

shorter, largely because fresh data can sometimes be in error in crucial regions. Data quality control and evaluation is one of the most important aspects of the man-machine mix in forecasting today.

In the short term the forecasters were simply not able to predict with any confidence the precise detail of the developments during the evening of the 15th over Biscay to the extent of being able to provide more than a few hours warning of violent winds across most of southern England. In this respect it should be noted that warnings of severe gales for the English Channel and adjacent coastal areas were issued some 12 hours in advance although warning of the hurricane force winds actually obtained was issued less than 3 hours in advance.

Whether forecasters will be able to give more accurate and more timely advice on the occurrence of such extreme weather events in the future depends very much on the availability of good data in crucially important regions of the ocean and atmosphere. It may also depend upon the way we communicate our forecasts to the public; weather forecasting is a risk assessment business and there is always some degree of uncertainty in every forecast. Such information could greatly influence decisions made by the public from their interpretation of the forecast.

#### REFERENCE

- Lorenc, A. C., Bell, R. S., Davies, T. and Shutts, G. J. (1988) Numerical forecast studies of the October 1987 storm over southern England. *Meteorol. Mag.* **117**(1389) (to be published April 1988)

## THE GREAT STORM OF 15-16 OCTOBER 1987

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ON the night of 15/16 October 1987, a fast-moving vigorous depression caused the most severe storm damage for many generations in southern England. At least 18 people lost their lives as a direct result of the gale, and if the winds had not been at their peak during the hours of darkness there can be little doubt that many more would have died. Hundreds of millions of pounds worth of damage resulted and millions of trees were blown down in what Home Secretary Douglas Hurd describes as "... the worst, most widespread night of disaster in the south-east of England since 1945". This article attempts to reconstruct the synoptic background to the storm (including a chronology of significant events), to provide an indication of the peak winds reached and their rarity and to comment upon other exceptional meteorological features of the storm, in particular the rapid changes in temperature and pressure. Lessons that might be learned from the storm are discussed. Finally, the extent and severity of the storm damage is described.

#### THE SYNOPTIC BACKGROUND

At 1200 GMT on Thursday 15 October, the British Isles lay in a slack gradient in a complex area of low pressure (Fig. 1); pressure was highest in the Shetland Islands, at 990 mbar. A very pronounced thermal gradient was in evidence over the eastern North Atlantic; cold air from high latitudes (only 3°C at Reykjavik) was rapidly streaming south to below 45°N off the coast of Portugal. At Belfast, the temperature reached only 6.4°C during the day. At the same time, very warm and moist air from the vicinity of the Canary Islands was being quickly advected over Spain and France (the temperature at Corunna on Spain's north-west coast was 22°C with a south-westerly 50 kn wind). Not surprisingly, the polar front was very pronounced and Low M was identified as an open wave on this front in the Bay of Biscay at about 970 mbar. It will be appreciated that the generally low pressure in the area of formation provided something of a 'head start' to its exceptional depth, rather than subsequent rapid deepening (compare, for instance, the

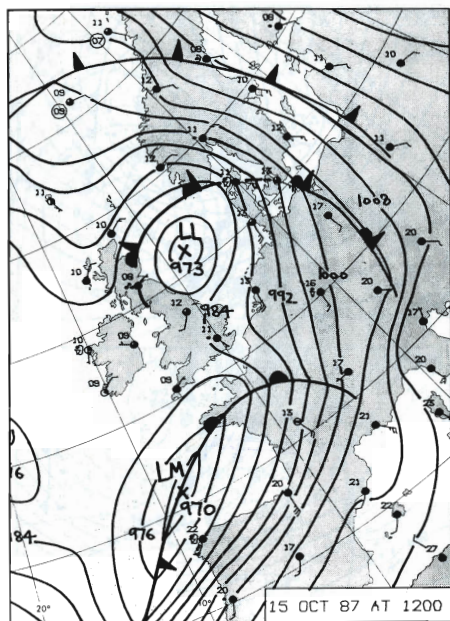


Fig. 1 Surface analysis over the eastern North Atlantic, 1200 GMT 15 October 1987 (source: London Weather Centre Daily Summary)

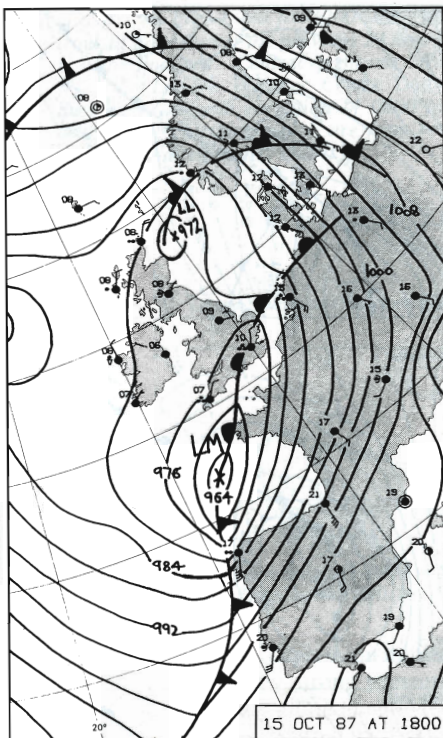


Fig. 2 As Fig. 1, but for 1800 GMT

explosive deepening of the exceptional depression of 915–916 mbar on 14/15 December 1986 – Burt 1987a).

By 1800 GMT the depression centre had tightened considerably, moved north-east and deepened by 6 mbar (Fig. 2). Winds of 40–50 kn blew in the warm sector, but all areas except the extreme south-east of the British Isles lay in the slack pressure field to the north of the warm front and winds were mostly 10 knots or less. Over the next six hours, however (Fig. 3 shows the situation at 0000 GMT Friday, 16 October), the depression moved north-east rather more rapidly while deepening further – the London Weather Centre *Daily Summary* shows the centre at 960 mbar over south Cornwall, but the analysed hourly charts (Fig. 5a) indicate a centre midway between Cornwall and

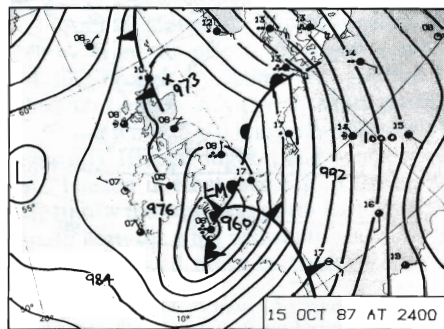


Fig. 3 As Fig. 2, but for 0000 GMT 16 October 1987. Note that this chart differs in detail from the re-analysed hourly chart (Fig. 5a).

