Polarimetric radar observations of the Jersey supercell and tornado of 1 – 2 Nov 2023

Matthew R. Clark[1] September 2024

Introduction

Just before midnight on 1 – 2 November 2023, the strongest tornado to have occurred in the UK and Crown Dependencies since 1954 struck the island of Jersey, Channel Islands. The thunderstorm responsible formed close to the cold front of an intense extratropical cyclone, named Storm Ciarán by the Met Office (Figures 1 and 2). The tornado produced a damage track 100 – 550 m wide across eastern parts of Jersey. Hail of diameter ≥ 5 cm fell over a broader swath of the island (Figure 3).

The storm was sampled at close range by the weather radar located on Jersey. The tornado was located between 10 km east and 15 km east-northeast of the radar as it tracked across the island (Figure 3). The radar captured signatures of the rotating updraft of the storm, and the rotation and debris cloud associated with the tornado itself (a polarimetric Tornado Debris Signature; TDS). These are the first observations of a polarimetric TDS in the UK and Crown Dependencies.

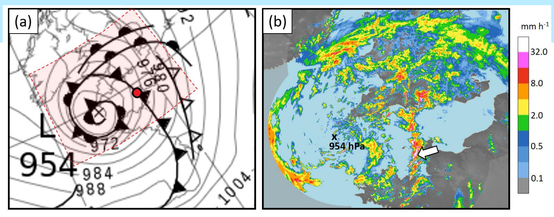


Figure 1 (right): (a) Met Office surface analysis chart at 0000 UTC 2 November 2023 showing Storm Ciarán approaching southwest England; (b) Network radar rainfall rate at the same time. The location of the storm responsible for the Jersey tornado is shown by the red dot in panel (a) and the arrow in panel (b). Red-shaded polygon in (a) represents the area shown in panel (b).

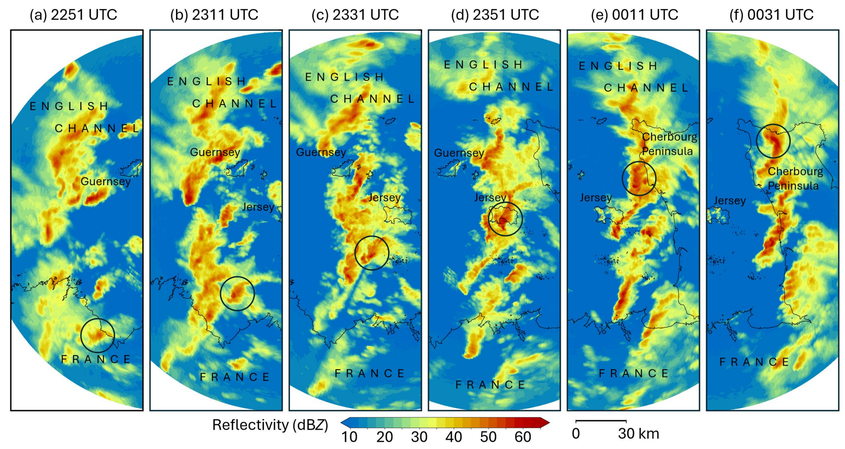


Figure 2 (above): Sequence of 1° elevation-angle reflectivity images from the Channel Islands radar at 20-minute intervals between 2251 UTC 1 November and 0031 UTC 2 November 2023, showing evolution of the cell responsible for the Jersey tornado and hailstorm (circled).

