

## Author Replies to Reviewer #2 Comments

Manuscript Title: Clutter Mitigation, Multiple Peaks, and High-Order Spectral Moments in 35-GHz Vertically Pointing Radar Velocity Spectra

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We thank both reviewers for taking the time from their busy schedules to read and provide valuable feedback to our manuscript. All comments were thoughtful and lead to changes to the manuscript. Thank you.

Please find below specific replies to reviewer #2 comments. The packet of documents uploaded to AMT includes this document as well as the revised manuscript with and without Track Changes.

{*Reviewer comments are italic.* Author comments are indented and in regular font and.}

### Reviewer #2.

Thank you for your helpful and insightful comments.

#### **Major Comments**

*Abstract: You mention cloud and drizzle particles causing non-zero skewness. Since you do not explicitly mention what kind of clouds you are analyzing, the reader might think you focus on liquid-only clouds. This is misleading as you actually look at mixed-phase clouds, too. Please mention in the abstract to which clouds your technique can be applied to. Also specify briefly, if the described three techniques will be/are implemented in routine data processing of the ARM program or if new data products are planned or older ones enhanced by your methods. In technical papers, the challenge is always to provide detailed description of the methodologies while at the same time maintaining readability. This is often reached by splitting long sentences into two. Please check where this can be done.*

- a. Liquid-only vs. mixed-phased clouds: Good suggestion. Text was added to the manuscript stating the multiple peaks can be applied to both types of cloud systems. (See page 1, line 24 in Track Change version.)
- b. Implementing code as routine data processing in ARM program. Text was added to the manuscript describing how this code is benefiting ARM data products. (See page 1, line 30 in Track Change version.)
- c. Splitting long sentences into two sentences. Thank you. Several sentences were broken into shorter sentences.

*Some of the thresholds described in the flow diagram (Fig10) seem a bit random: p.8 line 22: Shouldn't the requirement of "number of spectral points above noise threshold" be a function to the spectral resolution thus be different for let's say the 256 vs 512 FFT points?*

Yes, the thresholds do seem a bit random because they were selected for the Oliktok Point data set after many tests that are not presented in the manuscript. Text was added to the manuscript to describe the trade-offs a reader will have to make when they process their own datasets. (See page 8, line 34 in Track Change version.)

*p.8 line 36: Why did you opt for "at least three neighboring pixels" in the 3x3 time-height continuity filter? Did you try other thresholds and if so, did results differ much?*

Three neighboring pixels was chosen because it was found as the lowest value that efficiently removed remaining clear sky clutter. We found that the 3x3 time-height continuity filter helps remove isolated pixels that occur when clouds or precipitation are not nearby.

This comment made us look at the logic of applying the 3x3 time-height filter to the whole dataset. Since the 3x3 time-height continuity filter is not part of the actual clutter routine described in Fig. 10, we decided to make the 3x3 time-height filter a QC flag added to the netCDF output data file. The user can choose to apply this additional QC flag to mask data before their analysis, or, they can develop their own time-height continuity filter from the decluttered moments. Text was modified to reflect this change in the body and for fig. 11 caption. (See page 9, line 17 and page 13, line 3 in the Track Change version.)

*p.9 line 36: How did you come up with a 6dB "valley" between the most significant peak and the subpeak? Did you try other thresholds and if so, did results differ much? Is this threshold based on radar forward simulations or empirically-based? Shupe et al., 2004 for example described that their peak-picking criteria were empirically based. They state that "For two continuous modes above the noise to be considered distinct modes, the saddle point between the peaks must be lower than 65% of the lowest of the two peaks from the noise level." – Did you try this instead of a fixed 6dB threshold?*

Our experience with working with multiple peak spectra is that the valley between peaks is highly dependent on the bin-to-bin power fluctuations across the spectrum. These fluctuations are due to both noise fluctuations and signal power fluctuations. The bin-to-bin fluctuations of the Oliktok Point data tended to have a mean of about 2 dB with fluctuations exceeding 4 dB. These fluctuations are explored for the drop from the peak magnitude in Fig. 7a, but were not addressed for all points between the integration limits. Text was added to highlight how a user needs to evaluate their

dataset to determine the valley threshold. (See page 10, line 22 in the Track Change version.)

