# A climatology of heavy rain–producing convective systems in the UK

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## 1. Introduction

**Flash flooding represents a significant natural hazard due to its rapid onset which gives little time for warning dissemination and response. Compounding the issue is the difficulty in accurately forecasting the small-scale convective systems which typically cause these floods. While many regional NWP models now operate at sufficiently fine horizontal resolution to permit the explicit representation of convection, significant difficulties remain in forecasting the exact timing and location of storms. For such high-impact, low-predictability events, climatologies can be a valuable component of the forecaster's toolbox, providing an expectation of when and where hazardous weather might occur under different large-scale conditions. Here, we present a five-year climatology of heavy-rain-producing convective events in the UK, with a focus on quasi-stationary systems.**

## 2. Data and Methodology

- Previous studies have generally identified heavy convective rain events based gauge observations of extreme daily precipitation totals [1][2]
- Extreme convective precipitation is less common in the UK so to achieve a reasonable sample size we consider long-duration convective rain events; i.e. those with the *potential* to produce extreme rainfall totals given sufficiently high rain rates
- Rain rate data from the UK 1-km radar composite [3] (see Fig. 1 for coverage) for 2008–2012 was used to identify events based on three main criteria:
  1. Accumulations of at least 15 mm over an area of 100 km² or more
  2. Large rainfall gradients within the causative rainfall objects (convection)
  3. A rainfall duration of at least three hours

