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TORRO Site Investigation - Suffolk (March 2009)

Tornadoes in Birmingham, England 1931 and 1946 to 2005

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SPATIAL ANALYSIS OF MANDAL-WISE RAINFALL VARIABILITY FOR DROUGHT IN ANANTAPUR DISTRICT OF ANDHRA PRADESH IN INDIA

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Abstract: The objective of this study is to find out the probabilities of occurrence of meteorological and agricultural droughts in various mandals of Anantapur district based on rainfall. For this, daily rainfall data for the period 1971-2001 has been collected from Directorate of Economics and Statistics, Andhra Pradesh. Monthly drought probabilities have been estimated for all the mandals in Anantapur district based on rainfall departures from the average mean value and depicted using GIS. Agricultural drought probabilities have been estimated as the ratio of available water to available water capacity. It is observed that the probabilities of droughts are high at low rainfall areas; it is low at high rainfall areas. The annual meteorological drought probabilities are high at Atmakur and Pamidi mandals whereas agricultural drought probabilities are high at Atmakur, Kurair and C.K.Palle mandals. It varies between 70 to 80 %.

Keywords: Rainfall, drought probability, Agricultural & Meteorological Droughts and GIS.

INTRODUCTION

Rainfall is the major determinant of agricultural production, especially in rainfed areas. The amount and distribution of rainfall holds the key for success of agricultural production. Since rainfall distribution varies greatly over time, it is imperative to analyze the rainfall pattern over a long period, which would help in crop planning. Frequency of drought is generally higher than that of the floods in the area of study. Indian sub continent receive adequate amount of rainfall annually through the different types of weather phenomena- south west monsoon (70 %), northeast monsoon (3 %), premonsoon (13 %) and winter (10 %) (Mahale, *et al.,* 2003). The distribution in time and space is erratic thus resulting in a limitation on the length of crop growing periods or the occurrence of flood. Drought and its impact on crop production had been reported earlier in our country (Srivastava, *et al.,* 2000, Parthasarathy, *et al.,* 1988, 1987, Ramana Rao, *et al.,* 1981, Ramakrishna, *et al.,* 1984, Sastri and Patel, 1984, Sastri, 1985 and Chaudhry *et al.,* 1989). In this paper, an attempt has been made to study the magnitude and frequency of meteorological and agricultural droughts with rainfall deficiency at all mandals in Anantapur district. The study area lies between covering a geographical area of 14.68 NX, 77.62 EX104 km^2 that falls under scarce rainfall zone (agroclimatic zone) of Andhra Pradesh. The area is dominant with black soils. This district consists of 63 mandals. The principle crop grown in this district is groundnut in Kharif season mainly under rainfed conditions.

Victor, *et al.,* (1991) analyzed the weekly rainfall data of 21 district of Andhra Pradesh for contingency crop planning. In this paper statistical analysis of distribution of monthly and annual droughts was carried out for Anantapur district in Andhra Pradesh by Deka *et al.,* (2000). Agricultural drought conditions during monsoon season over the district have been assessed.

MATERIALS AND METHODS

The daily rainfall data for each mandal at Anantpur district has been collected for each of the mandals for the period 1971-2001 from Directorate of Economics and Statistics, Andhra Pradesh. Anantpur district, Andhra Pradesh which is located at 14°68' N latitude, 77°62' E longitude and with altitude of 350 meters above mean sea level (MSL) have been used for analysis of the probability and variability. The analysis has been carried out to those mandals whose rainfall data is available for at least more than 15-year period. The area is dominant with black soils. This district consists of 63 mandals. The analysis includes weekly and monthly rainfall probabilities. The departures of annual rainfall from the water requirements of groundnut crop, the drought situations in each mandal over different years have been computed. From these, the probabilities of droughts at each mandal have been computed. Similarly, the probabilities of occurrence of various intensities of meteorological droughts for the months of June to November for all the mandals in Anantapur districts have been computed. The principle crop grown in this district is groundnut in kharif season mainly under rainfed conditions. Monthly, weekly, seasonal and yearly total rainfall was determined for each mandal for each year (Saha, *et al.,* 2005, Mahale, *et al.,* 2003 and Deka, *et al.,* 2000). Drought is one of the major natural disasters, which affects agriculture industry. In this context, there are various definitions of droughts. It is generally understood as the prolonged deficiency in rainfall over a place. Here we considered the meteorological drought, which is defined as the rainfall deficiency by more than 25 % of the long-term average value of rainfall (Sitangshu Sarkar, 2002).

The probabilities of occurrence of various intensities of droughts during the months June to September have been computed using the following criteria. Monthly drought probabilities were classified as follows:

% Departure from Mean	Intensity
0-25	Mild
26-50	Moderate
> 50	Severe

The departures of annual rainfall from the water requirements of agricultural crop like groundnut have been computed. From these, the probabilities of agricultural droughts at each mandal have been computed.

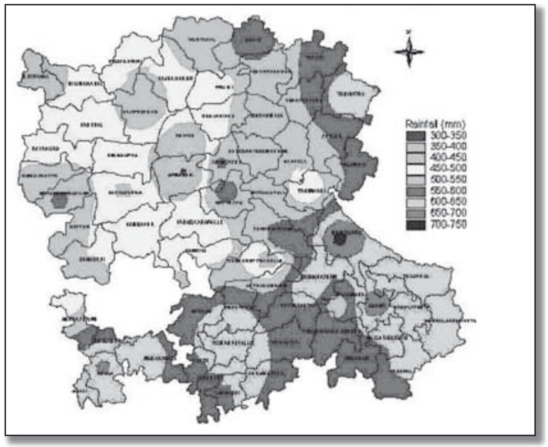

Figure 1. Annual rainfall distribution in Anantapur district.

GIS METHODOLOGIES

The district boundary of AER 12.0 extracted from Agro-ecological regions of India map, prepared by National Bureau of Soil Survey and Land Use Planning (ICAR), Nagpur (Velayutham *et al.,* 1999) was scanned and digitized using ARCINFO GIS package coverage was prepared and base maps with correct coordinates are essential.

The errors detected during the process of digitization were removed. The map has been projected to real coordinates through geo-processing techniques. The attribute table, which is created by default, contains the identity of each polygon (mandal) .The names of the mandals in the maps entered against identified blocks to facilitate to enter the different parameters that are required to be analyzed. The analysis can be carried out either from the data available in the attributes table or from the same data available in excel format. With the help of GIS maps, the drought prone regions have been identified.

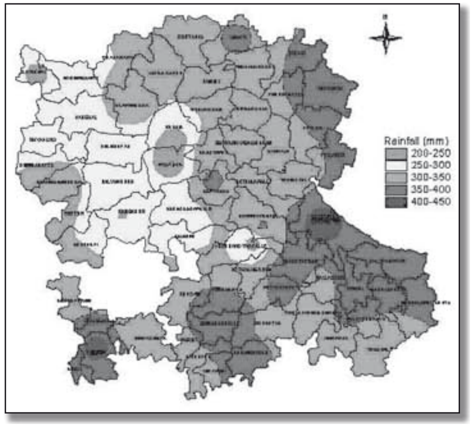

Figure 2. Southwest monsoon rainfall distribution in Anantapur district.

RESULTS AND DISCUSSIONS

The annual rainfall in the district range between 300 to 750 mm (Figure 1). The coefficient of variation (C.V.) of annual rainfall varied between 20 to 50 percent. High rainfall region has been found associated with low variability. While, highest C.V. of above 40 % is found at Atmakur mandal, which happens to receive lowest rainfall in the district (350 mm). In most of the areas, the rainfall variability range between 30 to 40 %. The reason why it is well identified as drought prone. The annual rainfall is seen increasing in eastward direction with high rainfall (more than 700 mm) at Mudigubba mandal. The seasonal rainfall (June-September) in the district varied between 200 mm to 450 mm (Figure 2). The monsoon season rainfall variability in the district ranged between 30 to 70 %. The trend of monsoon season rainfall is similar to that of annual rainfall. Post monsoon season's total rainfall (Figure 3) ranged between 50 to 250 mm in the district whereas the rainfall variability ranged between 40 to 90 %. The high rainfall (>200 mm) was observed at Kadiri, Tanakal mandals, whereas low rainfall (<100 mm) areas comprised of Atmakur mandal. The monthly rainfall maps of the district for the period June to November are shown in Figure 4. The results show that September is the highest rainfall month followed by October. It has been observed that the rainfall increased from June to September and thereafter, it started decreasing.

The annual meteorological drought probabilities estimated based on rainfall departures are shown in Figure 5. It is observed that annual drought probability of Anantapur district varies between 10 to 40 %. The probabilities are low in the southern and western portions of the district, while in rest of the portion of the district it was slightly on the higher side. Monthly drought probabilities (Figure 6) indicate that chances of getting rains during September, October are assured, hence the probability for getting agricultural droughts during these months is also less. The probability of getting droughts between 30 to 80 % is more in the months July and again in November. Mandal wise probabilities of droughts of different intensities viz. Mild, Moderate and Severe for the months June Table2 that probabilities of getting severe drought conditions are very less among all the mandals. The highest probability is only 11 percent recorded at Atmakur mandal. The combined probabilities of mild and moderate is above 50 % at all the centres indicating deficit condition once in every two years. Probability of occurrence of agricultural drought in respect of groundnut crop (Figure 7) indicates that the central portion and a part of western part of the district are more prone to drought conditions that affects groundnut productivity while the southeastern parts, it is slightly better.

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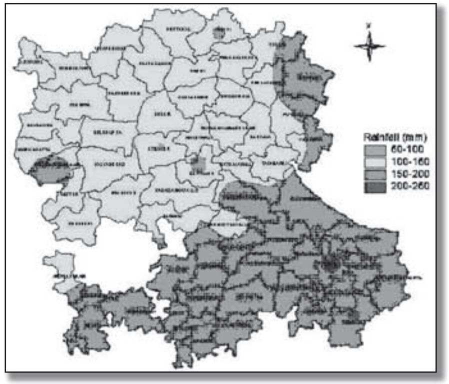
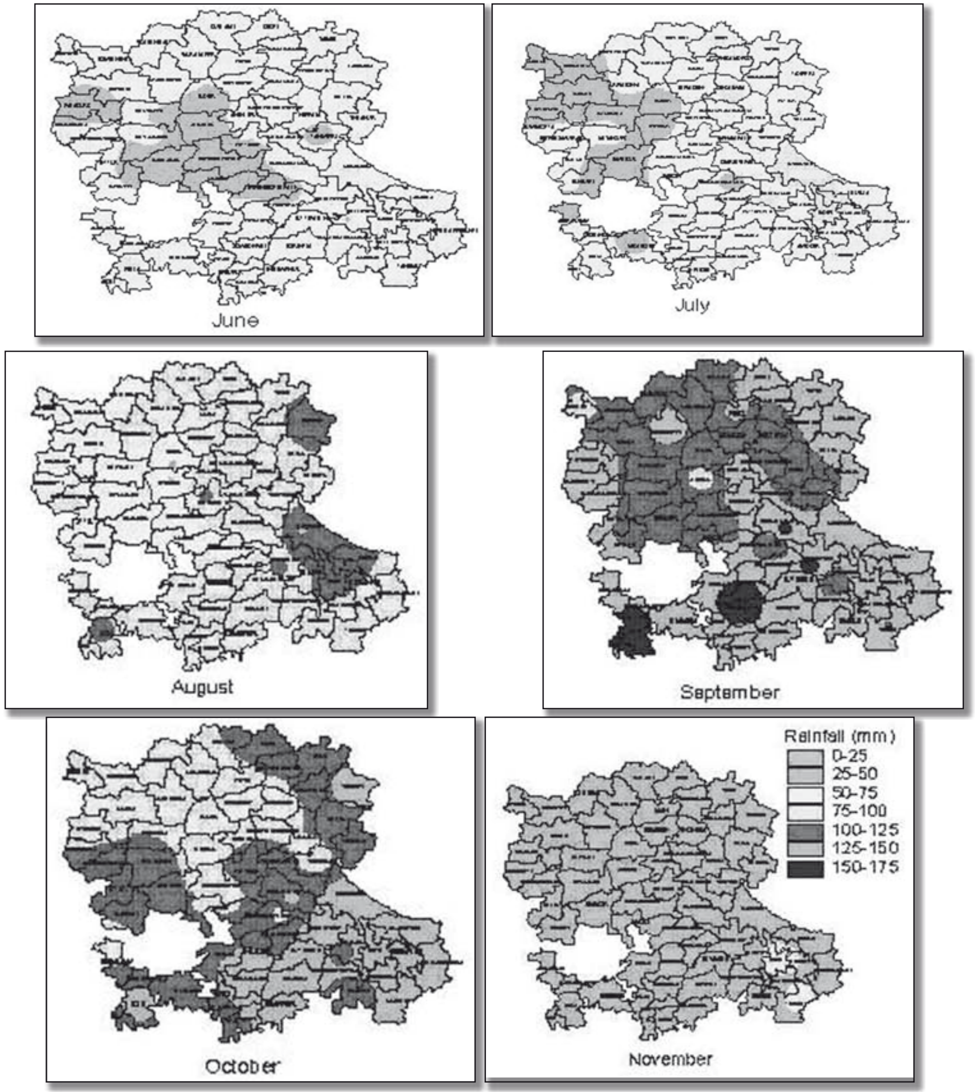


Figure 3. Northeast monsoon rainfall distribution in Anantapur district

Figure 4. Monthly rainfall distribution in Anantapur district (June – November).



