reader with limited attention span. Please consider either reducing it, or dividing it into subsections. Section 2 has been divided into three subsections, following the suggestion of the reviewer.

- References are Professor-Kollias-heavy, which is not a slight. However, a lot of work has been done prior to that, going back to Meneghini and Kozu, or Marzoug and Amanyec. Also these references have been added to the revised version of the paper.

- The caption of Fig.1 mentions the Pacific, which is it? Please add the latitude, longitude and times to the X-axis of your figures. That helps figure out over which part of the world the data are from as well as the direction of travel of the aircraft. All Figs. in the manuscript have been updated, as well as their captions, according to this suggestion.

- Why don't you show surface echo and clutter? This is useful info as well. The clutter and surface echo have been added to complete the figures in the updated version of the manuscript.

- This threshold is very high (referring to Doppler velocity showed only where reflectivity¿-15dBZ)! Isn't the noise floor in the whereabouts of -35 dbZ? If so, you are really focusing on SNR >14 dB. Is there a reason for that? No, the noise floor for EarthCARE is -21 dBZ (that defines the reflectivity at SNR=0 dB). In order to produce good Doppler estimates, reflectivities above such thresholds should be used. At negative SNRs the quality of the Doppler measurements very quickly deteriorates.

- (Referring to along-track averaging of Doppler velocity, from 1-km to 4-km.) Please clarify: even though the averaging is done on the complex- valued quantities (lag-1 PP correls) the resulting Doppler velocity may still be aliased. The aliasing is generally reduced because the high velocities encountered at the km-scale are averaged out at 4 km scale. As suggested however, the averaged Doppler velocity is not immune to aliasing.

- The value of V_N varies along the orbit (because of the PRF). What was the V_N for these data? (Referring to Fig. 3) The Nyquist velocity for this piece of orbit was 5.08 m/s. It has been added to the text, along with the PRF, for all the analysed scenes.

- Computing the spectral width like this is better than using the spectral width posted in the EC-CPR data because of its prohibitive broadening, right? If so, please clarify.(Referring to Doppler velocity standard deviation, computed with a 3kmx2km running window). No, this is not an estimate of the spectral width (which is typically of the order of 3 m/s due to spectral broadening associated to the platform movement). This is an estimate of the local variability of the Doppler velocity field. High standard deviations are expected to be associated to convective clusters.

- How do you determine the residual error? Do you have a truth/reference? The estimate of the residual errors is based on previous simulation studies based on synthetic scenes where the truth is known from the model output.

Dear Authors,
I have taken note of your initial reaction to my review (i.e. suggestions you agree with and those you disagree with). However, I would like to invite you to please consider

1. points that are also made by the second reviewer (e.g. regarding the convention for the sign of velocities, which is an easy fix);

2. more importantly, the PDF I attached which details the corrections and edits that I invite you to apply (I only see your reaction to the paragraph posted online, which is only one of many suggested corrections from your title to your references).

Respectfully,

Dear Reviewer,
Thank you very much for your thoughtful feedback, and for the considerable effort you have invested in providing such detailed comments and suggestions. We truly appreciate the time you took to not only review the manuscript but also to prepare the comprehensive PDF with corrections and edits across the entire document. We acknowledge the importance of the additional points raised—especially those that align with the second reviewer's comments, such as the convention for the sign of velocities—and we are currently working on a revised version of the manuscript that carefully implements all the suggested changes. We are committed to addressing your comments in full and will ensure that our revision reflects this.

2 Reviewer 2 Comments:

This manuscript describes initial Doppler velocity measurements made by the EarthCARE Cloud Profiling Radar. These initial measurements are exciting and are the initial "pay back" for years of analysis and feasibility studies this team has made exploring the challenges of making Doppler velocity measurements from space. This manuscript is appropriate for Atmospheric Measurement Techniques and will need some minor changes before being ready for publication.

We appreciate the reviewer's careful reading of the manuscript and their constructive comments, which have contributed to improving the clarity and focus of the paper.

General Comments.
This reviewer's comments are aimed at clarifying text that could be confusing to the reader. In general, the manuscript is well written. However, there are a couple paragraphs in the middle of the manuscript that are not of the same quality as the rest of the manuscript and will need editing and clarification (details are described below). One concern in these paragraphs is the inclusion

and analysis of Doppler velocity estimates in the regions below multiple scattering, which, I believe, should not have valid atmospheric observations.

Specific Comments.

1. Line 74. Please correct satellite speed (7.6 km/s). Thank you for highlighting the typo. It has been corrected in the revised version of the manuscript.

2. Line 99 and Fig. 1a. Please clarify for the reader whether the spatial resolution of the reflectivity measurements shown in Fig. 1a is at 500-m, 4-km, or some other spatial resolution. In Fig. 1a, the resolution of the reflectivity measurements is 1km. It has been clarified in the text of the revised version of the manuscript.