It is interesting to examine the Shupe et al. 2004 valley threshold. The 65% of the lower peak corresponds to a valley threshold of  $10 \log(0.65) = -1.9$  dB. Before looking for the valley, Shupe et al. applied a 3-point boxcar averaging window to the spectrum to remove bin-to-bin spectrum variability. Thus, it is hard to compare our un-smoothed spectrum 6-dB threshold to Shupe et al.'s smoothed spectrum 1.9 dB valley threshold.

*In general, it would be desirable if you motivate the choice of your thresholds, compare your threshold values against literature values and discuss differences/advantages of your thresholds.*

Good suggestion. This suggestion was the primary reason to provide the MATLAB code used to process the Oliktok Point KAZR spectra as supplemental material. If users had the same code used in this study, they could start with these thresholds and modify them for their dataset.

Text was added to the manuscript to motivate threshold choices and describing the availability of the MATLAB code (See page 1, line 33; page 3, line 28; page 7, line 29; page 8, line 26; page 9, line 1; page 9, line 16; page 12, line 35 in the Track Change version.)

*p.10 line 29: Again, please motivate why you chose 15-s integration intervals.*

Text was added to the manuscript describing the compromise between 4-, 15-, and 60-s integration intervals. (See page 11, line 13 in the Track Change version.)

*Please specify the thresholds for moment estimation: mean or max. noise floor?*

The text was added to the manuscript clarifying the use of mean noise and maximum noise. (See page 13, line 12 in the Track Change version.)

### **Minor Comments**

*p.1 Line 13: The phrasing is a little bit misleading: It sounds as if only the first method is applied to KAZR data.*

Modified Text. (See page 1, lines 12, 13, and 15 in the Track Change version.)

*p.1 Line 18: Unclear if "unique peak" refers to noise---floor separated peak. Please rephrase to clarify.*

Modified Text. (See page 1, lines 18 and 19 in the Track Change version.)

*p.1 Line 19 etc.: Explain why you use the term “breadth” instead of spectrum “width”*

Changed to “variance”. We purposely do not use spectrum width because of the extra factor of 2 in the spectrum width definition,  $\text{spectrum width} = 2 \cdot \sqrt{\text{variance}}$ , where variance is the velocity spectrum variance. (See page 1, line 20 in the Track Change version.)

*p.1 Line 20: Last sentence of the paragraph explains the third method (in the previous sentence) again. – For the abstract, I suggest leaving out this last sentence or merging the two sentences to save space.*

Good suggestion. Sentences merged together. (See page 1, line 21 in the Track Change version.)

*p.1 Line 27: I suggest rephrasing to “...indicator of possible multiple hydrometeor populations”*

Done. (See page 1, line 29 in the Track Change version.)

*p.2 Line 24: I suggest replacing “weather signal” with “hydrometeor signal”*

Done. (See page 2, line 24 in the Track Change version.)

*p.4 Line 25: switch “only” and “for”*

Done. (See page 4, line 27 in the Track Change version.)

*p.7 Line 22 - 24: This sentence is unclear. – Please rephrase.*

Rewrote the sentence. (See page 7, line 27 in the Track Change version.)

*p.8 Line 9 - 10: This sentence is unclear. – Please rephrase.*

Rewrote the sentence. (See page 8, line 17 in the Track Change version.)

*p.8 line 14: How can the residual peak magnitude velocity be at “either” 3---point interpolation edge velocity?: The middle velocity of the 3---point interpolation is not an edge velocity. – Please rephrase for clarity.*

Thank you for your comment. Rewrote the sentence. (See page 8, line 23 in the Track Change version.)

*p.9 line 12: Did you have a look at the radar spectral LDR signature to discriminate spherical (likely liquid) particles from non---spherical ice particles?*

That is a good suggestion, but no, we did not look at LDR signatures in the cross-pol spectra measurements. Added this suggestion to text (See page 9, line 32 in the Track Change version.)