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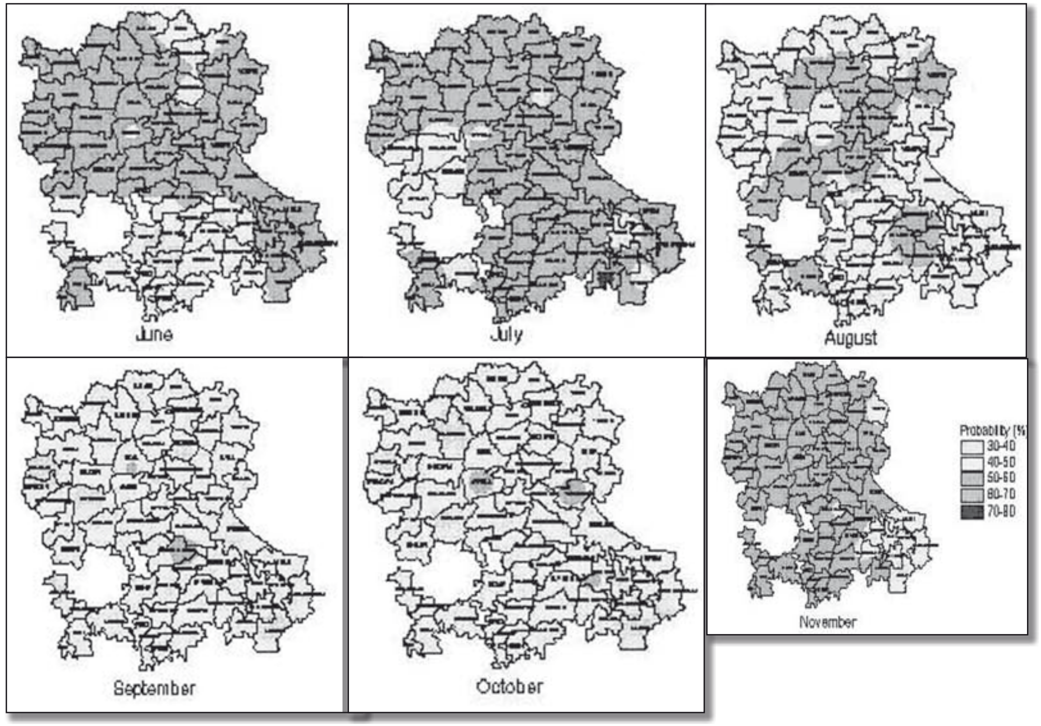
Highest probabilities of agricultural droughts of above 80 % are seen in Kudair, Atmakur and C. K. Palle.

Figure 5. Annual drought probability in Anantapur district.

Figure 6. Monthly drought probabilities in Anantapur district (June – November).



Subsequent rains received during the month of July, helped in good germination of crops. Groundnut, a major crop of the region experienced moisture stress between 13th August to 27th August (15 days), coinciding with peg penetration and 32 days at pod development and filling phases during the cropping periods. This period the lack of rainfall severely affects the production of groundnut. The deficiency of rainfall may result in to agricultural drought for the groundnut crop. The rainfall distribution mostly remains almost even during the rest-cropping period, resulting in normal yields of groundnut crop.

Figure 7. Agricultural drought (Groundnut) probability in Anantapur district.

CONCLUSION

The yearly rainfall records statistically show that the region under study has still a high probability of drought in relation of rest of the regions of the state and always need a special attention for mitigating the stress situation result due to drought. For this, it necessary to record the rainfall through out the year and particularly the month of August for the western and central parts of the district to save groundnut, the main crop of the region. The agricultural drought is most sensitive for the groundnut crop for the period 10th to 30th August. Meteorological droughts have an immense impact on the overall region. But the economic impact on the farmers growing groundnut affects badly when the agricultural drought is not met out. Even though there may not a meteorological drought at times, there could be a high probability of agricultural drought in terms of the groundnut cultivation in the designated region.

Table 1. Probabilities of different intensities of drought during rainy season at different mandals in Anantapur district at Andhra Pradesh. (Continues onto page 153)

Station Name	JUN (%)			JUL (%)			AUG (%)			SEP (%)		
	Mild	Mod	Severe	Mild	Mod	Severe	Mild	Mod	Severe	Mild	Mod	Severe
AGALI	25	33	8	25	8	42	17	8	42	33	8	17
AMADAGURU	7	0	47	7	20	53	7	7	40	27	33	7
AMARAPURAM	19	19	23	19	15	31	0	31	27	19	23	15
ATMAKURU	5	0	48	19	5	43	19	10	38	14	14	33
ANANTAPUR	7	11	43	7	7	46	11	11	43	14	14	25
BATHALAPALLI	8	31	23	0	23	46	0	8	38	15	23	23
BELUGUPPA	8	23	31	15	23	38	15	23	15	23	0	38
BKSAMUDRAM	15	15	31	0	23	46	8	31	31	8	8	38
BOMMANAHALU	14	14	29	0	7	57	7	21	21	7	14	29
BRAHMASAMUDRAM	0	20	40	20	13	33	13	7	33	27	13	27
BUKKAPATNAM	13	3	35	13	16	45	13	10	42	10	6	35
CKPALLI	9	17	35	0	9	48	9	9	39	9	22	35
DHARMAVARAM	10	10	41	17	14	38	17	10	38	10	14	34
DHIREHAL	6	25	38	0	19	50	13	19	19	6	6	44
ELLANURU	11	0	56	0	11	44	11	11	33	22	11	22
GANDLAPENTA	17	25	33	17	50	8	17	17	25	25	8	17
GARLADINNE	0	14	29	0	0	57	14	0	43	0	14	29
GOOTY	17	27	17	13	20	40	3	13	20	7	17	23
GORANTLA	9	18	36	0	18	55	9	27	27	27	9	27
GUDIBANDA	8	23	38	23	0	38	15	38	8	31	23	15
GUMMAGATTA	15	8	23	8	23	31	8	15	46	15	31	15
GUNTAKAL	20	13	20	13	20	33	13	13	33	7	20	27
KADIRI	10	26	32	19	10	32	13	13	29	10	13	32
KALYANDURG	13	20	30	23	10	30	7	10	40	20	10	27
KAMBADURU	10	0	52	14	5	43	0	24	33	10	10	33
KANAGANAPALLI	4	22	30	0	13	43	0	9	39	22	17	26
KOTTACHERUVU	25	8	33	8	17	42	25	8	33	0	25	33
KUDERU	4	9	48	17	13	39	22	9	35	4	13	39
KUNDURPI	8	8	46	23	23	31	31	23	15	15	23	23
LEPAKSHI	15	15	38	0	31	23	15	15	31	8	38	15
MADAKASIRA	16	10	35	10	13	32	10	19	32	16	29	16
MUDIGUBBA	6	25	38	6	13	44	19	19	25	13	19	19
NALLACHERUVU	31	0	46	8	38	31	8	0	38	8	15	31
NALLAMADA	27	13	27	0	13	40	13	27	33	20	0	40
NARAPALA	25	25	25	0	13	50	13	25	13	13	13	38
NPKUNTA												
ODCHERUVU	8	31	31	0	15	46	31	0	31	38	15	8
PAMIDI	14	14	41	5	0	55	14	32	23	14	23	18
PARIGI	36	0	36	0	27	27	18	0	55	9	18	27
PEDDAPAPPUR	0	25	50	50	0	25	0	0	25	25	25	25
PEDDAVADUGURU	24	12	35	12	12	47	6	6	35	18	18	29
PENUKONDA	26	6	26	6	16	39	13	6	39	13	26	19
PUTLURU	15	8	31	8	8	54	0	8	46	15	8	23
PUTTAPARTHI	21	21	29	7	7	50	14	21	29	14	29	21
RAMAGIRI	0	15	38	8	8	54	15	8	38	23	8	31
RAPTADU	7	13	40	7	13	53	0	27	40	13	20	27
RAYADURG	10	32	23	0	39	23	13	16	29	19	19	19
RODDAM	26	0	37	11	5	53	11	16	42	5	26	32
ROLLA	7	27	27	7	20	40	7	7	40	20	7	33
SETTURU	0	38	31	0	15	46	15	15	38	15	23	38
SINGANAMALA	9	26	22	9	9	39	9	22	30	13	13	26
SOMANDEPALLI	33	11	22	0	11	56	11	11	44	0	33	11
TADIMARRI	13	20	33	7	13	53	13	7	33	13	27	20
TADPATRI	3	23	27	13	7	47	3	20	33	13	20	27
TALUPULA	8	8	54	8	31	38	23	8	31	23	23	23
TANAKALLU	11	14	39	11	18	29	11	14	32	18	18	21
URAVAKONDA	16	13	39	6	19	42	6	26	26	13	26	16
VIDAPANAKALLU	0	31	31	8	23	38	15	0	31	31	0	23
WAJRAKARUR	15	0	46	8	15	38	31	0	31	8	15	23
YADIKI	11	16	37	11	0	53	21	11	32	5	11	37

Table 2. Probabilities of different intensities of drought during northeast season and annual at different mandals in Anantapur district at Andhra Pradesh. Continues onto page 154)

Station Name	OCT (%)			NOV (%)			Annual (%)		
	Mild	Moderate	Severe	Mild	Moderate	Severe	Mild	Moderate	Severe
AGALI	17	17	25	17	8	33	58	8	0
AMADAGURU	13	0	40	0	7	53	33	7	7
AMARAPURAM	8	15	31	12	15	38	27	19	4
ATMAKURU	5	14	43	5	24	48	29	24	10
ANANTAPUR	11	14	36	18	7	43	29	14	11
BATHALAPALLI	8	15	31	0	23	38	15	31	0
BELUGUPPA	15	8	31	8	0	54	54	8	0
BKSAMUDRAM	8	31	23	15	0	46	15	38	0
BOMMANAHALU	14	14	21	7	7	36	43	14	0
BRAHMASAMUDRAM	7	20	27	7	13	40	53	7	0
BUKKAPATNAM	16	6	35	6	13	42	29	29	0
CKPALLI	9	17	22	4	4	43	43	17	4
DHARMAVARAM	14	17	28	7	7	48	28	24	3
DHIREHAL	6	0	44	25	13	38	6	13	6
ELLANURU	11	11	33	11	0	56	44	11	0
GANDLAPENTA	17	17	33	8	8	42	50	17	0
GARLADINNE	0	29	14	0	29	29	29	14	0
GOOTY	7	13	37	10	17	43	43	20	0
GORANTLA	0	0	45	0	9	45	36	9	9
GUDIBANDA	15	31	15	0	23	38	38	15	0
GUMMAGATTA	8	23	23	0	0	54	54	8	0
GUNTAKAL	13	20	27	7	7	53	20	33	0
KADIRI	16	10	29	13	6	35	42	19	0
KALYANDURG	13	13	30	7	7	47	30	13	7
KAMBADURU	14	14	24	0	10	43	33	10	5
KANAGANAPALLI	9	9	39	4	17	39	26	17	9
KOTTACHERUVU	50	17	0	8	25	25	33	25	0
KUDERU	9	9	35	13	4	48	26	17	9
KUNDURPI	8	0	38	8	0	46	0	23	8
LEPAKSHI	15	23	23	0	8	38	31	15	0
MADAKASIRA	16	13	29	6	10	45	23	29	0
MUDIGUBBA	13	19	25	6	31	31	44	19	0
NALLACHERUVU	0	38	15	15	8	23	31	8	8