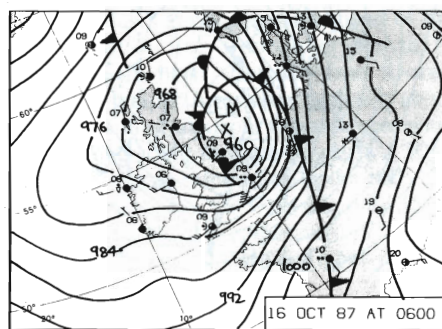


Fig. 4 As Fig. 3, but for 0600 GMT



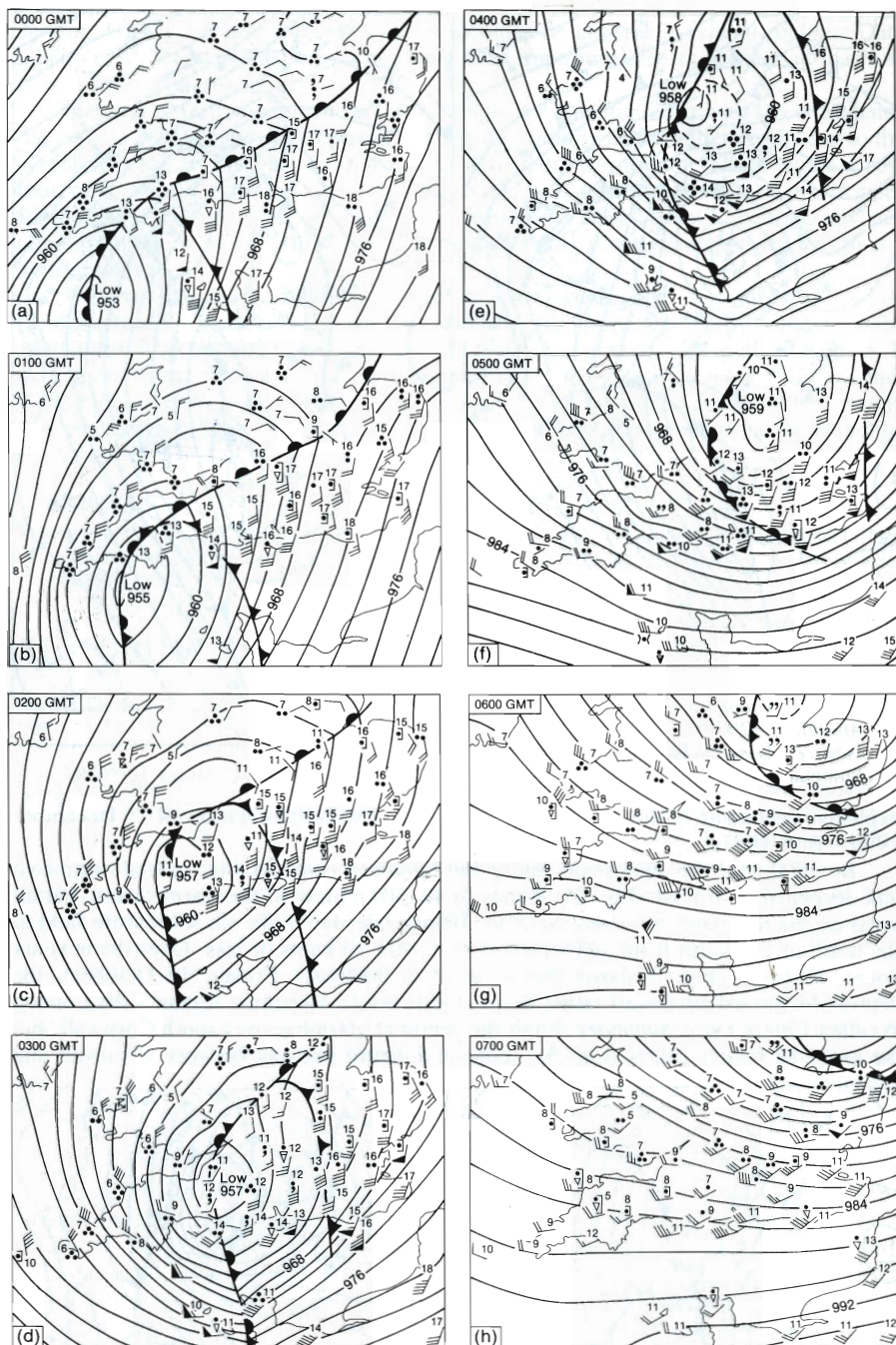


Fig. 5 (a) to (h): Hourly 'wind and weather' charts for part of southern England, 0000 to 0700 GMT 16 October 1987. The frontal positions are based upon thermograph records in addition to synoptic reports – the warm front from the sudden rise in air temperature, the cold front from the time the temperature fell through  $12-13^{\circ}\text{C}$  and the occlusion from the time the temperature fell back through  $10^{\circ}\text{C}$

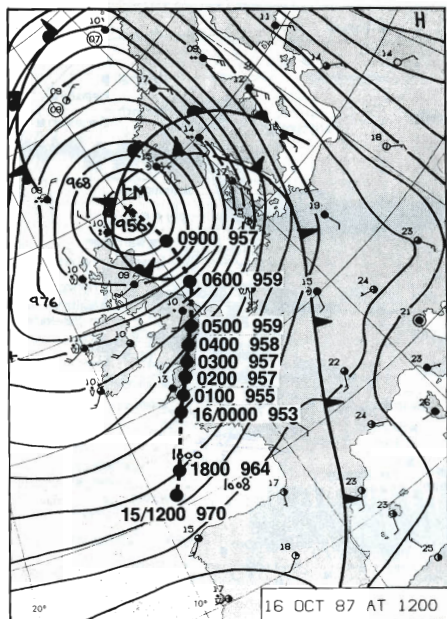


Fig. 6 (left) As Fig. 4, but for 1200 GMT. The track of Low M over the previous 24 hours is superimposed. Central positions are from the London Weather Centre Daily Summary with the exception of 0000 to 0900 GMT 16 October which are from re-analysed plotted hourly charts

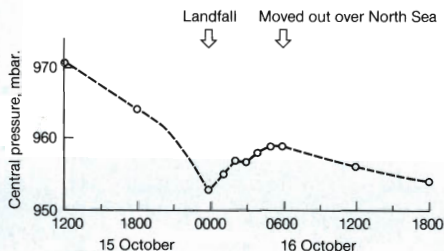


Fig. 7 (above) Central pressure of Low M with time, 1200 GMT 15 October to 1800 GMT 16 October 1987

Brittany of about 953 mbar. During the next six hours the centre of the depression moved from south-west to north-east across England, with the exceptionally strong pressure gradient on its southern flank contrasting strongly with the slack flow around and to the north of the centre. Fig. 4 shows the situation at 0600 GMT, while Fig. 5 provides a more detailed 'wind and weather' analysis over a smaller area for each hour from 0000 to 0700 GMT. These analyses are based upon the re-analysis of hourly Meteorological Office working charts. (Since chart analysis is in many ways a subjective exercise, it must be expected that slight differences will exist between the analyses presented here and those published elsewhere.)

By 1200 GMT the depression was well occluded and lay between Scotland and Norway (Fig. 6). It is noteworthy that it began to deepen once more after it left the land (Fig. 7), at 1800 GMT it was at 954 mbar north-east of the Shetland Islands and giving a very severe gale in the northern North Sea and on the coast of Norway. The track of the depression is mapped onto Fig. 6.

#### A CHRONOLOGY OF THE STORM

As the depression moved towards the British Isles, rain had spread ahead of the warm front to affect all areas south and east of a line from Aberystwyth to Middlesbrough by 2100 GMT. At that time the warm front stretched from Dorset through London to Norwich: to the north of the front temperatures were typically about 7°C and winds 5–10 knots north-easterly\*. To the south of the front temperatures were typically 10 degC higher, and winds were a freshening south to south-westerly – 30 kn at Manston in Kent (see Fig. 8 for the locations of places referred to in the text). At Heathrow the wind was north-easterly 5 knots, temperature 9°C; at Gatwick, only 35 km south-east, the wind was south-south-westerly, 15 knots, and the temperature 17°C. The largest reported pressure falls were off the coast of Norfolk, down 6.8 mbar in three hours at an oil platform at 53.5°N 2.1°E, although a fall of 5.7 mbar was reported from

\*Wind speeds in this section are from synoptic reports, some of which may be estimates. The reported mean speeds refer to the 10 minutes approximately prior to the hour while gust speeds are the maximum in the hour ending at that time. Maximum values from quality-controlled anemograph records appear in Table 2.



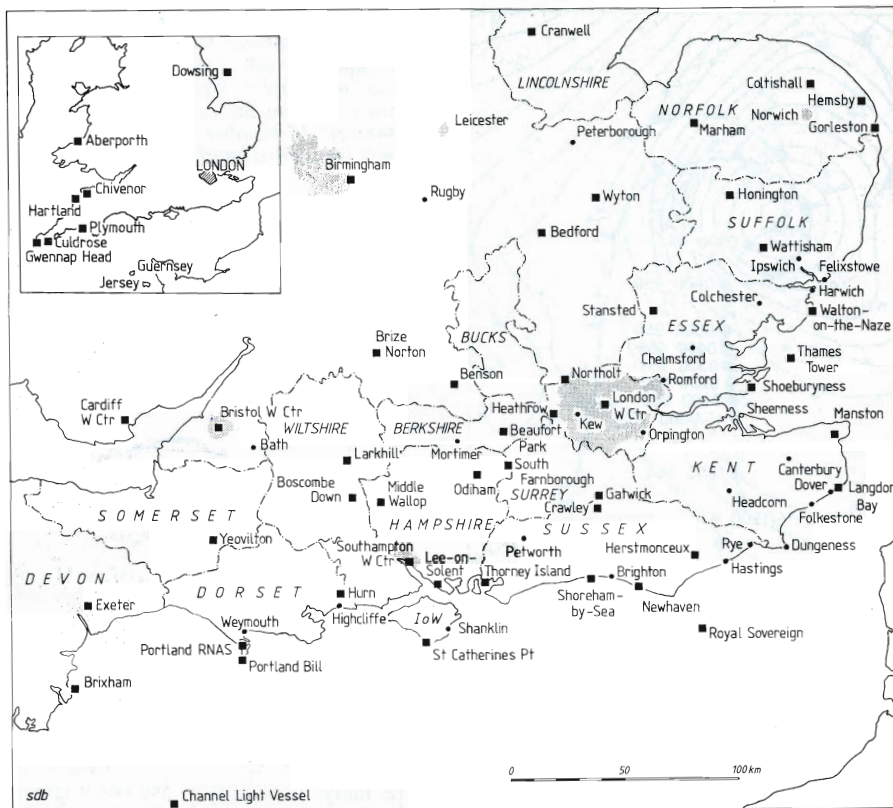


Fig. 8 Locations of places referred to in the text. Owing to pressure of space, not every location can be shown

Culdrose in Cornwall. As the warm front drifted slowly north, remarkable rises in temperature occurred. At Mortimer (south of Reading), for example, the temperature rose almost 8 degC in 20 minutes from 2220 GMT (Burt 1987b). The passage of the warm front also resulted in a 180° wind reversal and brisk freshening – at London Weather Centre the wind changed from east-north-east 3–4 kn at 2140 to south-south-west 20 kn, gusting to 34, only 20 minutes later; at 2233 there was a gust of 43 kn (Fig. 9, top). On the 2200 GMT chart the large pressure falls in the North Sea had lessened, while those in the south-west increased (7.9 mbar since 1900 GMT at Culdrose). On the south coast of England the southerly wind was now above gale force, 40 knots in the Channel and 35 kn at Manston, while, in south-western England, Hartland was reporting a north-easterly gale. An hour later, the pressure falls had increased further (down 9.1 mbar in three hours at Plymouth); the wind had reached 40 knots at Jersey, where the temperature was 17°C with 3 oktas of cloud.

