Atmospheric Measurement Techniques Discussions

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Reply on RC1

Laura M. Tomkins et al.

Author comment on "Image muting of mixed precipitation to improve identification of regions of heavy snow in radar data" by Laura M. Tomkins et al., Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2022-160-AC1, 2022

We would first like to thank the reviewer for their comments and feedback on the manuscript. Original comments are in regular text and our replies are in bold.

This paper describes a visual technique to remove regions of melting hydrometeors in radar displays in winter storms. The technique allows forecasters and researchers to readily identify regions of heavy snowfall and associated hazards. This paper describes one implementation of such a product using NEXRAD data in the USA and corroborates the technique with some independent data. Overall the paper does a good job describing the technique and its general application. The contribution is worthy of publication, however I wish to suggest some improvements to the paper to help the reader through the reasoning behind it as well as comment on the particular application of the technique. Thus, I am returning the paper for major revisions.

L24: It might be worth noting that correlation coefficient is insensitve to radar power calibration issues, and intrinsic measurements of correlation coefficient should be consistent amongst radars with similar hardware and signal processing techniques (such as NEXRAD). Some intrinsic differences/biases could exist with radars with different transmission and signal processing techniques (number of pulses; antenna crosspolar performance; radome effects; determination of noise and receiver accuracy; spectral vs pulse pair processing).

We agree and have added the following text to the Introduction:

“This variable is insensitive to radar calibration and yields comparable values for the same set of hydrometeors across radar networks with identical hardware and signal processing methods.” *(lines 26-27)*

L53:

(a) Polarimetric data quality is known to degrade with range, causing correlation coefficient values to decrease uniformly due to factors such as non-uniform beam filling. Does this impact the classification of pixels as "mixed" uniformly with range?

We investigated further by seeking out expert opinions from radar experts Dr. Chandraskar at CSU and Scott Ellis at NCAR and obtained more information that resulted in the following text to Introduction.

"With increasing range from a radar, radar resolution volume size increases and signal to noise ratio (SNR) decreases. For example near the melting layer, larger radar resolution volumes are more likely to have non-uniform beam filling than smaller radar resolution volumes. In theory, non-uniform beam filling would tend to decrease correlation coefficient (Ryzhkov, 2007). Unlike radars that transmit at horizontal and vertical polarizations, the NEXRAD radar transmits at a single polarization oriented at 45 degrees. The current method used to compute correlation coefficient in US NEXRAD operational radars yields increased values with decreasing SNR (Ivić, 2019). In practice, the impact of SNR tends to be much more prevalent than nonuniform beam filling. This suggests that the SNR effect masks most of the effects of non-uniform beam filling in NEXRAD correlation coefficient data quality." *(lines 32-29)*

We are not defining a new method to detect all melting regions. Rather, we seek to de-emphasize melting regions that could be misinterpreted as heavy snow. Hence, applying our muting technique to regions where the correlation coefficient is < 0.97 and reflectivity is greater than 20 dBZ was appropriate. We clarified our reasoning for the Z threshold in the text.

"Adding the criterion of reflectivity 20 dBZ was essential in distinguishing regions of melting or mixed precipitation that could be confused with heavy snow from regions of light precipitation with noisy, unreliable HV values." *(lines 85-87)*

(b) In addition to mixed populations of hydrometeors, correlation coefficient also is lowered in regions of partial beam blockage and mainlobe and sidelobe clutter (terrain being one factor leading to this). Do you notice any stationary regions where mixed precipitation is more likely to be classified due to these effects?

In some of the older data (late 1990s and early 2000s) we do see some stationary features in the regional maps likely associated with the clutter types you mention. In the paper, we rely on the US NWS algorithms for the removal of ground clutter. Before plotting, we despeckle the fields (areas of echo less than 20 km^2 are removed) which removes some of the remaining clutter points. In a movie presentation the clutter points that remain are stationary and have a higher reflectivity than the background so they are easy to visually discount. To remove these residual points it would be necessary to implement our own ground clutter removal algorithm but this is a separate topic outside of the scope of this paper.

We have added a sentence with citations to the Introduction to describe more fully that low correlation coefficient can also occur in ground clutter.

