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Severe hailstorms in Britain and Ireland, a climatological survey and hazard assessment

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A B S T R A C T

In 1986, the Tornado and Storm Research Organisation (TORRO) developed and published an eleven point Hailstorm Intensity Scale and this has been used to characterise more than 2500 hailstorms known to have occurred in Britain and Ireland since the first documented hailstorm event of 1141 AD; this scale has recently (2005) been revised with additional parameters. Most analyses relate to Great Britain, but reference is made to the more extreme recorded events in Ireland. The most intense hailstorm in these Islands reached intensity H8 on the TORRO international scale which extends from intensities H0 to H10.

For the 75 years 1930 to 2004 this paper examines significant, damaging (H2 or more intensity) storms in respect of seasonal frequency and geographical distribution.

This paper also discusses the climatology (including diurnal incidence) of the less common, but potentially devastating storms of H5 intensity or more, using the much longer period 1800 to 2004 and with particular attention to hail swath lengths and widths. The synoptic origins for these major events, where known, are discussed, with particular reference to Lamb's classification of weather types across the British Isles from 1861 onwards.

More than 2500 British and Irish hailstorms are recorded in TORRO's database of which over 1300 are of hailstorm intensity H2 or more, including 156 British storms since 1800 that reached intensity H4–5 or more on the TORRO H scale.

The geographical distribution of hailstorms in the British Isles shows that the highest frequency of significant, damaging storms (H2 or more intensity with hailstones usually over 15 mm diameter) is in central and eastern England, with the East Midlands, East Anglia and the lower Thames Valley most conspicuous when the incidences are mapped.

Since 1870 the severest (H5 intensity or greater) events have been predominantly associated with cyclonic, southerly or south-easterly weather types; however a significant minority (19%) occurred with an anticyclonic element in the classification. For storms of this severity (e.g. with potential for severe structural damage, pitting of aircraft bodywork and even the risk of serious injuries), reporting will have been more consistent over a longer period. These destructive storms, (the most recent "cluster" of which was between 1992 and 1997) have typically followed a track from the S, SSW or SW to the N, NNE or NE with a swath length often 25 km or more (reaching 335 km in one case) and a swath width sometimes in excess of 10 km. Analysis of the database since 1800 indicates a very conspicuous July maximum for these more extreme (H5 intensity plus) events.

1. Introduction

1.1. Establishment of a TORRO database of hail events

The Tornado and Storm Research Organisation (TORRO) was founded in 1974 and one of its aims was to document the

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distribution (spatial and temporal) and intensity of hailstorms in the British Isles, and, through forging links, throughout Europe (Elsom, 1985). Data collection from current sources (increasingly digitalized communications), as well as extensive historical searches of meteorological journals (e.g. British Rainfall 1861–1968), earlier scientific journals (e.g. Philosophical Transactions of the Royal Society), Gentleman's Magazine, The Times newspaper, regional newspapers and historical documents, have enabled the construction of a database containing more than 2500 hailstorm events (in Britain and Ireland) which extends back to the first known storm in 1141 AD. The hailstorm database includes key information such as: dates, times, locations affected, confirmed hail sizes if available and estimated maximum hailstone size. Initial public and media descriptive reports, usually comparatives with familiar objects like marbles and golf balls, are liable to slightly over-estimate hail size as noted by Changnon (1971). However, with recent events, correspondence following on from responses to media appeals has resulted in clarification, e.g. some initial reports of golf ball sized hail have been subsequently found to refer to hail in the 31–40 mm diameter range. The database for all significant, damaging (H2 or more intensity — see Section 2.1) events has now been made available in electronic form and 25 years have been published (TORRO, 2006). Annual summaries of hailstorm events have also been published in the *Int. Journal of Meteorology* since 1984.

TORRO's wider research structure includes a forecasting division which focuses (within the scope of it's research), on identifying, and thus predicting, the synoptic and meteorological conditions which give rise to damaging hailstorms. The two most severe hail events in 2006, on 12th June and 26th July, with hailstones up to 40 mm diameter and 30 mm diameter respectively, occurred on days for which a forecast of severe convective weather had been issued by TORRO (Knightley, 2007).

