A Provisional Climatology of Cool-Season QLCSs in the UK

Matt Clark, October 2011

Introduction

Quasi-linear convective systems (QLCSs) occur frequently during the autumn and winter months in the UK. Tornadoes and other localised, damaging winds have been documented in association with these 'cool-season' QLCSs on numerous occasions. An example of a cold-frontal QLCS is shown in Figure 1.

A seven-year climatology of cool-season QLCSs has been constructed for the period 2003–4 to 2009–10. Tornado occurrence within identified QLCSs has been investigated using the Tornado and Storm Research Organisation (TORRO) tornado database.

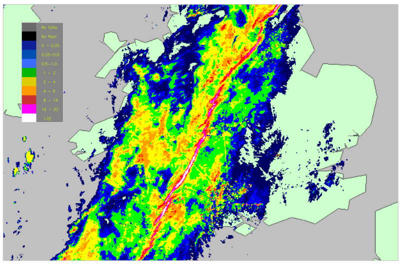


Figure 1: Composite rainfall-rate (mmh^{-1}) imagery showing an example of a cold-frontal QLCS, which occurred on 25 November 2009.

Method

QLCSs were identified from an archive of composite Met Office rainfall radar imagery, using the following criteria:

- •Size: length ≥ 100 km, and length ≥ (10 x width).
- •Duration: meets the above criteria for ≥ 2 hours.
- •Intensity: A continuous, or near continuous, line of rainfall rates ≥ 4 mmh^{-1} (equivalent to 32.6 dBZ).

QLCSs were classed as tornadic if one or more tornadoes in the TORRO database could be unambiguously attributed to the line. Remaining lines were classed as non-tornadic.

The tornadic class was further sub-divided into weakly- and strongly-tornadic classes. Weakly-tornadic lines were those in which only a single, weak (T0 – T3) tornado could be attributed to the line. Strongly-tornadic events were those in which one tornado of intensity ≥ T4, or two or more tornadoes of any intensity, could be attributed to the line.

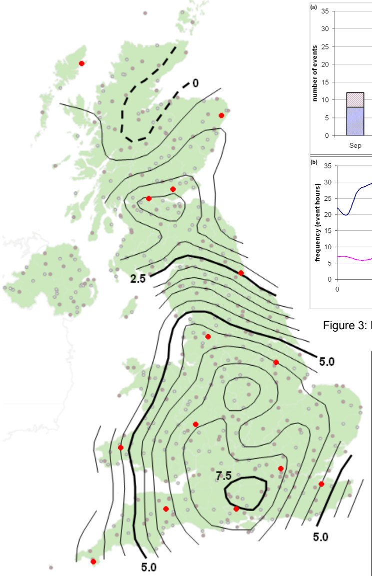


Figure 2: Frequency of cool-season QLCSs over the UK, expressed as the number of events per 10,000 km^2 per year. Large red dots indicate the locations of radars in the current UK network.

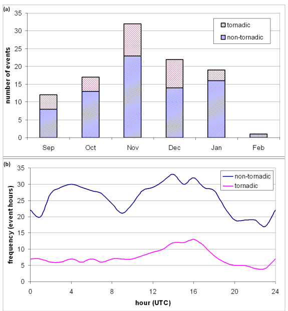


Figure 3: Monthly (a) and diurnal (b) QLCS distribution.

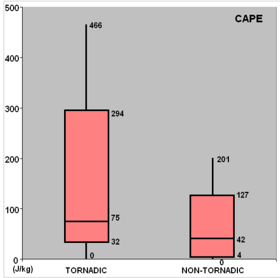
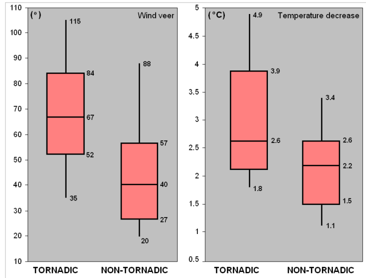


Figure 4 (left): Box and whisker plots showing CAPE distribution for tornadic and non-tornadic lines. The tails show the 10th and 90th percentile values.

Figure 5 (right): Box and whisker plots showing cross-line wind veer and temperature decrease for tornadic and non-tornadic lines. The tails show the 10th and 90th percentile values.



