JP1.8 FORECASTING EXTREME RAINFALL LEADING TO FLASH FLOOD EVENTS IN THE UK

Neil I. Fox *
University of Missouri – Columbia, Columbia, Missouri

Chris G. Collier
University of Salford, Greater Manchester, UK

Will Hand
Met Office, Bracknell, UK

1. INTRODUCTION

A study has been undertaken of the most extreme, mainly short-period, rainfall events in the UK during the 20th century. Many of the events led to flash-flooding and consequent loss of life and substantial property damage. The importance of being able to forecast these events is clear.

The events were identified from a database of "notable rainfall events" held in the Met Office by picking out those that greatly exceeded classifications, derived from Bilham's (1935) method of distinguishing rarity, which are based on the depth-duration profile of the rainfall. Data were then collected for each of the events and the atmospheric conditions for each event were examined. This paper presents the results of this study, showing the commonalities and differences between the situations prior to the various events. It is believed that the findings can be used to identify situations in which extreme rainfall events may develop over the British Isles and therefore provide guidance to forecasters of the likelihood of extreme rainfall and flooding.

Fifty events were found to be classified as 'extreme' for the 20th Century and were categorized in four ways: frontal, convective, frontal with a significant convective component and convective with significant frontal forcing. There were also a number of events where it was found that orographic factors played a considerable role in the heavy rainfall.

* *Corresponding author address:* Neil I. Fox, Department of Atmospheric Science, 204 Gentry Hall, University of Missouri – Columbia, Columbia, MO 65211; email: foxn@missouri.edu.

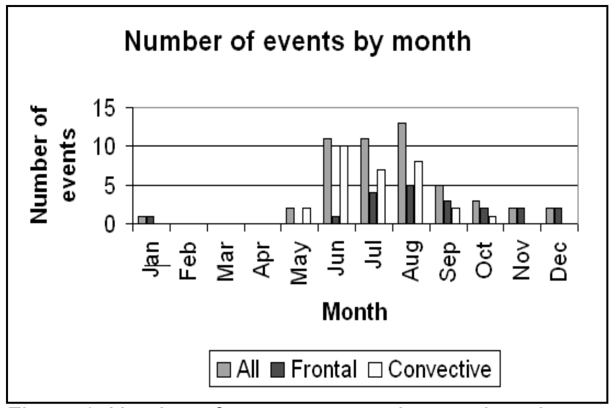

Figure 1: Number of extreme events by month and type.

The overall monthly distribution of events is shown in figure 1. It is clear that the peak time for extreme rainfall occurs in the summer, suggesting that these events are, typically, convective in nature. It is also notable that there have been no extreme events in February March or April.

2. FRONTAL EVENTS

For frontal events it was found that the extreme rainfall took place within 450 km of the central low of the associated slow-moving depression. In 75% the separation was less than 200 km. In all cases the rainfall occurred to the North of the low pressure and this indicates the effect of warm moist air advected from the south (or southwest) and lifted at the front.

In the most extreme frontal cases slow moving fronts contained significant embedded instability. An example of this condition is the Martinstown flood of 1955 which holds the record for 24 hour rainfall in the UK at 280mm.

The typical synoptic situation for an extreme frontal rainfall event in the UK is shown in figure 2.

In the shaded area above and ahead (to the north) of the warm front one can find significant areas with high values of CAPE. The unstable air may be elevated, requiring the presence of the front to initiate convection. It is also notable that many of the most extreme rainfalls have occurred in the extreme southwest of England where the southerly flow impacts on significant orography adding to the ability of localised convection to be triggered in frontal systems.

3. CONVECTIVE EVENTS

The convective cases broadly fell into two categories:

(a) Either where forcing was from a synoptic scale feature such as a front, or updraughts and downdraughts in the system were very strong with a high value of convectively available potential energy (CAPE).

(b) Forcing was either from insolation or a meso-scale feature such as a convergence line or sea breeze and smaller values of CAPE.

Unlike the frontal and orographic cases it was not possible to identify common synoptic causes. Each case was different in some aspect of detail and an extreme event would not necessarily occur given a similar looking synoptic pattern on another occasion. Identification of cases where frontal forcing was dominant was straightforward by looking at sequences of plotted observations and reading published accounts. Assessment of CAPE was somewhat laborious with limited upper air information (especially from cases earlier in the century). Therefore, in most cases accounts and observations of large hail were used as a proxy. However, looking in broad terms it was found that out of the 30 convective events, 16 were "weakly forced".

Weakly forced means that there was no discernible triggering mechanism on the synoptic scale, however, potential instability could be released by mesoscale features such as troughs, convergence lines, sea breezes, temperature hot-spots, local orography etc. This, of course, poses a forecasting problem in the identification of which mesoscale features are capable of triggering extreme rainfall for a given value of CAPE. It was also encouraging that only 33% of type (a) cases were weakly forced (those that were, produced multicells or large hail) whereas 73% of type (b) cases were weakly forced.

