

Response to the Reviewer #2

Dear editor,

We sincerely thank Reviewer #2 for their insightful and constructive comments, which have significantly improved the quality of our manuscript.

We hope that the comments and suggestions provided by reviewer #1 and reviewer #2 have been thoroughly addressed in the reply letter and the updated manuscript. Consequently, we would like to submit the revised manuscript and the diff-version of the revised manuscript together with our responses to all the comments provided by reviewer #1 and reviewer #2. In our replies, all references to modified lines are given with respect to the tracked-changes version of the manuscript.

Thank you for considering our work,

Best regards,

Audrey Teisseire, Patric Seifert, Kevin Ohneiser, Maximilian Maahn, Robert Spirig, and Jan Henneberger

I. General Comments

This paper presents a validation of the VDPS method, introduced in an earlier paper by the same research group, expanding and illustrating its applicability to different case studies using independent VISSS observations recorded in the framework of the CLOUDLAB campaign. Two important contributions of the study are the use of SLDR based on cross-polarized Doppler spectra to detect hydrometeor populations and the assessment of non-Rayleigh effects trying to quantify biases at Ka/W band. Overall I think it is a valuable contribution to the field so, with a few clarifications and minor formal corrections (see Specific Comments), should be considered for publication – I suggest considering three general items in the text:

Comment 1:

Authors could describe more explicitly the contribution of the SLDR approach used (why is it important).

Response 1:

We added in the introduction Section in lines 40-42: *“The SLDR approach provides complementary information on particle shape and orientation that cannot be retrieved from co-polarized radar variables alone. This makes SLDR particularly valuable for identifying the particle shape and microphysical processes, which is a key aspect of this study.”* and in VDPS method section in lines 134-136: *“Indeed, the SLDR approach is particularly advantageous due to its slanted geometry, which enhances sensitivity to particle shape while reducing the impact of particle oscillations while falling.”*

Comment 2:

The particle size limits considered as thresholds for Rayleigh scattering in the two bands used (Ka and W) could be mentioned in the introduction (not in a results section).

Response 2:

Thank you for the comment, we added in lines 50-53: *“The Rayleigh scattering approximation is assumed to be valid for water droplet diameters smaller than approximately 300 μm at Ka-band and 100 μm at W-band (Bohren & Huffman, 1983/1998, Chapter 4). For less dense ice particles, the Rayleigh range covers larger size ranges, depending on shape and density.”*

Comment 3:

A brief discussion could be added on potential limitations of using ECMWF IFS temperature profiles instead of local measurements such as those obtained by tethered-balloons or from microwave radiometers (which in principle were also available during the campaign according to <https://cloudlab.ethz.ch/the-project.html>) – given the uncertainty associated to IFS profiles perhaps they could be plotted without one decimal digit as they are now.

Response 3:

The issue has already been raised by Reviewer #1. Unfortunately, temperature profiles from radiosonde or microwave radiometers are not available for all case studies during the CLOUDLAB campaign. However, the IFS temperature contours are compared with the Payerne radiosonde measurements to validate the agreement of the IFS temperature fields. We acknowledge that, for the first case study on 22 February 2024, we observed a temperature deviation between the IFS calculation and the radiosonde measurement in Payerne exceeding one kelvin. As a result, we decided to remove the temperature contour from Fig. 1, since it is not used in the interpretation.

A paragraph addressing the limitations of the IFS has been added to the Instrumentation section in lines 120-128 ; *“Finally, the temperature information used in this study is obtained from the European Centre for Medium-Range Weather Forecasts (ECMWF) Integrated Forecasting System (IFS). Indeed, IFS temperature profiles represent grid-box averages and rely on model physics and data assimilation, which may limit their ability to capture local-scale and small-scale temperature variability, particularly in the boundary layer and under stable conditions. However, Illingworth et al. (2007) report generally good agreement between IFS and ground-based observations, while also highlighting differences on the order of several tenths of a Kelvin, which is sufficient for the purposes of our analysis. However, the temperature contours are compared with the Payerne atmospheric soundings for all case studies in order to verify the reliability of the measurements and the associated interpretations. For this reason, the temperature contour has been removed from Figure 1 due to the poor agreement between the IFS and radiosonde profiles.”*

II. Specific Comments

Comment 1:

Page 1, line 9. Typo: co channel -> co-channel (as in the rest of the text)? Please check.

Response 1:

Corrected as suggested in line 9.

Comment 2:

Page 2, line 43. Typo: Non-Rayleigh -> non-Rayleigh (as earlier in the same line and elsewhere).

Response 2:

Corrected as suggested in line 48.

Comment 3:

Page 3, end of Section 1. Section 5, unlike sections 2 to 4, is not mentioned here; please add a sentence to briefly describe it (I think it is ok to omit Section 5).

Response 3:

We thank Reviewer #2 for this comment. We modified the sentence in lines 60-64 by "*Section 4 is dedicated to the comparison of the VDPS results with in-situ measurements. Finally, two case studies featuring large aggregates and dense graupel are presented in Section 5, in order to evaluate the possible effect of non-Rayleigh scattering on SLDR measurements and the corresponding influence on the particle shapes derived by the VDPS method.*"

Comment 4:

Page 3, line 82. What does MBR mean? I assume is an internal naming convention, but readers might be curious (as I am) and a brief explanation can probably be added easily.

Response 4:

We added in line 89: "*... MIRA-35 MBR5 (MicroBlaze Radar with serial number 5) ...*"

Comment 5:

Page 4, line 90. Typo: 2016b)) -> 2016b)

Response 5:

Corrected as suggested in line 98.

Comment 6:

Page 4, lines 98-99. ... of type (?)... Please check sentence and rewrite.

Response 6:

We removed the parentheses following "*of type*" in line 107.

Comment 7:

Page 4, line 104. Format: Tab. or Table? Please be consistent – I suggest using Table.

Response 7:

Corrected as suggested in all the manuscript.

Comment 8:

Page 8, Figure 1 caption. Please add something as 'Temperature levels plotted correspond to ECMWF IFS forecasts' or similar.

Response 8:

Corrected as suggested in all figures representing overviews.

Comment 9:

Page 11, Figure 4 caption. 10:10:17 -> 10:10:17 UTC

Response 9:

We added „UTC“ in caption 4.

Comment 10:

Page 12, line 218. Please check meaning of this sentence. [and similarly Page 13, line 239].

Response 10:

We change the sentence in lines 239-240 in *“Next, the blue-framed case from 10:08 UTC (Fig.3), which represents an early stage of a riming process, is discussed.”*

Regarding the sentence in line 260 (*“The following analysis is divided into two separate case studies.”*), we have checked its meaning and confirm that it is correct.

Comment 11:

Page 16, line 275. Typo: the presence supercooled liquid droplets -> the presence of supercooled liquid droplets

Response 11:

Corrected as suggested in line 297.

Comment 12:

Page 23, line 405. ... that were... that was? Please check meaning.

Response 12:

In the sentence *“The second case study presents large graupel that were detected between 12:50 and 13:10 UTC on 24 February 2024”* we used “were” because “large graupel” is plural in this context.

Comment 13:

Page 26, Figure 18 caption. Suggest: Surface hydrometeor shapes detected with VISSS ...

Response 13:

corrected as suggested.

Comment 14:

References: some DOIs have duplicated 'doi.org' strings in the URL.

Response 14:

Corrected.

Comment 15:

Page 29, line 526. Typo: Journals -> Journal

Response 15:

Corrected as suggested.