

Review of Improved spectral processing for a multi-mode pulse compression Ka/Ku-band cloud radar system

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1. General comments

The authors present a framework for processing the Doppler spectra collected by a vertically-pointing, dual-frequency radar operating at the bands Ka and Ku. The framework includes a method for the removal of clutter and range sidelobe artifacts. The resulting clean spectra from three of the operational modes of the radar are merged and used to compute four moments of the spectrum.

In my opinion, the proposed framework is a good contribution to the radar community. It is presented in a clear way and most of the methods are described with a sufficient level of detail. However, there are few additional details (discussed in the next two sections of the review) that I believe need to be included in the explanation of the framework. I also found no major issues in the writing, but there are some instances (listed among the “Technical corrections”) in which I suggest some modifications to make the text easier to understand.

I recommend the article for publication after addressing the issues listed below.

2. Specific comments

- Section 3.1
The clutter mitigation algorithm is described clearly.
The examples shown in the figures 1 and 3 illustrate its correct functioning when the tail of the power distribution of the precipitation signal is far enough from the 0 m/s fall velocity. In my opinion, it would be useful to briefly discuss in the text how the algorithm reacts in cases in which the meteorological signal is closer to 0 m/s (e.g. light precipitation, drizzle) and there is a more significant overlap between the signal and the clutter. Are there specific cases in which the algorithm fails or mislabels part of the precipitation as clutter?
- Sections 3.1 – 4.2
The techniques illustrated in this section are always applied to the Ku-band in the various examples and their associated figures. This choice is motivated by the more common appearance of clutter for this band (Section 3.1) and the better functioning of the standard artifacts removal technique for the Ka-band (Section 3.2). Similarly, during the description of the mode merging in Section 4.1, only the statistics for ΔZ and ΔV for the Ku-band are shown.
However, section 4.2 describes the result of the shift-then-average method for both the Ka and Ku bands. I have a couple of questions regarding this last section:
 - Are all the techniques described before section 4.2 also applied to the Ka-band?
 - If the same techniques developed for the Ku-band are used also for the Ka-band, are they applied in exactly the same way? (for example: is the mode 1 excluded from the shift-then-average method also for the Ka-band? Are the statistics of ΔZ and ΔV similar to the Ku-band case?)

To address these two points in the main text, I suggest including a few sentences in Subsections 3.1, 3.2, and 4.1, mentioning how each step applies to the Ka-band and the (eventual) particularity of their implementation to this band.

3. Technical corrections

In each of the comments of this section, direct quotes from the article are highlighted in red and italic.

- Line 16
“Then, the abnormal distribution of the probability density of the Doppler spectrum in presence of range sidelobe due to the implementation of the pulse compression technique was identified and used to separate sidelobe artifacts.”
This sentence stands out to me as particularly long and slightly convoluted. If possible, I would suggest to re-phrase it, maybe splitting it into two shorter sentences to make it easier to understand for the reader.
- Line 28
“As a remote sensing instrument, cloud radars [...]”
Since “*cloud radars*” is plural, I would suggest using the plural for the first part of the sentence too (i.e. “As remote sensing instruments”)
- Line 49
“Alternatively, cloud/precipitation signals can be well reserved if the clutter removal is made in the radar Doppler spectrum”
I did not fully understand the sentence. Is the term “*reserved*” correct here?
- Line 60
“[...] a wider pulse is used which on the other hand decreases [...]”
In my opinion, this part of the sentence would benefit from being re-phrased more clearly.
- Line 76
“[...] the emitting of long pulses leads to an increase in radar blind range, [...]”
In my opinion it should be “emission” instead of “*emitting*”.
- Line 86
Could you provide the altitude of the site at which the radar has been deployed?
- Lines 97-98
“[...] to improve the sensitivity to detect clouds with weaker radar echoes at higher latitudes”
Do you mean “higher altitudes”?
- Line 100
“There are four different modes routinely cycled in operations [...]”
Since the four modes have already been introduced in the previous sentences, the beginning of this sentence feels like repetition. In my opinion, it could be rephrased as “These four different modes are routinely cycled in operations [...]”.
- Line 105
Since the height of the blind zone for two of the modes is mentioned, I would also explicitly write in the text the height for the remaining ones.