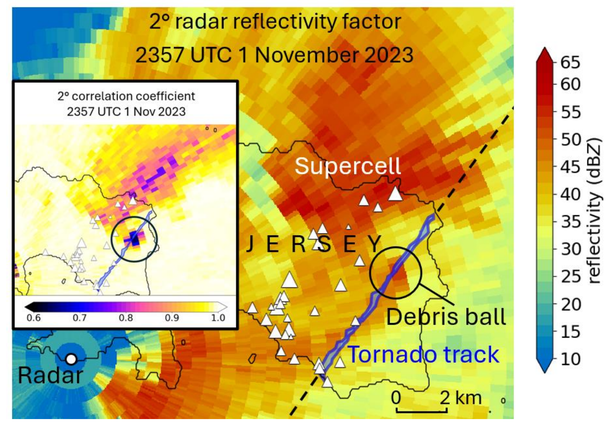
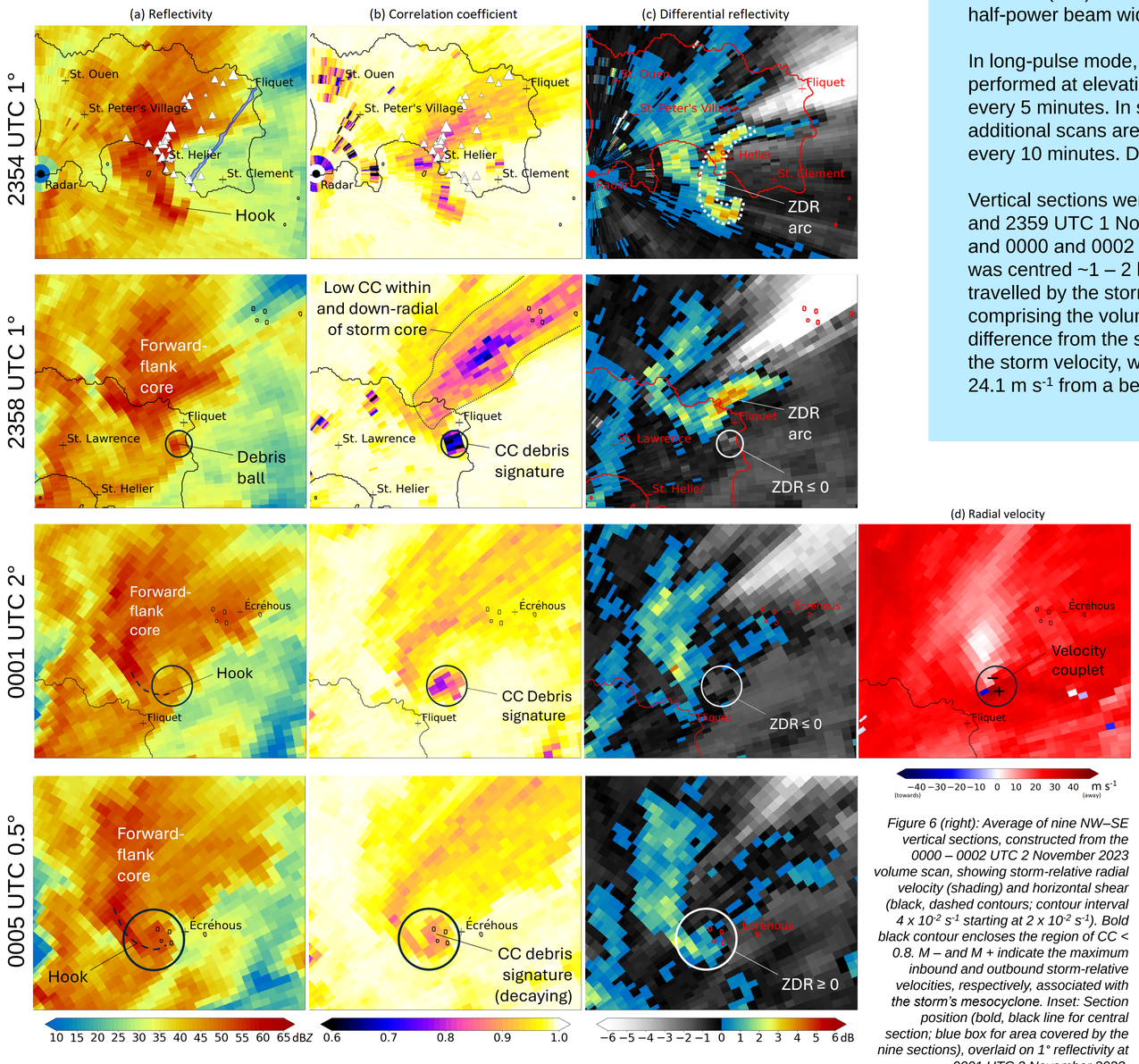


Figure 3 (above): Tornado track (blue polygon) and hail reports (white triangles; marker size proportional to reported diameter, max. 70 mm). Mesocyclone track is shown by black, dashed line. Features are overlaid on 2° elevation-angle reflectivity at 2357 UTC 1 November 2023 from the Channel Islands radar. Inset: Correlation coefficient (CC) from the same scan. Low CC region associated with tornado debris cloud is circled.

Figure 4 (below): Sequence of images from selected plan-position indicator (PPI) scans of the Channel Islands radar on 1 – 2 November 2023 (scan times and elevation angles are indicated to the left of each row). (a) (left column) radar reflectivity factor (Z); (b) (middle column) correlation coefficient (CC); (c) (right column) differential reflectivity (ZDR); (d) Radial velocity (available only for the 0001 UTC short-pulse scan). Features of interest are annotated. Triangle markers and the blue polygon in 2354 UTC panels represent hail reports and tornado track, respectively.



Data and Methods

Data come from the weather radar located at the southwestern tip of Jersey (49.177°N, 2.224°W; hereafter the 'Channel Islands' radar; Figure 3). This C-band, Doppler, polarimetric radar is operated by Jersey Met using hardware and software developed by the Met Office. The radar operates in Plan Position Indicator (PPI) mode. Data are available at range intervals of 0.6 km and the half-power beam width is 1°.

