Use of Z_{DR} columns for early detection of severe convection within the operational radar network of the United Kingdom

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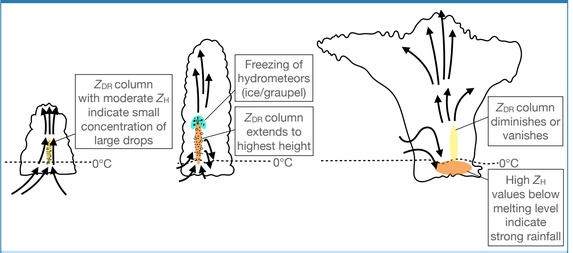
Introduction



Differential reflectivity (Z_{DR}) columns are regions of enhanced Z_{DR} within convective storms that intersect and extend above the 0°C level. Such columns are collocated with strong updrafts within storms and are precursors of severe convection.

In this study, we extend the Met Office 3D radar composite to include Z_{DR} to investigate how the detection of Z_{DR} columns could be used operationally in detecting severe convection. We assess the effectiveness of an implemented threshold-based Z_{DR} column detection algorithm for diagnosing severe convective development across three different case days within the UK.

Data and Methods

- Volumes from 16 single-site C-band radars
- 3D radar composite of Z_H and Z_{DR} constructed using Zhang et al. (2005) weighting scheme
- Cell identification using dynamically-thresholded image processing algorithm on MAXDBZ field
- Cell tracking with object-based optical flow algorithm (Stein, 2015)
- Z_{DR} column detection with primary (Snyder, 2015) and secondary thresholds in Z_H and Z_{DR}

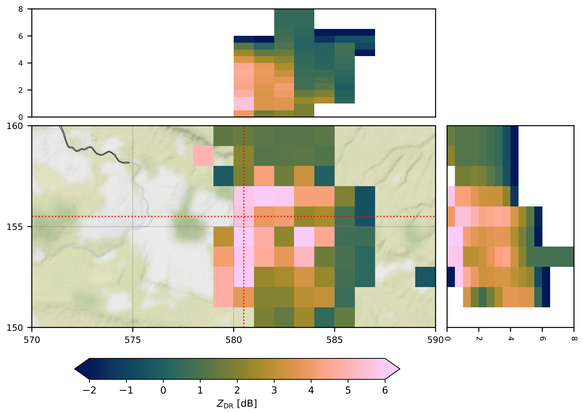


Figure 1. A maximum Z_{DR} plot with vertical cross sections on 20 July 2021 at 1310Z. Red dotted lines show the position of the vertical cross sections. Vertical cross section plots have 2km tick labels in height. Spatial domain covers one of the developing cells. Enhanced Z_{DR} values exceeding 3.0dB are present near the western flank of the cell suggesting presence of a Z_{DR} column.

How effective are Z_{DR} columns as precursors for severe convection?

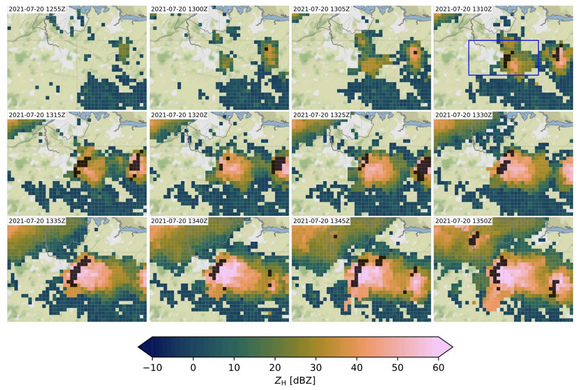


Figure 2. A series of MAXDBZ showing convective storm development for a convective cell on 20 July 2021 from 1255 to 1350Z. Panels are radar composites generated every five minutes. Black pixels are detections of Z_{DR} columns. The blue rectangle in the 1310Z plot demarcates the region of the cross section of the convective cell in Figure 1.

Radar definition of severe convection in UK

There is no standard definition of severe convection in the UK. Because our focus is on heavy precipitation, we have chosen 50 accumulated 50dBZ pixels in the MAXDBZ field as a criterion for labelling a tracked storm as severe in this study. This criterion corresponds well to the 99th percentile of accumulated MAXDBZ pixels across tracked cells.

We accumulate the number of Z_{DR} column pixels as well to test the importance of size and persistence of the Z_{DR} column for severe weather detection. This study considers column footprints rather than their vertical extents. We see steepest increases in Z_{DR} column pixel accumulation at approximately 10 to 20 minutes of lead time.

