The Southern England Tornadoes of 30 December 2006

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Introduction

Current estimates suggest that the UK experiences around 70 tornadoes per year. The majority of these occur in outbreaks in the winter season (Reynolds, 1999; Meaden and Chatfield, 2007). On 30 December 2006, one such outbreak of tornadoes affected parts of southern and eastern England. At the time, a TORRO (Tornado and Storm Research Organisation) tornado watch was active. On this occasion 11 reports of tornadic damage were confirmed by TORRO. The tornadoes occurred between 1530 and 1830UTC. Of those to which an intensity rating could be assigned, the strongest was T3 and the weakest T1 on the TORRO tornado intensity scale.

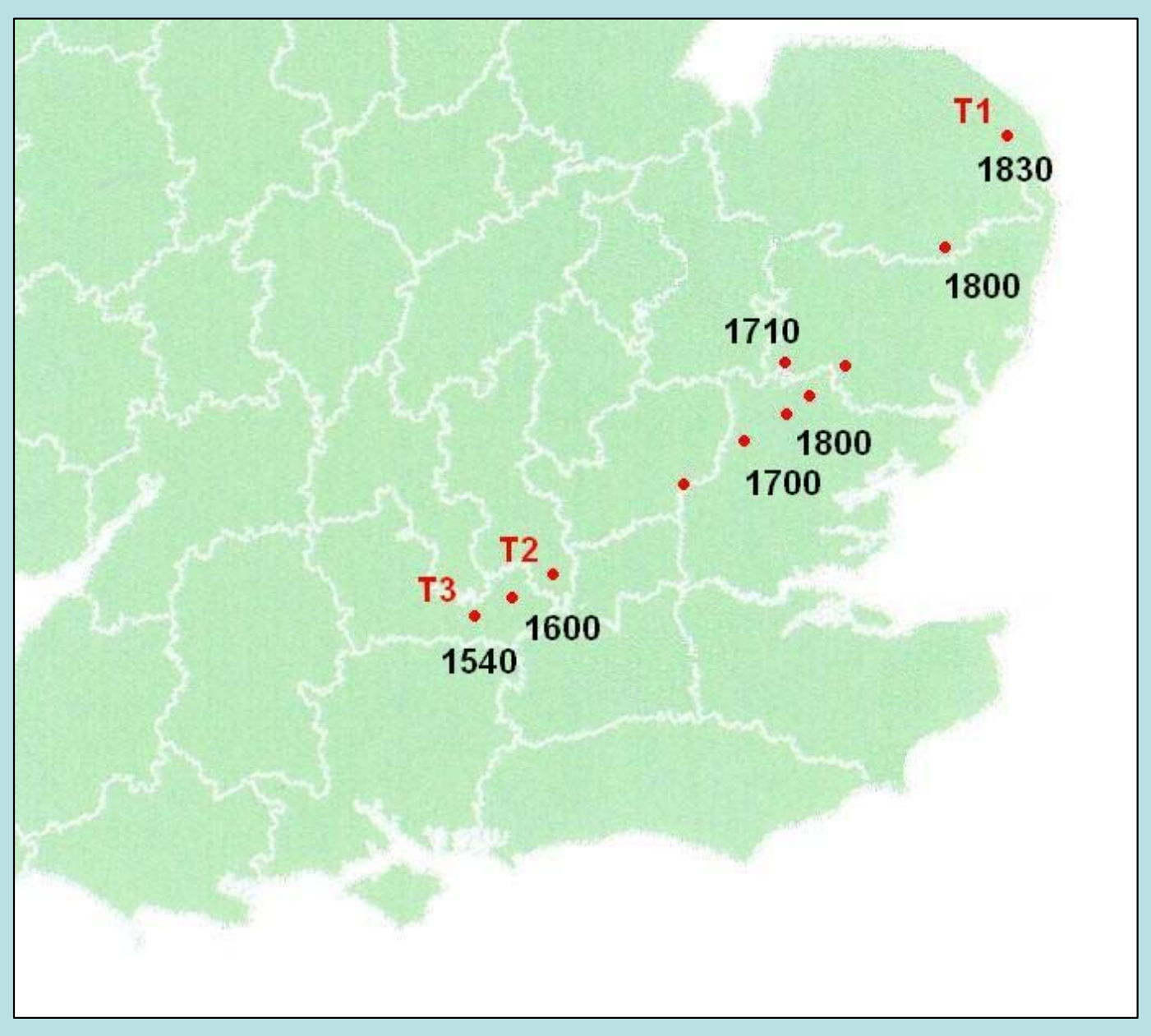


Figure 1. Map showing location of each of the confirmed tornadoes (shown by the red dots). Intensity ratings (T scale) and times of occurrence (UTC) are given where known.

With the exception of one event, the locations of reported damage lie along a clearly defined SW-NE path (Fig. 1). The persistent storm responsible for all of the tornadoes on this day developed close to a surface cold front, associated with a small, developing depression, which moved eastwards across southern parts of England through the afternoon.

Storm environment

- Satellite imagery shows a dry slot overtook the surface cold front during the afternoon, resulting in a shallow moist zone and an associated increase in potential instability.
- 40 J/kg of CAPE is indicated by available ascent data (Fig. 2), though the actual value is likely to have been somewhat higher owing to the introduction of dry air associated with the dry slot.
- The CAPE was located in a relatively shallow layer at low levels (900 – 700 hPa).
- The wind veered through 50˚ between the surface and 2 km, with unidirectional shear (no turning of shear vector with height) above this level.
- Wind speed increased from 16 to 65 knots between 0 and 2 km, with a more gradual increase of 45 knots between 2 and 8 km.
- Storm relative helicity (SRH) was found to be strongly concentrated to within the lowest kilometre; the 0 to 1 km storm relative helicity was calculated to be in the region of 330 J/kg compared to 0 to 3 km SRH of approximately 360 J/kg.