In long-pulse mode, the lowest elevation angle is 0.5° and additional scans are performed at elevation angles of 1, 2, 3 and 4°, to make a single volume scan every 5 minutes. In short-pulse mode, the lowest elevation angle is 1° and additional scans are performed at 2, 4, 6 and 9° to make a single volume scan every 10 minutes. Doppler data are only available in short-pulse mode.

Vertical sections were constructed using volume scans obtained between 2356 and 2359 UTC 1 November, when the storm was located over northeast Jersey, and 0000 and 0002 UTC 2 November 2023, when the storm's mesocyclone was centred ~1 – 2 km northeast of the island. To account for the distance travelled by the storm between the different storm sample times in each scan comprising the volume scan, data were translated horizontally using the time difference from the storm sample time in the lowest elevation-angle scan, and the storm velocity, which was estimated from loops of radar data to be 24.1 m s^{-1} from a bearing of 218° (i.e., u = 15.0 m s^{-1}, v = 18.9 m s^{-1}).

Correlation coefficient (CC) is a measure of how similarly the horizontal and vertical pulses are fluctuating from pulse to pulse. CC < 0.8 suggests complex scattering and the likely presence of scatterers other than hydrometeors (for example, insects and debris).

Differential reflectivity (ZDR) is the difference in intensity of the backscattered echo in the vertical and horizontal pulses. Scatterers that are wider than they are tall (e.g., large raindrops or small, rain-coated hailstones) give positive ZDR. Spherical scatterers, or those with no preferred orientation on average, give ZDR ≈ 0.

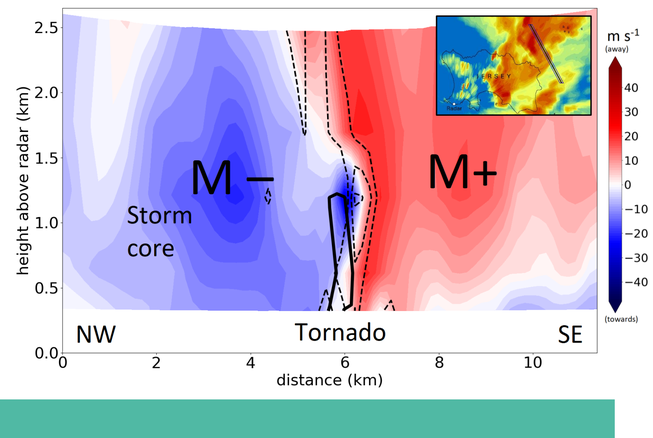


Figure 6 (right): Average of nine NW–SE vertical sections, constructed from the 0000 – 0002 UTC 2 November 2023 volume scan, showing storm-relative radial velocity (shading) and horizontal shear (black, dashed contours; contour interval 4 x 10^{-2} s^{-1} starting at 2 x 10^{-2} s^{-1}). Bold black contour encloses the region of CC < 0.8. M – and M + indicate the maximum inbound and outbound storm-relative velocities, respectively, associated with the storm's mesocyclone. Inset: Section position (bold, black line for central section; blue box for area covered by the nine sections), overlaid on 1° reflectivity at 0001 UTC 2 November 2023.