NALLAMADA	13	13	40	7	7	33	33	20	0
NARAPALA	0	25	25	13	0	38	63	0	0
NPKUNTA									
ODCHERUVU	8	15	31	31	8	31	54	8	0
PAMIDI	9	14	27	14	23	36	18	32	0
PARIGI	18	18	27	9	9	45	18	18	0
PEDDAPAPPUR	25	25	0	0	50	25	50	25	0
PEDDAVADUGURU	6	29	29	12	12	53	35	18	6
PENUKONDA	10	16	29	6	19	35	55	3	0
PUTLURU	15	15	15	0	15	38	23	23	0
PUTTAPARTHI	21	21	21	7	0	50	43	21	0
RAMAGIRI	0	23	23	0	8	46	23	23	0
RAPTADU	13	13	27	20	7	47	40	13	0
RAYADURG	13	13	26	3	6	48	32	16	3
RODDAM	11	11	42	5	16	47	21	11	16
ROLLA	7	20	27	7	20	40	40	20	0
SETTURU	8	23	8	0	0	54	62	8	0
SINGANAMALA	4	9	35	4	13	48	39	9	4
SOMANDEPALLI	33	11	22	0	44	22	33	11	0
TADIMARRI	0	20	33	13	13	40	47	20	0
TADPATRI	20	20	23	23	7	40	30	23	3
TALUPULA	23	31	8	15	23	23	38	8	0
TANAKALLU	25	11	25	7	7	32	36	18	0
URAVAKONDA	13	6	29	6	16	48	35	16	0
VIDAPANAKALLU	15	23	8	0	8	54	54	15	0
WAJRAKARUR	15	8	23	15	0	62	38	15	0
YADIKI	11	5	42	0	21	47	21	16	5

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TORNADOES IN BIRMINGHAM, ENGLAND, 1931 AND 1946 TO 2005

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Abstract: Birmingham, whose population of one million makes it Britain's second largest city, has a high rate of reported tornado activity. Altogether, 15 significant tornado events are known to have occurred over a central area of 150 km^2 in this Midlands city on 12 different days in the 60 years from 1946 to 2005. The numbers come from reviewing tornado sightings and actual tornado damage in this highly urbanised part of the city, most of them daytime occurrences at force T2 or higher (c.37 ms^{-1} or more). The high figures relate to the high density of housing and big number of potential observers, which are much greater than for neighbouring smaller cities and the feebly populated areas of the countryside. This could be helpful to the building-standards research industry. As a rough approximation towards gaining some insight towards the annual rate of actual tornado occurrences more widely in Britain, it might be argued that a similar rate of reported tornado numbers could broadly apply to neighbouring regions of central England if they were similarly urbanised as to housing density and population. In addition, the synoptic conditions for the two strongest tornadoes of the century in Birmingham are briefly described. Latest was the T5 tornado (c.67 ms^{-1}) of 28 July 2005 which blazed a trail of damage 11 km long up to 500 m wide from south to north through the eastern side of central Birmingham. Similar devastation happened 75 years earlier on 14 June 1931 when a T6 tornado (c.78 ms^{-1}) up to 0.8 km wide followed a nearly-parallel track nearby at least 9 km long. Hundreds of stone or brick houses were destroyed or badly damaged on both occasions.

Keywords: Tornadoes, T-Scale, Birmingham (England), tornado climatology.

INTRODUCTION

Birmingham is Britain's biggest city after London. Like the nation's other cities, towns and villages, it is occasionally struck by the damaging winds of powerful tornadoes, some of which are severe and pose considerable risk to life and with costly property repairs. However, of the many British tornadoes that cross open countryside, few get recorded whereas probably most of the tornadoes that hit cities, because they cause recognisable property damage, do get reported to the media and to the Tornado and Storm Research Organisation. It is therefore worthwhile using records for the biggest city in Central England as a basis for seeking to obtain a more realistic if only approximate estimate for the tornado hazard to property in England.

Very many tornadoes develop in Birmingham. One may ask why? Fundamentally, it is for the same reasons that so many tornadoes and waterspouts occur in the British Isles; and this is because:

(1) Britain and Ireland occupy a temperate maritime location within a zone where subtropical humid air can meet air of arctic or polar origin;

(2) Britain and Ireland have long coastlines with frequent sea-breezes and zones of convergence;

(3) Depressions often cross the islands or pass nearby;

(4) and sometimes mesocyclones form, as with the devastating T5 tornadoes of 7 December 2006 in London and 28 July 2005 in Birmingham.

Tornadoes develop at any time of year but the months most often affected are the summer and autumn months. The primary synoptic situations that lead to tornadoes in Britain and Ireland have been discussed by Bolton, Elsom and Meaden (2003). Many damaging tornadoes develop on cold fronts and vigorous troughs, including the hours of autumn and winter darkness.

TORNADOES IN CENTRAL BIRMINGHAM 1931 TO 2005

The tornadoes known for Birmingham from 1946 to 2005 are listed in Table 1, to which is added the severe tornado for 1931. Note that weak tornadoes of strength T0 and T1 are limited to 1986 and later. Table 2 lists tornadoes for Birmingham that are beyond the central area.

Table 1. Tornadoes known for the Birmingham area over the period 1931 to 2005.

Date	Areas of Birmingham Affected	Highest Strength on T-Scale
1931 June 14	SSW to NNE 9km track through the SE , E and NE parts of Birmingham City	T 6
1946 Feb 04	Witton, ~ W. to E. (incl. railway station)	T 4
1951 Feb 22	Balsall Heath	T 2
1964 June 07	Northfield (35 houses damaged)	T 2-T3
1968 June 28	SSE to NNW from Weoley Castle to Harborne	T 2
1968 June 28	Approx. S to N from Selly Oak to Edgbaston (and the Birmingham University Campus)	T 4
1981 Nov 23	Erdington (Norfolk Road area)	T 2
1981 Nov 23	Selly Oak (Oak Tree Lane area)	T 2
1981 Nov 23	Alcester Lane's End (King's Heath)	T 2
1982 August 13	Smethwick	T 2
1986 Oct 19	Sparkbrook	T 1-T2
1999 July 05	Selly Oak	T 3-T4
1999 August 01	Birmingham	T 0
2001 Feb06	Birmingham	T 1-T2
2005 July 28	From SSW to NNE through Barnt Green and Hopwood in South Birmingham	T 1
2005 July 28	SSW to NNE 11 km long track through S.E., E and N.E. parts of Birmingham City	T 5
2005 Oct 12	Through Moseley and Billesley	T 2-T3

TORNADOES IN THE 150 KM² OF CENTRAL BIRMINGHAM 1946-2005

Place names in black in Figure 1 indicate known tornado sites, chiefly for the 60-year period for which 15 separate tornado events are known for the central 150 km^2 of the city. This is equivalent to one tornado per 10 km^2 when measured over a 60-year period, or (only very approximately) 16 per year per 10,000 km^2.

For tornado-hazard analysis by area, the British Isles can usefully be divided into two zones: 1) An Atlantic zone in the west and north, comprising all Ireland, Wales and Scotland plus Cumbria, Northumberland, Durham, Tyne and Wear with Cleveland, North Yorkshire, Cornwall and Channel Islands.

This is called "Outer Britain with Ireland", area ~205,000 km^2; 2) The rest of England which is called Southern-Central Britain, having an area of about 95,700 km^2. Together, the area of the British Isles is about 300,700 km^2.

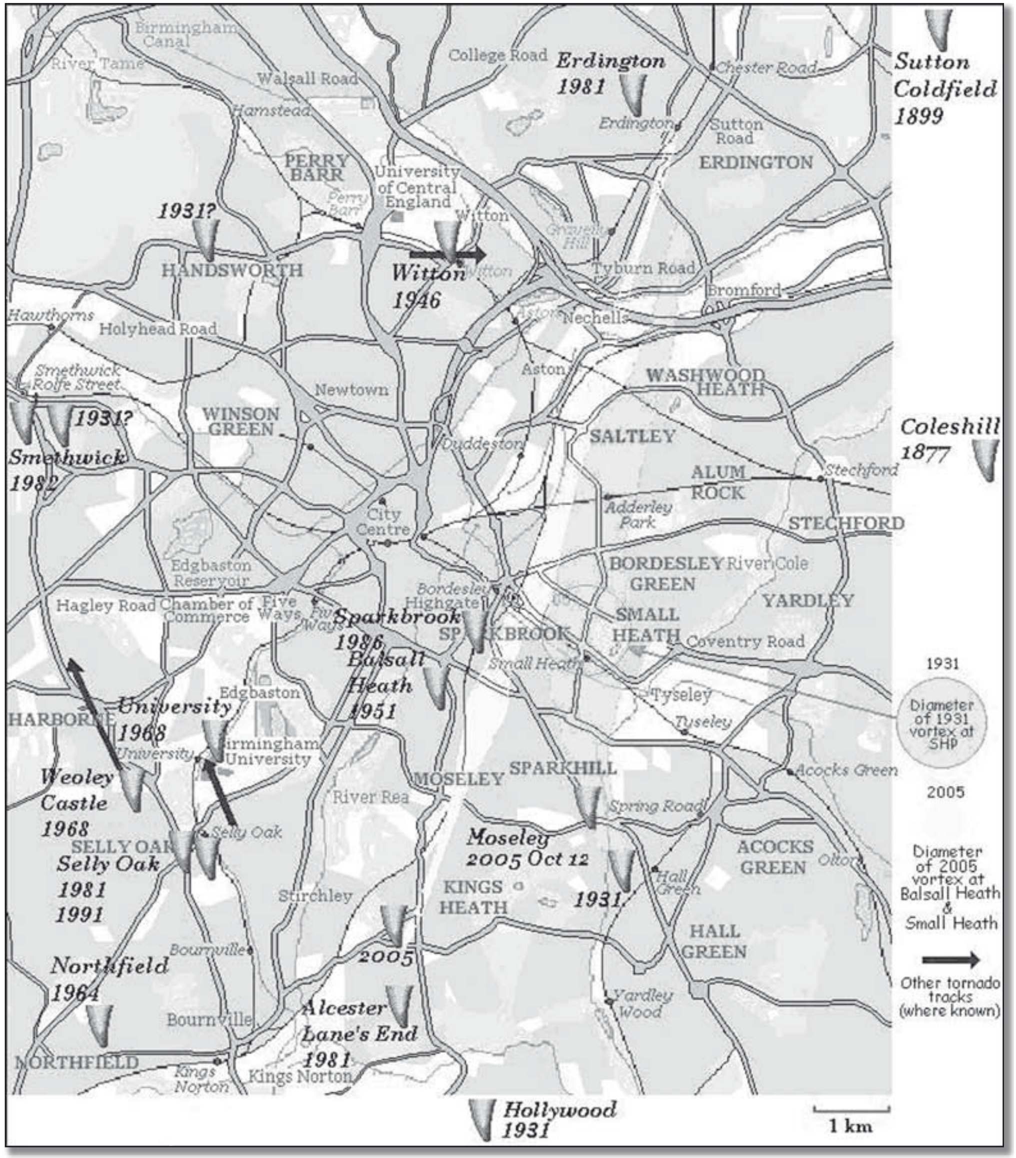

Figure 1. Tornadoes known for Birmingham, Central England, 1946 to 2005. Marked in yellow is the tornado track of 28 July 2005 and in blue-green the tornado track of 14 June 1931.

Date	Areas Affected	Highest Strength T-Scale
1899 Feb 08	Sutton Coldfield	
1948 Dec 13	Dudley (Quarry Bank to Bowling Green)	T5
1966 Nov 15	Walsall (Rushall Hall)	T2-T3
1968 June 28	Cradley to Blackheath (Coombeswood)	T2
1968 June 28	Quinton	
1971 Aug 07	Dudley (Pensnett)	(T1)-T2
1973 Apr 02	Walsall (Leamore)	T3
1978 Jun 01	Walsall (The Delves)	T2
1981 Nov 23	Wolverhampton Fordhouses/Winchester Rd	T2
1981 Nov 23	Walsall, Rushall	T2
1981 Nov 23	Solihull (Solihull Lodge/Windmill Road)	T1
1982 Sept 26	Dudley (T2) and Kingswinford (T2-3)	T2-T3
1982 Dec 07	Wolverhampton Castlecroft	T4
1982 Dec07	Lanesfield	T2
1989 Dec 16	Tipton (Princes End)	T2-T3
1990 Feb 21	Bloxwich and Oldbury	T1-T2
2000 Oct 30	Bloxwich and Brownhills	T1-T2
2005 July	East of Kingswinford	Unknown intensity
2005 Oct 28	Kingswinford to Himley	T1

Table 2. Some Additional Tornadoes known for Outer Birmingham.

As a rough approximation to gaining some insight towards the annual rate of actual tornado occurrences more widely, it could be argued that a similar rate might broadly apply to part or much of central England if it was all urbanised to a similar level of property and population distribution. If, therefore, it was effectively possible to consider all of central and southern Britain this way (95,700 km^2), it would swell the estimated rate of tornado occurrence for the same 60 years in this bigger area to an approximate average 160 tornadoes annually.

