Development of a hydrometeor classifier for the Met Office C-band weather radar network

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1. Introduction

The UK Met Office has been trialling a version of the hydrometeor classifier described by Al-Sakka et al. (2013) to process real-time data from the UK C-band weather radar network. The trial has initially proven successful, and work is now underway to develop and improve the algorithm. Here we describe developmental changes made to the algorithm, and present case studies to illustrate the resulting gains in performance.

2. The "Baseline" Algorithm

The classifier described by Al-Sakka et al. (2013), developed at Metéo France, is a Fuzzy Logic- type classifier. The membership functions (MFs) therein are defined for the seven hydrometeor types (rain, wet snow, dry snow, ice, small hail, medium hail, large hail) and for each of the radar / environmental variables considered (Z_H, Z_{DR}, K_{DP}, ρ_{HV}, and T (temperature)). The MFs are derived from datasets built from many individual hand-picked radar observations of 'unambiguous' hydrometeor types. MFs of both one-dimensional trapezoidal ($F(x)$), and two-dimensional Gaussian ($F(x, y)$) form are used. The inference rule used to combine the individual membership values has a combined additive/multiplicative form:

$$P_i = F_i(Z_H) * F_i(T) * F_i(BB) * [F_i(Z_H, Z_{DR}) + F_i(Z_H, K_{DP}) + F_i(Z_H, \rho_{HV})],$$

Here, P_i is the overall probability of occurrence of hydrometeor type i, and $F_i(\ldots)$ is the 'membership' of that type based on the just given input parameter(s). $F_i(BB)$ acts as a 'bright band' MF, and is used as a 'safety net' to exclude certain hydrometeor types within a certain region of the 0°C isotherm (which is provided by NWP data from the Met Office unified model).

3. Case Study Example →

In the example to the right, the Metéo France classifier (described above) was used to process radar data collected during a storm system which swept across northern England on the 1st July 2015. Figure 1 (a) shows the number of counts of hail registered by the classifier during the storm period, while Fig 1 (b) shows the ground reports of hail - from both traditional observations and social media reports – recorded during the same period. The correlation between the two sets of results is encouraging.

4. Algorithm Developments

As part of ongoing developmental work, some simple changes have been made to the Metéo France algorithm with the aim of further improving its performance:

- Use of the K_{DP} membership function (MF) has been omitted. As K_{DP} is not a raw radar variable, and its calculation method can produce noisy / unreliable results, the classifier is likely to perform better without it.
- The Z_H dimensions of the two-dimensional MFs have been pre-multiplied by the one-dimensional trapezoidal Z_H MF – this is a fairly ineffectual change, but simplifies the inference rule slightly.
- The 'bright band' MF has been omitted. This change improves the appearance of wet snow classifications, which previously showed sharp-looking, regular boundaries.
- The one-dimensional trapezoidal temperature MF has been replaced with a one-dimensional beta function, as described by Dolan et al. (2013). This produces smoother, more natural-looking boundaries between regions of hydrometeors at increasing elevations.
- A convection-permitting exception is activated when a reflectivity of 30 dBZ or more is detected 1 km or more above the 0 °C isotherm. i.e., under these circumstances, classification of rain is not suppressed above the melting layer.
- The three hail classes have been combined into one. In the UK, where the occurrence of hail is relatively rare, the definition of three different sizes of hail is not necessary.
- The two-dimensional $F_i(Z_H, \rho_{HV})$ MF is used multiplicatively, instead of additively. This improves the appearance of the rain / wet snow boundary below the melting layer, at the cost of reducing the classification confidence to zero in regions where ρ_{HV} is affected by reduced signal-to-noise ratio.
- The new inference rule thus looks as follows:

$$P_i = F_i(T) * [F_i(Z_H, Z_{DR}) * F_i(Z_H, \rho_{HV})]$$

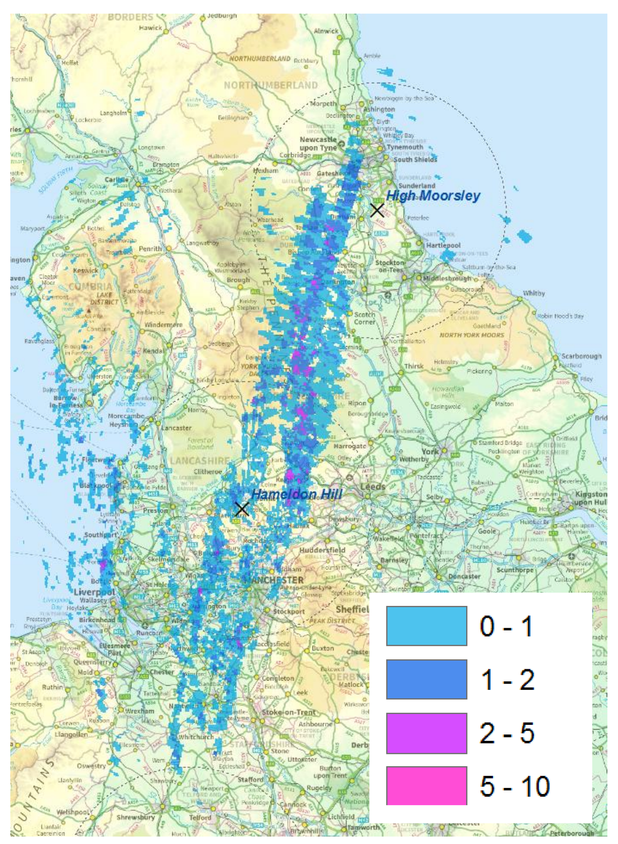
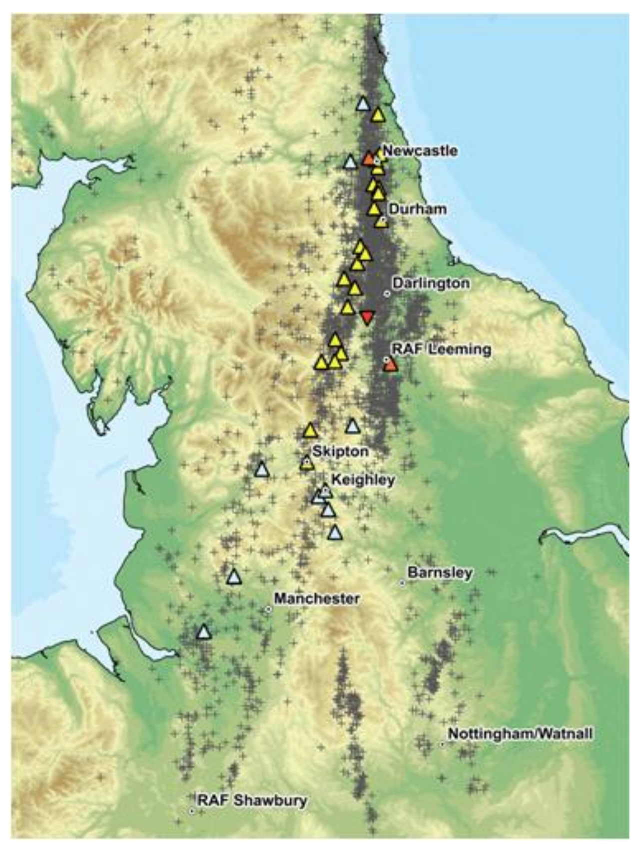
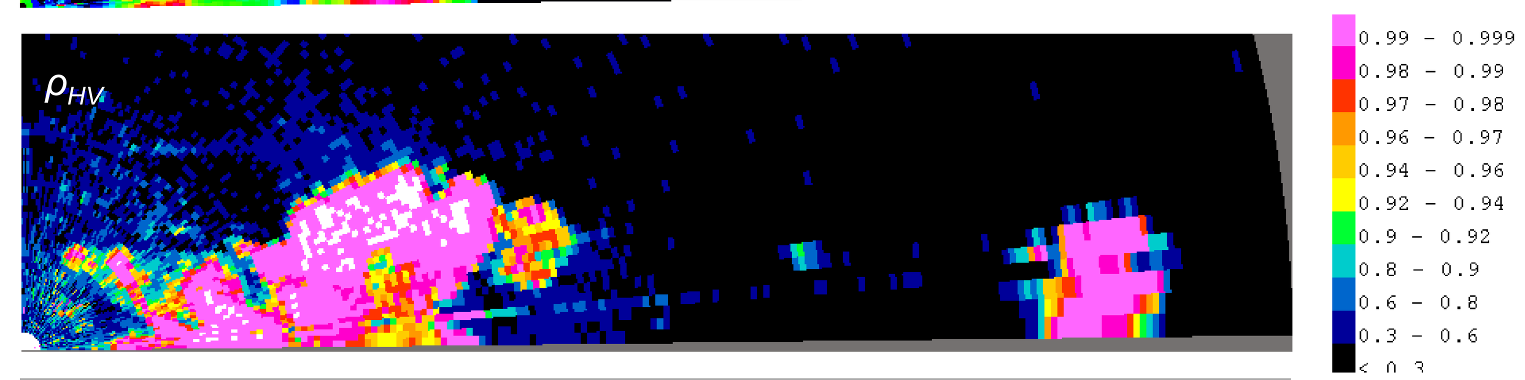