- Line 116
 “[...] *the implementation of pulse compression techniques in modes 2 and 4 usually results in significant range sidelobe around the melting layer*”
 Why specifically around the melting layer? Is it just because the melting layer is often characterized by a strong echo?
- Line 135
 “*The cause of such clutter signals is unclear yet and we hesitate to classify them to insects (Williams et al., (2018), since the spectral powers at different modes deviate from each other significantly.*”
 In my opinion, the verb “attribute” would fit better the sentence than “*classify*”.
 Additionally, the parenthesis opened before the name “*Williams*” is not closed later in the phrase.
- Figure 1
 In my opinion, there is a mismatch between the label and the unit on the y-axis.
 The unit “*dBZ*” is used for reflectivity, but the label of the axis says “*power*”.
- Line 172
 “*(see for example (Li and Moisseev, 2020))*”
 I think that the parenthesis around “*Li and Moisseev, 2020*” could be removed.
- Line 179
 “[...] *received spectral power from 2 km and 7 km*”.
 From my understanding of the figure, in this sentence the “*and*” should be substituted by “*to*” (i.e. “from 2 km to 7 km”).
- Line 180
 “*For Doppler spectra without the sidelobe contamination, PDFs are relatively uniform.*”
 From what I understood from panel (a) of figure 4, the term “*uniform*” may be confusing here. If I understood correctly, what is meant by this sentence is that the PDF observed at different range gates are similar to each other, in absence of the sidelobe issue. If this is the case, I suggest rewriting the sentence, avoiding the term “*uniform*”, since it can create ambiguity with the idea of “uniform distribution” (which the various PDF of panel 4.a are not).
- Figure 4
 In my opinion, there are two small issues with this figure:
 - In panel (a) the orange and red curves cover completely the ones below. I would suggest adding some transparency to the lines so that also the curves below are visible. I also suggest inverting the order in which the lines are plotted, so that the light blue ones sit on top of the darker red ones.
 - Panel (b) is never mentioned in the main text of the article. Since the quantity S_{thresh} is introduced in line 184 of the text, maybe you could expand the explanation including a mention of the panel (b).
- Line 186
 “*The procedures are briefly summarized as follows,*”
 I would replace the comma (“*,*”) with a colon (“*:*”) since the procedure is provided in a numbered list just after this sentence.

- Lines 199-201
“Below half of the peak power above the noise level of the Doppler spectrum, find the power bins’ probability density just exceeds the PDF_{thresh} , and the corresponding spectral power is set as S_{thresh} ”
 I did not fully understand this step in the procedure. Could the sentence be rewritten differently?
- Line 245
“[...] Doppler spectra observations from the modes 2, 3, and 4 were merged as follows [...],”
 I suggest the same correction as for Line 186.
- Lines 270-273
“Although the agreement among different modes is better than that at Ku-band thanks to higher spectral velocity resolution and less uncertainties for the Ka-band radar, while the bias of kurtosis in snow at mode 3 (Fig. 11c) is more contrasting.”
 I think that “Although” should be removed from the beginning of the sentence.
- Figures 12 and 13
 In the period of approximately 10 minutes before 21:00 LST, in both bands it is possible to see some very faint returns around 2 km of altitude. Do you know what is causing their appearance? In case it is unfiltered clutter, I would recommend discussing its appearance in the text, describing briefly why the proposed method does not filter it.
- Lines 314-315
“[...] and the results show good performance of clutter/sidelobe suppression and spectral merging.”
 Since the performances were not measured quantitatively, I would modify this sentence by using a less strong statement (e.g. “a visual inspection of the processed data suggests that clutter/sidelobe suppression and spectral merging demonstrated good performances”).