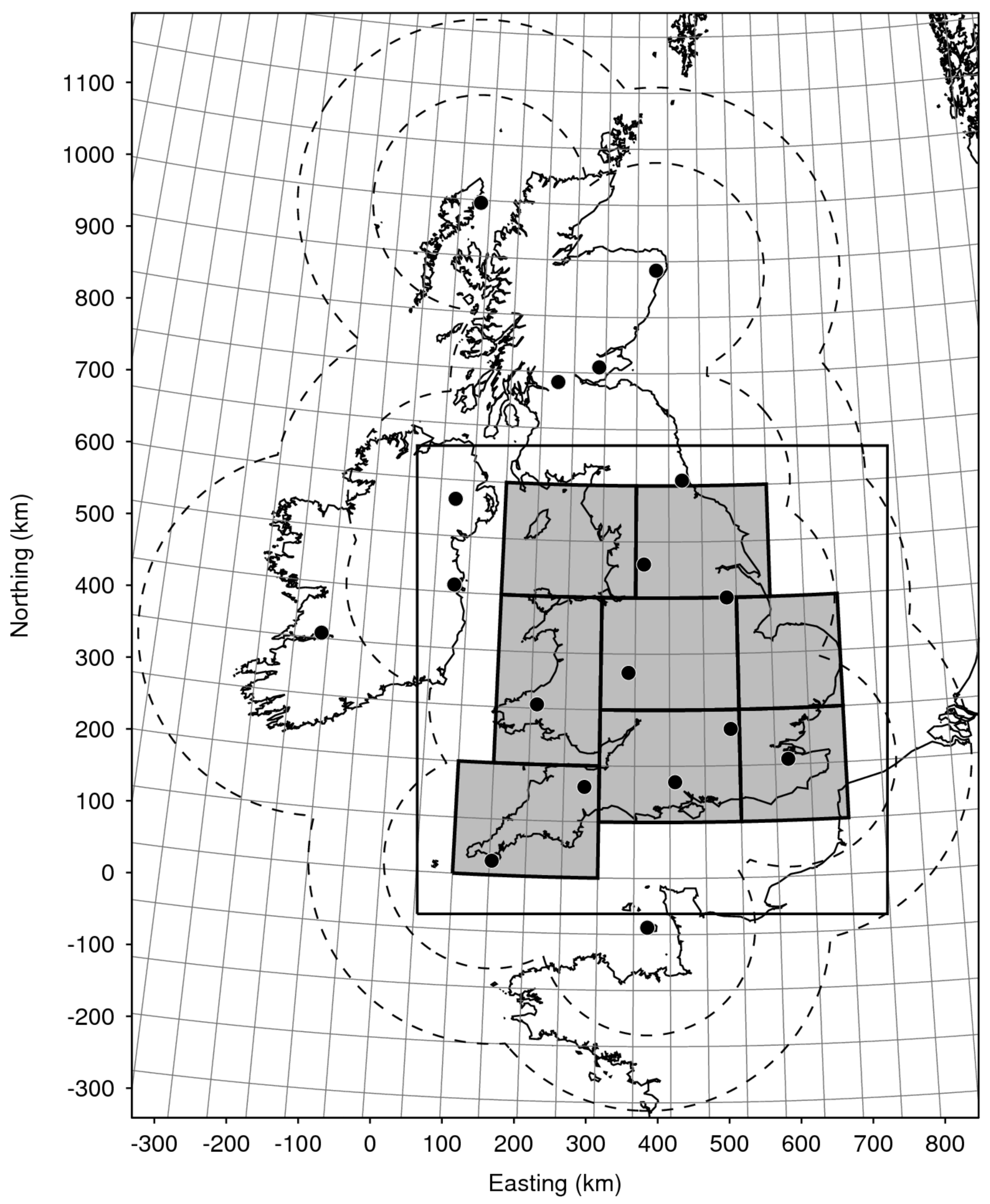


Figure 1. Map showing the coverage of the UK 1-km radar composite (outer dashed line) with black dots indicating the locations of the individual radars. The inner dashed line marks a distance of 150 km from the radars (excluding Shannon in SW Ireland), beyond which data was ignored by the identification algorithm. Grey lines mark ERA-Interim grid boxes. Solid box shows the area used for our convection climatology with grey-shaded ERA grid boxes defining the eight 'regions' (see Section 5).

## 3. Classification of Identified Events

- 519 identified events: 103 rejected, either due to false identification (frontal rain; 30) or data quality issues (73)
- Remaining 416 events placed into one of six categories based on the dominant cause of the long rainfall duration, as determined from radar animations:

| Category | No. Events | Description |
|---|---|---|
| 1 | 88 | Back-building / quasi-stationary convective systems (roughly fixed initiation point) |
| 2 | 109 | Non-stationary training of linearly organised convection (no fixed initiation point) |
| 3 | 46 | Near-stationary convection with repeated / slow cell development |
| 4 | 14 | Training / slow system motion associated with rotation of the flow around a low centre |
| 5 | 100 | Training of cells without any clear linear organisation |
| 6 | 59 | Large and/or slow-moving convective cluster without a clear cellular structure |

- In subsequent analysis, we focus on Type 1 events which will be referred to as *quasi-stationary convective systems* (QSCSs)

## 4. QSCSs: Event Characteristics

- Events are widely distributed but concentrated somewhat near coastlines and regions of significant orography (Fig. 2a)
- The diurnal and seasonal cycle of events (Fig. 2b) closely resembles that of UK convection in general (not shown)
- Most events (76 %) occur during the summer (JJA) with the rest distributed either side of these months (none in Nov–Mar; Fig. 2b)
- Two-thirds occurred within 24 h of another event (Fig. 2c) – this suggests some relation to the large-scale conditions