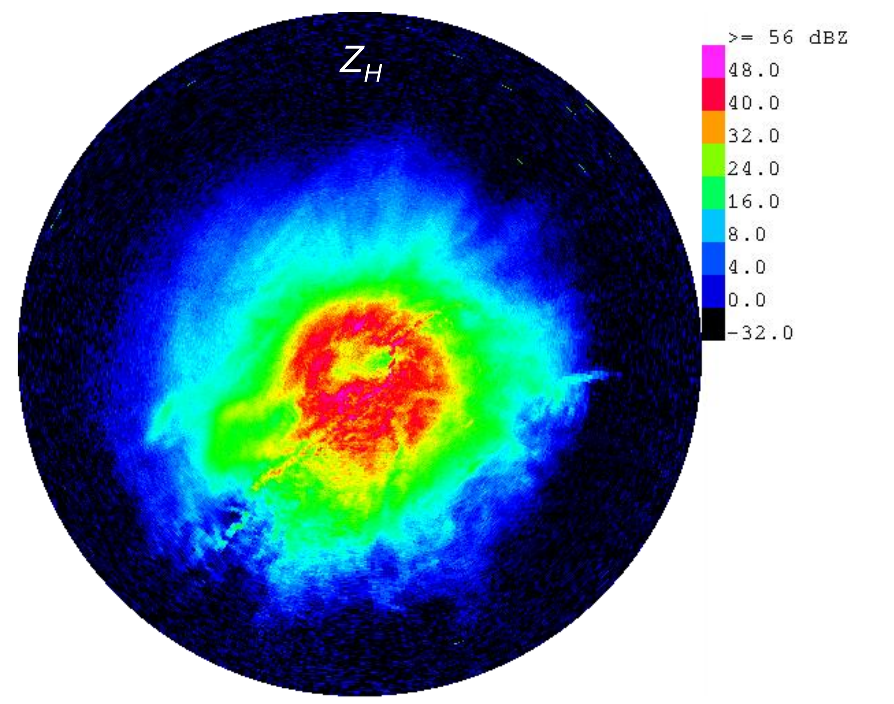
Figure 1 a) Hail classification count using 0.5° elevation scan radar data from Hameldon Hill radar, UK