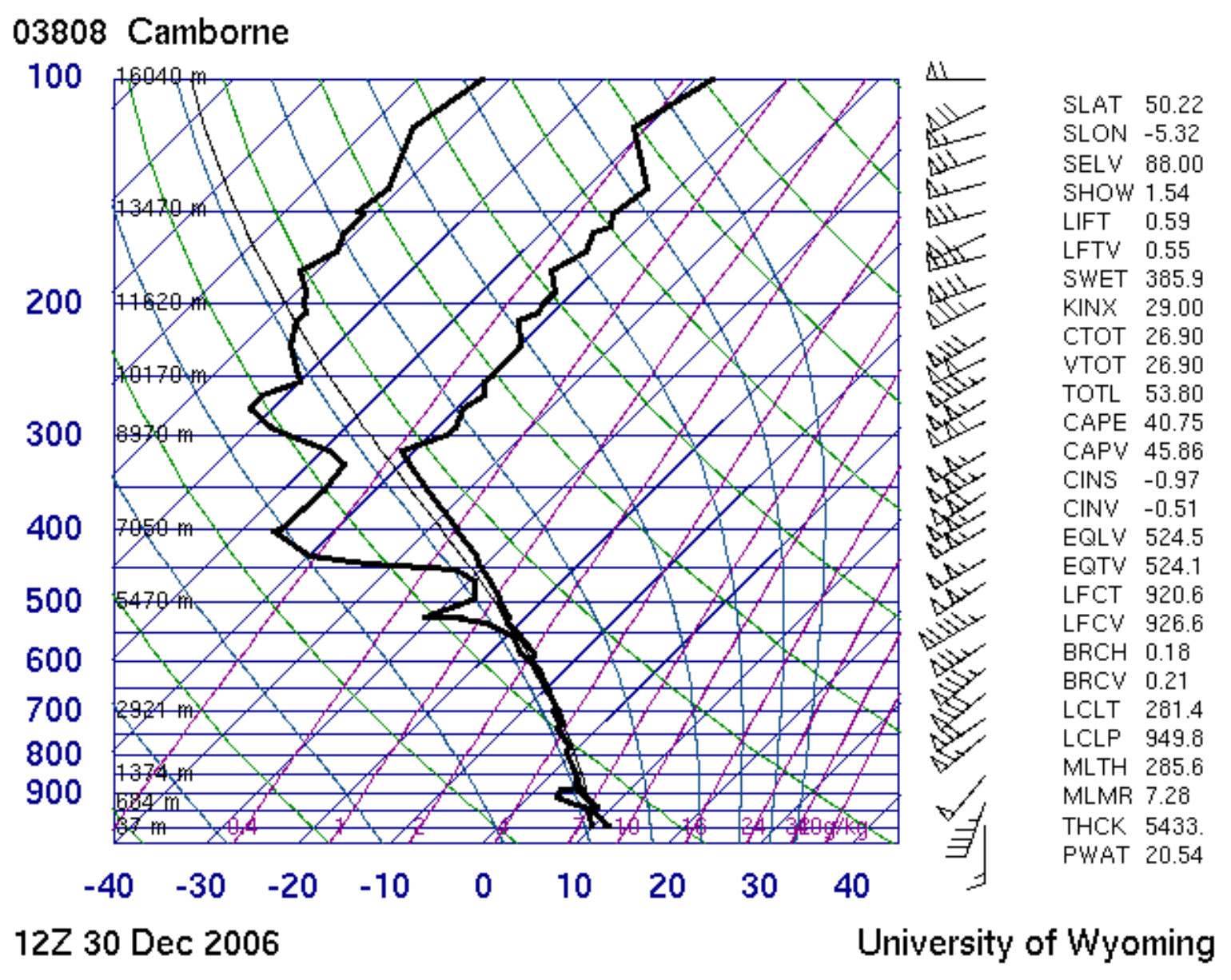


Figure 2. Tephigram constructed from the 1200UTC Camborne radiosonde ascent. Courtesy of the University of Wyoming.

Radar analysis

A narrow squall line developed in the vicinity of the cold front by mid-afternoon. As the line moved north-east it evolved rapidly. Around 1500UTC a small reflectivity notch developed on the eastern side of the echo. At 1530UTC this notch was still evident. The reflectivity pattern in its vicinity at this time resembled that of a high precipitation supercell (Fig. 3).

Subsequently, the part of the echo to the south of the reflectivity notch rapidly developed into a bow echo. The evolution of this bow is shown in Figure 4. From 1615 UTC, reflectivity data showed the development of a large, hook-shaped feature at the northern end and immediately behind (west of) the bow echo (Fig. 4). This feature became increasingly well formed, and was identifiable in the reflectivity images until 1700UTC, after which time the echo moved sufficiently far form the radar as to be un-resolvable. The echo as a whole assumed a distinctive 'S' shape during this phase.