This compares with the latest actual reported annual average for the four years 2004 to 2007 of 75 observed tornadoes per year for the whole of the British Isles whose area is 300,700 km^2. But it is highly doubtful whether such a rate as the Birmingham City one can be sustained for the whole of Southern-Central Britain. What is needed is a check for other urban areas of similar size but there are very few having enough data, and only London can be considered yet. Thus, for the whole of Greater London one finds that in the 45 years from 1962 to 2006 there were 32 reported tornadoes. Noting that the actual area of all Greater London is 1577 km^2, this gives an annual rate of 4.5 tornadoes per 10,000 km^2 which would amount to four tornadoes for 60 years across 150 km^2 when taking the same area as high-density central Birmingham. Note carefully, however, that the calculation for Greater London is not at all optimum because only about a third to a half of this great area (about 40 km by 40 km) can be considered highly populated.

Next follow some synoptic remarks for Birmingham's two greatest recorded tornadoes.

THE BIRMINGHAM TORNADO OF THURSDAY 28 JULY 2005

In Birmingham on the afternoon of 28 July 2005 many hundreds of homes and businesses and a primary school were badly damaged by a devastating tornado (Figure 2).

Several dozen houses were hit so badly that they had to be completely demolished. In the Ladypool Road shopping area, 115 business premises were damaged. The Association of British Insurers reported that claims surpassed £25 million. A similar amount of uninsured damage resulted too but exact figures are unknown because many householders and businesses had no insurance cover and made no claims. Additionally, the cost to the Birmingham City Corporation is reported as £40 million. Twenty injured people were taken to hospital. We estimate the force as T5 /F2 (as did Marshall and Robinson 2006).

Figure 2. Tornado over King's Heath, Birmingham, 28 July 2005. Photograph by Ian Dunsford © (2005), Birmingham City Council.

The Birmingham tornado developed within a strong thunderstorm (Type D on the scheme of Bolton *et al*., 2003), moving from the south. It was tied to the point of occlusion associated with a depression, viz. at the triple point (Type E on the scheme of Bolton *et al*., 2003) with very warm moist tropical maritime air occupying the warm sector. The wind close to the surface was blowing from east or north-east, but a few hundred metres higher it was blowing strongly from the south. Low-level shear was extreme and helicity high. Ahead of the cold front, a plume of very warm/moist air existed, marked by a trough with wind-shift line. The cold front having intersected the trough in the morning, the intersection reached the Birmingham region and carried on to Cambridgeshire and Lincolnshire (Knightley, 2006). Close to the intersection, supercell storms developed and tracked north-northeast. The first which led to the Birmingham tornado seems to have had a strong mesocyclone for part of its life-cycle. TORRO forecasters were watching the situation and issued a tornado watch for "tornadoes to T3 for Birmingham and the region as far north-east as Lincolnshire". In fact, damaging and life-threatening tornadoes were also reported for Wymondham (Leicestershire), Peterborough (Cambridgeshire) and Moulton (Lincolnshire).

THE BIRMINGHAM TORNADO OF SUNDAY 14 JUNE 1931

On the late afternoon of 14 June 1931, a thunderstorm spawned a devastating tornado which travelled from south to north across east Birmingham for a distance of 9 km along a track which at its broadest was 0.8 km wide. The tornado touched down some miles to the south of the 2005 tornado track (Figure 1). The tracks converge, and in the northern section they run parallel, almost overlapping. The 1931 tornado which reached T6 on the International T-scale was one of the most intense known for Britain. Immense damage was done, one person was killed and nine people badly injured.

The first sign of a tornado was at Hollywood, to the south of Birmingham. A whirlwind coming from the south damaged farm buildings and lifted cattle. This may have been the first touchdown of the major tornado, which lifted again for several miles, or, as Hollywood is not quite in line with the main track, a separate vortex, and one of three other possible tornadoes in Birmingham during this storm. Another was at Handsworth, where the roof of a well-built house was torn off, and there were press reports of possible tornadic damage in Walsall.

Figure 3. Tornado damage of 14 June 1931 at a level of T6 /F3.

The main tornado began its continuous damage track in Hall Green at 4 pm, and moved north at a forward speed reported to be 48 kmh^{-1} (30 mph). It followed the course of the River Cole, and grew steadily wider as it progressed through Greet, Sparkhill and Sparkbrook. By the time it reached Small Heath (Figure 3) it was at its most intense. At T6 this indicates a wind speed of 259-299 kmh^{-1} (161 to 186 mph). The track had widened to 0.8 km and was probably of a multiple-vortex structure.

Witnesses included Emily Butler at Washwood Heath who made a sketch of a column of whirling debris which she said took about 30 seconds to pass her. Slates, bricks and corrugated iron spilled from it like water from a fountain. The window from which Emily Butler had watched was sucked out as the tornado passed. Mrs Annie Freeman, aged 61, caught outside in the storm, was killed when a brick wall she was sheltering against collapsed upon her. The tornado grew to an awesome size and intensity as it reached Small Heath. A witness described it as a black cloud spinning at terrific speed, followed by a blast of wind which took 30 seconds to pass. Another said that it was a rolling, twisting black cloud, with the noise of six aeroplanes.

The keeper at Small Heath Park called hundreds of children who were playing in the park into the refreshment room as the torrential rain ahead of the tornado began. The refreshment room was unharmed, but Small Heath Park was devastated, "literally razed to the ground", as one witness said, with its greenhouses wrecked and hundreds of trees uprooted. In Small Heath hundreds of houses were unroofed and once again many lost an upper floor.

Small Heath was the peak of the tornado's life. After this it started to become narrower and its track turned to the northeast. But it was still on the ground, still wide and powerful. In Bordesley Green and Washwood Heath large trees were uprooted, houses unroofed and cars overturned.

The air was still filled with a cloud of corrugated iron sheets, slates and chimney pots, flying through the air like pigeons. The tornado's path narrowed rapidly as it approached Erdington, where it appeared as a twisting funnel making a rumbling noise and still strong enough to uproot trees. Soon after this the tornado left the ground. There were reports of possible tornadic damage in Walsall, but this, if it was a tornado, must have been a smaller separate one.

The synoptic chart for 14 June 1931 shows a complex area of low pressure over the British Isles, with warm air from the south (Figure 4). There is a small low centre over the Midlands, and another on the South Coast. Thunderstorms were widespread on 14 June; one man was killed by lightning in Newcastle, there were hailstones of 50 mm diameter on Salisbury Plain, and 38 mm of rain in three hours at Southampton. Near Hall Green in Birmingham almost 25 mm of rain fell in less than an hour before the tornado arrived.

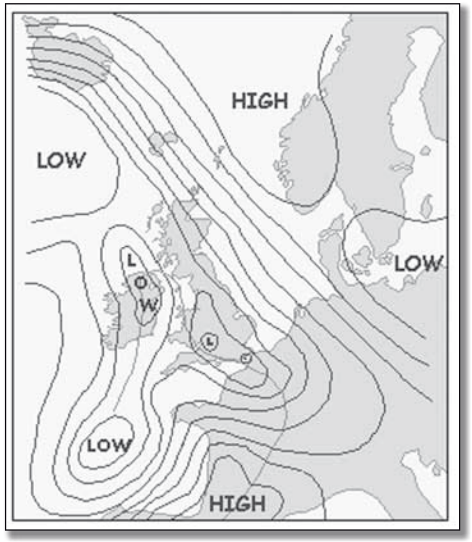

Figure 4. Synoptic chart for 14 June 1931.

CONCLUDING REMARKS

Britain lies in a zone of frequent tornado formation due to its temperate North Atlantic seaboard location in middle latitudes where cold Arctic air can encounter humid warm subtropical air, and where sea-breeze formation, leading to convergence zones, often produce storms with locally heavy rainfalls and tornadoes.

Previous contributions to the study of Britain's tornado climatology produced data on return periods for wind-speed hazards at selected sites (Meaden, 1985) or regional data based on tornadoes that had affected a broad mixture of town and country. But the true numbers are underestimated because few tornadoes get reported from empty countryside. In this paper - as an attempt towards gaining a better insight towards a truer annual rate for actual tornado occurrences in central England - it could be argued that a long-term rate similar to that for central Birmingham 1946-2005 might broadly apply to part or even much of central England centered on Birmingham if it was all urbanized with a similar population density and therefore similar amounts of property to damage and similar numbers of potential reporters. If, moreover, it was effectively possible to consider all of central and southern Britain in this way, it would swell the estimated rate of tornado occurrence for the same 60 years in this bigger area to an average 160 tornadoes annually. This compares with the latest recorded annual average for the four years 2004-2007 of 75 observed tornadoes per year for all the British Isles whose area is about three times bigger. Such information will be extended, refined and tested in due course with regard to other cities when enough data are available, and will begin with a reappraisal of tornadoes as known for London (cf. Elsom and Meaden, 1982; Meaden, 1985).

ACKNOWLEDGEMENTS
The authors wish to thank all members of the Tornado and Storm Research Organisation (TORRO) who since 1974 have contributed to data collection and tornado-track inspection and analysis; and R. Paul Knightley and Nigel Bolton for valuable discussions about the two great Birmingham events.

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© John Wright
Great Plains (2008)

© Howard Kirby
"Spring Weather in the Marches" (UK)

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Great Plains - 13 June 2008

The picture was taken at approximately 9.00 pm in Frederick, Oklahoma... As I recall sunset was about 8.00-8.30 pm that night. *John Wright*

MetPix - *what's goin' on?*

This is a great example of an anvil cloud from a cumulonimbus, taken on the Great Plains. The SPC reports show a few scattered hail/wind reports across TX and OK at the approximate time this picture was taken. *Paul Knightley*

TORRO SITE INVESTIGATION LANE FARM, SUFFOLK, UK: 26 MARCH 2009

By CHRIS BELL and CHRIS WARNER

(chrisbell12@yahoo.com; chris_jwnr@hotmail.com)

Incident Location: Lane Farm, Brundish, Woodbridge, Suffolk, IP13 8BW, UK
Investigated by: Chris Warner
Date of Incident: 26 March 2009
Date of Investigation: 28 March 2009

Abstract: A site investigation was conducted by TORRO member Chris Warner at Lane Farm in Suffolk, UK after a report was received of a severe weather event/tornado occurrence in the area on 26 March 2009. After the site investigation on the 28th March, it was concluded that the event was a tornado of T2 classification. After the investigation Chris Bell carried out a synoptic discussion as well as upper air and radar analysis of the weather set-up that lead to this event.

Keywords: TORRO Site Investigation, Lane Farm, Suffolk, UK, 26 March 2009, tornado

INTRODUCTION

This report details an incident that took place at approximately 15:00 GMT Thursday 26 March 2009 at: Lane Farm, Brundish, Woodbridge, Suffolk, IP13 8BW, UK Ordnance Survey: TM 269 715 GB Grid Lat = 52° 17’ 39.48”, Long = 001° 19’ 40.02”

The location is a working farm with the main site consisting of several outbuildings made of ‘breeze block’ foundations and lower walls, timber and corrugated metal sheeting. It is exposed on all sides with open fields and no tree lines or other structure to shelter the site. The map in Figure 1 shows the location as per *‘Ordnance Survey’* mapping. In Figure 2 there is a bird’s eye view of the location as per *‘Google’* mapping, with annotations. Readers of this report may find it useful to locate the site on ‘Google maps’ or other similar website available in order to see the un-annotated view, which may give a better perspective.

The weather incident in question mainly caused the collapse of a farm building that will be described in more depth later and it also carried the associated debris some distance.

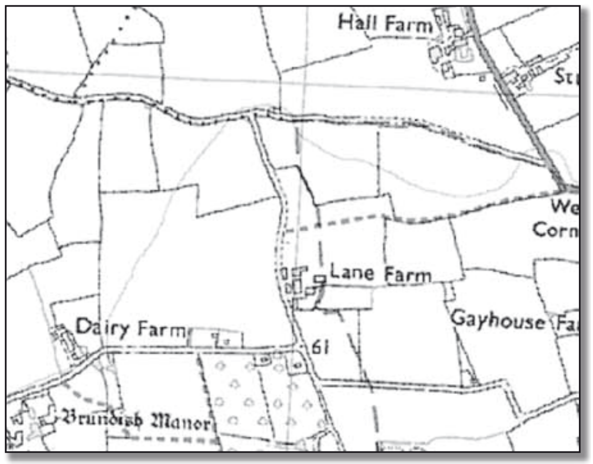


Figure 1. OS Map of Lane Farm (orientated to North).