"Additionally, correlation coefficient can have low values in various types of ground clutter and is used in identifying non-meteorological echo (e.g. Zrnić et al., 2006; Alku et al., 2015; Kumjian, 2013b)." *(lines 30-31)*

We have also added a sentence describing the despeckling step:

"Before plotting the fields, we despeckle the data to remove areas of echo that are less than 20 km^2." *(lines 78-79)*

L71: What is the sensitivity of choosing a value of 0.97? In a fuzzy logic scheme, which is the current state of the art method for hydrometeor classification, uniform thresholds are not used, rather many variables are used and the "winning" hydrometeor classification is then selected. Can you comment on why a more sophisticated scheme was not used? Or even the operational hydrometeor classification in the NEXRAD? Perhaps it could be stated that the technique could be applied to any effort to censor data that might confound the user (clutter, biological scatter, partial beam blockage, non-uniform beam filling, etc.)

We did sensitivity testing on the threshold and found that 0.97 worked best overall and was supported by Giangrande et al. (2008). Fuzzy logic hydrometer algorithms cluster points associated with multiple variables (Bringi and Chandrasekar 2001).

We found that a simple correlation coefficient threshold worked well for our intended purpose which is to de-emphasize melting that could be misinterpreted as heavy snow.

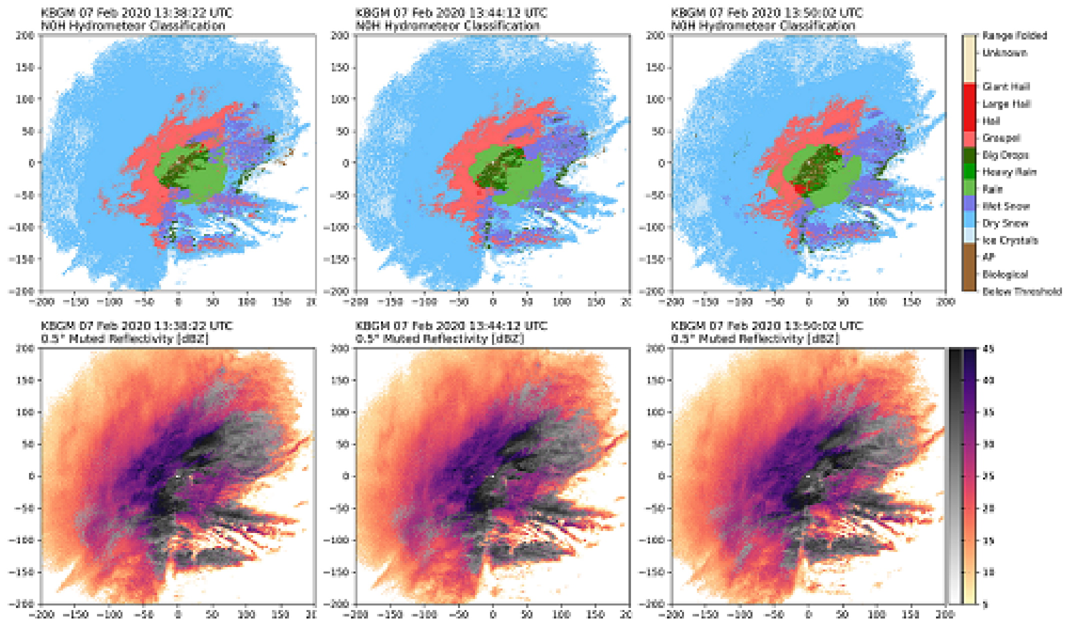
The current US NWS hydrometeor identification algorithm often struggles in winter storms. For example, Figure R1 shows a sequence of images comparing the hydrometeor classification and image muted reflectivity. While the NWS hydrometeor classification algorithm correctly identifies some of the areas with low RHOHV as wet snow, it also miscategorizes portions of the melting areas as graupel, big drops, and heavy rain. Additionally, there are "jumps" in spatial continuity of regions with a given classification. On balance, we determined that the NWS hydrometeor classification algorithm's performance in winter weather was not well suited to our purpose.

Image muting as a visualization method has many uses. A colleague who was inspired by our paper is using image muting for some their climate model visualizations. Ground clutter echoes are usually just removed from the radar display (e.g. https://www.canada.ca/en/environment-climate-change/services/weather-general-tools-resources/radar-overview/about-radar.html#toc2)

We have added text to describe how the hydrometeor classification product could be used as an input to the technique:

"Users could apply this visualization technique using operational hydrometeor classification as an input and mute other specific regions depending on the application." ***(lines 175-176)***

Figure R1: Sequence of images from KBGM radar on 7 Feb 2020 valid 13:38 UTC (left), 13:44 UTC (center), and 13:50 UTC (right). Top panel is Hydrometeor classification, bottom panel is image muted reflectivity



General comment: The video files in the supplement seem to suffer from video compression issues. If the authors could change their compression settings, that would be helpful to the reader.

Thank you for the comment. The animations have been changed to their original quality in the portal.