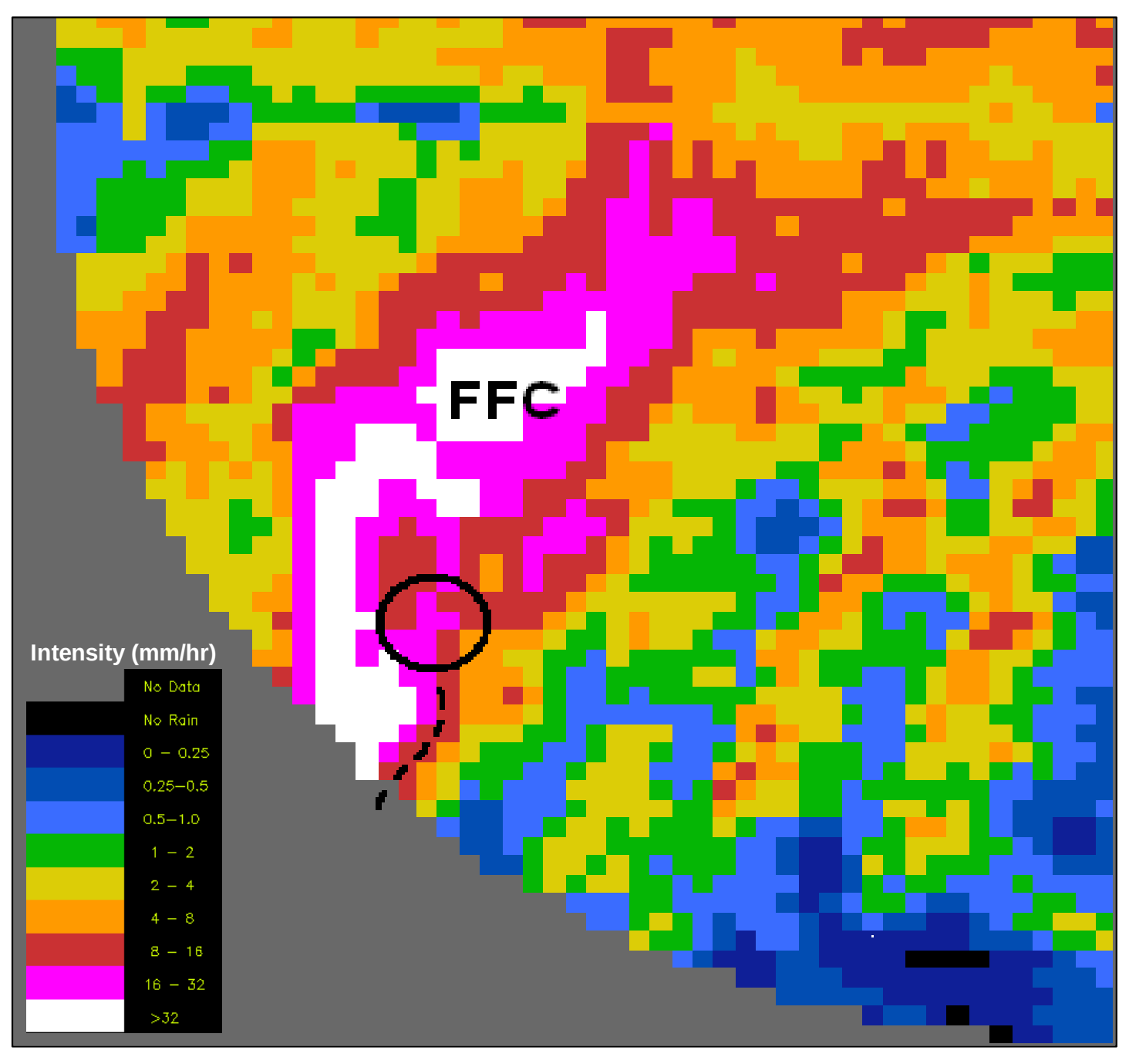


Figure 3. 1km resolution radar reflectivity image at 1535UTC from Met office Chenies radar. Annotations show probable locations of features associated with a HP supercell, including mesocyclone (black circle), approximate leading edge of rear flank downdraft (black dotted line) and forward flank precipitation core (FFC). Copyright Met Office 2007.

Several instances of tornadic damage were associated with the southern tip of this large 'hook' around 1700UTC (Fig. 5). Although the hook was no longer resolvable as the storm moved into East Anglia, further tornadic damage was associated with the same part of the storm echo as late as 1830UTC.