Results: general climatology

The highest frequency of QLCSs (≥ 7.5 events, per 10,000 km^2, per year) was found over central southern England (Figure 2). Frequencies were lowest over northern Scotland with < 1 event per 10,000 km^2 per year. Of the 103 identified lines:

- •87% were associated with frontal systems (mainly cold fronts)
- •13% occurred in post-frontal situations
- •27% were tornadic (9% weakly tornadic, 18% strongly tornadic)

QLCS were most frequent in November, though relatively high frequencies also occurred in October, December and January (Figure 3(a)). Only one event was identified during February during the whole analysis period. The lower number of weakly-tornadic QLCSs, as compared to strongly-tornadic QLCSs, suggests a possible under-reporting of isolated, weak tornadoes within cool-season QLCSs.

The diurnal distribution of QLCSs (Figure 3(b)) shows no clear cycle. The distribution of tornadoes shows a somewhat stronger afternoon peak, though tornadoes were observed at all times of day and night.

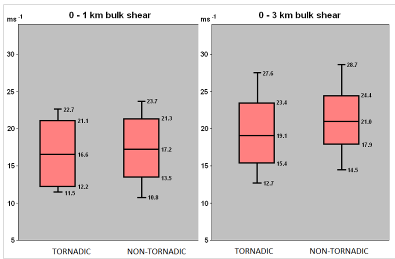


Figure 6: 0 – 1-km and 0 – 3-km bulk shear distributions for tornadic and non-tornadic lines. The tails show the 10th and 90th percentile values.

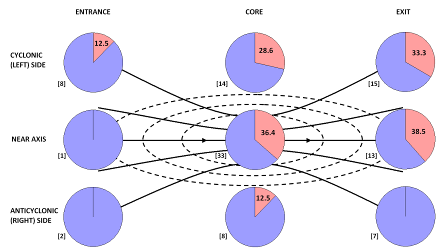


Figure 7: Probabilities (%) of one or more tornadoes, given a QLCS, as a function of QLCS location relative to the 700 hPa jet. Numbers in brackets give total number of QLCSs in each jet-relative location.

Results: comparison of tornadic and non-tornadic lines

Various environmental parameters were obtained from available observations for each identified QLCS. Statistically significant differences were found for a number of parameters:

- •CAPE larger in tornadic lines (Figure 4)
- •Cross-line wind veer and temperature decrease larger in tornadic lines (Figure 5)
- •Line-normal forward motion larger for tornadic lines (not shown)

Contrary to expectations, no significant differences were found between tornadic and non-tornadic lines for 0 – 1-km and 0 – 3-km bulk shear (Figure 6). Strong shear was an almost universal feature of the QLCS environments, suggesting that other limiting factors for tornadogenesis must dominate in non-tornadic cases.

Tornadic lines showed a strong tendency to occur close to the core, exit region, or under the cyclonic-shear flank of the 700 hPa jet (Figure 7). Very few tornadic lines occurred in the jet entrance regions or on the anticyclonic-shear side.

Conclusions

Cool-season QLCSs occur frequently over the southern half of the UK. Although no definite threshold values exist, tornadoes are most likely within these QLCSs when the following criteria are met:

- •CAPE > 200 Jkg^{-1}
- •Cross-line wind veer > 50°
- •Cross-line temperature decrease > 3.0°C
- •Line-normal forward motion > 15 ms^{-1}
- •The line is located under the core, exit region, or cyclonic-shear flank of the mid-level jet

Table 1 shows the probability of one or more tornadoes, given a QLCS, as a function of the number of satisfied criteria in each case. Tornadoes become substantially more likely when three or more criteria are met.

Further research is required in order to test whether these parameters can realistically be forecast ahead of potential QLCS events and, if so, whether the above-defined criteria are of any practical benefit for tornado forecasting.

Table 1: probability of one or more tornadoes as a function of the number of satisfied discriminating criteria (as given in the Conclusions).

Number of criteria met	Probability of one or more tornadoes (%) [ ] = sample size
5	100 [1]
4	75 [8]
3	55 [22]
2	18 [28]
1	6 [33]
0	0 [4]

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