

General comment by the authors to the Reviewer #2:

We thank the reviewer for the time and effort in reading the manuscript and for the constructive comments and suggestion which we in the following address point by point (our answers are marked with blue font color and the modified text are in italic blue).

Reviewer #2

This manuscript describes a dataset of two-months of observations from the JOYCE-CF instrument suite in Germany. This work focuses on three ground-based radarsat frequencies of 13, 35, and 94 GHz. There is a detailed description of the data processing and filtering methods implemented in producing the triple-frequency co-located observations. These triple-frequency patterns of clouds and precipitation are examined with ancillary meteorological measurements to isolate processes. Aggregation and melting particle signatures are isolated and identified. In general, I believe this work is unique and important, and builds well on previous triple-frequency radar precipitation studies (i.e., Kulie et al., 2014). Consequently, I think this work should be published after adequately addressing concerns I have outlined below. I would classify my review of this paper as a major amount of minor revisions – however, I want to emphasize that the writing needs to be thoroughly edited and clarified; this is especially important in Section 3, as the details of the filtering of the dataset need to be very clear.

Major Comments:

1) My main issue with the paper is the writing. Word usage, punctuation issues, and change of author voice (inconsistencies) throughout the manuscript make it a difficult read. The author(s) need to carefully go through the manuscript, as there are several places with incorrect or missing punctuation (i.e., lots of missing commas, semicolons are often used incorrectly). Run on sentences and long phrasing needs to be broken up in places for clarity. Please be careful with tense as well – there are statements voiced as present and past together. And try and avoid passive voice statements if possible.

We thank the reviewer for all the specific comments on this point. Apart from the punctual corrections, the text has undergone an extensive review and we hope that the writing quality has sufficiently improved compared to the first submission.

Some examples of proper comma usage (with comma added):

2) Page 2, Line 15 . . . characteristic particle size, as well as...

3) Page 3, Line 4 . . . other two radars, which were installed...

4) Page 9, Line 14 . . . close to cloud edges, or for Ze close to...

A: We thank the reviewer for the examples. We reworded those sentences. We tried our best to apply the reviewer's suggestion throughout the text whenever appropriate.

5) Please be consistent in how the citations are presented (i.e., Löhnert et al., 2015 vs. Löhnert et al. (2015)).

A: We reviewed the entire manuscript and made the citation style consistent.

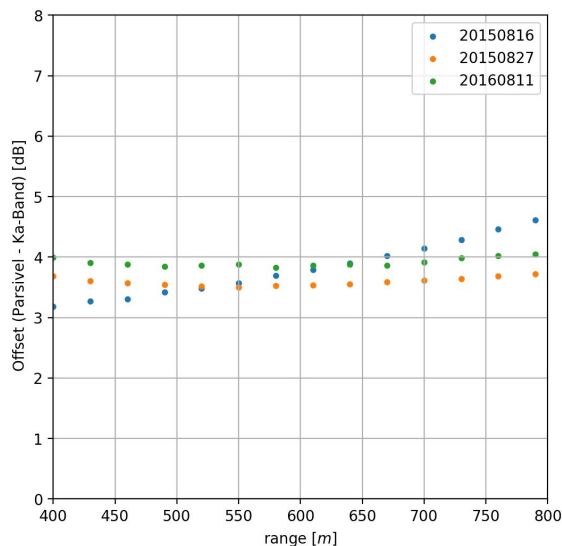
6) The radars are referred to as X, Ka, W bands and X-band, Ka-band, W-band – please choose one to use consistently in the manuscript. It is confusing that throughout the paper the author uses the names of the respective radars (KiXPol, JOYRAD-35, and JOYRAD-94), but in the figures it is often the bands being referenced (ie., X, Ka, W). . . it would be best to make these consistent for the reader. I suggest using the names when initially introducing the radars in Section 2, but then use X-, Ka-, and W-band radars in the text when talking about the figures, as it is easier to follow the statements. These inconsistencies are distracting

A: Thanks for this suggestion, after section 2 the radars are referred as X Band, Ka Band, W Band.