At 0000 GMT, 16 October, (Fig. 5a) the depression lay between Cornwall and Brittany, and had already begun to occlude. At Chivenor the barometer had fallen 10.2 mbar since 2100. Northerly or north-easterly gales or severe gales blew on the north coast of Cornwall (350° 50 kn, gusting to 73 at Gwennap Head), while southerly gales or severe gales affected Devon and the English Channel (170° 51 kn, gusting 72 at Brixham, only 150 km east-north-east of Gwennap Head: 180° 55 kn at Channel Light Vessel). Over much of south-east England the night remained exceptionally warm (18.0°C at St Catherine's Point) with temperatures of 17°C, with dew-point 15°C, widespread, the wind a freshening southerly of 20–25 knots. To the north of the warm front the wind remained light north-easterly. Between 0000 and 0100 GMT the warm

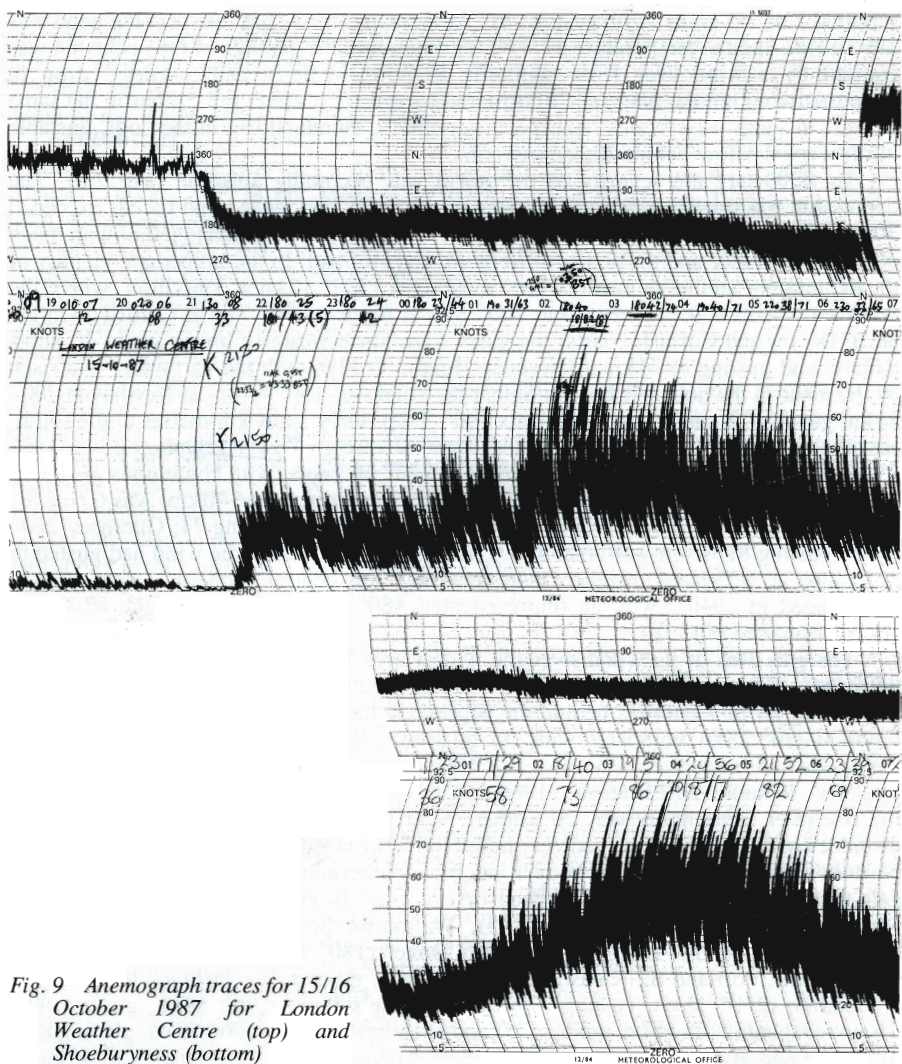


Fig. 9 Anemograph traces for 15/16 October 1987 for London Weather Centre (top) and Shoeburyness (bottom)

front passed Brize Norton, in Oxfordshire; the temperature picked up from  $7^{\circ}\text{C}$  to  $16^{\circ}\text{C}$ , while the wind veered from  $060^{\circ}$  11 kn to  $180^{\circ}$  22 kn. At 0100 GMT the depression centre lay not far south of Plymouth (Fig. 5b), where the barometer stood at 957.2 mbar (the lowest pressure reported from any British synoptic station during the storm). At Culdrose the wind was  $350^{\circ}$  45 kn, with continuous heavy rain and a temperature of  $6.6^{\circ}\text{C}$ ; at Portland Bill, where the cold front had just gone through, the temperature was  $14.4^{\circ}\text{C}$  with a heavy shower, the wind  $180^{\circ}$  48 knots. At Jersey the wind was  $190^{\circ}$  52 knots, gusting to 81. Inland, winds first reached gale force: at Middle Wallop on Salisbury Plain the wind was  $190^{\circ}$  45 kn, gusting 75. An hour later (0200 GMT, Fig. 5c) the depression had crossed the coast of south Devon and was centred close to Exeter with a central pressure about 957 mbar – the deepest depression to be centred over England or Wales in October in at least 150 years. It was at 0200 that winds inland first touched storm force – at Middle Wallop the wind was  $200^{\circ}$  50 kn gusting 78, while gusts of 70 kn had occurred at both Boscombe Down (Wiltshire) and at Odiham (Hampshire). Even in central London the wind gusted to 63 knots at 0135 GMT. In the Channel, Jersey



reported 230° 55 knots, with gusts to 81. At Herstmonceux (East Sussex) the wind was 190° 43 kn, and the temperature 17.8°C. At Plymouth the passage of the occlusion was marked by a wind veer from southerly to north-westerly and a 4degC drop in temperature within the hour; at Culdrose the barometer picked up 8.5mbar in the same period. In south-west Wales, Aberporth reported a thunderstorm in the cool, unstable north-westerly flow behind the depression.

By 0300GMT the severity of the storm was becoming apparent (Fig. 5d). The depression was now centred over the Somerset Levels, and mean wind speeds exceeded 30 knots over all of south-west, central southern and eastern England together with much of northern France and the coasts of Belgium and Holland. In the immediate vicinity of the depression, and to its north, winds were slack (200° 12 kn at Yeovilton, where the barometer stood at 957.5mbar, and 200° 8 kn at Bristol; 010° 7 kn at Cardiff). On the north Devon and Cornish coasts, the gales were north-westerly (mean speed 40 knots widely, and gusting to 74 kn at Gwennap Head). At Plymouth the barometer had risen by 9.2mbar in the hour. At Lee-on-Solent the wind was 150° 65 kn; at Newhaven 200° 54 kn, gusting 73; and at Herstmonceux 190° 53 kn. Only a few kilometres to the south-east in the English Channel, the wind at Royal Sovereign Tower Lighthouse was 180° 75 kn. At Channel Light Vessel the wind was 270° 60 knots (with continuous moderate rain). The pressure gradient between Jersey and Guernsey (some 40km) was 6.6mbar, or 16.5mbar/100km; Jersey reported winds of 260° 50kn, gusting 74; Guernsey 260° 56 kn, gusting 81. Even well inland, at London Weather Centre the wind had gusted to 82 knots at 0250GMT (higher than anything for central London since records commenced in 1940), with an unprecedented 180° 44kn reported at the 0300GMT observation (see Fig. 9).