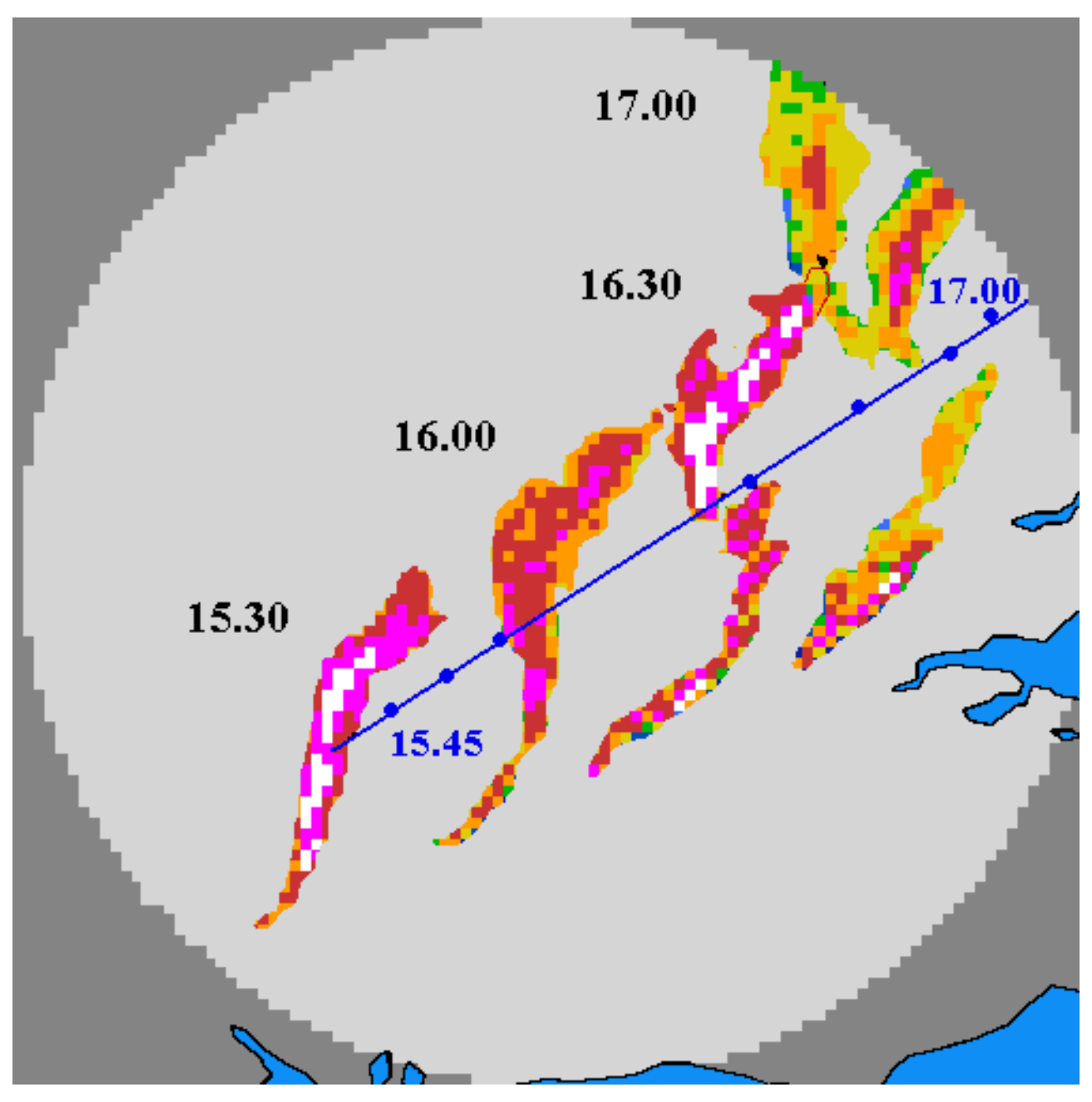


Figure 5: Storm radar reflectivity echo, after removal of surrounding weaker echoes, at 30 minute intervals beginning 1530UTC and ending 1700UTC. Time (UTC) is shown in black type to the NW of the corresponding echo. Locations of tornadic damage are given by blue dots. Reported times of tornadic damage are given to SE of damage location, in blue type. Coastlines are shown by the black line. Light grey circle marks the area for which 2km resolution reflectivity data is available, which has diameter 200 km. Copyright Met Office 2007.