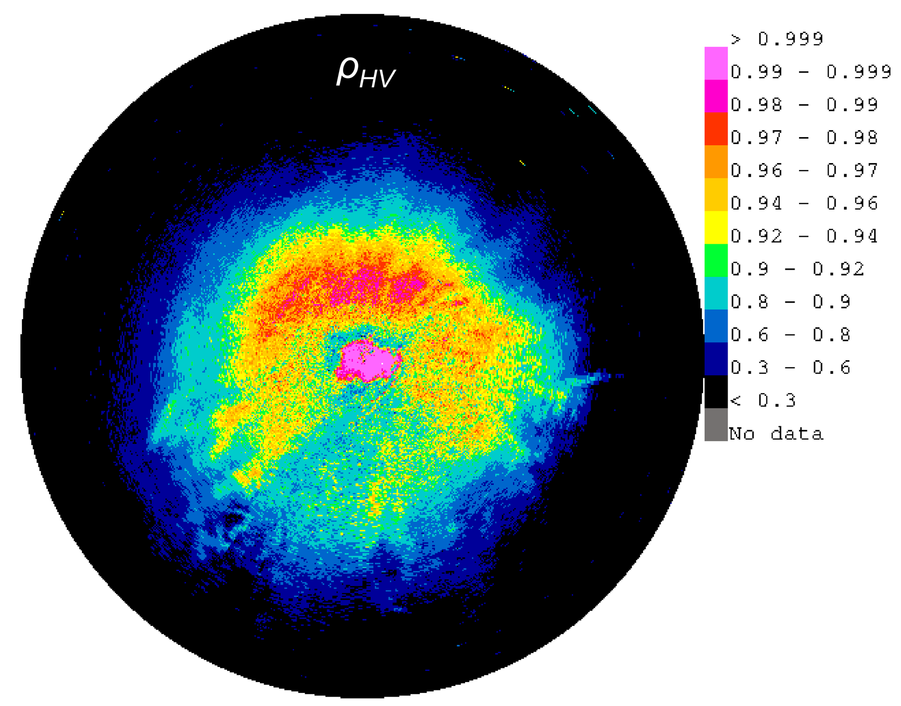


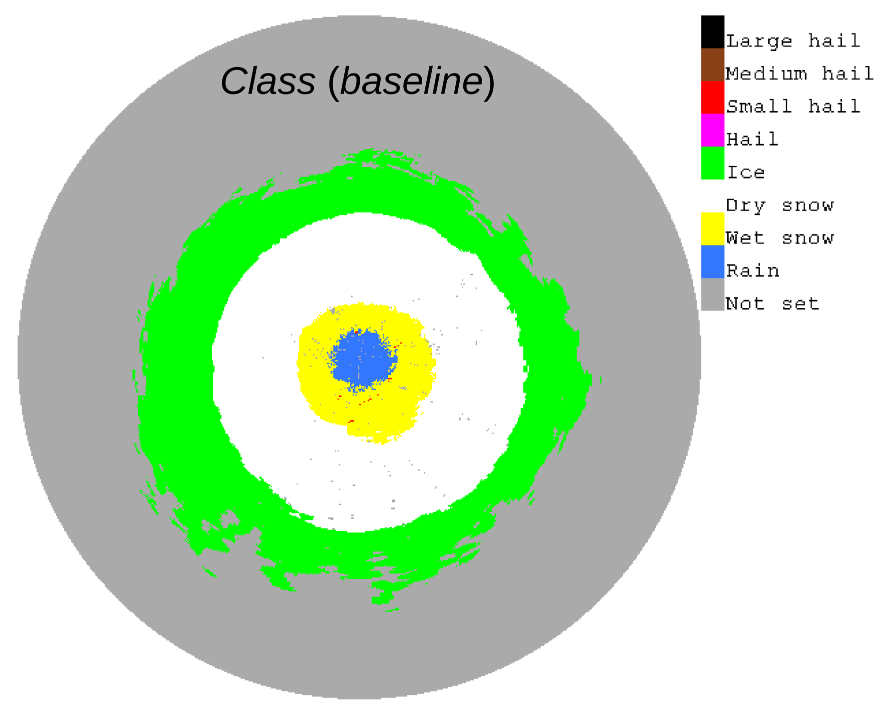
b) Hail (Δ) and lightning (+) reports for 01 July 2015 (from Lewis and Silkstone (2017))

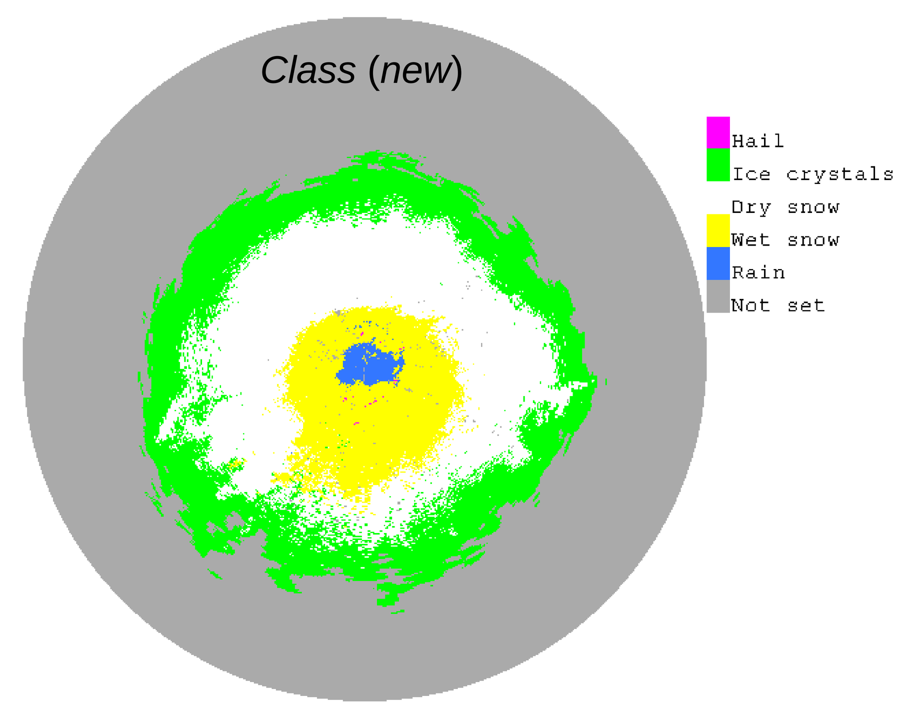
5. Results: Classifications of data from a stratiform event (left) and a convective event (right)











The stratiform event shown in the PPI images to the left (1° elevation scan) happened in south-west England on the 12th January 2017. The new classification appears to better represent the rain region towards the centre of the image, and the classification of ice also looks slightly more realistic.

In the RHI images above, which show a convective event in southern England on 3rd July 2015, the effects of the convection-permitting mechanism in the new scheme are evident in the appearance of rain above the melting layer; though the presence of the melting layer at all in this case is still questionable.

6. Summary and Future Work

- The Metéo France hydrometeor classifier, which the Met Office is currently trialling, has shown encouraging results - particularly for the identification of hail.
- The developments made to the algorithm have helped to produce more realistic-looking results at the boundaries of the melting layer, and snow/ice regions. Convection is also now better represented, though this still requires further attention.
- A comprehensive validation campaign is planned for the next 12 months, in collaboration with the University of Leeds. This will make use of a wide range of data sources including laser disdrometers, optical probe data from the FAAM (Facility for Airborne Atmospheric Measurement, Cranfield, UK) research aircraft, and social media reports.

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