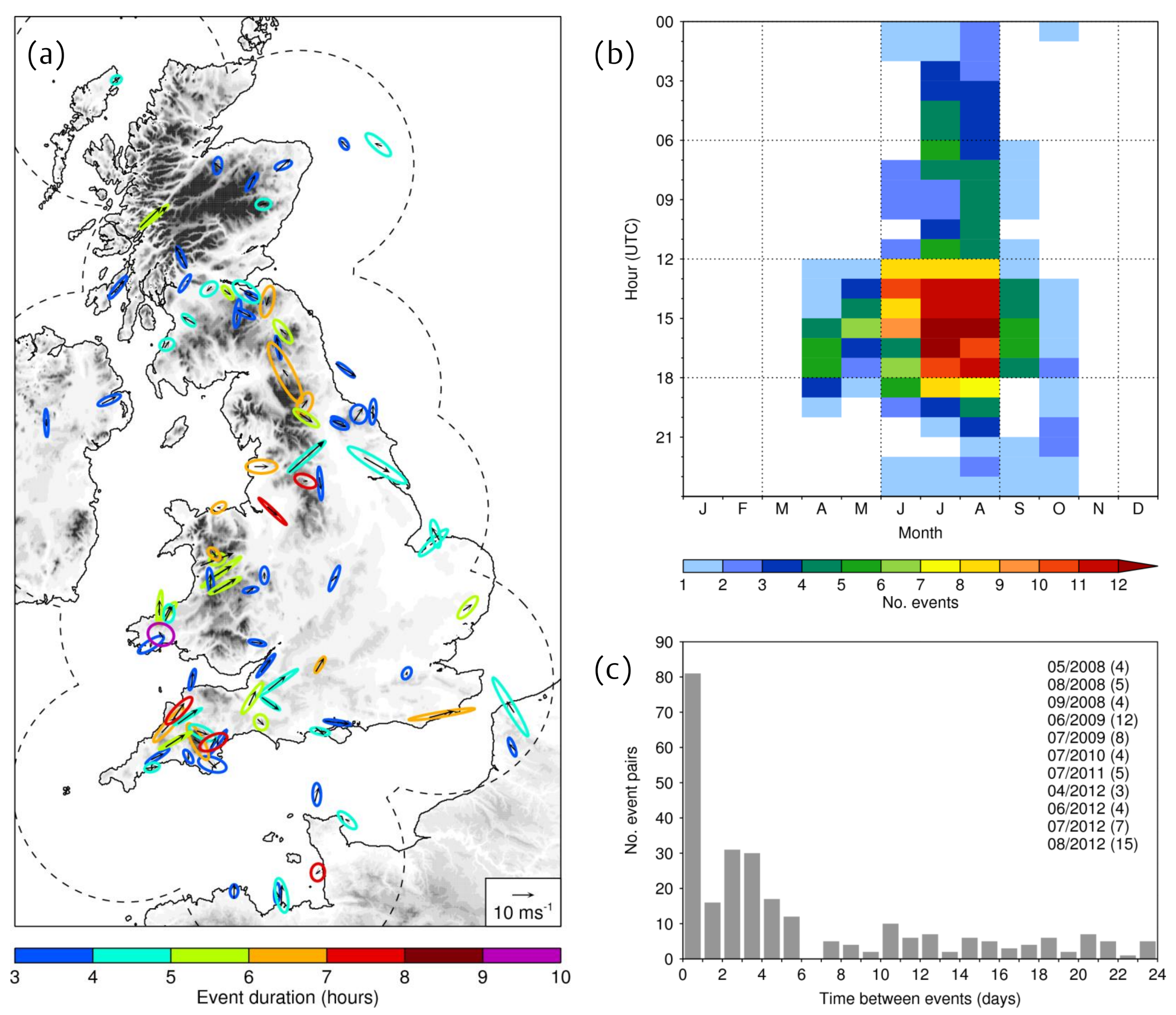


Figure 2. (a) Map showing the location of all identified QSCS events. Ellipses approximate the accumulation area, their colour indicates the event duration, and vectors show the time-averaged cell velocity (computed through correlation of successive radar images covering a small region centred on the event). Orography is contoured in grey-scale with an interval of 100m. (b) Bivariate histogram showing the diurnal and seasonal variation of QSCSs. (c) Histogram of time between events for 11 'active' months (i.e. with three or more events); dates and event counts for these are shown on the right.