There are a wide variety of stability indices that are used in different areas of the world as indicators of the potential for severe weather. In the UK, traditionally, the Rackliff index has been used as an indicator of thunderstorm likelihood, although Collier and Lilley (1994) demonstrated the effectiveness of the Boyden index over western Europe. These indices are computationally simple, requiring observations at only two or three levels in the atmosphere, but for this reason may lack robustness as the entire thermodynamic profile is not considered and the spatial and temporal representativity of such indices derived from sonde data is questionable. When using model-generated parameters this is still a problem as convective development is very sensitive to small-scale variations. More recently there has been the adaptation of CAPE as the diagnostic parameter of choice. This appears more robust. These indices appear suited to the task of forecasting convective storms, but do not include any measure of the vertical wind profile which determines the type of storm that could result. In the USA (and elsewhere) where severe storms are common, indices such as the Severe Weather Threat (SWEAT: Miller et al., 1971) index take into account both the shear and veering of the wind, although for real application one must examine these components separately. Bluestein (1993) presents a table of threshold conditions of CAPE and shear for different types of convective storm. However the long-lived convective systems are not found to be responsible for what is considered an extreme UK rainfall event and, therefore, these indicators do not appear relevant to the UK situation. On the other hand, large values of CAPE ahead of slow moving weak frontal zones are an indicator of potential extreme rainfall.

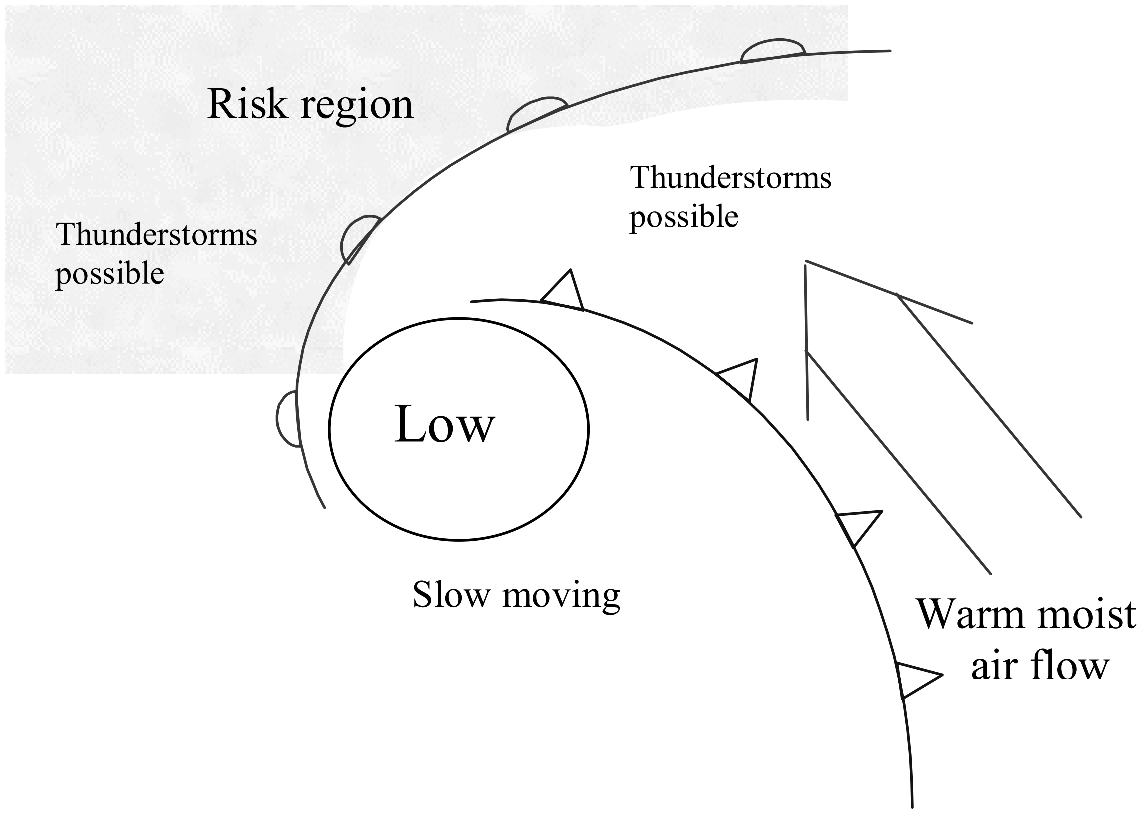

Figure 2: *Schematic diagram showing archetypal situation that occurred in several of the extreme frontal events. The main region at risk of extreme rainfall is shaded. The direction of the main warm and moist airflow is shown by the broad arrow.*

4. COMBINED ANALYSIS OF FRONTAL AND CONVECTIVE CASES

Figure 3 shows the overall distribution of events separated by type and rainfall depth-duration. The types of event in the diagram are as follows:

(a) Severe convective events that are triggered by synoptic scale cold frontal forcing or have large hail. This class also includes isolated near stationary clusters and large multicells in a strongly sheared environment.