3. Line 102. Please clarify for the reader, is the averaging immune to velocity folding, or is the lag-1 velocity estimator immune to velocity folding? Or, is this statement even necessary? The average is performed in the complex space, to keep it as less sensitive as possible to the velocity folding.

4. Line 122. Please inform the reader the value of the Pulse Repetition Frequency and the Nyquist velocity for the examples shown in the manuscript. Frame 1752E (Fig. 3): $V_N = 5.08$ m/s; PRF=6.38 kHz . Frame 1760E (Fig. 1): $V_N = 5.09$ m/s ; PRF=6.38 kHz. This has been added in the revised version of the manuscript.

5. Line 126. Please inform the reader that this estimated maximum value of 6.5 m/s is obtained only when using a radar operating at W-band and that larger reflectivity-weighted mean velocities are measured when using radars operating at lower frequencies. (Readers may be more familiar with Ka-, Ku-, or X-band airborne radars; or Ka-, K-, C-, or S-band ground based radars.) Because Doppler velocities are reflectivity-weighted, and at W-band non-Rayleigh scattering effects tend to reduce the reflectivity of large particles, the maximum reflectivity-weighted terminal velocity at W-band does not exceed 6.5 m/s. We have clarified this point in the revised manuscript.

6. Line 136. The phrase 'requires knowledge' is the incorrect phrase to use here because we will never "know" the exact Doppler terminal fall speed (aka, reflectivity-weighted mean fall speed) of the hydrometeors within the radar resolution volume. This sentence is shifting from observations to a retrieval algorithm, so a more appropriate phrase to use here is 'requires parameterization', or some other expression that reflects that the Doppler terminal fall speed is not measured. This is clarified in the revised paper.

7. Line 136. Please clarify the text. As written, the phrase "...V_T^D can be..." is equivalent to the phrase "...it could be done, but was not done in this study". This is clarified in the revised version of the manuscript.

8. Line 135-137. After reviewing comments 6 and 7, maybe the discussion of retrieving air motion will be confusing to the reader because air motion is not retrieved in this manuscript. Possibly, the sentences from lines 135 to 137 can be deleted. Thank you for spotting this, probably best choice is to delete it.

9. Lines 143 to 188. The paragraphs from line 143 through 188 are not of the same quality as other paragraphs in this manuscript. These paragraphs contain grammar errors, errors in logic, and a change in variable notation. These paragraphs need to be rewritten and then proof-read for consistency with the rest of the manuscript. A couple major concerns (and not all concerns) include:

    - Line 170, the text is, "...V_D is positive indicating the presence of an updraft." This is inconsistent with Equation (1) that defines positive values as downward motion. It is an error, the convention is to have positive sign for downward velocity, negative velocities are updrafts. We are correcting it in the revised version of the paper. Equation (1) thus is correct.
    - Figures 4 and 5. The variable V_{SED} is shown in Fig. 4 and 5, but it is not described in the body. Also, is V_{SED} the same as V_T^D? Yes, they are the same variable. It is clarified in the revised text.

- Line 185, Fig. 4b and 4c below 11 km, and Fig. 5b and 5c below 14 km. Are the authors suggesting that the Doppler velocity measurements below the reflectivity 'knee" corresponding to the height region below multiple scattering are valid and represent atmospheric observations? The authors will need to describe how the change in phase of signals coming from non-radial directions are representative of motions along the radial direction. Doppler velocity measurements in regions affected by multiple scattering cannot be considered reliable. Although these regions were expected to exhibit significantly more noise, this is not always observed. This aspect needs to be further investigated in future studies. By adopting a conservative approach, the Doppler velocity values in such parts of convective cell profiles should not be trusted.

10. Lines 257 to 259 and Figure 8. Where are the green bars in Fig. 8a? Added the corrected figure in the revised version of the manuscript.

11. Figure 8. What are the symbols in Fig. 8a and 8b? The symbols in Fig. 8 are intended to guide the reader in matching the imagery from different instruments. Indeed, they are reported both on the CPR image and on the MSG image (accounting for parallax correction). A sentence for clarification to this point has been added in the revised version of the manuscript.

12. Figure 8. Can you please label Cell 1 and Cell 2 in the figure to help follow the discussion in the text? Done in the revised paper.

13. Line 316, the phrase "... unprecedented view of convective motions on a global scale" is incorrect and very misleading. The satellite makes nadir measurements and is in an orbit around the globe. These measurements are not at a "global scale". Also, this work shows images of a few individual precipitation events that do not represent motions on the global scale. Therefore, the phrase can be reduced to, "... unprecedented view of convective motions." We agree, it has been updated in the revised version of the manuscript. In the updated conclusion we will mention the new global perspective.