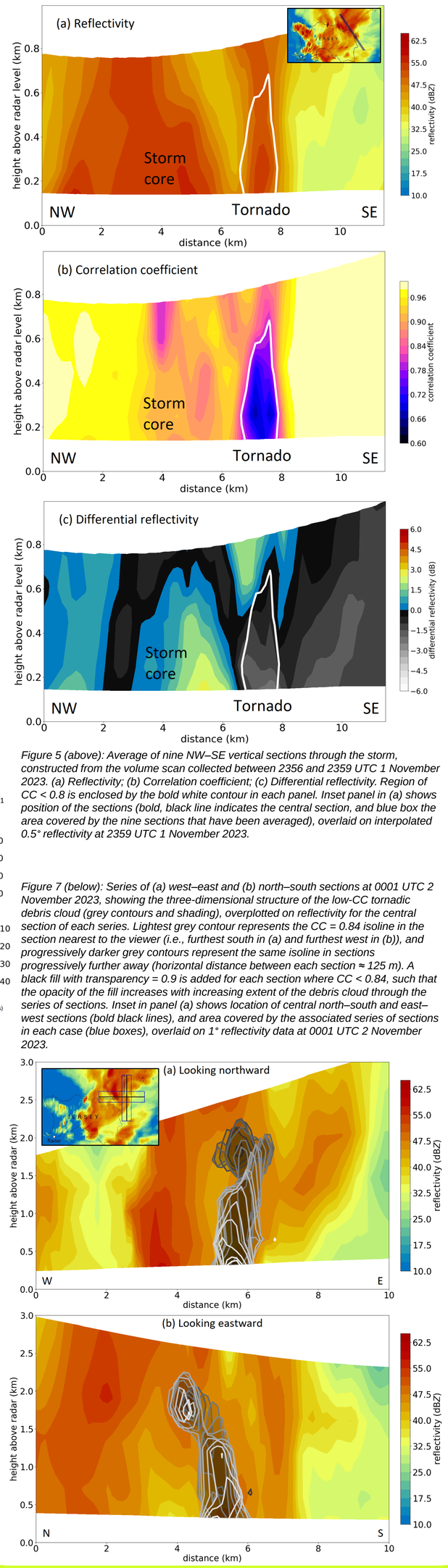


Figure 5 (above): Average of nine NW–SE vertical sections through the storm, constructed from the volume scan collected between 2356 and 2359 UTC 1 November 2023. (a) Reflectivity; (b) Correlation coefficient; (c) Differential reflectivity. Region of CC < 0.8 is enclosed by the bold white contour in each panel. Inset panel in (a) shows position of the sections (bold, black line indicates the central section, and blue box the area covered by the nine sections that have been averaged), overlaid on interpolated 0.5° reflectivity at 2359 UTC 1 November 2023.

Figure 7 (below): Series of (a) west–east and (b) north–south sections at 0001 UTC 2 November 2023, showing the three-dimensional structure of the low-CC tornadic debris cloud (grey contours and shading), overplotted on reflectivity for the central section of each series. Lightest grey contour represents the CC = 0.84 isoline in the section nearest to the viewer (i.e., furthest south in (a) and furthest west in (b)), and progressively darker grey contours represent the same isoline in sections progressively further away (horizontal distance between each section ≈ 125 m). A black fill with transparency = 0.9 is added for each section where CC < 0.84, such that the opacity of the fill increases with increasing extent of the debris cloud through the series of sections. Inset in panel (a) shows location of central north–south and east–west sections (bold black lines), and area covered by the associated series of sections in each case (blue boxes), overlaid on 1° reflectivity data at 0001 UTC 2 November 2023.

Results and Conclusions

The Channel Islands radar captured close-range observations of the tornadic supercell over Jersey on 1 – 2 November 2023. Key features included:

- A hook echo and persistent velocity couplet associated with the supercell's mesocyclone (e.g., 2354 UTC panel of Figure 4(a)).
- A prominent ZDR arc on the right (southeast) flank of the storm core (e.g., 2354 and 2358 UTC panels of Figure 4(c)), suggesting a predominance of large, oblate raindrops here.
- A region of reduced CC (between 0.8 and 0.9), slightly positive ZDR, and reflectivity >50 dBZ, suggesting the likely presence of wet hail, or rain mixed with hail, within the forward-flank core of the supercell thunderstorm (e.g., 2354 UTC panel of Figure 4(b)).
- Once over Jersey, a much smaller region of particularly low CC (<0.8 and locally <0.6) developed near the tip of the hook echo, collocated with an area of near-zero or negative ZDR (2358 and 0001 UTC panels of Figures 4(b) and (c). These features were collocated with a small, roundish reflectivity maximum (i.e., a 'debris ball'; 2358 UTC panel of Figure 4(a)) and a velocity couplet (Figure 4(d)).
- ***Taken together, the above features meet established criteria for a polarimetric Tornado Debris Signature (TDS). The TDS developed only after the hook echo had made landfall in Jersey*** (*cf.* 2354 and 2358 UTC panels of Figure 4(b)).
- After leaving Jersey, CC and ZDR values recovered gradually within the residual TDS, suggesting the gradual fallout of debris (0005 UTC panel of Figures 4(b) and (c)).
- In vertical sections, the low-CC, low-ZDR, high-reflectivity region comprising the TDS formed a column of width ~1.0 – 1.5 km extending to ~2 km AGL (Figures 5 and 7). The column tilted to the north-northeast with height (Figure 7).
- Vertical sections through the radial velocity field showed a 5-km-wide velocity couplet associated with the storm's mesocyclone, and a much narrower, stronger couplet associated with the tornado vortex itself (Figure 6).

The occurrence of a T6/IF3 intensity tornado within 15 km of an operational radar can be expected to be an extremely rare occurrence in the UK and Crown Dependencies (noting that only 13 tornadoes of intensity T5 or greater have been recorded in the region since 1950, and that less than 5% of the region's land areas lie within 15 km of the nearest radar). However, it remains to be seen whether the polarimetric radars in the UK network can detect similar signatures for weaker tornadoes and/or those at larger range from the radar.

[1]**Met Office** FitzRoy Road, Exeter, Devon, EX1 3PB United Kingdom
Tel: +44 1392 885680 Fax: +44 1392 885681
Email: matthew.clark@metoffice.gov.uk