The gale was at its worst over the widest area between 0400 and 0500GMT. At 0400GMT, the centre of the depression lay at the mouth of the Severn Estuary (Fig. 5e). The strong north-westerlies behind the depression had penetrated further east; Cardiff reported 310° 28 kn, compared with 7 kn an hour earlier, but in the extreme south-west the winds had moderated somewhat. At Channel Light Vessel the reported wind was westerly, 70 knots. At Exeter the pressure had risen 10.6mbar in the hour; at Plymouth the rise over three hours was 20.9mbar. Near the depression centre, and for some distance around, winds remained very light (160° 7 kn at Birmingham; 220° 5 kn at Brize Norton; 260° 6 kn at Bristol) but over much of southern and south-eastern England the gale was at its height. Winds reached or exceeded Beaufort Force 10 (48 knots) at Shoeburyness (190° 54 kn, gusting 75), Walton-on-the-Naze, Essex (190° 55 kn), Odiham (180° 48 kn), Langdon Bay, near Dover (180° 62 kn, gusting 90), Manston (230° 52 kn), Portland Bill Coastguard (270° 55 kn, gusting 76), Portland Royal Naval Air Station (250° 56 kn, gusting 77), St Catherine's Point (230° 56 kn, gusting 90), Thorney Island (210° 56 kn, gusting 75) and at Herstmonceux (200° 58 kn, gusting 83). The wind had also reached gale force in East Anglia. Winds were gusting to 45 kn or more around all but the northern periphery of the depression, and the increasing effect of the gale upon telecommunications channels began to be felt in widening gaps in the observational cover in south-east England. By 0500GMT the depression was centred between Leicester and Peterborough (Fig. 5f): the occlusion was swinging rapidly across southern England, its passage being marked by a sharp fall in temperature (typically 5 degC). Between 0400 and 0500GMT the pressure had risen by an astounding 12.2mbar at Hurn and 11.0mbar at Southampton Weather Centre: at both stations the temperature had fallen by 6 degC and the wind had picked up from the south-west, while further west and south-west the winds continued to moderate. Some of the highest gusts of all occurred between 0400 and 0500 (Tables 1 and 2): at Gorleston there was a gust of 106 kn at 0424. Amongst the highest winds reported at 0500 were 210° 55 kn, gusting 83, at Shoeburyness; 190° 55 kn at Walton-on-the-Naze (with continuous moderate rain); 200° 55 kn at Odiham (continuous moderate rain); 200° 61 kn, gusting 86, at Manston; 270° 50 kn, gusting 78, at Portland Bill Coastguard and 260° 52 kn, gusting 77, at Portland RNAS; 240° 58 kn, gusting 80, at St Catherine's Point; 130° 50 kn, gusting 79, at Thorney Island; 200° 70 kn at Lee-on-Solent, with continuous moderate

rain and 200° 60kn, gusting 88, at Herstmonceux. Gatwick Airport was closed after a gust of 86 knots although the mean wind was only 210° 31kn. In East Anglia, at Coltishall the wind was 190° 40kn gusting 71, and at Dowsing Light Vessel (off the mouth of the Humber Estuary) 200° 54kn.

At 0600 GMT (Fig. 5g) the depression was centred north of Hull. Winds had begun to abate very slightly over much of the south-east; only three stations exceeded 50kn (Thames Tower, 230° 60kn; Manston, 210° 51kn and Newhaven Lighthouse, 230° 54kn with continuous moderate rain). In the English Channel, Channel Light Vessel reported 320° 70kn. Gust speeds reported at this hour exceeded 55–60kn over a huge swathe from the southern North Sea through East Anglia (71kn at Hemsby, 78kn at Shoeburyness) through south-east England (84kn at Manston, 71kn at London Weather Centre, 69kn at Northolt), along the south coast (90kn at Herstmonceux, 85kn at Newhaven, 60kn at Hurn and St Catherine's Point, 68kn at Portland RNAS), into the West Country (66kn at Bristol, 63kn at Middle Wallop) and the extreme south-west of England (57kn at Gwennap Head). Even on the west coast of Wales at Aberporth the wind was 290° 35kn, gusting to 50. Winds also exceeded 50–60 knots in the southern North Sea (180° 50kn, with continuous moderate rain, at Dowsing Light Vessel; 190° 63kn from a platform at 53.1°N 2.2°E, about 45km north-east of the coast of Norfolk). On the original 0600 GMT working chart, the storm disruption was such that Manston was the only station plotted within a 120km circle centred on the Thames Estuary: the nearest plot to the north-west was Birmingham/Elmdon, some 250km distant, and to the west Odiham, some 160km. In the hour since 0500, the barometer had risen 11.0mbar at South Farnborough and 10.2mbar at Benson: at the latter, the temperature had fallen 5.4degC in the hour. Very large three-hour pressure tendencies were now widespread in the south-west – +25.5mbar at Portland RNAS (957.8mbar at 0300 to 983.3mbar at 0600 GMT), +23.4mbar at Portland Bill Coastguard, +23.2mbar at Yeovilton. (These values are differences between observed barometer readings and not interpolations from barograph traces.) By 0700 GMT, as Low M moved out into the North Sea (Fig. 5h), winds had started to drop everywhere except in East Anglia; at this time a platform at 53.5°N 2.2°E (about 100km north-east of Coltishall) reported 190° 59kn, with continuous heavy rain. On land, Hemsby reported 200° 44kn, gusting 74, while at Wattisham the wind was 220° 48kn, gusting 70. Over most of south-east and southern England winds had abated to between 30 and 40kn (Manston 220° 44kn, gusting 66; St Catherine's Point 250° 43kn, gusting 58; Lee-on-Solent 270° 50kn) – at Scilly the wind had fallen to 12kn. The impressive rise in pressure continued as the depression moved away: at 0700 GMT the barometer at Southampton Weather Centre was 23.6mbar higher than at 0400, while at Bedford it had risen 9.3mbar in the previous hour. By 0800 GMT the wind had reached gale force in Lincolnshire (240° 39kn, gusting 52, at Cranwell) but gale force winds were otherwise confined to the North Sea (210° 57kn at a platform at 53.2°N 3.2°E), East Anglia (230° 43kn, gusting 60, at Wattisham; 220° 44kn, gusting 70, at Coltishall), the extreme east coast (230° 35kn at Walton-on-the-Naze and at Manston, the latter with gusts to 60kn), the Channel coast (250° 36kn at Portland RNAS; 270° 35kn at Lee-on-Solent) and in the English Channel proper (320° 50kn at Channel Light Vessel). Over the next four hours the strongest of the winds followed the depression out into the North Sea and by 1200 GMT the strongest winds over land were below gale force (30kn in Norfolk and Lincolnshire, and on the Lancashire coast). In the eastern English Channel and in the North Sea winds still exceeded 40kn (Dowsing Light Vessel 270° 60kn) – but to all intents and purposes 'The Great Storm' was over.

#### HOW RARE WERE THE WINDS?

The highest gusts and associated hourly mean wind speeds known to have occurred within the British Isles are listed in Table 2, while Fig. 10 shows the distribution of the highest gust speeds. The band of strongest gusts with maxima over 100kn in places extended across the Channel from north-west France in a band about 150km wide parallel to the track of the low centre and centred 200km to the south-east.



TABLE 1 Reported 10-minute winds (degrees/kn) and maximum with highest gusts (degrees/kn) where available, at selected stations. Stations with a tick in the 'R/P' column have assessed return periods for mean and gust speeds (see Table 4). *Source:* original synoptic observations as received at the Meteorological Office, Bracknell. Gust data are from anemograph records wherever possible

Station	R/P	Observation hour (GMT)								Max wind	Max gust	Gust time GMT	
		0000	0100	0200	0300	0400	0500	0600	0700				0800
South-west England													
Culdrose		010/32	350/45	330/34	310/31	300/27	290/22	280/20	270/19	270/14	350/45	350/72	0020
Plymouth		160/13	180/12	310/22	290/26	270/25	260/22	250/15	240/17	240/17	290/26	280/45	0230
Exeter		180/25	180/26	180/15	280/22	280/26	280/26	270/20	240/16	240/16	Vs/26	180/55	0002
Bristol W. Ctr		050/12	090/06	190/20	200/08	260/06	280/20	270/24	270/20	260/18	270/24	270/66	0535
Yeovilton		140/10	180/31	170/22	200/12	280/31	260/26	260/25	260/20	230/15	Vs/31	260/61	0357
Central southern England, south coast and Channel Islands													
Portland Bill CG		170/38	180/48	180/45	220/32	270/55	270/50	270/40	260/36	260/30	270/55	270/78	0348
Hurn	✓	170/24	170/33	180/37	180/31	230/23	240/36	250/30	240/20	240/19	180/37	180/61	0140
Southampton W. Ctr		160/17	160/30	150/27	160/32	180/25	230/26	240/21	240/15	240/15	160/32	170/75	0215
St Catherine's Pt		180/28	190/30	210/37	210/38	230/56	240/58	250/45	250/43	250/34	240/58	90	-
Lee-on-Solent		140/35	150/45	150/40	150/65	-	270/70	-	270/50	270/35	270/70	-	-
Channel Lt Vessel		180/55	-	-	270/60	270/70	270/60	320/70	-	320/50	Vs/70	-	-
Jersey	✓	190/46	190/52	230/55	260/50	260/40	270/30	270/26	270/21	240/20	230/55	200/85	0102
Boscombe Down	✓	160/30	170/32	170/36	180/31	220/21	240/35	250/31	240/21	240/18	170/36	170/70	0129
Odiham		170/29	170/30	170/34	180/42	180/48	200/55	230/45	290/38	230/30	200/55	>70	??
South-east England													
Heathrow (SW) <sup>1</sup>	✓	180/23	170/19	190/27	170/38	170/32	200/29	220/39	230/27	230/22	220/39	230/66	0535
Gatwick	✓	170/16	170/16	200/18	180/28	190/31	210/31	230/34	240/25	240/20	230/34	210/86	0430
London W. Ctr	✓	180/23	170/23	190/31	180/44	190/42	190/37	230/40	230/34	230/26	180/44	180/82	0248
Langdon Bay		160/32	150/36	150/22	180/48	180/62	-	-	-	-	180/62	190/94	0448
Mansion	✓	180/26	170/33	170/35	200/35	230/52	200/61	210/51	220/44	230/35	200/61	210/86	0436
Hersmonceux		170/20	170/27	190/43	190/53	200/58	200/60	230/44	230/34	230/34	200/58	200/90	0455
Royal Sovereign		160/40	-	-	180/75	-	-	-	-	-	180/75	-	-
Midland Counties													
Birmingham		060/09	050/07	070/05	170/13	160/07	220/03	280/18	240/19	240/18	240/19	230/36	-
Brize Norton	✓	060/11	180/22	190/23	170/14	220/05	230/14	250/20	240/25	240/22	240/25	190/50	0124
Benson		200/11	170/28	180/30	180/27	180/23	230/22	240/34	240/32	220/24	240/34	170/59	0201