Discussion

The configuration of the radar reflectivity pattern around 1530UTC (Fig. 3) suggests that a mesocyclone probably existed in the early stages of the storm's evolution. The location of the first two tornadoes is consistent with the position of the mesocyclone as inferred from this reflectivity data.

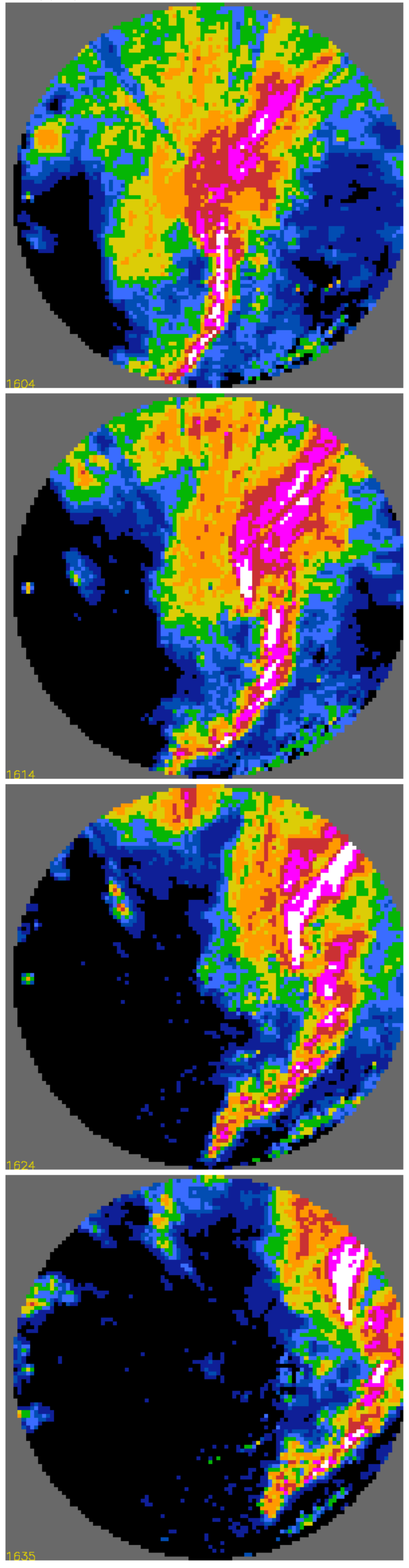
The large hook-shaped reflectivity pattern which subsequently developed was likely associated with a larger area of rotation. Given its location to the north of the bowing echo, and its development shortly after significant bowing occurred, it is probable that the hook was associated with a cyclonic book-end vortex.

The evolution of the echo is similar to conceptual models of high-precipitation supercell to bow echo transitions (Moller *et al*. 1990). Some similarity can also be found to previously documented cases of supercell and squall line interactions; specifically, Wolf (1998) and Sabones *et al*. (1996). In particular, Sabones *et al*. (1996) noted the development of a similar 'S' shaped reflectivity pattern in two separate cases, in which tornadoes also occurred near the inflection point of the 'S'.

Conclusions

- Radar reflectivity data suggests the presence of i) a mesocyclone and ii) a larger area of cyclonic rotation. Both features produced tornadoes.
- The co-location of CAPE and the strongest shear at low levels may have been important for low level mesocyclone development in this case.
- The storm environment was characterised by very small CAPE and very large 0 to 1 km SRH.
- Further research is required into the characteristics of cool-season tornadic storms in the UK, which are responsible for almost all of the larger outbreaks.
- Such outbreaks have in the past been attributed to non-mesocyclonic storms, most often squall lines along active cold fronts.
- The unavailability of Doppler radar data was a limiting factor in the analysis of the evolution of this storm. The recent introduction by the Met Office of Doppler capability at several sites will aid in the analysis of future events.

Figure 4. 1km resolution reflectivity data at 10 minute intervals beginning 1604UTC, showing evolution of bow echo and 'hook' feature. Rainfall intensities as in Figure 3. Area covered has diameter 100km. Copyright Met Office 2007



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