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Atmospheric Measurement Techniques
Discussions

Interactive comment on "Fuzzy logic filtering of radar reflectivity to remove non-meteorological echoes using dual polarization radar moments" *by* D. R. L. Dufton and C. G. Collier

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We would like to thank the reviewer for his honest assessment of our work, we've taken his comments on board and amended the paper to improve its clarity. Below are the reviewers points in italics, followed by our response and then the amendments we have made to the paper in blue.

1. "Fuzzy logic, as used in this paper, is worst of such possible models because it relies on subjective human tuning."

Subjectivity is a recognised element of science; particularly machine learning, which

relies on many subjective choices. These include the choice of method, the choice of suitable training data, the human identification of echoes to use for training or the choice of skill metrics to validate the method chosen. Perhaps through the use of a fully unsupervised clustering approach, such as GDBSCAN (Sander et al., 1998), could we minimise this subjectivity, and this is something to pursue once we have more data available. But even then we must subjectively post classify the identified clusters to fit our assessment of the data, which may not always be possible. We have added to section 1.2 to reflect this. (p5031 l5).

Added: "When more data is available a more autonomous clustering algorithm, such as GDBSCAN (Sander et al., 1998) or agglomerative hierarchical clustering (Grazioli et al., 2015) can be implemented to remove the need for subjective human identification of training data, which is one of the current limitations of fuzzy logic and similar trained machine learning techniques."

2. Should use a "principled optimization approach (support vector machines, neural networks, decision trees, etc.)" instead of using fuzzy logic.

There are several possible principled optimization approaches, as noted, each of which has its own advantages and limitations. Covering all of these is beyond the scope of our paper but it is worth noting that the black box approaches of neural networks do not allow causal relationships to be easily identified, which is useful to the research applications of our mobile system. Our experience also shows the hard boundaries found in heuristic decision trees are always open to exceptions. As such the soft boundary open structure of the fuzzy logic scheme we use offers the required compromise between concurrent multi variable decision making and traceable decisions.

3. "It is true that because fuzzy logic is subjective, human expertise can be used to augment a small dataset (Point 2). However, it is not clear that the dataset needs to be small for the problem for radar quality control."

As the reviewer acknowledges, human augmentation is useful for smaller datasets.

Given our application applies to a mobile research radar, which operates for short durations with changeable scan parameters (including rotation speed, pulse width and PRF) a method that can be adapted to these changes, if necessary, is required. While it would be fantastic to have the wealth of data provided by the NEXRAD system to train a fully autonomous learning system, our mobile research system does not operate for these extended lengths of time. For our longer, future field campaigns, with continuous radar operations and unchanged scan parameters, we will take on board these suggestions and can then investigate whether an alternative approach will yield better end results in our future work. We acknowledge in the conclusions that further data will allow improvements to the work to be assessed, but we have amended the point for clarity. (p.5043, l.10)

Changed: "There are obvious cases where the filter is not correctly detecting spurious echoes. Over a longer time period it would be possible to determine whether these occasions are isolated in space or if they are due to a systematic error."

To: "A longer period of data needs to be analysed to fully evaluate the scheme, particularly to identify any systematic biases in classification and assess performance in winter conditions, where ice phase hydrometeors are more likely. More data will also allow a comparison with more data intensive, fully autonomous methodologies, which could yield interesting insights into their applicability."

4. "What is the relative importance of these membership functions?"

Our investigations showed no benefits to applying variable weighting to the membership functions, which we investigated using an implementation of a genetic optimisation approach. We have added a clarification to the paper to highlight this.

Added: "During the analysis it was found that using equally weighted membership functions (maximum score of 1) was no less effective than using variable weighting optimised with a genetic algorithm. Ultimately the most parsimonious set of variables was chosen for each class. This was tested using a validation set of problem cases,

where identification was deemed to be challenging, including rainfall signals mixed with wind farm ground clutter and convection embedded within probable insect returns."

5. "What is the sensitivity of these functions to the variables? For example, if the Zdr variable is miscalibrated (as it is on the NEXRAD system), how much will the resulting classification suffer?"

The issue of radar miss-calibration is important. In the examples provided ZDR and Z have been corrected for total system calibrations errors using a self-consistency approach. Other, localised sources of bias have not been corrected for, and by computing the frequency distributions using this uncorrected data any errors affect both the initial membership functions and the predictions equally. The fuzzy logic classifiers soft boundaries allow for these variations as opposed to a hard decision boundary that may be utilised in a decision tree or similar. This is not an uncommon approach to take, and is in many ways required as non-meteorological echoes need to be removed before computation of attenuation corrections using the ZPHI technique, for example. The fuzzy logic approach presented here is more robust in this regard than a simple threshold based approach that is often used prior to the application of these correction techniques. We have amended section 2 of the paper to clarify the corrections applied to the radar data.

Added: "Prior to the analysis presented here, reflectivity and differential reflectivity were corrected for radar miss-calibration and frequency drift using a modified version of the self consistency approach presented by Gourley et al. (2009). Correction for attenuation has not been applied, as correction using the commonly applied ZPHI method (Testud et al., 2000) requires clutter filtered data to accurately distribute attenuation along the rain path. Attenuation correction of the data will follow in future work, after the application of the clutter filter and removal of non-meteorological echoes."

6. "We have done this for polarimetric radar, and I was a little disappointed that the only paper of ours that was cited was on single-pol quality control"

We have attempted to cover a broad spectrum of papers that cover the field and it is impossible to include all available material, particularly those papers that were not yet in print at the time of publishing. Those papers you list are indeed valuable additions to the field and provide interesting insights into the possible future direction of machine learning in the context of weather radar. We shall consider them with interest when we come to formulating a more complete hydrometeor classification algorithm for our mobile X-band system.

7. "Bottom line: Please, please, stop using fuzzy logic as a crutch. We have enough radar data to carry out more principled approaches. As a community, we can do better than this."

It is interesting that you consider fuzzy logic a crutch despite its continued successful implementation in a wide range of papers (Bechini and Chandrasekar, 2015, Mahale et al., 2014, Thompson et al., 2014, Vulpiani et al. 2012, for example). Perhaps this would be a useful topic to raise as a workshop or open discussion at one of the next AMS or ERAD radar conferences.

References

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