TABLE 1 *Continued.*

Station	R/P	Observation hour (GMT)								Max wind	Max gust	Gust time GMT	
		0000	0100	0200	0300	0400	0500	0600	0700				0800
Eastern England and East Anglia													
Bedford		070/07	120/07	170/26	180/28	180/25	180/21	230/24	250/35	240/30	250/35	250/53	0636 <sup>2</sup>
Wyton		070/02	120/07	160/21	190/23	180/31	180/25	230/23	250/30	240/29	180/31	250/56	0705
Honington		180/20	170/20	160/24	170/30	180/38	180/35	180/40	220/36	230/34	180/40	> 60	??
Watsham	✓	180/22	170/23	160/25	190/29	190/40	190/42	190/42	220/48	230/43	220/48	180/72	0342
Stansted	✓	200/18	190/20	190/25	200/25	210/33	210/34	230/30	260/30	260/30	210/34	240/65	0610
Shoeburyness <sup>3</sup>	✓	180/25	170/23	170/30	190/47	190/54	210/55	220/46	230/36	220/30	210/55	210/87	0443
Marham		160/05	170/20	160/22	170/24	180/40	180/35	190/32	220/31	230/41	230/41	180/63	0416 <sup>4</sup>
Coltishall		180/20	180/23	160/21	160/23	180/36	190/40	190/39	200/40	220/44	220/44	180/71	0407 <sup>5</sup>
Hemby		170/25	190/26	170/22	160/26	190/32	200/45	200/44	200/44	220/41	200/45	190/79	0420
Dowsing Lt Vessel		200/12	-	-	-	180/36	160/26	200/54	180/50	-	200/54	-	-

## NOTES

- Data not available

Vs Various (see preceding columns)

*Estimates are shown in italics*<sup>1</sup> Heathrow: there was a gust of 170° 80 kn at the north-east anemometer site at 0240 GMT<sup>2</sup> Bedford: highest gust equalled at 0650 and 0652 GMT<sup>3</sup> Shoeburyness: data 00-06h from SAWS (Synoptic Automatic Weather Station)<sup>4</sup> Marham: highest gust equalled at 0725 GMT<sup>5</sup> Coltishall: highest gust equalled at 0416, 0426 and at 0618 GMT

At both Odiham and Honington the loss of mains power resulted in the loss of the anemometer record. The highest gust shown is the highest recorded before power was lost



In the region of greatest damage over south-east England (roughly bounded by the 80 kn isotach) maximum gusts occurred between about 0300 and 0600 GMT. Gusts of 70 kn or more were reported for 3–4 consecutive hours during which time the mean wind veered from 180° to 230°: the Shoeburyness anemograph trace (Fig. 9, bottom) is typical of this region. To the north-west there were two maxima in gust speeds separated by a clear minimum in wind strength – the first peak was associated with mean winds from between 170° and 190°, the latter with a direction of around 230°. In the double-peak region, strongest gusts were mostly from southerly directions at around 0200 GMT

TABLE 2 Extreme gust speeds and corresponding hourly mean winds in the British Isles on 16 October 1987. Gust ratios are also given. (The highest gust occurred in the windiest hour at all stations except Gorleston, London W. Ctr, Hemsby, Wattisham and Boscombe Down)

Station	Highest gust	Time GMT	Hourly Mean	Gust Ratio	Notes
Gorleston	— /106	0424	—/66	1.6	Highest hourly mean 68 kn Power lost 0400 to 0740; probable 100 kn gust during hour 04/05 GMT
Shoreham-by-Sea	220°/98	0310 = 0330	220°/74	1.3	
Langdon Bay	190°/94	0448	190°/56	1.7	No record 0320 to 1208 GMT
London, BT Tower†	170°/94	0248	170°/54	1.7	
Sheerness	200°/93	0430	200°/63	1.5	
Headcorn Aero	— /92	0440*	190°/38	2.4	*Between 0435 and 0445. Power lost 0435, not restored until 22nd
Ashford, Kent					
Herstmonceux	200°/90	0455	200°/60	1.5	Power lost from about 0400 to 0630; gust to 83 kn after 0400 GMT
Thorney Island	210°/90	0342	200°/59	1.5	
Shoeburyness	210°/87	0443	230°/56	1.6	Highest hourly mean 180°/42 hour ended 0400; max gust in that hour was 180°/74 at 0325, gust ratio 1.8
Gatwick	210°/86	0430	210°/34	2.5	
Manston	210°/86	0436	210°/58	1.5	
Portland RNAS	260°/86	0318	270°/55	1.6	
Jersey Airport	200°/85	0102	220°/55	1.5	
London W. Ctr†	180°/82	0248	180°/40	2.1	
Guernsey Airport	250°/81	0218	250°/55	1.5	Highest hourly mean 48 kn
Heathrow (NE site)	170°/80	0240	170°/43	1.9	
Hemsby	190°/79	0420	190°/45	1.8	
Middle Wallop	— /78	0122	— /48	1.6	
Portland Bill CG	270°/78	0348	260°/52	1.5	
Southampton W. Ctr	170°/75	0215	170°/30	2.5	
Norwich W. Ctr	— /74	0416	210°/34	2.2	
Amersham	180°/73	0225	180°/36	2.3	Highest hourly mean 220°/46 hour ended 0700; max gust in that hour was 220°/70 at 0622, gust ratio 1.5
Culdrose	350°/72	0020	350°/48	1.5	
Wattisham	180°/72	0342	180°/35	2.1	
Coltishall	180°/71	0407*	190°/44	1.6	
Boscombe Down	170°/70	0129	170°/37	1.9	*Equalled at 0416, 0426 and 0618 GMT Highest hourly mean 39 kn Power lost after 0200, no further record
Odiham	180°/70	0100	170°/40	1.7	

*Estimated values are in italics*

† The British Telecom tower anemometer is located at 195 m above ground level, with an 'effective height' of 174 m; the London Weather Centre anemograph is at 70 m above ground, with an 'effective height' of 38 m

over central southern England to 0400 GMT over East Anglia. Over Dorset and Somerset and north of a line from Bath to Norwich, the west to south-west winds were strongest with maximum gusts at around 0500 GMT in the west and 0800 GMT in the east. A separate area of strong northerly winds affected Cornwall from midnight to about 0200 GMT. The strongest gust over the British Isles was 106 kn at 0424 GMT at Gorleston: two other gusts exceeded 100 kn and over 20 gusts of 90 kn or more were recorded between 0400 and 0715 GMT. Over France, most of the strongest gusts were from the south-west or south-south-west and occurred between midnight and 0100 GMT over southern Brittany, and between 0100 and 0300 GMT further east and north. The extreme north-west of Brittany experienced maximum gusts from the west between 0100 and 0200 GMT. The highest gust reported during the storm was an estimated 119 knots ( $61 \text{ ms}^{-1}$ , 137 mph) at Pointe du Raz ( $48^{\circ}02'N$ ,  $4^{\circ}44'W$ ), a coastguard station west of Quimper in Brittany. The highest measured gust (117 knots) was recorded at 0030 GMT at Pointe du Roc ( $48^{\circ}51'N$   $1^{\circ}37'W$ ), a coastguard lookout at Granville in Normandy. Further north-east over the Low Countries only the coastal strip had gusts greater than 70 kn: again the direction was from south-south-west, and times varied from 0400 to 0500 GMT in Belgium to 1000 GMT in northern Holland.