7) In Section 3.2 a Parsivel is used to correct the calibration of the 35GHz radar at the lowest noise-free bin (500 m AGL). My question is how confident are the authors that the DSDs at 500 m and the ground are so comparable that they feel this is an ideal means of evaluating the radar? My experience is that the DSD can change a lot with in the BL and certainly in 500 m. Additionally, if we assume growth of droplets for these

cases, then the shift in the histograms shown in Fig 3 is in the correct direction for a DSD with larger droplets at the surface compared to 500 m. So, my question is how can you separate out changes in DSD as a possibility for the results you see in Fig 3 (since you have no way of truly knowing the DSD at 500 m)? In other words, how are you accounting for the ambiguity of any growth mechanisms in the lowest 500 m?

A: The calibration method using Parsivel as reference assumes that the rainfall properties at 500 m and ground level are similar in a statistical sense. By assuming this, we are already avoiding the discrepancies we would face by directly comparing time series of simulated and observed Z. However, we agree with the reviewer that this method is prone to uncertainties, especially if processes like drop growth, drop breakup, or evaporation systematically alter the rain distribution within the lowest 500m. Nevertheless, we are confident in our approach because we compared the estimated offset to other techniques (for example, applying the reflectivity saturation technique described in Hogan et al., JTECH, 2003 using a W-Band radar). Recently, we were able to apply this method to several radars with smaller blind zones and found very consistent results. We also applied a different test to the rain cases we selected for this study. Based on the Parsivel PSD, we calculate a reflectivity profile assuming constant PSD and accounting for attenuation. Then we compare the measured reflectivity profile to the attenuated Parsivel-Ze profile at the first useable range gates (500-600m). In that way, we are able to see whether the reflectivity change is mainly due to attenuation or whether there might be other processes affecting the Ze profile. In two of the three cases, the measured changes in the profile are very close to the ones predicted by attenuation and constant PSD (shown in figure below). Of course, this does not answer the question how much the PSD is altered below 500m. Our main motivation to analyze several rainfall cases is that it is rather unlikely that the same processes are present in the different rain events in a similar way. Hence, we are aware that the method is prone to uncertainties but the fact, that the variation of estimated offsets is much smaller than the offsets itself indicates that the method has merit. We extended the discussion of the technique in Section 3.3 in order to address the issues raised by the reviewer.



8) In general, Section 3 needs attention, as it could be written more clearly. The data processing and filtering methods are complicated, and I think more attention needs to be focused on cultivating a very clear description of issues presented. As it stands, Section 3 tends to go back and forth between concepts. For example, the 3-minute moving window average is introduced on Page 11, Line 4 (in reference to Figure 5), but it is not explained why it is implemented. Later on, in Section 3.6, the 3-minute moving window average is re-introduced and explained as to why it is used. This is one example of many in Section 3 that I feel muddle the message and confuse the reader. Another issue is that discussion of the Errors and Warnings is disorganized. I think reorganizing and clarifying sections 3.4, 3.4.1, and 3.6 are needed. All of these sections feel somewhat random and the narrative thread is lost.

A: We agree and are grateful for the suggestions. We modified the structure of the sections in order to separate concepts and avoid confusion. Now section 3 is only dedicated to the data processing as the section title suggest. The former sections 3.4.1, 3.5 and 3.6 have been moved to a new section 4 titled “overview of the dataset”. In this section, we give an example of applying the filtering flags, show remaining limitations of the dataset and present the sensitivity of the X, Ka and W Band radars during the campaign. Moreover, the discussion of error and warning flags has been made more linear and easier to follow (see the new text at sections 4.1 and 4.2).

9) DGZ is defined as -17.5 to -12.5 C...so you could have some possible DG happening in coldest T range. Why not show what is happening even lower temps (Fig 9), why stop at -20C? Is it possible to make figure 10 with cutoffs of <-17C, between -17 and -12, and >-12C to try and to best isolate the DGZ?