SYNOPTIC SETUP

On Thursday morning, 26 March 2009 a deep low-pressure centre passed to the north of Scotland with associated fronts pushing across Britain during the day (Figure 3).

The low pressure generated gusty winds across much of England with many areas, even inland, experiencing gusts between 40-50 mph.

A weak warm front crossed Britain in the early morning hours followed by a split cold frontal feature. The upper cold front crossed southern Britain during the morning hours between 0700 GMT and 1000 GMT and produced some showery rain across southern and eastern England. The passage of the upper front helped to destabilise the middle atmosphere with a cold pool of mid-troposphere air. This combined with moderate to strong low-level shear, generated by the approaching surface cold front, made conditions conducive to tornadic development.

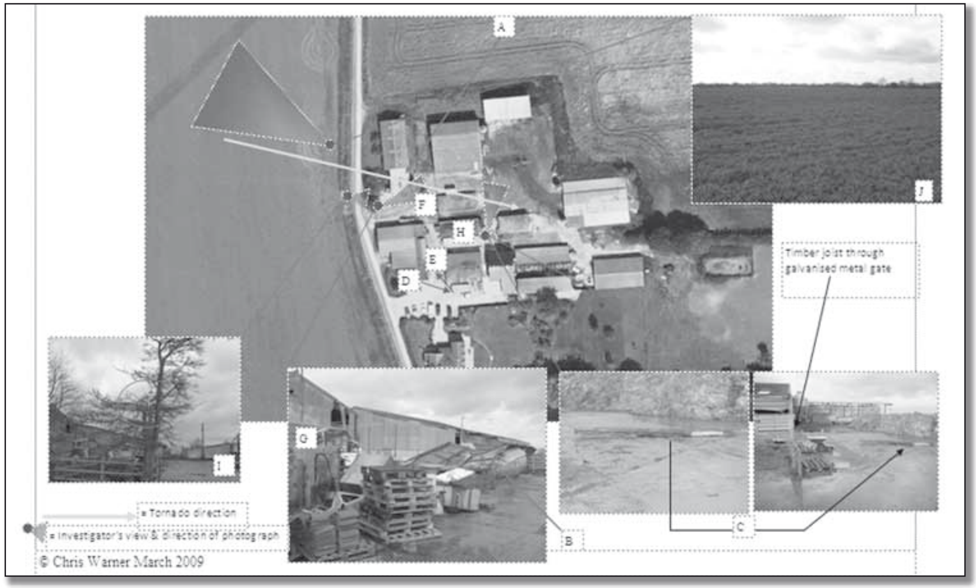


Figure 2. Bird's eye view of Lane Farm (orientated to North) with annotations. Photos © Chris Warner; map © Google, Google Earth.

By midday a band of shallow convection had become organised along the surface cold front in a line from the mouth of the Humber River to Swansea and moved rapidly eastwards during the first part of the afternoon. As it crossed into Norfolk and Suffolk the line began to show signs of discrete convective cells, signalling the potential for rotating updraughts. There were also sferics/lightning reported off the north coast of Norfolk during this period. At around 1500 GMT the line made its way through the Brundish area of Suffolk producing a small tornado, before it passed to the east into the North Sea.

Upper Air profile

The midday upper air profile from Nottingham was chosen for analysis, as the most representative sounding profile. The mean atmospheric flow was just slightly north of due west and Nottingham was located just ahead of the surface cold front at that time.

Instability Parameters

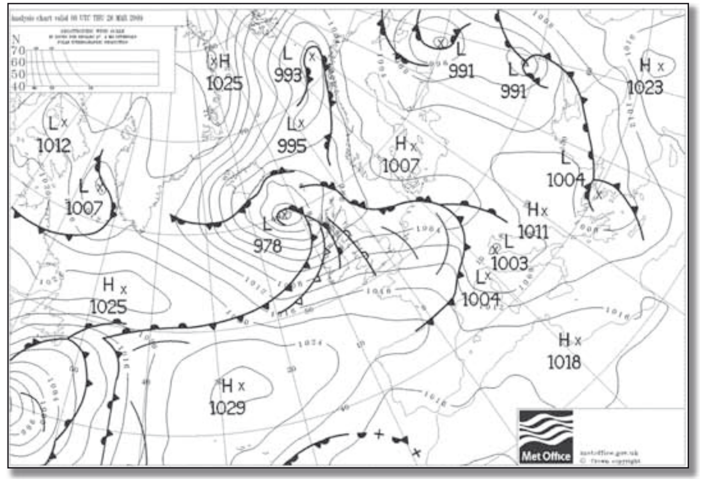
The upper air profile was adjusted for the maximum surface temperatures in East Anglia of 14.5 °C and this gave the potential for about 350 J/kg of mean layer CAPE during the afternoon (Figure 4 - inside rear cover).
172 J/kg of the CAPE was located in the lowest 3 km of the atmosphere putting it in the

moderate category even for Great Plains storms. This shallow CAPE along with the strong low level shear described in the section below, was more than likely enough to generate the spin needed for tornadic development.

The Lifted Index was measured at -1.3. The negative value represents some instability but this is on the low end of the scale generally for severe weather outbreaks.

The KO index, an index developed by the German Weather Bureau to measure thunderstorm potential (generally in Europe), uses moisture and temperature differences between the 1000 mb to 850 mb layer compared to the 700 mb to 500 mb (RAOB, 2004) showed a value of -4.2, putting it in the strong category for severe storms. This likely highlights the unstable layer created by the upper front as it passed through a few hours before.

Figure 3. Met Office Synoptic Chart for 0z 26 March 2009.



Shear Parameters

Perhaps the most significant trigger in the development of this tornado was the low level shear generated by the rapidly advancing surface cold front. Wind speeds increased significantly with height; from 19 kts at the surface to 45 kts at 800 mb (roughly 9,000 ft AGL). This aided in the development of ample horizontal vorticity for tornadogenesis.

Speed sheer combined with a slight directional wind veer with height, about 35 - 40° and a 0-3 km storm relative helicity (a measure of the tendency for a supercell to rotate) value of around 244 m^2/s^2, which falls in the moderate category for Great Plains supercells, suggests the environment was conducive to the development of weak/shallow supercells.
*Other severe weather parameters can be found in Table 1

Radar Analysis

Without the aid of Doppler radar it is impossible to assess whether the individual/ discrete cells clearly visible along the cold front were in fact rotating, however given the atmospheric conditions rotating cells may have been possible. The radar image at 1455 GMT (Figure 5 - inside rear cover) shows at least five discrete "cells" extending from just off of the coast southwestwards. The cell just west of Brundish (circled on the radar), appears to be displaying a "kidney shape" / inflow notch which is often observed in Great Plains supercells. This is associated with the part of the storm in which the inflow/updraught of air is impeding or evaporating the precipitation, and is a further indication or sign of a "rotating updraught".

Table 1. Severe weather parameters for RAOB.
Note: Thresholds used are RAOB defaults relating to values found in research of Great Plains storms.

Parameter	Wk	Mod	Strong	Parameter	Wk	Mod	Strong
200 mb Wind Speed (kt)		60		S Index			50.4
500 mb Wind Speed (kt)		50		SI - Showalter Index		2	
850 mb Wind Speed (kt)			42	srH - storm-relative Helicity (0-3 km)		244	
850 mb Dewpoint (C)	-0.1			Supercell Composite Parameter (SPC)	1.4		
00 - 500 mb lapse rate (C/km)	-6.7			Surface Dewpoint (C)	6.6		
LFC - Level of Free Convection (mb)			871	SWEAT Index	232		
BRN - Bulk Richardson No	6			T1/T2 Gust (kt)	30		
BRN Shear (m^2/s^2)			63.2	TI - Thompson Index	26		
CAP Strength			0	TQ Index			17
CAPE 0-3 km, AGL		172		TT - Total Totals		53.9	
CAPE Total	351			VGP - Vorticity Generation Parameter		0.274	
CT - Cross Totals			25.4	VT - Vertical Totals			28.5
DCAPE 0-6 km, MSL	163			WBZ - WetBulb Zero Hgt (ft,AGL)	4481		
EHI - Energy Helicity Index	0.7			Windex (kt)			48
JI - Jefferson Index		30					
K Index	24.9						
KO Index			-4.2				
LFC - Level of Free Convection (mb)			871				
LI - Lifted Index	-1.3						

WITNESS REPORTS

On the day in question the owners Ian and Sue Whitehead were working in outbuildings on the site. They describe the weather at the location before the event as having dark cloud to the West-North-West where the storm approached the location, with very light rain/wind. This is the thunderstorm that then passed over the location, during which there was very strong wind with little rain. Some lightning was noted. The actual incident didn't last very long and heavier rain immediately followed. After a few minutes the cloud cover moved on and there was bright sunshine again.

DAMAGE

The main damage was a large outbuilding that was demolished by the wind (marked at point 'A' in Figure 2. This was a mainly timber structure with corrugated metal panels on the roof and sides. It has been in place for at least 30 years and there were no immediate defects with the structure.

The structure is relatively lightweight in its construction with little brickwork but this must be placed into context with the forces that were at work on the structure at the time of the incident. As you will see in Figure 2 the photographs detail the main damage, this will include a feed bin (marked at point 'B') that at the time of the incident would have weighed in the region of 3 tonnes and was knocked over. This feed bin is a large metal structure that contains animal feed; it is of cylindrical design and sits on metal legs that support its weight several metres off the ground. It was positioned immediately next to the outbuilding which may explain why it was knocked onto its side, potentially as a result of both the wind and the outbuilding striking against it during the collapse.

Two large sections of timber from the outbuilding were carried east for approx 60 metres and ended up in another part of the site, coming to rest at point 'C' in Figure 2, one placed through the bars of a galvanised metal gate by the wind.

A 660 litre wheeled bin was moved (from its original position at point 'D') into a space marked at point 'E'. The bin did contain rubbish but was not full. The purple line and arrows from point 'D' to 'E' shows the motion it was observed moving in during the incident. The investigator suggests that the bin ended up at point 'E' because of the wind tunnel effect created by the increased wind speed at ground level within the passageway. The passageway where point 'E' is located is approximately 4 metres wide. The investigator has previously seen a wind tunnel effect in Great Yarmouth in 2002 where a gable end was demolished during gale force winds.

On the western side of the site, there is a tree that had a large branch snapped off the main trunk and carried approximately 30 metres where it landed (at point 'F') amongst the debris of the outbuilding that was demolished. A metal oil tank was knocked from its stand made from 'breeze blocks' and stands several metres from the ground (point 'G') and an industrial freezer component (this is heavy and made of metal) taken from the roof of the freezer and carried a few metres to the North of it (point 'H').The outbuilding next to the wheeled bin had its sliding door opened slightly by the wind. This is a large industrial sliding door and as such is quite heavy. It is worth noting that several lighter pieces of potential debris were not collected by the wind, such as stacked patio chairs, wooden pallets and bales of straw, further showing exactly how localised this incident was.

CONCLUSION

It is Chris Bell's opinion that the line of convection generated along the cold front moving through East Anglia during the afternoon of the 26 March 2009 exhibited the characteristics of low topped supercells and produced a small path/width tornado near Brundish, Suffolk at around 1500 GMT.

The investigator suggests that this incident is classed as a tornado of T2/3 on the T scale (73-114 mph). It is suggested that the tornado was short lived whilst it briefly touched down at the location. It is worth noting that the damage is localised. There is potential for the tornado to have been on the ground before reaching the location however there is no evidence of this as the arable field that the tornado would have had to move through does not lend itself to showing such scrub marks and none were noted by the investigator (image 5 at Figure 2). The width of the damage path is no more than approximately 10 metres, identified through the lack of damage to any other structure within that distance, particularly to the extent that the damaged outbuilding suffered. For the same reasons the length of the tornado's track will be no more than 50 metres. The investigator suggests that the main damage was caused as the tornado entered the site, where it started to shift the walls. Then as the tornado passed over the outbuilding it pulled the structure over and away from its foundations.

Straight line winds in this incident have been discounted because the amount of damage would have covered a larger area and I would expect debris to be spread in the same direction, where here there is no particular pattern to where debris has landed. Equally the investigator has discounted a microburst, again the area covered and the amount of damage caused does not indicate a microburst is responsible. Having checked the immediate vicinity the investigator is unable to locate any damage away from the main area at Lane Farm.

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RAOB (2004) RAOB User Guide – The Universal RAwinsonde Observation Program User Guide and Technical Manual, Version 5.6, © 1994-2004

WEATHER AND ME

By MARTIN COLLINS

My interest in the weather started more though necessity than any real enthusiastic compulsion. For me, it all started in the late 80s when I became part of the voluntary crew on an inshore rescue boat in the Solent and understandably there was a slight requirement to be able to 'read' the local weather and sea conditions to enable us to carry out our job safely and efficiently. Knowing when to duck would also prove to be asset on an open rigid inflatable that tended to be heading out of harbour when most sensible people were coming in.