### *Gust ratios*

Numerous reports of lightning from casual observers have given rise to the speculation that the exceptional gust strengths may be associated with an unusually high

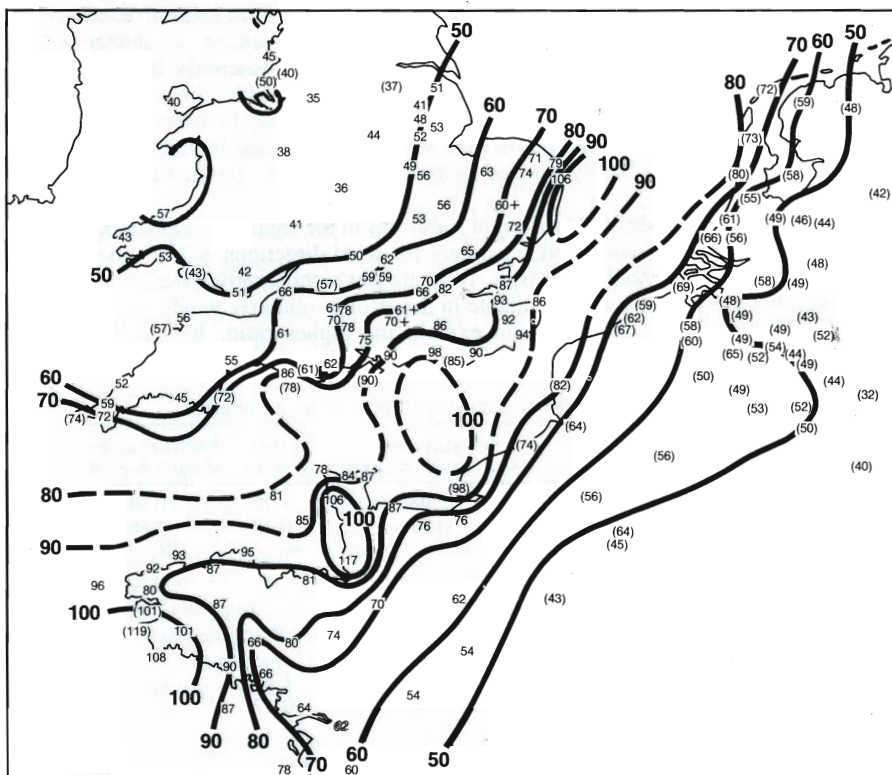


Fig. 10 Highest reported gusts (knots) over southern England and the near continent, 16 October 1987. The data were mostly obtained from anemograph data; those in parentheses are unchecked synoptic messages, or estimated values over France



gust ratio (the ratio of the gust speed to the prevailing mean speed) perhaps due to the presence of deep convection. However, as detailed above there were no reports of thunder except in the north-westerly winds at Aberporth at 0200 GMT, and also at Bristol Weather Centre between 0800 and 0900 GMT. Three stations (Hurn, Honington and Wattisham) reported lightning (at 0100, 0400 and 0500 GMT respectively) but it seems most likely that these flashes were due to power lines colliding in the strong winds. The 2300 GMT Crawley ascent showed a lapse rate close to the moist adiabatic, but just stable, with wet-bulb potential temperature ( $\theta_w$ ) increasing very slowly with height from about 17°C at the surface to 19°C at 300 mbar. This ascent was ahead of the cold front heralding the onset of the really strong winds. The Larkhill ascent at 0600 GMT indicated a possibility of only shallow convection from the surface. Unfortunately there was no sounding in the air behind the cold front and ahead of the bent-back occlusion. A few stations in the south reported showers between 0100 and 0300 GMT but these were not in the region of strongest winds. It therefore seems unlikely that convection played a major role in producing the extreme gusts, except perhaps at Bristol.

Gust ratios for the mean wind and maximum gust over an hour have been calculated for the severe gales of 27 March 1987 which also affected southern England, for 24 March 1986 when strongest gusts of just over 70 kn occurred in a band through south Wales, the south Midlands and East Anglia and for 2 January 1976 when many stations in the south Midlands had their highest recorded gusts. When compared with these values (Table 3), on average the gust ratios for this storm are unexceptional. However, some individual stations did produce very high ratios for the extreme gust (Table 2), notably Bristol Weather Centre (2.9), Southampton (2.5), Gatwick (2.4) and Ashford, Kent (2.4). Southampton and Ashford are non-standard sites. Gust ratios in excess of 2.3 have occurred on several occasions in the past at Gatwick and since a site change in 1983 mean winds have been considered unrealistically low for southerly directions. The Bristol gust was very isolated and may have been associated with convection. All other ratios in excess of 2.0 occurred in areas where such ratios may be expected so that the conclusion remains that the gust ratios were within the expected bounds – i.e. 1.5–2.0 for farmland, 1.7–2.1 for highly wooded areas and outskirts of cities and 1.9–2.3 for city centres.

Because of the possibility of different stabilities in the southerly and south-westerly winds, gust ratios were calculated separately for wind directions  $\leq 200^\circ$  and  $\geq 210^\circ$ . The mean values of 1.88 and 1.72 respectively are just significantly different at the 5 per cent level, but there is no ascent available in the strong southerly winds to enable us to determine if decreased stability could explain the higher ratio. It is perhaps more

TABLE 3 Gust ratios (gust speed/mean speed) for several recent gales

		All gusts for mean speed $\geq 25$ kn	Gusts $\geq 60$ kn	Extreme gusts at each station
16 October 1987	<i>mean</i>	1.68	1.70	1.76
	<i>s.d.</i>	0.23	0.37	0.36
	<i>n</i>	111	46	39
27 March 1987	<i>mean</i>	–	–	1.77
	<i>s.d.</i>	–	–	0.23
	<i>n</i>	–	–	49
24 March 1986	<i>mean</i>	1.70	1.68	1.71
	<i>s.d.</i>	0.16	0.12	0.15
	<i>n</i>	148	25	23
2 January 1976	<i>mean</i>	–	–	1.73
	<i>s.d.</i>	–	–	0.27
	<i>n</i>	–	–	30

*s.d.* standard deviation

*n* number of occurrences

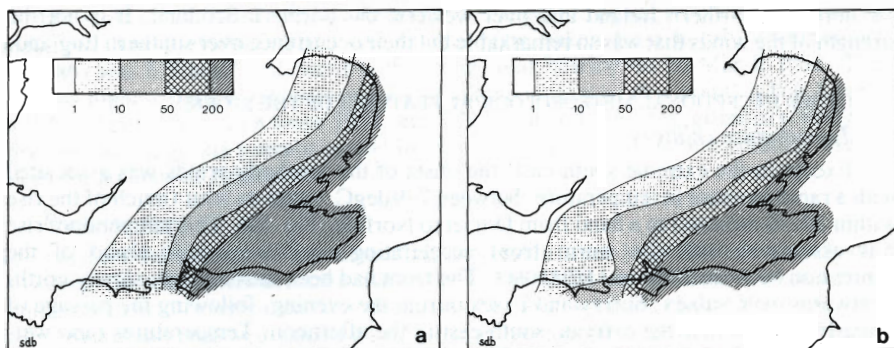


Fig. 11 (a) Approximate return period (years) of the highest hourly mean wind  
(b) Approximate return period (years) of the highest gust

remarkable that the strongest winds did not occur at the surface until after the passage of the cold front. The wind at Crawley at 2300 GMT increased from 14 kn at the surface to 53 kn at 300 m and at Hemsby from 22 kn at the surface to 65 kn at 450 m. Maximum gusts for the hour ending 0000 GMT were around 35 kn over south-east England and it was not until after 0100 that gusts in excess of 50 kn began to be reported. At 0600 GMT the 300 m wind at Crawley was 70 kn, with 89 kn at 800 m. Maximum gusts during this hour were around 70 kn in the area with the surface wind at Crawley given as 42 kn. The staff at the radiosonde station should be congratulated on the successful launch of a pilot balloon ascent under these exceptionally difficult conditions.

#### *Return periods*

Since the gust ratios were not abnormal, the mean wind strengths must have been exceptional and this is confirmed by the return periods: south-east of a line from Norwich through London to Southampton return periods for both the highest hourly mean and maximum gust speed exceed 200 years (Table 4 and Fig. 11). This coincides with the area of maximum gusts greater than 80 kn and greatest damage referred to in the Appendix. It is not necessary to look much further than the return periods for the maximum gusts to explain the extent of damage, but an additional factor may have been that trees were still in full leaf (in contrast to the three other storms noted above)\*. The previous highest gust in the last 50 years inland over southern England and East Anglia when trees were likely to have been in leaf was 70 kn at Boscombe Down on 24 October 1945. Dover recorded 79 kn on 27 October 1959 and 80 kn on 4 November 1957. The storm which produced a 94 kn gust at Jersey on 9 October 1967 did not affect southern England. Officials from the Jersey Meteorological Department reported that the rarity of severe gales from a southerly direction together with funnelling in south-facing valleys on the island were major factors in causing more damage with lower speeds in the recent storm (winds from between 170° and 220° contributed only 3.3 per cent of mean hourly winds in excess of 33 kn at Jersey Airport over the period 1958–87). A brief analysis of the mean wind when gusts exceeded 50 kn at three stations in south-east England showed 21 per cent of directions between 170° and 220°, and thus it seems likely that foliage cover was more important than the wind direction over the mainland: however, the combination of these factors is likely to have a return period even longer than values given above.