The main analyses that follow focus on Great Britain (i.e. England, Scotland and Wales). However reference is also made to the more extreme events recorded in neighbouring Ireland and also the Channel Islands. Comparisons with the results of some other hail climatology studies from Europe and elsewhere in the world are also included.

2. Assessing the intensity of hailfalls

2.1. Hailstorm Intensity Scale

In 1986, the TORRO Hailstorm Intensity (H) Scale was first introduced (Webb et al., 1986) and a slightly revised and more compact scale has been in use since 2005 (Sioutas et al., 2005). The characteristic damage in Britain and Ireland associated with each increment (from H0 to H10) is listed in Table 1, but may need to be slightly modified for other countries to reflect differences in building materials and types; e.g. whether roofing materials are predominantly slate, shingle, concrete or corrugated iron. The scale also has six broader categories, potentially useful for forecasting and analysis. Elsewhere, a six point hail intensity classification, the ANELFA (A) scale, has been published with public forecasting in mind by Dessens et al. (2007). Correlation between the two scales is indicated in a comparative assessment of Northern Greece hail falls by Sioutas et al. (2009-this issue).

Since the seventeenth century, only one British hailstorm (15 May 1697 in Hertfordshire) is assessed to have attained an intensity of H8 on the H scale, while seven others have reached a definite H7. The H8 Hertfordshire event of 1697 is assessed as the same intensity as the great Munich storm of 11 July 1984 in Germany which resulted in some very serious injuries as well as widespread damage to buildings, vehicles and commercial aircraft.

2.2. Kinetic energy

An indication of equivalent hail kinetic energy ranges (in joules per square metre) has now been added to the first six increments on the TORRO H scale, and this may be derived from hail pads or radar reflectivities. Hail pads have been extensively used in several European countries (e.g. Vinet, 2001; Gaiotti et al., 2003; Sioutas, M — Pers Comm 2005; Sioutas et al. (2009-this issue)). Use of simple hail gauges has been pioneered by individual observers in Great Britain e.g. by Meaden (1976) who discussed various designs and the potential for recording hail frequencies and (through calibration) diameters. However, on account of the relatively local and narrow swathed nature of

Table 1
TORRO International Hailstorm intensity (H) scale.

Level	Intensity category	Typical hail diameter (mm) [a]	Probable kinetic energy, J-m^2	Typical damage impacts
H0	True (hard) hail	5–**9** (pea)	0–20	No noticeable damage
H1	Potentially damaging	10–**15** (large pea, mothball)	>20	Slight general damage to plants, crops
H2	Significant, damaging	16–**20** (marble, grape)	>100	Significant damage to fruit, crops, vegetation
H3	Severe	21–**30** (large marble, walnut)	>300 [b]	Severe damage to fruit and crops, damage to glass and plastic structures, paint and wood scored
H4	″	31–**40** (pigeon's egg, squash ball)	>500 [c]	Widespread glass damage, vehicle bodywork damage
H5	Destructive	41–**50** (golf ball, pullet's egg)	>800	Wholesale destruction of glass, damage to tiled roofs, significant risk of injuries
H6	″	51–**60** (hen's egg)		Bodywork of grounded aircraft dented, brick walls pitted
H7	″	61–**75** (tennis ball>cricket ball)		Severe roof damage, risk of serious injuries
H8	″	76–**90** (large orange>small soft ball)		(Severest recorded in the British Isles) Severe damage to aircraft bodywork
H9	Super hailstorms	91–**110** (soft ball, grapefruit)		Extensive structural damage. Risk of severe or even fatal injuries to persons caught in the open
H10	″	>**11**0 (melon)		″

[a] Approximate range (typical maximum size in bold), since other factors (e.g. number and density of hailstones, hail fall speed and surface wind speeds) affect severity. For non spheroidal hailstones, the diameter refers to the mean of the co-ordinates.
[b] Vinet (2001) noted that kinetic energies >300 J-m^2 were associated with total crop losses in France.
[c] Fraile et al. (2003) indicated that "very severe" hailfalls were those with kinetic energy >500 J-m^2 and/or maximum hail size >30 mm diameter.