## 5. QSCSs: Environment Characteristics

- Previous studies have linked synoptic-scale patterns to flash flooding in particular geographical regions [4][5]
- We have used 6-hourly analyses from the ERA-Interim dataset to examine the environmental conditions during QSCS events
- Initial analysis of synoptic maps revealed great diversity in the large-scale conditions (Fig. 3)
- Wind profiles suggest a tendency for approximately unidirectional flow with weak speed shear (Fig. 4)

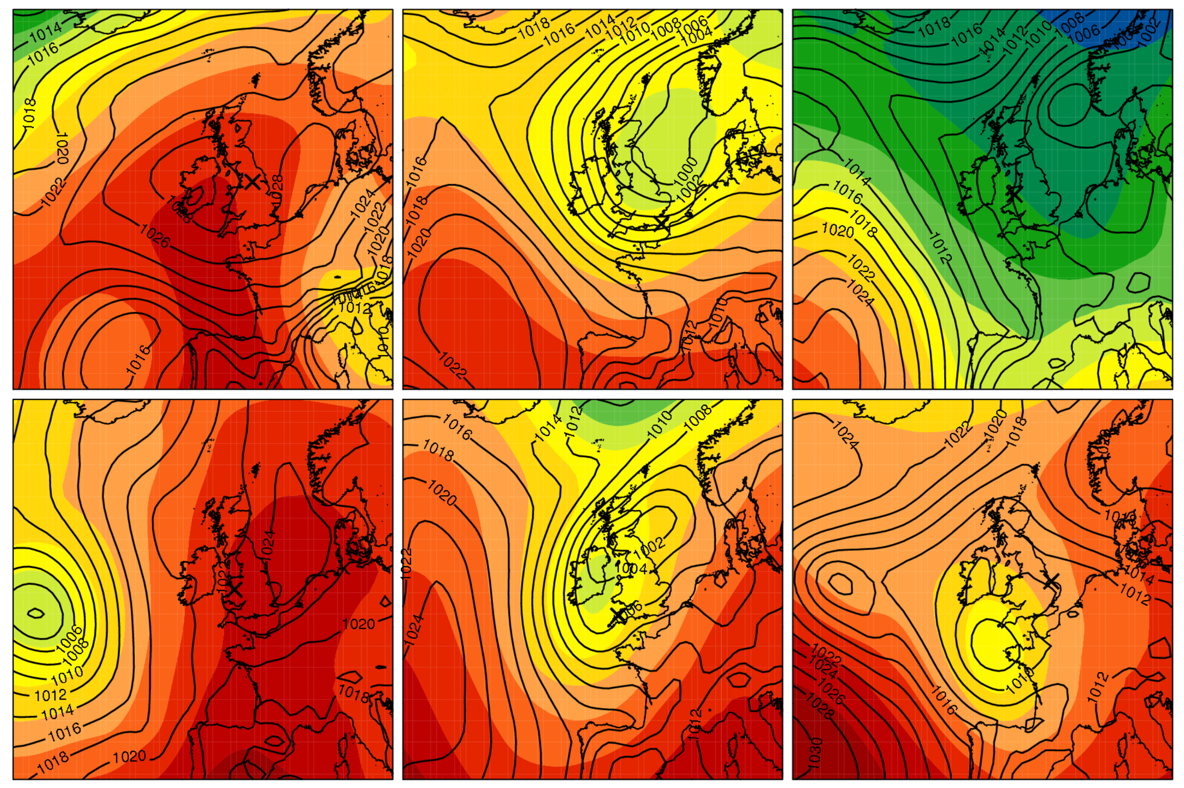

Figure 3. ERA-Interim analyses of 500 hPa geopotential height (colours, 6 dam interval) and mean sea-level pressure (contours, 2 hPa interval) for six of the identified QSCS events (location marked with a cross). In each case the analysis time closest to the event central time was chosen.