We modified both axis as suggested, but we limited the y axis to -30 C. The main reason for this is that both DWRs are very small at temperatures lower than -30. A figure covering the entire temperature range has been made available as supplementary material. Regarding Figure 10: We agree that the suggested temperature regimes better cover the DGZ according to previous cloud chamber experiments. Due to the fact that we lack direct measurements of temperature and that the CloudNet temperature is based on model data, we decided to enlarge the suggested temperature range to -20 to -10°C. In this way the DGZ is certainly included and the main feature of increasing DWR is captured as well. We have included a discussion about this point in the manuscript at section 5.1.

Minor Comments (my suggestion and comments after the –):

10) Page 1, Line 1 – a two-month dataset

A: Done

11) Page 1, Line 1 – “Doppler cloud” – the X-band does not see cloud droplets, so maybe amend the abstract to say cloud and precipitation radar observations

A: Agree

12) Page 1, Line 2 – capitalize Core Facility **A: Done**

13) Page 1, Line 19 – remove extra **A: Done**

14) Page 2, Line 5/6 – unclear sentence “The microwave . . .”

A: The sentence has been reworded

15) Page 2, Line 18 – two months of winter

A: Done

16) Page 3, Line 6 – capable of measuring

A: Done

17) Page 3, Line 7 – (LDR) – when you define an acronym, put () around it

A: Done

18) Page 3, Line 15 – “interrupts” is not the correct usage here

A: The phrase has been reworded

After each complete rotation, the radar stops the measurements for few seconds before the next scan starts, introducing thus a small measurement gap at each scan routine.

19) Page 4, Line 5 – already defined LDR, no need to repeat

A: Agree

20) Page 4, Line 9/10 – Passive voice, rewrite with the clauses reversed “JOYRAD was vertically pointing most of the time, as the main . . .”

A: Accepted

21) Page 4, Line 15 – 2nd

A: Done

22) Page 4, Line 23 – “consequence of the use . . .” does not make sense

A: We reworded this sentence

The FMCW system allows the user to set different range resolutions for different altitude by acting on the frequency modulation settings (chirp sequence).

23) Page 5, Line 1 – “include the exclusion” does not make sense

A: We changed our word choices

These processing steps include the detection and removal of measurements affected by ground clutter, an offset correction of the radars based on independent sources, the compensation for estimated differential attenuation caused by atmospheric gases ...

24) Page 5, Line 10 – (DWRs)

A: Accepted

25) Page 6, Line 5/6 – why is nearest neighbor italicized with no dash and then not belowand with a dash?

A: We avoided the use of italic and made it consistent throughout the text?

26) Page 6, Line 6 – ensures conservation of

A: Done

27) Page 7, Line 2 – relative to each other

A: Done

28) Page 7, Line 4 – extra)

A: Done

30) Page 7, Line 16 – Citation needed

We are not sure if we understood the comment properly. We could not identify the sentence where we should add a reference. We just commented on the duration of the selected rain events.

31) Page 7, Line 28 – two-way

A: Done

32) Page 8, Line 1 – Inter-radar

A: Done

33) Page 9, Line 8/9 – Run on sentence. Break up and clarify

A: The sentence has been rephrased according to the reviewer suggestion.

The relative offset correction is estimated for each measuring time from the data inside a moving time window of 15 minutes. The selected data are restricted to the reflectivity pairs which are within threshold values defined above.

34) Page 9, Line 10 – inter-radar

A: Accepted

35) Page 9, Line 18/19 – “upper, frozen part” of what? I assume the cloud. Also, this sentence is a run on and needs to be clarified

A: This phrase has been rewritten

The described adjustment technique accounts for all processes that affect relative offsets of the radars in the upper and frozen part of clouds.

36) Page 10, Line 28 – “Apparently”?

A: Corrected

37) Page 10, Line 29 – cannot

A: Done

38) Page 10, Line 32/33 – “This . . .” what does This refer to here?

A: We have avoided implicit subject.

39) Page 11, Line 5 – “even more accentuates” is not clear

A: This phrase has been rewritten

An additional 3-minutes running-window averaging of the reflectivities keeps the most stable signatures (Panels d and e in Figure 5), further removes scatter, and thus accentuates the aggregation signature in triple-frequency plot ...