(b) Convective events triggered by mesoscale features (e.g. convergence, sea breezes, troughs, upper cold pools, orography or local heating). These events may also have hail but the hail should not be large and damaging or be very prolonged. Some multicellular organisation may also be possible but should not be too self-organizing or long lasting.

(c) Prolonged frontal or orographic events that have little or no convective element.

(d) Frontal (widespread rainfall) events that have a significant convective element (embedded instability).

The following conclusions are drawn.

- Extreme rainfall events are very unlikely to occur in February, March or April.
- Convective events are most likely in June, July, and August and are very unlikely in November, December, January, February, March or April.
- An extreme rainfall event is highly likely to produce serious flooding situations particularly if it occurs over a sensitive catchment or steep orography or when the ground is already very wet from previous rainfalls.
- There was generally a clear distinction between wholly convective and wholly frontal events but with 25% of cases being a mixture of both.

- All frontal cases involved prolonged ascent of very moist air with 75% of cases having a depression pass slowly by within 200 Km at closest approach to the south or east of the event.

- 75% of frontal cases also involved a slow moving front, usually a warm occlusion, in the situation.

- Frontal cases with embedded instability (53%) generally produced larger totals for a given duration and were close to a depression centre.

Acknowledgements

This work was funded by the UK Department of the Environment, Food and Rural Affairs (DEFRA).

References

Bilham, E.G., 1935: Classification of heavy falls of rain in short periods. *British Rainfall*, 262-280. HMSO, London.
Bluestein, H.B., 1993: Synoptic-dynamic meteorology in midlatitudes: Volume II. Oxford University Press. pp 594.
Boyden, C.J., 1963: A simple instability index for use as a synoptic parameter. *Met. Mag.*, **92**, 198-210.
Collier, C.G. and R.B.E. Lilley, 1994: Forecasting thunderstorm initiation in north-west Europe using thermodynamic indices, satellite and radar data. *Met. Apps.*, **1**, 75-84.
Miller, R.C., A. Bidner and R.A. Maddox, 1971: The use of computer products in severe weather forecasting (the SWEAT index). Preprints, Seventh Conf. On Severe Local Storms, Kansas City. AMS, 1-6.
Rackliff, P.G., 1962: Application of an instability index to regional forecasting. *Met. Mag.,* **91,** 113-120.

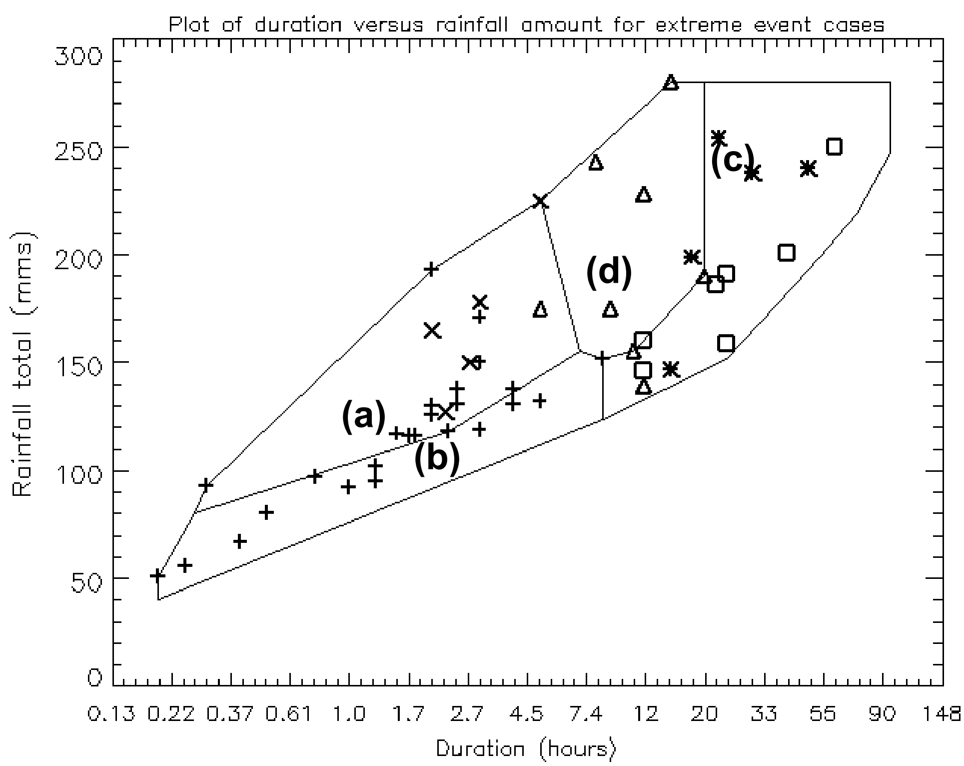

Figure 3: *Diagram showing different regions labelled (a), (b), (c) and (d), which correspond to different types of extreme rainfall event. See text for details. Individual events are marked with '+' = convective , 'X' = convective*** (frontal forcing), ∗ = orographic, Δ = frontal*** (with embedded instability) and 'square' = frontal.*