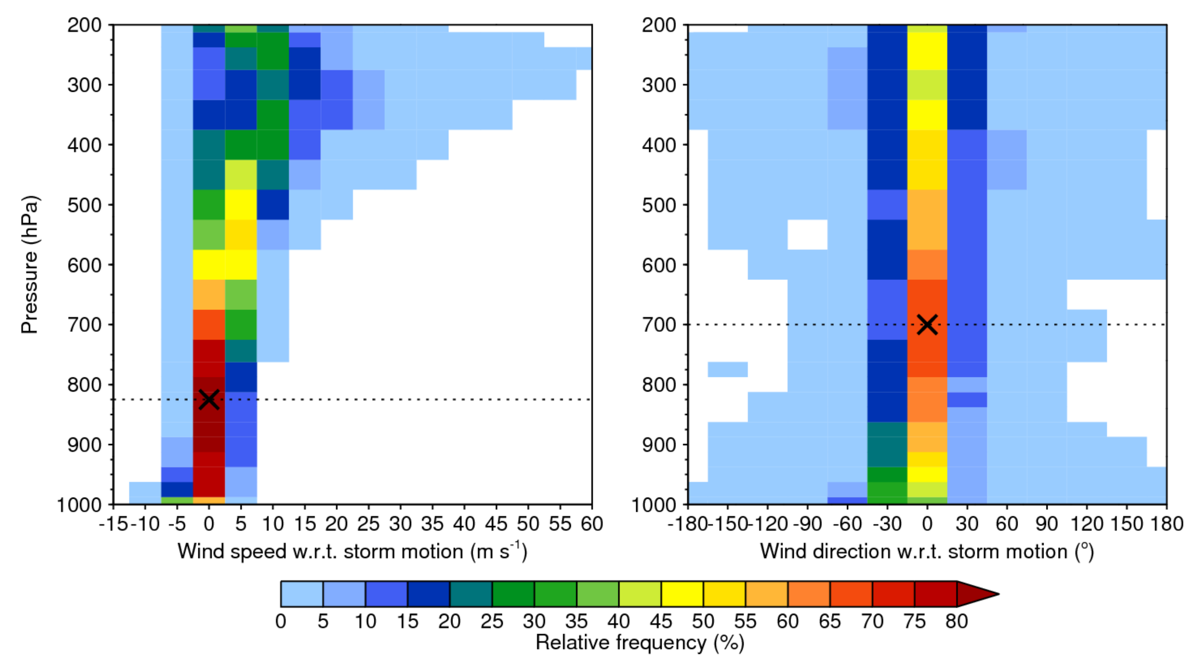


Figure 4. Bivariate histograms showing relative frequency of wind speeds (left) and directions (right) computed with respect to convective cell motion as a function of pressure for all of the identified QSCSs. In each case, profiles were extracted for an array of 3 x 2 grid points around on the accumulation centroid. Crosses mark the maximum value with the dotted line indicating the pressure level at which the wind most closely matches the storm motion.

- To provide information useful to forecasters, we must determine whether the environmental conditions during QSCSs are significantly different from those during other convective episodes
- Convective days were identified for each of the 8 regions in Fig. 1 (covering most of England and Wales) for June–September 2008–2012, based on the presence of convective precipitation covering an area of at least 500 km² at some time between 11 and 18 UTC
- This gave 2513 convective 'events'; for each, ERA-Interim analysis data was extracted for the region grid points allowing for a statistical comparison with the QSCS environments (Fig. 5)
- Based on Fig. 4, we use the 850–700 hPa mean wind to quantify the 'steering level' flow