Around five years later, this lead to me joining HM Coastguard as a Watch Officer in the Maritime Rescue Co-ordination Centre on the Clyde which involved a years training with exams at the end of it, one of which was Met. As Clyde Coastguard was a Met Reporting Station for the UK Met Office, I was soon reporting the three hourly obs to the Met Office and booked myself on an Auxiliary Observers Course run by the Met Office at their college in Reading.

I have to say that this course was really what started me into all things weather and is THE best course I have ever been on. Highlights included a tour of the Met Office archives where they laid out some notable records including the barograph paper from HMS Price of Wales while it was engaging the Bismarck during WWII, the obs book from Port Stanley Airfield noting a bombing run by Royal Navy Sea Harriers and Mr Beaufort's original Beaufort Scale.

One mistake was to feed us a three course lunch and then show us a film about cloud types. The first run through was fine but they then ran the film a second time, without sound, and asked us to note the different cloud types. Now, a three course meal, darkened room and no sound can only lead to one thing – snoring! When the lights came up 90 % of the class were asleep.

I spent seven years reporting the obs at that station before moving to Stornoway in the Western Isles, off the Northwest coast of Scotland, where I'm fortunate that most of the interesting weather tends to come to us. These islands tend to be in the front line for any weather systems coming across the North Atlantic and are the first landfall for the remains of any hurricanes that run up the Eastern Seaboard of the US.

In my time on the Isle of Lewis I've witnessed mammatus and noctilucent clouds for the first time, a shelf cloud (photos of which have featured in the *IJMet*), the Aurora and an Annular Eclipse. We have also have storms with winds gusting 90 mph, one of which unfortunately cost the lives of five members of the same family back in January 2005.

It was shortly after this event that I got my first weather station, a La Crosse WS2300 that I linked to a PC in March of 2007 and started to create my own weather website to run alongside a photo website which had been running since 2000.

The weather website has become my main hobby now and has grown over the last few years to include forecasts and lightning detection. In November 2008 I replaced the WS2300 with a Davis Vantage Pro2, which proved a good decision as 2009 arrived.

On the 17 January 2009 the island was hit by a storm that would break my own records to that point. Overnight I recorded sustained with speeds of over 70 knots with the highest gust of 85 knots. After a few hours of this it was amazing how quiet the wind sounded when speeds dropped to around 60 knots.

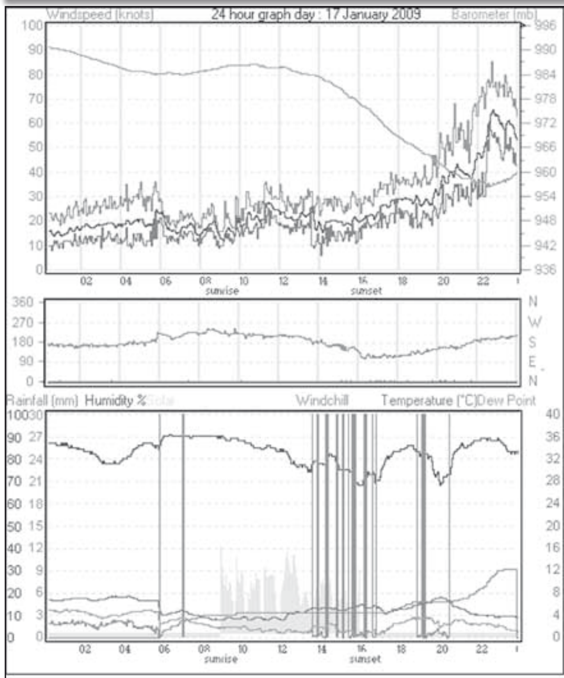
I had over 650 individual hits on the website that night, the average up to that point was a around 70 a day, with visitors from the likes of Germany, America and New Zealand all watching the event unfold through my live weather feed.

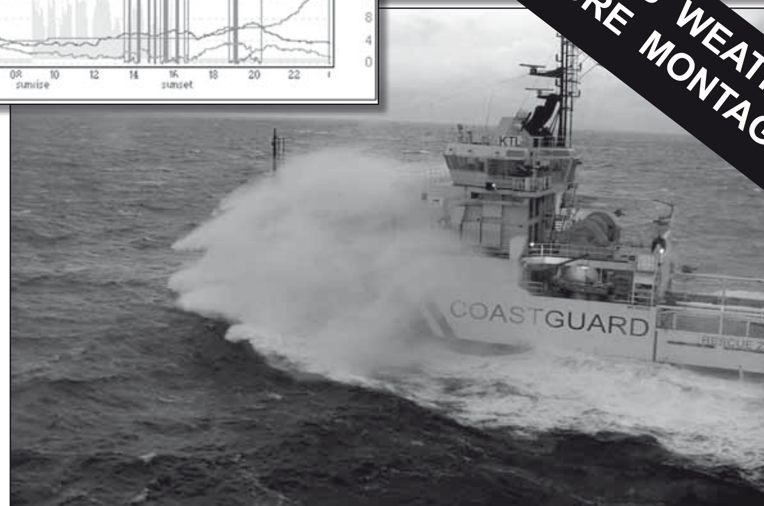
I have now got myself involved with TORRO, which started by answering a letter I spotted in the local newspaper looking for people who were interested in extreme weather. I did my first site investigation of a T1 tornado that struck a house on the West side of Lewis late in 2008 and I am now nearing completion of an updated TORRO website which should be ‘live’ this year.

So, for me, weather is a hobby and has allowed me to bring together three different interests; photography, weather observation and web design. Through my website I try to provide a service to the local community so that they can see, and hopefully better understand, the weather that they experience on these islands as well as giving a wider audience a taste of what these islands are all about.

I feel privileged to live where I do as I have seen and experienced things here that most people will never see or experience in their lifetime and it’s all right on my doorstep.

Send your *Weather and Me* articles with pictures to sam@ijmet.org!





MARTIN’S WEATHER PICTURE MONTAGE

TORRO TORNADO DIVISION REPORT: November and December 2008

By PAUL R. BROWN and G. TERENCE MEADEN

Much of November 2008 had changeable westerly types, but there were northeasterlies at the beginning and end: four tornadoes (three definite), one waterspout, and one funnel cloud were reported. The first part of December was cyclonic, the middle of the month was westerly, and the end was anticyclonic: there was just one probable tornado this month.

q/tn2008Nov08 *Benniworth, Lincolnshire (53° 19' N 0° 11' W, TF 2181)*

BBC Lincolnshire (9th November) stated that part of a roof was damaged and trees uprooted when winds, "which seemed like a tornado", struck the village at 2230 GMT. Mr Keith Robson said: "I was awake when it hit and there was an enormous noise. The ceiling of the bedroom was heaving up and down. We had three very large conifers in our garden - over 70 ft tall - and two of them have been uprooted and one embedded in our greenhouse - and one snapped off about 15 ft above the ground." He said about one-third of the tiles on his roof were ripped off in a circular pattern.

Ian Loxley of TORRO visited the area on the 10th November, but was unable to reach any firm conclusion about the nature of the event: there was tree and roof damage at the southern edge of the village (TF 212811), another fallen tree about 300 m to the northeast, and a collapsed outbuilding in between, but no obvious path of damage (the terrain before and beyond these points is open fields).

At 1800 GMT a low, 969 mb, was moving northeast to the west of Scotland, and its occluding frontal system was crossing the British Isles; by midnight, the fronts were just clearing the east coast (the triple point being analysed near the Humber Estuary). Both events of this evening were on the cold front/occlusion, which produced widespread rain, heavy in places.

tn2008Nov08 *Whittlesey, Cambridgeshire (52° 33' N 0° 08' W, TL 271972)*

The *Peterborough Evening Telegraph* of the 10th November described how about 10 houses were damaged and trees blown over on Saturday evening, shortly before midnight. The streets affected were Queen Street, High Causeway, and Elm Park, which lie on a line about 300 m long from southwest to northeast. One of the residents, Ms Kim Kynaston said she was woken by a horrendous noise: "It didn't sound like wind as it was much worse than that. It only lasted about 20 seconds and when I got up and looked out of the window there was debris all over the street. The tornado looked like it just swept through the town in a diagonal line taking down roof tiles, trees, fences and chimneys." Force T1.

TN2008Nov09 *Kidwelly (to NNE), Carmarthenshire* (51° 46' N 4° 17' W, SN 420094 to SN 425099)

After hearing about possible lightning damage in his locality, TORRO's local observer, Mr Chris Smith, went out to have a look, and discovered that a tornado had gone through the area. He conducted a full investigation on the 17th November, which showed that the tornado began in the valley of the Gwendraeth Fach (river), travelled in a general northerly direction for a few hundred metres, then lifted temporarily and turned to the right before making ground contact again some 400 m to the northeast; beyond this point he could find no further evidence.

The total length, allowing for curvature (and including the above-ground section), was about 700 m, and maximum width 80-90 m. All the evidence came from damage to trees, many of which had had their top halves broken or twisted off, but a few of which had been torn up by the roots. Force T2. Because no-one saw the tornado in action, the time of occurrence is not known (heavy thundery showers affected west Wales for much of the afternoon). At 1200 GMT the previous day's low, now 957 mb, was centred northwest of Scotland, and a brisk westerly maritime Polar airmass covered the British Isles, with bands of showers moving east on troughs.

Wind2008Nov09 *Tydd St Giles, Cambridgeshire (52° 44' N 0° 08' E, TF 437166)*

The *Wisbech Standard* (11th November) reported that the roof of a newly-built summer house in Sandy Lane, Tydd St Giles, was ripped off by the wind at 9.40 pm (2140 GMT), and one of the owners suggested that a 'mini-tornado' was responsible, but there is no evidence for this.

Case2008Nov10 *Chelmsford, Essex (51° 46' N 0° 28' E, TL 702113)*

The *TotalEssex* web site of the 13th November reported that a building worker had been killed when a block of concrete fell from the crane on which it was being hoisted at Broomfield Hospital at lunchtime (shortly after 1300 GMT) on Monday the 10th, and quoted an anonymous witness, who said that a 'mini-tornado' was responsible. This cannot as yet be substantiated, and we await the outcome of the coroner's inquest before coming to a conclusion (it might not have been weather-related at all).

TN2008Nov10/I *Pettistree, Suffolk (52° 08' N 1° 21' E, TM 294545)*

This tornado struck the Presmere Road area of Pettistree at about 2.30 pm (1430 GMT), and was reported in the *East Anglian Daily Times* of the 11th November. One of the witnesses was Ms Maureen Stollery, who said: "Everything just went up in the air. It came through in a passage and took out everything in its path. I ... heard a noise and I saw the top of our 20-foot tree had come out of the ground, turned and fell back down to earth." Tiles were removed from a neighbour's garage roof and 'solid teak' garden furniture was blown through a fence. Another witness, Ms Jacki Franklin, said: "It started to rain then the wind got up and became very strong, then there was a gust of wind at the bottom of the garden and a whirlwind and then I saw two tops of my trees come off and blow right up against the hedge." And Ms Cherry White said: "It was as if the walls were going to fall in. It was like a twister coming through the garden. We could see it and it was quite extraordinary. We heard the noise first." Force T1. There was also a report of wind damage at the Crown Nursery in Ufford, two kilometres to the south.

In a separate account, Mrs Clare Borrett described being thrown to the ground by the wind while out walking at Blaxhall (TM 3657), some eight kilometres to the northeast; she "... had to crawl up a grass verge and throw myself in a hedge, if not I think that I would have gone up with it." Although this can hardly be regarded as confirmation of a tornado, Blaxhall is on a line joining Pettistree and Leiston (see following entry), and midway between the two places; so there might have been a single tornado (perhaps with only intermittent descent to ground) with a track length of 17 km from westsouthwest to eastnortheast.

At 1200 GMT the low of the previous two days, now 967 mb, was still centred off northwest Scotland, but a shallow wave of 1001 mb was moving east across southern England, the centre passing over Suffolk at the time of the tornadoes. There was an area of heavy rain associated with the wave, and showers in western and northern parts of Britain.

(Incidentally, the Meteorological Office had earlier issued a public warning that "There is a possibility of one or two tornadoes'' within the band of rain; as far as we know, this is the first time they have ever done this.)