It should be borne in mind that north and west of a line from Cornwall to Durham mean winds in excess of 55 kn and gusts in excess of 90 kn can be expected more frequently than once in 50 years, and 100 kn gusts can be expected at this frequency over

\*Quine (this issue) presents evidence that trees being in leaf may not have been as significant a factor in causing the widespread damage as has often been stated. *Editor*



the north of Northern Ireland and over western and northern Scotland. It is not the strength of the winds that was so remarkable but their occurrence over southern England.

#### OTHER EXCEPTIONAL METEOROLOGICAL FEATURES OF THE STORM

##### *Temperature changes*

Except in the extreme south-east, the onset of the southerly winds was associated with a rapid increase in temperature, between 7–9 degC within an hour (much of the rise within 20–30 minutes) in a band from Dorset to Norfolk (Fig. 12). This temperature rise was associated with the warm front accelerating north-westwards ahead of the depression between 2200 and 0200 GMT. The front had been moving only slowly north-westwards over Sussex, Surrey and Essex during the evening, following the passage of an early wave across the extreme south-east in the afternoon. Temperatures (and wet-bulb potential temperatures, since the humidity was close to 100 per cent) were around 17°C in the warm air. However, in the west this temperature rise was very short-lived as a sharp drop in temperature of about 4 degC was evident moving eastwards from Dorset around 0100 GMT to reach Norwich around 0500. This feature has been drawn on Fig. 5 as the cold front, although it is not clear whether this was a true cold front since a fall in dew point but with no marked temperature change preceded the temperature drop by 1–2 hours at many stations. As the humidity returned to close to 100 per cent as the temperature fell, a greater change in  $\theta_w$  was associated with the earlier feature. The change to south-westerly to westerly winds was accompanied by a further temperature drop of typically 4–5 degC in an hour associated with the passage of the bent-back occlusion over southern England, but falls of such magnitude are not uncommon.

TABLE 4 Return period (years) of the highest hourly mean wind speed (kn) and the highest gust (kn) at selected stations, 16 October 1987

Station	First year of period analysed	Highest hourly mean	Return period	Highest gust	Return period
<i>Central southern England, south coast and Channel Islands</i>					
Portland Bill	1970	52	7	78†	18
Hurn	1960	36	6	61	8
Thorney Island	1943 <sup>1</sup>	59*	>200	90*	>200
Jersey	1958	55	10	85	15
Boscombe Down	1933	39	7	70	22
South Farnborough <sup>2</sup>	1971	35*	120	61†	16
<i>South-east England</i>					
Heathrow (SW site)	1959	39*	20	66*	35
Gatwick	1960	34 <sup>3</sup>	4	86*	>200
London W. Ctr	1965	42*	100	82*	120
Manston	1967	58*	>200	86*	>200
<i>Midland Counties</i>					
Brize Norton	1969	26	1	50	1
<i>Eastern England and East Anglia</i>					
Wattisham	1970	46	20	72	10
Stansted	1962	35	12	65	20
Shoeburyness	1926	56*	>200	87*	>200
Coltishall	1968	44	12	71	6
Gorleston	1913 <sup>1</sup>	68*	>200	106*	>200

\* New station extreme during period of record

† Speed has been reached, but not exceeded, during period of record

<sup>1</sup> There are gaps in the records for these stations

<sup>2</sup> Power lost during the storm, maximum values lost

<sup>3</sup> Unrepresentative, because of exposure of anemometer

The rapid temperature rises mentioned above appear to be unprecedented, at least at Heathrow. The previous highest rise in one hour (taken from hourly observations 1949–86) was 6.7degC associated with strong solar heating on 26 March 1953. The previous highest frontal rise (detected by simultaneous rise in dew point) was 6.1degC on 9 October 1951, 16 October 1952 and 7 November 1956. A preliminary study of previous rises suggests a return period in excess of 200 years for a temperature rise of 8degC in an hour at Heathrow.

### Pressure rises

The pressure falls ahead of the advancing depression were large but not remarkable. However, the subsequent pressure rise seems to have been exceptional. A large area of southern England experienced rises in excess of 8 mbar in 1 hour (Table 5 and Fig. 13), with a maximum observed value of 12.2 mbar at Hurn in the hour to 0500 GMT. Higher values than this may have occurred elsewhere but not between exact hours. Machinable hourly surface pressures are not available before 1982 except at Kew and Eskdalemuir (Dumfries and Galloway region) and then only back to 1973, although hourly station level pressures are available at the same stations back to 1957. The previous highest hourly rise in this period was 6.9 mbar at Eskdalemuir on 8 December 1964 and at Kew was 5.4 mbar on 28 January 1961. On 2 January 1976 rises of 6.0 and 6.7 mbar were recorded over successive hours at Eskdalemuir. Analysis of the hourly pressure changes in the recent storm from many stations shows a ratio of about 1.3 between those stations where the maximum rise occurred between hourly reports and those where it occurred close to the hour and so gave two similar (smaller) rises over two hours. Applying this

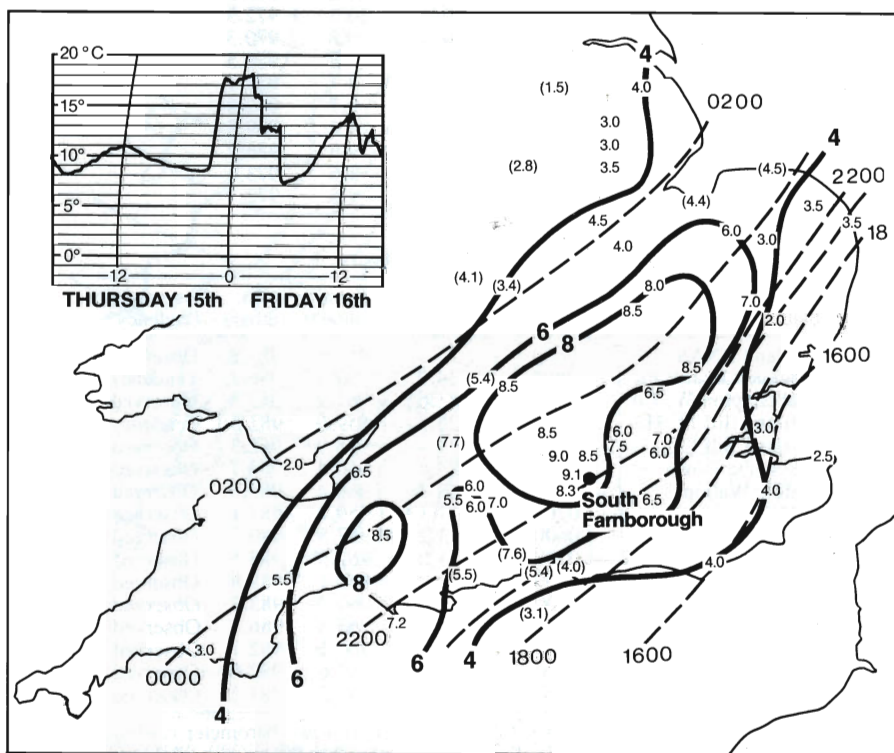


Fig. 12 Magnitude (degC) and time of occurrence (GMT) of temperature rises across the warm front, 15/16 October 1987 (data from thermograph records and synoptic reports). Inset: thermogram from South Farnborough Met. Office, where a rise of 9.1degC occurred in 20 minutes 2140–2200 GMT



ratio to the two values from Eskdalemuir in January 1976 gives an estimated maximum hourly rise of 8.3 mbar. Shaw *et al.* (1976) in referring to this occasion quote a maximum hourly pressure rise of 8.2 mbar at Prestwick. This figure, which is probably the previous highest hourly change over the last 30 years over most of the UK, is only two-thirds that of the maximum value for 16 October 1987. A rough analysis of previous pressure rises at Eskdalemuir gives a return period in excess of 200 years for a rise in excess of 12 mbar within the hour.