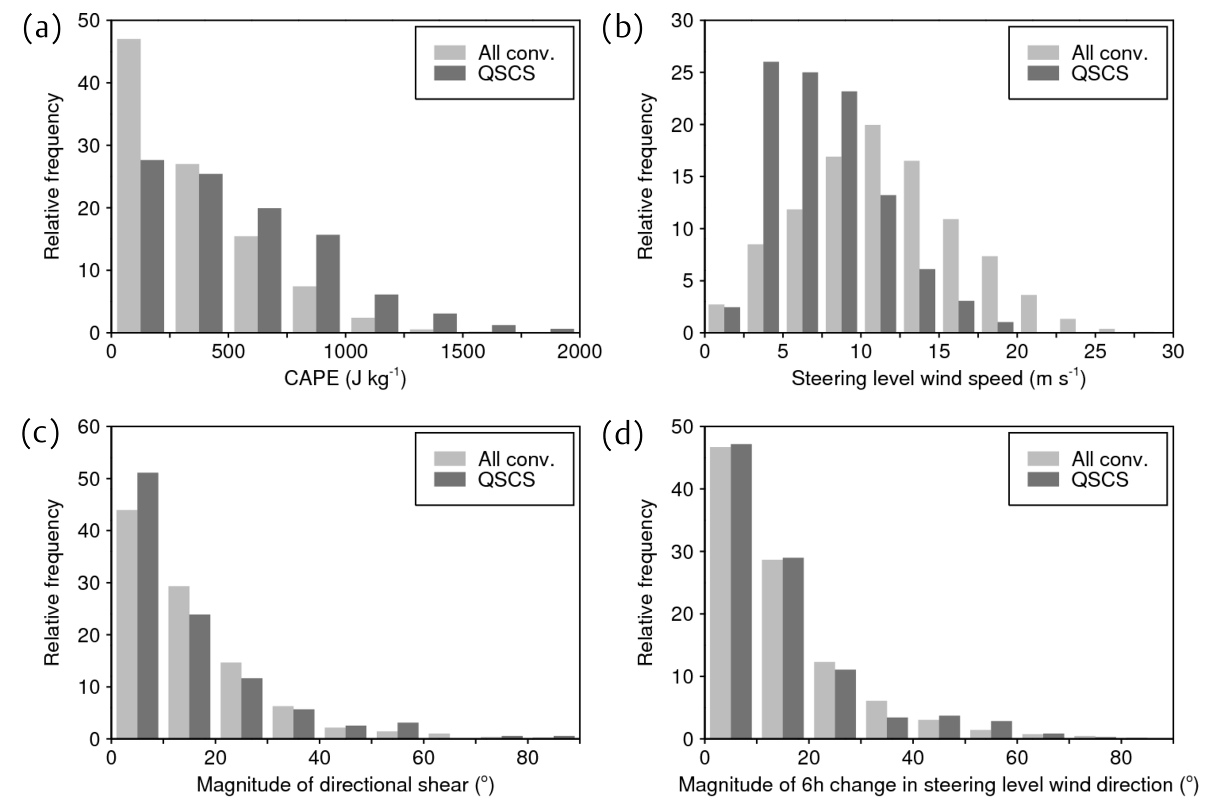


Figure 5. Histograms showing (a) CAPE, (b) steering level (850–700 hPa mean) wind speed, (c) absolute difference in mean wind direction between lower (1000–700 hPa) and upper (700–300 hPa) layers, and (d) absolute difference in steering level wind direction between analysis times before and after event central time. Light and dark grey bars show, respectively, all convective events and QSCSs. For (c) and (d), profiles with a steering level wind less than 5 m s⁻¹ have been neglected.

- QSCS environments show a tendency towards higher CAPE and weaker steering level winds; indeed, winds at all levels are weaker on average (not shown)
- No significant differences are present in the degree of directional shear or rate of change of steering level wind direction with time

## 6. Conclusions

- **On average, 17 QSCSs occur in the UK each year, most during the summer; however, there is large interannual variability**
- **Topography likely plays an important role in the repeated initiation of cells in many QSCS events in the UK**
- **It does not appear that particular synoptic-scale patterns favour the occurrence of QSCSs generally; however, there is a clear relationship for events in some locations (e.g. the SW Peninsula)**
- **The environments of QSCSs are on average more unstable with weaker winds; however, individual cases may be characterised by small CAPE and/or strong flow**
- **The variety of suitable conditions for QSCSs may relate to the different mechanisms by which repeated cell triggering can occur (forced orographic lifting, topographically related convergence lines, back-building along convective outflow)**
- **Future work should investigate the sensitivity of QSCSs associated with particular forcing mechanisms to small changes in ambient conditions, in particular wind direction and shear**

## References

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