TN2008Nov10/II *Knodishall Common to Leiston, Suffolk (52° 11' N 1° 33' E, TM 433607 to 52° 12' N 1° 35' E, TM 452612)*

A tree was reported to have hit a power line, ripping a chimney off a bungalow in Snape Road, Knodishall (*Evening Star*, 10th November); and at Leiston High School a sky-light window was blown out and bins were seen flying through the air. The headmaster, Mr Ian Flintoff, said: "Very suddenly there was a major gust of wind in an extreme way I have not experienced before. Trees were moving around quite violently and the building shook... It was a very short-lived but violent episode. The tornado came across the front of the school. I was talking to another teacher and it took my breath away, it stopped what we were doing, it was very eerie inside." He added that it lasted for about 30 seconds (*East Anglian Daily Times*, 11th November). The school's site supervisor (caretaker, presumably), Mr Bryan Duncan, described how he was unable to close the front doors against the strength of the wind. The time was given as about 2.30 pm (1430 GMT). Force T1.

WS2008Nov11 *30 miles northeast of Aberdeen, North Sea*

A helicopter reported a waterspout 30 miles (50 km) northeast of Aberdeen at 1300 GMT. At 1200 GMT a low, 986 mb, (the previous day's main low) was drifting slowly east through this area while gradually filling.

FC2008Nov17 *Guernsey (Airport), Channel Islands (49° 26' N 2° 36' W)*

Funnel clouds were reported in the METARs from Guernsey Airport at 0820 and 0850 GMT. At 0600 GMT a belt of high pressure, with centres 1035-1039 mb, extended from mid-Atlantic through the English Channel to the southern North Sea; a returning warm front lay from the Hebrides to the Cotentin. Despite the high pressure, there was radar evidence of a few light showers near the Channel Islands in the morning.

Wind2008Dec05? *Caerwedros, New Quay, Cardiganshire (52° 10' N 4° 22' W, SN 3755)*

Mr Tony Herron informed us that an acquaintance of his was woken in the early hours of the morning by a very loud roar of wind; and when daylight came she discovered that her stable (of substantial wooden construction) had been dislodged several inches from its base, and a tree had been blown over. The lady was of opinion that a 'small tornado' may have been responsible, but there is insufficient evidence to classify it as such. There is a slight uncertainty over whether the date was the 5th or the 6th, but the former is the more likely. At 0000 GMT on the 5th a low, 972 mb, was slow-moving off eastern Scotland, while a small cold-air secondary of 975 mb was moving southeast across Ireland; there were showers during the night in north and east Scotland, and also on western coasts of England and Wales.

tn2008Dec13 *Forest, Guernsey, Channel Islands (49° 26' N 2° 36' W)*

The Guernsey Press (15th December) reported this under the headline 'Early-morning tornado strikes Forest family', and described how the Brouard family, of Rue des Reines, were woken at 5.50 am (0550 GMT) by a huge bang as a trampoline was thrown against their house, cracking a window - it was eventually found some 400 metres away. The garden shed was demolished, and two adjacent greenhouses were damaged beyond repair.

Paul Domaille, TORRO's representative on Guernsey, made a careful examination of the site soon afterwards, and while there was no clear indication that a tornado was the cause, neither was there any more obvious explanation for the damage, which appeared to have required winds of at least 70 knots (gradient winds at the time were not gusting to much above 40 knots).

At 0600 GMT a low, 975 mb, was moving slowly north near the Faeroe Islands while its occluding frontal system was moving east across England and Scotland, later coming to a halt over eastern areas as new low centres formed along it. The fronts were crossing Guernsey at the time of the tornado, the triple point at that time being analysed close to Portland Bill. There was widespread rain, heavy in places, in the frontal zone.

Whirlwind in the Irish Republic

MB2008Nov08 *Waterford, County Waterford (52° 15' N 7° 08' W, S 5911)*

Following a brief report by *RTE News* on the 8th November, a more detailed account appeared in the Irish *Independent* of the 10th. Roof tiles were removed by the wind, damaging a motor car; and chimneys, television aerials, and garden sheds were said to have been damaged in the Church Road/Manor St John Road area of Larchville, Waterford. And in a further account in the *Waterford News & Star* (14th November) a man surfing off the beach was said to have been badly injured when he was thrown into the air and landed on the promenade. According to the *Waterford News & Star* the tornado occurred at 3.05 pm (1505 GMT), though the *Independent*, quoting Met Eireann, gave the time, apparently erroneously, as just after 4 pm (1600 GMT). There were thunderstorms in the area at the time. TORRO's Dr John Tyrrell paid a visit to the town a few days later, but was unable to find any certain evidence of a tornado, and concluded that it was more likely to have been a microburst. See the *Benniworth* entry above for the synoptic situation.

Annual totals for 2008

Following several years of high tornado frequency, 2008 was much quieter. There were just 14 tornadoes - 12 in the United Kingdom (which appears to be the lowest annual total since 1992) and two in the Republic of Ireland; two of the UK tornadoes were also waterspouts, and there were nine other reports of waterspouts, plus one in the Irish Republic, making a yearly total of 12; there were 68 reports of funnel clouds in the UK, and 14 in the Irish Republic, giving a total of 82 for the whole of the British Isles. All these whirlwinds were spread over a total of at least 60 days during the year. There were also four land devils and one whirlwind of unknown type.

ACKNOWLEDGEMENTS

TORRO is extremely grateful to all the members and other correspondents who have provided information on the whirlwinds of 2008, or who carried out site investigations; without their enthusiasm it would be impossible to produce these reports. Full details are stored in TORRO's Databank. Further observations of any of the cases mentioned in the 2008 summaries will be very welcome, as will details of any previously-unreported cases.

SHORT COMMUNICATION

THE MISSED METEOROLOGICAL ASPECTS OF MUMBAI (SANTACRUZ AIRPORT) RAINFALL OF 94 CM ON 27 JULY 2005

By R. LAKSHMINARAYANAN

"Arul', T.C.2/1371 (1), Manganoor Konam "A" lane, Pattom, Thiruvananthapuram – 695004, Kerala, India.

Mumbai airport (Santacruz) created history by recording a rainfall of 94.4 cm for the 24 hour period ending at 0830 hrs IST on 27 July 2005 while Colaba meteorological observatory which is about 30 km away in the south reported only a rainfall of 7.3 cm during the same period. Central, East and North Mumbai appears to have borne the brunt of the heavy rainfall. Vihar lake which is in the northeast of Mumbai, one of the main water supply lakes for the metropolitan city reported a record rainfall of 105 cm for the 0830 hrs IST on 27 July 2005. Bhandup in Mumbai reported 81 cm of rain.

The rainfall received on the 27th July by Santacruz exceeded the normal July monthly rainfall of 90 cm on a single day. Santacruz airport recorded the second highest July monthly rainfall of 143.0 cm since 1959 in July 2005 thus 65 % of the normal July monthly rainfall occurring on a single day.

Train services were disrupted for about a week and airport was closed for two days. One million people rendered homeless. Maharashtra experienced floods with about more than 1000 deaths out of which 409 happened in Mumbai. About 5000 Crores of Rupees loss was estimated by Mahrashtra Government.

Mumbai Santacruz receives a normal monsoon seasonal rainfall of 230 cm during the period June to September while Colaba receives a normal rainfall of 205 cm. However, in this year (2005), 42 % of the monsoonal seasonal rainfall was received in a single day in Santacruz. The highest July monthly rainfall of Santacruz received in the month of July during the period 1959 to 2004 is 146 cm in the year 1956 while Colaba received its highest July monthly rainfall of 144 cm in the year 1974. The earlier highest record of 24 hour rainfall recorded by Mumbai Santacruz airport and Colaba were 39.9 cm on 10 June 1991 and 57.8 cm on 5 July 1974. The highest one day rainfall recorded by Santacruz during the period 1974 to 2004 in July occurred only four times, when Santacruz airport recorded more than 25 cm in 24 hours (as follows): 5 July 1974: 37.5 cm; 19 July 1982: 27.6 cm; 12 July 1983: 25.3 cm; 19 July 2000: 35.1 cm

Thus the rainfall 94.4 cm recorded by Santacruz for the 24 hour period ending at 0830 hrs IST on 27 July 2005 is indeed unprecedented. Colaba meteorological observatory recorded the highest one day rainfall exceeding 40 cm in 24 hours in the month of July are the following during the period 1974 – 2004: 5 July 1974 - 57.8 cm; 31 July 1975 - 40.7 cm; 2 July 1984 - 54.4 cm. In association with cyclonic storms some stations and a couple of hill stations receive exceptionally very heavy rainfall. Rainfall at stations which received more than 94.4 cm in India are given in Table 1.

From the above table it can be seen that there were only 10 occasions by Indian rain gauge stations when rainfall was reported to be more than 94.4 cm, reported by Mumbai airport Santacruz. Thus this rainfall is perhaps the 11th highest in India. It is very interesting to note that 65 cm of rainfall in Santacruz fell between 1430 hrs and 2030 hrs IST on 26 July 2005 which is about 70 % of the total rainfall recorded during the 24 hours ending at 0830 hrs IST on the day in study. It may be mentioned that the highest hourly rainfall of 19 cm was recorded between 1430 hrs IST to 1530 hrs IST while it was 10 cm between 1630 – 1730 IST, 1730 -1830 IST and while it was 9 cm between 1530 to 16 30 hrs IST on 26 July 2005. Some of the world rainfall records (outside India) are given in Table 2.

St. no	Station	State	Rainfall in cm	Date and year
1	Cheerapunji	Meghalaya	184.0	10 June 2003
2	Cheerapunji	Meghalaya	156.3	16 June 1995
3	Amni devi	Lakshadweep	116.8	6 May 2004
4	Cheerapunji	Meghalaya	103.6	14 June 1876
5	Jowai	Meghalaya	102.0	11 September 1877
6	Cheerapunji	Megalaya	99.8	12 July 1990
7	Kasautii	Himachala Pradesh	99.6	18 June 1899
8	Mawsynram	Meghalaya	98.9	10 July 1952
9	Dharampur	Gujarat	98.7	2 July 1941
10	Cheerapunji	Meghalaya	98.5	13 September 1974

Table 1. Rainfall stations in India which have received more than 94.4 cm of rainfall.

St. no	Station	Rainfall amount cm	Date and year
1	Cilas, Reunion island	187.1	15-16 March 1952
2	Foc Foc, Reunion island	179.6	7-8 January 1966
3	Belouve, Reunion island	166.2	27 – 28 February 1964
4	Auvere, Reunion island	155.2	7 – 8 April 1958
5	Muuocaicang, NeiMouggol, China	137.8	1 – 2 August 1977
6	Paishis, Taiwan	122.8	10 -11 September 1963
7	Halaho, Taiwan	117.5	9 – 10 September 1963
8	Bageno, Philippines	115.0	14 – 15 July 1911
9	Bellendenker, QLD ,Australia	112.3	3 – 4 January 1979

Table 2. Rainfall records at different stations over the world.

During the monsoon period (June to September) Mumbai, Santacruz receives more rainfall in July and August while Colaba receives more rainfall than Santacruz in June and September. Some of the very heavy rainfall events in the period 1901 to 2004 recorded in Mumbai Colaba and Santacruz airport during the monsoon months June to September are given below:

Colaba
10 June 1991 - 47.8 cm; 5 July 1974 - 57.8 cm; - 10 September 1930 - 54.8 cm.
Santacruz
10 June 1991 - 39.9 cm; 5 July 1974 - 37.5 cm; 23 August 1997 - 34.6 cm; 23 September 1981 - 31.8 cm.

A recent study of monsoon rainfall of Mumbai Colaba and Santacruz (Jenamani,Bhan and Kalsi. May 2006) it is given that during the one hundred year period 1901-2000 the number of occasions when Colaba had rainfall of 20 cm or more was 50 while rainfall >20 cm occurred 37 times in Santacruz and the number of occasions when two consecutive days of rainfall greater than 20 cm per day occurred were five and three respectively. Again the number of occasions of rainfall greater than 30 cm per day in Colaba and Santacruz was 13 and 11 while the number of occasions when two consecutive days rainfall of 30 cm per day occurred was two and one. It can be said that the occurrence of intense rainstorms is nothing unusual at Mumbai in monsoon months. Hence the probability of the occurrence of 30 cm rainfall and above in Mumbai is of the order of 10 to 15 % while the probability of occurrence of 20 cm or more is of the order of 35 to 50 % in each monsoon season. However the rainfall of the 27th July of Santacruz is unprecedented. The rainfall recorded by both Santacruz and Colaba between 0830 hrs on the 26th and 0830 hrs IST on the 27th every three hours is given in Table 3.

From the above table one can see the heaviest rainfall of 65 cm occurred in six hours between 1430 and 2030 hrs on 26 July 2005 at Santacruz Airport.