40) Page 13, Line 11/12 – “kinks in the . . .” Could you be more descriptive and specific about the feature you are highlighting here? Perhaps add values?

A: We have accepted the reviewer suggestion

The X band Ze distribution shows a crisp enhancement of the largest recorded values at 2 km from 30 dBZ to 40 dBZ.

41) Page 13, Line 12 – “did not allow to monitor” does not make sense

A: We have clarified our sentence

The X Band sensitivity limitations did not allow to observe signals above 7 km with reflectivities below -10 dBZ...

42) Page 14, Line 5/6/7 – the “slowly descends” is indicated by MDV – so it would help to add a time/height plot of the MDV here to Figure 7. I think this will help clarify what you are trying to highlight

A: Thanks for your suggestion, but decided to not include the MDV plot. It takes more than 4 hours for the chaff to descend 4 km. In our opinion the plot of MDV does not give any additional information but it would overload the plot.

43) Page 14, Line 8 – Use of chaff with radar implies aircraft deployed material to scramble a signal. Is that the case here – was this actual chaff from an aircraft coordinated with the site? Or is it that the use of “chaff” is to highlight that there is some garbage in radar signal with high LDR and should be ignored?

A: This chaff event was not coordinated with the site. The most probable explanation is that the chaff was deployed by a military aircraft during training operations, and then the metal particles entered the radar observed volume.

44) Page 16, Line 21 – space (and comma) needed between dB and while

A: Corrected

45) Page 16, Line 24 – estimation of

A: Corrected

46) Page 16, Line 25 – “In the following . . .” following what?

A: In the following sections ...

47) Page 16, Line 29 – dataset

A: Corrected

49) Page 17, Line 10 – inter-radar

A: Corrected

50) Page 17, Line 17 – “are about to decrease” there is no time information in these plots, how do you know they are about to decrease?

A: Thanks for the comment. Here we inadvertently used an incorrect term. We have rephrased the sentence

In the fourth regime between 0 C and the LDR maximum, DWR_{KaW} tends to further increase while DWR_{XKa} remains constant or even decreases.

51) Page 18, Line 22 – “CloudNet product” singular or plural?

A: Corrected, it is plural

52) Page 20, Line 6 – Since the riming periods were so short, how confident are you in these characterizations?

We agree with the reviewer that the periods are short for a good characterization, and this is the reason why at Page 20, line 10 (now line 16 of page 23) we say

“We speculate, that this mode might be related to only slightly rimed aggregates. A larger number of riming events is required to better investigate the sensitivities of MDV and triple-frequency signatures to various degrees of riming, ...”

Figure Comments:

53) The labeling for the panels in the figures is confusing. Convention is that the panel labels (A, B, C . . .) are in the upper-left corner and outside of the plotting area. Please adjust the labeling of the panels so that it is in line with convention and clearer for the reader. See attached figure as an example.

A: Thanks for the suggestion, we agree with the reviewer that the labeling were not standardized. We carefully went through the journal guidelines and corrected the labeling. The journal specifies that the label should be with lowercase and within brackets. Regarding the position, it appears to be common looking at recent ESSD articles to have the labeling in the plot area. We decided to follow this style because it does not increase the Figure.

54) Figure 4 – Note the log-scale on the colorbars in C and F

A: Done

55) Figure 5 – Note the log-scale on the colorbars in C and F and I

A: Done

56) Figure 6 – Note the log-scale on the colorbar

A: Done

57) Figure 7 – Add a panel for mean Doppler Velocities

A: See our answer to comment 42 where we address this question.

58) Figure 9 – It would be more useful to have these two plots with same x-axis limits for comparison

A: Accepted

59) Figure 10 – Note the log-scale on the colorbars in A and B and C

A: Done

60) Figure 11 – Note the log-scale on the colorbar

A: Done

61) Do Figure 10 and 11 have the same binning for the histograms?

A: Yes, figure 10 and 11 have the same binning and now we mention that in the figure caption

62) Figure 12 - Note the log-scale on the colorbar in A

A: Done