L81: "reflectivity < 20 dBZ is too low to reliably indicate mixed precipitation". Can you expound/give a physical basis for this? Is this due to the long ranges used in the analysis - a quick perusal of NEXRAD data shows very high values of correlation coefficient in reflectivities as low as 5 dBZ in drizzle?

We have changed the sentence to the following:

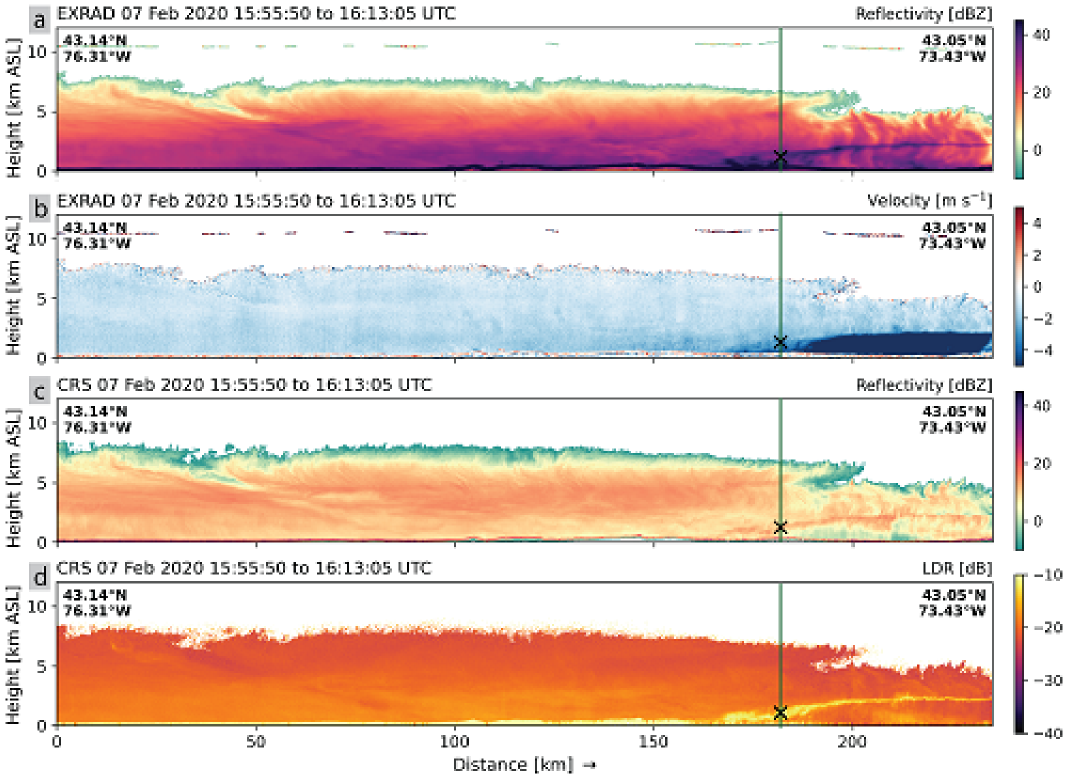
"We infer that the reflectivity < 20 dBZ is too low to reliably indicate mixed precipitation that can be mistaken for heavy snow." ***(line 95)***

L104: Are there other parameters in the EXRAD data or other data collected aboard the aircraft to more reliably denote the melting layer? Was doppler velocity or linear depolarization ratio measured by any of the suite of radars on board?

We have added an extra figure to the manuscript which shows several different fields from the same transect to better illustrate the melting layer and the rain layer beneath it (see Figure R2) with the following text.

"The melting layer can also be observed with other variables from the same transect presented in Fig. 3. In particular, the linear depolarization ratio from the ER-2 cloud radar shows the structure of the melting layer very well (Fig. 3d). Under the melting layer, the values of downward pointing Doppler velocity > -4 ms^{-1} indicate the rain layer." ***(lines 117-119)***

Figure R2: Other fields from the ER-2 radars to depict the melting layer. Has been added to the manuscript as Figure 3.


a
EXRAD 07 Feb 2020 15:55:50 to 16:13:05 UTC
Reflectivity [dBZ]
b
EXRAD 07 Feb 2020 15:55:50 to 16:13:05 UTC
Velocity [m s⁻¹]
c
CRS 07 Feb 2020 15:55:50 to 16:13:05 UTC
Reflectivity [dBZ]
d
CRS 07 Feb 2020 15:55:50 to 16:13:05 UTC
LDR [dB]
43.14°N
76.31°W
43.05°N
73.43°W
Height [km ASL]
Distance [km] →