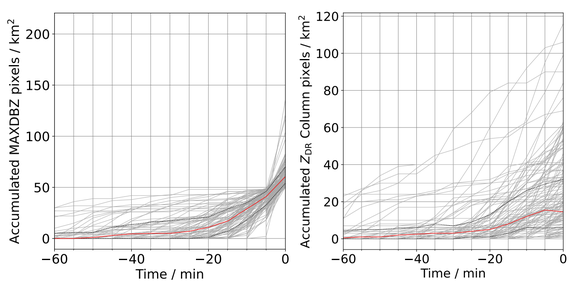


Figure 3. Grey lines showing time series of tracked storm properties on 16 June 2020. Zero time is defined as the tracked storm meeting 50 accumulated pixels of MAXDBZ. The left panel show MAXDBZ pixels within a tracked storm, whereas right panel show the accumulated number of detected Z_{DR} column pixels within each tracked storm. Red and black dotted lines show the median and quartiles of the time series, calculated from available data at each five minute time step.

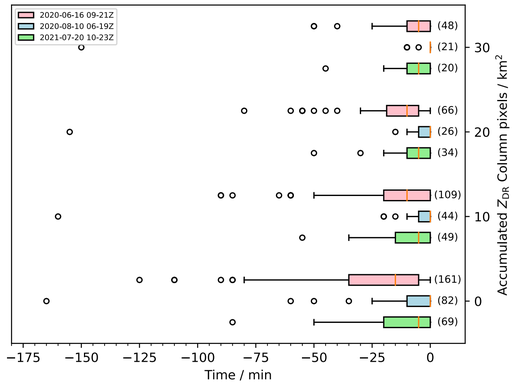


Figure 4. Box plots showing tracked storms that have met an accumulated Z_{DR} column pixel threshold and later lead to severe storm development. Lead time is the time between accumulated Z_{DR} column pixel threshold being met and the time when the tracked storm meets the severe requirement. Boxplots are grouped according to accumulated Z_{DR} column pixel threshold and sub-divided by different cases. The number of elements for each boxplot is shown in parentheses.

Lead times

For all cases, lead time decreases with increasing Z_{DR} column number threshold. This is expected since tracked storms should accumulate an increasing number of detected Z_{DR} column pixels throughout their lifetimes, such that a larger accumulation of such pixels is likely to occur closer in time to the occurrence of high reflectivity pixels. The spread of lead times also decreases when using a higher Z_{DR} column pixel threshold. Of course, a greater threshold shifts both Hits to Misses and False Alarms to Correct Negatives.

Secondary Threshold Sensitivity

To investigate the skill of Z_{DR} column detection as a precursor of severe convection, non-precursor and non-severe events must also be considered. To inform future development of nowcasting algorithms using Z_{DR} columns, we are also interested in the sensitivity of the detection algorithm to the various thresholds introduced, particularly

(a) the secondary Z_H threshold,

(b) the secondary Z_{DR} threshold and

(c) the Z_{DR} column accumulation threshold.

Informed by Figure 4, our severe weather precursor requires ten accumulated Z_{DR} column pixels between 5 and 30 minutes prior to the definition of severe weather being met within a tracked convective cell.

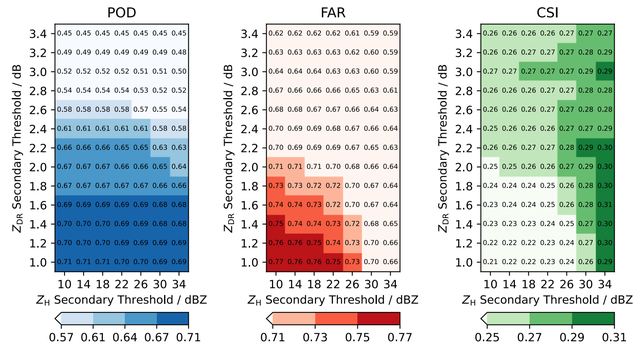


Figure 5. Metrics for verifying the effectiveness of Z_{DR} column appearance prior to severe convection for tracked storms on 16 June 2020 showing how probability of detection (POD), false alarm rate (FAR) and critical success index (CSI) vary over changing secondary reflectivity and differential reflectivity thresholds in Z_{DR} column detection algorithm. 18605 convective cells were tracked. From bootstrapping tracked storms at 25dBZ of Z_H and 2.5dB of Z_{DR}, each colour level represents one standard deviation of change in the verification metric.

Conclusions

- Across three case days, detected Z_{DR} columns were found to precede severe convection in tracked convective cells with a range of lead times from 0 to 20 minutes depending on the case day.
- Requiring maxima above 1.4dB and 30dBZ of Z_{DR} and Z_H respectively was an appropriate second condition for all three cases although the sensitivity of this result varied across case days.
- Low skill and data latency could limit the use of Z_{DR} columns in the Met Office's operational setting, but a promising development in nowcasting severe convection for the UK.

References

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