Based on the data 1875 to 1990 there have been only two stations recording rainfall in India - both in the Khasi hills of Meghalaya in north-east India which recorded a rainfall of more than 100 cm on a single day. The details of these stations and their records are as follows: 1) Cheerapunji -104 cm (14 June 1876); 2) Jowai - 102 cm (11 September 1877). Again Cheerapunji (1313 m ASL) reported a 24 hr rainfall of 156.3 cm on 16 June 1995. This record was again broken by Cheerapunji itself on 10 June 2003 by recording a 24 hr rainfall of 184 cm. It may be mentioned that the highest 24 hr rainfall of 187 cm in the world was reported by Cilaos (1201 m ASL) on 15 -16 March 1952 by a station in the La Reunion Island in the Indian Ocean, 400 miles east of Madagascar. The rainfall of 184 cm reported by Cheerapunji on 10 June 2003 is thus closer to the world record.

	26 July 2005				27 July 2005				
Station	0830 to 1130	1130 to 1430	1430 to 1730	1730 to 2030	2030 to 2330	2330 to 0230	0230 to 0530	0530 to 0830	Total (cm)
Santacruz	0.0	1.84	38.18	26.76	10.01	11.62	1.10	4.82	94.4
Colaba	0.09	0.7	1.95	0.66	0.0	0.0	2.4	1.63	7.3

Table 3. Santacruz and Colaba rainfall (cm) every three hours between 0830 on the 26 July 2005 and 0830 on the 27 July 2005.

In recent times, Amni Devi Island in Lakshadweep reported a rainfall of 117 cm in 24 hours ending at 0830 hrs on 6 May 2004 in association with a severe cyclonic storm which moved very close to the island about 50 km north-east to the island on 5 May 2004. In fact Amni Devi Island recorded a rainfall of 43, 117 and 24 cm of rain on 5, 6 and 7 May 2004 thus totaling a rainfall of 184 cm in three days. Therefore, Amni Devi Island holds the record of 24 hour rainfall of 117 cm in the plains of India while Cheerapunji holds the highest 24 hour record rainfall of 184 cm in the hills coming very close to the world record. Again yet in another study (Shyamala and Bhadram, December, 2006) of the exceptional rainfall event of 26 July 2005 over Mumbai it has been mentioned that it may have occurred due to the interaction between mesoscale and synoptic weather systems. Whatever may be the cause, there is no doubt that the exceptional rainfall event reported by Mumbai Santacruz Airport, Bhandup and Vihar lake near Mumbai are all unprecedented in rainfall records.

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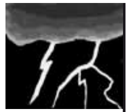

TORRO THUNDERSTORM REPORT FOR THE BRITISH ISLES: AUGUST 2008

By BOB PRICHARD

The overall impression this month is of fairly average thunderstorm frequency for August, but this masks some oddities – which mainly arise from the excessive prevalence of south-westerly winds; thus much of southwestern Britain had little or no thunder, whereas those districts with a particularly long land-track (and thus greater surface heating) for that airflow tended to report a lot. Eight days with thunder heard were recorded at Calthorpe (north Norfolk), and three or four days towards many other eastern and north-eastern coasts. There was a lack of any widespread thundery activity and, as in several recent summer months, the high rainfall totals of this very unsettled month do not primarily owe their existence to thundery outbreaks. The most active days were the 7th, 12th and 31st.

The month began with thunderstorms over parts of eastern and northern England in the early hours of the 1st as a cold front drifted north, taking away the late July warmth; lightning killed two horses at Redcar and damaged the roof of a house at Ilkeston. A showery south-westerly airflow followed, with isolated thunder in the afternoon, mainly over Northern Ireland. On the 2nd, there were thundery showers towards the coast of north-east England and eastern Scotland during the middle of the day and over Northern Ireland in the late afternoon. As the showery south-westerly airflow continued, there were a few more reports of thunder on the 3rd – again from Northern Ireland, and from widely separated parts of eastern Britain; a lively storm affected north Norfolk in the late afternoon. The showery weather retreated on the 4th, but a depression then drifted northeast towards southwest Britain, allowing warm air to move into south-eastern Britain on the 6th – when the temperature rose to 32.5 °C at Paris. Thundery outbreaks occurred in three separate zones. As a cold front edged eastwards across England during the afternoon and evening a few storms broke out near it, especially over North Yorkshire in the late afternoon, whilst there were a few more amongst the showers behind it - mainly over south and west Ireland – where 38 mm fell in 60 min at Shannon Airport. The most notable outbreak, though, developed in the warm air over the English Channel to the south-west of Brighton around sunset and moved north-east to the south and east of London during the next two or three hours. This was a typical medium-level outbreak (so there was very little lightning damage), fed by the very hot air from France and triggered as the cloud-tops cooled in the evening (thus eroding the inversion that had prevented earlier storm development); the storms were very active electrically and an impressive display of lightning was observed over a wide area of south-eastern England. Hail of 20-25 mm diameter was reported from Newhaven and Peacehaven, and pvc roofing was punctured. On the 7th, under a weak area of low pressure, there was thunder in some of the showers over England, especially in the east from Essex to North Yorkshire; there was considerable development over East Anglia and Lincolnshire in the evening, continuing near the Wash until midnight. A weak tornado damaged trees and fences and ripped off roof tiles at Lakenheath. 20-50 mm of rain fell widely over Norfolk, with a report of 58 mm from Langham, and there was heavy hail and flooding in places. A house was damaged by lightning at Louth (Lincolnshire).

During the 9th, a deep depression moved north-east off north-west Scotland, bringing a wet and windy Saturday to most of the country. There was some thunder near a wave on the cold front from central Ireland to southern Scotland during the late afternoon and night; 48 mm fell in 35 min at Dublin, where the airport received a record 76 mm in 24 hours.

A showery westerly airflow followed on the 10th, with isolated thunder possible over eastern Scotland. Another, complex, area of low pressure drifted across the country from the 11th to 14th. There were a few heavy, thundery downpours over Northern Ireland on the 11th and fairly widespread thundery activity across England and Wales on the 12th. Initially, this was linked to a cold front, which had given a little thunder over the Channel Islands soon after midnight. Rain from it became increasingly intense as it moved over East Anglia in mid-morning and it turned thundery over Norfolk, where 29 mm fell in 30 min at Buxton. Later, several of the thundery showers were quite fierce, especially over central England, with a few reports of large hail. An aeroplane was struck by lightning at Manchester Airport, whilst a few miles away at Blackley a house was struck and a power surge damaged electrical equipment in 20 houses. A few thundery showers also affected Ireland. There was some more thunder on the afternoon of the 13th near two depression centres – over the east Midlands, Lincolnshire and the north Norfolk coast (where 32 mm fell at Hunstanton, with large hail at Blofield), and Northern Ireland. Thundery showers affected parts of southern Scotland (with flooding in the Glasgow area) and various districts of southern Britain on the afternoon of the 14th, and there was a brief thundery shower over the Moray Firth on the late afternoon of the 15th.

A depression moved north-east into Northern Ireland on the 16th and gave considerable rainfall leading to severe flooding. Although this was a non-thundery frontal event, there were a few heavy, thundery showers behind the front over Ireland; these merged with, and exacerbated, the frontal rain as they moved north (the thunder dying out in the process). Another deep depression moved north-east across the British Isles during the 18th and 19th, with weaker low pressure areas following from the 20th to the 22nd. Thundery activity was scattered throughout this period; much of it was weak and insignificant, but there were exceptions. Heavy, thundery showers were fairly widespread during the afternoon of the 21st towards the coast of south-east Scotland and north-east England and over the north Midlands, whilst in the late afternoon of the 22nd hail covered roads near Potter Heigham (north Norfolk) for a time.

A quiet spell ensued, but the last day of the month brought thundery activity to, mainly, the south-east as cold frontal troughs drifted eastwards into warm air. Dying thunderstorms affected parts of south-west England during the early hours, then a lively outbreak (with its origins around the Pyrenees some 12 hours earlier) moved north over West Sussex, Surrey, London and Hertfordshire towards mid-morning. In places, this storm broke over thick radiation fog, creating rather an eerie effect – which probably added to the drama of a lightning strike, reported as 'a red ball of fire in the sky', at Enton Hall (a private residential estate near Godalming), where the gardener had a lucky escape after being knocked to the ground. Two fir trees suffered direct hits and had to be felled, whilst pictures fell off walls and the electricity supply was interrupted. Another storm developed over north-west Surrey in mid-afternoon and developed into a severe outbreak across parts of London, Hertfordshire, Buckinghamshire and Bedfordshire into the early evening. 32 mm of rain fell in under 20 min at Hampstead, and there was another possible report of ball lightning nearby. Meanwhile, much of Norfolk had been sunny and hot, with the temperature reaching 28 °C at Norwich Airport. The late afternoon brought a thundery outbreak to this area too, to round off a notably thundery month in what is, on average, Britain's most thundery county; Buxton had another deluge (see 12th, above), giving 25 mm in less than 30 min with very frequent thunder and lightning. The storms on the 31st gave 63 mm of rain at Chalfont St Peter and 51 mm at Chalfont St Giles (both in Buckinghamshire).

TORRO SITE INVESTIGATION LANE FARM, SUFFOLK, UK: 26 MARCH 2009

By CHRIS BELL and CHRIS WARNER

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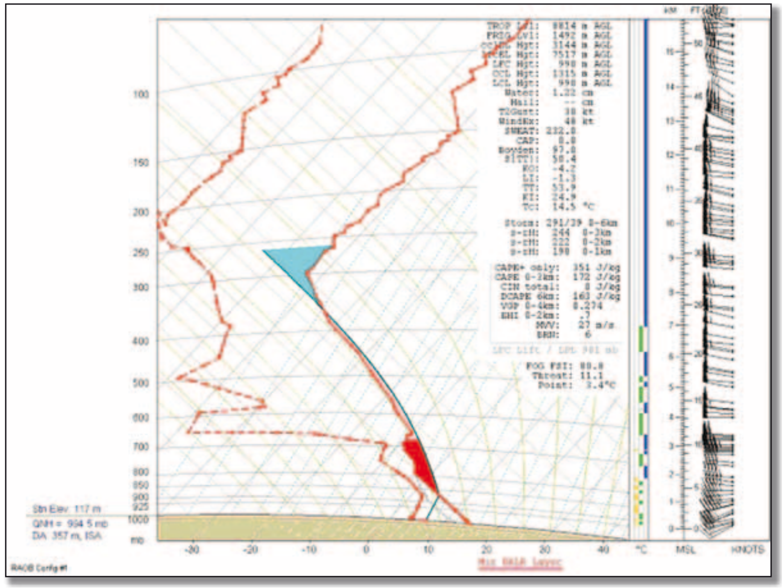

Figure 4. Tephigram for Nottingham 12z 26 March 2009 (adjusted for max temperature).

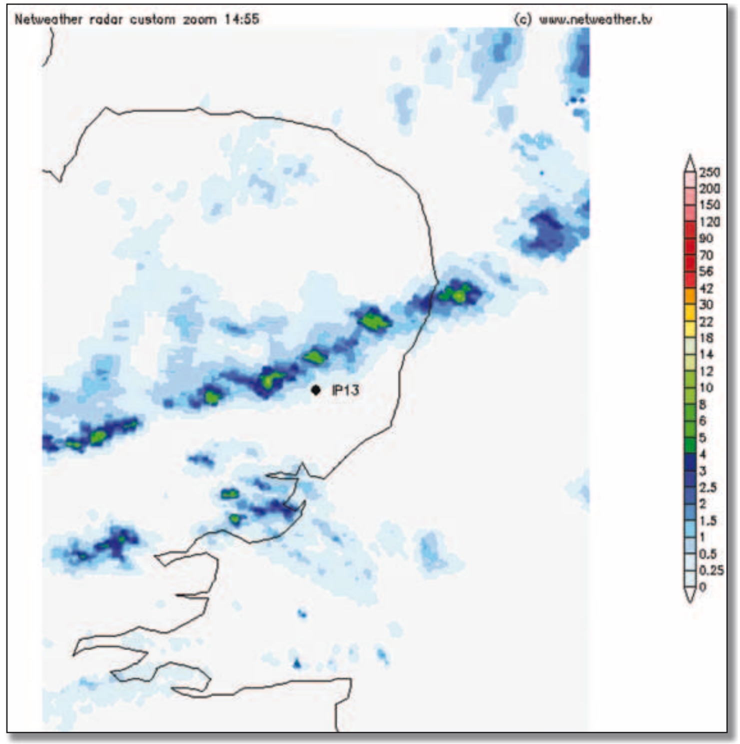

Figure 5. East Anglia radar display at 1455 GMT (NetWeather) IP3 near Brundish.

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