The three-hourly change had a maximum observed value of 25.5 mbar at Portland Royal Naval Air Station (Table 5). This value is comfortably in excess of the greatest three-hourly pressure change on record for the British Isles – rise or fall. Burt (1985) found the most rapid three-hour change from an extensive survey of the available

TABLE 5 Maximum observed pressure changes in one- and three-hour periods, 16 October 1987

(a) *Rises over one hour*

Station	Ending at time (GMT)	Rise (mbar)	Observed pressure (mbar)
Hurn	0500	12.2	974.7
Southampton W. Ctr	0500	11.0	972.9
South Farnborough	0600	11.0	977.7
Exeter	0400	10.6	971.8
Portland Bill CG	0500	10.3	975.9
Benson	0600	10.2	973.3
Brize Norton	0600	10.1	972.3
Bristol W. Ctr	0500	9.8	970.3
Marham	0800	9.8	976.5
Middle Wallop	0500	9.7	970.1
Netheravon	0600	9.7	977.8
Boscombe Down	0500	9.6	969.9
Portland RNAS	0500	9.6	976.7
Northolt	0600	9.6	973.4
Heathrow	0600	9.6	972.7

(b) *Rises over three hours*

Station	Ending at time (GMT)	Rise (mbar)	From (mbar)	To (mbar)	Observed or Tendency*
Portland RNAS	0600	25.5	957.8	983.3	Observed
Bracknell/Beaufort Pk	0800	24.0	962.5	986.5	Tendency
Southampton W. Ctr	0700	23.6	961.9	985.5	Observed
Portland Bill Lt. Ho.	0600	23.5	959.0	982.5	Tendency
Portland Bill CG	0600	23.4	958.9	982.3	Observed
Boscombe Down	0700	23.4	960.3	983.7	Observed
Middle Wallop	0700	23.4	960.4	983.8	Observed
Netheravon	0700	23.3	959.8	983.1	Observed
Yeovilton	0600	23.2	957.5	980.7	Observed
Hurn <sup>1</sup>	0700	23.0	962.5	985.5	Observed
Heathrow	0800	22.7	963.1	985.8	Observed
South Farnborough	0700	22.6	960.7	983.3	Observed
Northolt	0800	22.3	963.8	986.1	Observed
Bristol W. Ctr	0700	22.2	960.5	982.7	Observed
Plymouth	0500	22.0	960.6	982.6	Observed
Exeter	0600	22.0	961.2	983.2	Observed

\* *Observed* indicates an observed difference between two barometer readings (corrected as appropriate); *Tendency* indicates that the amount of the rise was read from a barograph trace (the reported 'pressure tendency') and may be subject to some instrumental error. The 'observed' value has been substituted wherever possible

<sup>1</sup> Hurn also reported a rise of 22.5 mbar from 0300 to 0600 GMT

literature and computerised synoptic archives to be a fall of 23.5 mbar at Valentia on 22 October 1961; the most rapid rise was one of 21.6 mbar at Lerwick on 15 January 1952 (the latter including 10.9 mbar in one hour). The pressure rose 9 mbar in 30 minutes at Valentia on 17–18 October 1984 (although the largest rise between hourly reports was 7 mbar). A very rough analysis suggests a return period of about 150 years for a 20 mbar rise in three hours at Lerwick and almost certainly much longer over south-east England.

#### WHAT CAN WE LEARN FROM THE STORM?

There are few events that it is impossible to derive some good from – there is truth in the apt saying “it’s an ill wind that blows no good”. There are examples of this in the sudden glut of normally rare timbers that became available from places such as Kew Gardens and the various arboreta in southern England – although, sadly, the virtues of ensuring 4 m lengths rather than logs were often not appreciated in time. Equally, there are lessons that we can learn from the event.

• It has been a long time since there was such a severe gale in southern England, and many trees have grown beyond what might have been expected in a less benign period. At the same time planning and conservation laws have resulted in the over-zealous conservation of many trees which have outgrown their abilities to cope with the increased weight. Many housing estates have, quite rightly, been built about established trees but the trees themselves have been damaged, and weakened, in the process. It should come as no surprise that many ‘listed’ trees were victims of the storm. Perhaps,

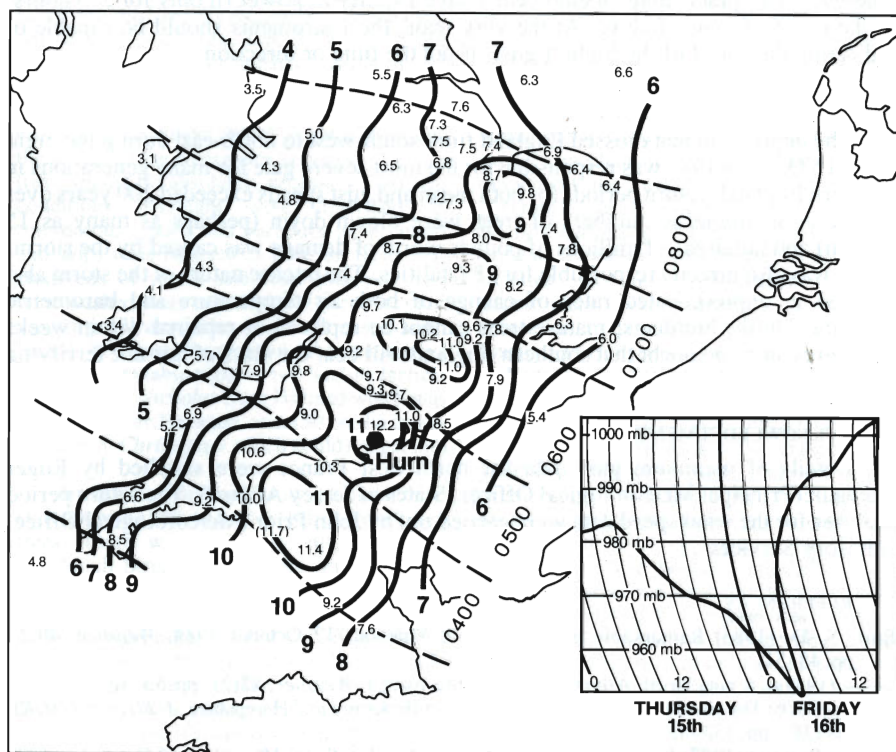


Fig. 13 Magnitude (mbar) and approximate time of occurrence (GMT) of maximum one-hour rise in barometric pressure, 16 October 1987 (data from synoptic reports). Inset: barogram from Hurn Met. Office, where a rise of 12.2 mbar occurred between 0400 and 0500 GMT. (The barograph trace was recording 3–5 mbar too low; the lowest recorded pressure was 958.8 mbar at the 0300 observation)



if judicious pruning on objective professional advice had been allowed to correct top-heavy imbalances, some of those trees might still be standing today. After all, gales are only nature's way of correcting those imbalances.

- Four of the 18 people killed died as a direct result of the failure of chimney-pots (see Appendix). The wind forces became too strong for these perilously-exposed structures, many weighing several tonnes, which then crashed through the minimal resistance of roofs onto the occupants (normally in upstairs bedrooms). Two of the fatalities occurred in hotels. It ought to be possible for the chimney structures to be regularly inspected by the local authorities at, say, an annual inspection of the hotel premises. Statutory powers should be provided to enable the authority to refuse a hotel license unless specified repairs or strengthening (or even the removal of the chimney-stack) were provided within a specified period, for much the same reasons as we would expect a hotel that did not comply with fire regulations to be closed down.

- There were widespread failures of mains electrical power during the storm – at one stage, almost the whole of south-east England from the Hampshire coast through London to Ipswich was in darkness for the first time since the Second World War. The extent of the power cuts was huge but the interruptions to power supplies were not, in themselves, too surprising considering the conditions. What is surprising, and disappointing, is that so many anemometer records should be absolutely dependent upon mains power, with the consequent loss of irreplaceable data representing new extremes at several sites. It is precisely when conditions are at their worst, when power is most likely to be interrupted, that these records are most valuable. Meteorological Office sites should ensure that, wherever at all practicable, anemometers have a source of power (if only for 2–3 hours) in the event of mains failure. At the very least, the instruments should be capable of indicating the speed of the highest gust, if not the time or direction.

#### SUMMARY

The depression that crossed England from south-west to north-east during the night of 15/16 October 1987 was responsible for the most severe gale for many generations in southern England: return periods for both mean and gust speeds exceeded 200 years over a wide area. Immense numbers of trees were blown down (perhaps as many as 15 million) and hundreds of millions of pounds worth of damage was caused by the storm, which was also directly responsible for 18 fatalities. The intense nature of the storm also resulted in unprecedented rates of change of both air temperature and barometric pressure. Unlike buildings, mature trees cannot be replaced or repaired within weeks and there can be no doubt that southern England will bear the scars of this one terrifying night for generations to come.

#### ACKNOWLEDGEMENTS

Details of maximum gust data for north-west France were supplied by Roger Thebault (Principal Meteorological Officer, States of Jersey Airport). The return period analyses for the wind speed data were carried out by John Prior (Meteorological Office, Advisory Services).

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## Appendix

### STORM DAMAGE

Examining the meteorological significance of such a storm is only part of the story: the damage that resulted from the gale, of a severity only very rarely experienced in southern England, also deserves to be put on record. The damage assessment presented here was gleaned primarily from the media in the days following the storm – *The Times*, the *Daily Telegraph*, *Today* and the *Daily Express* were amongst those newspapers that carried extensive coverage of the storm, including many impressive photographs.

This section attempts to parcel the events into the effects of the storm upon transport, utility services, the landscape and upon the 25 million people affected.

#### *Transport*

The storm carved a swathe of destruction from the tip of Cornwall across southern England and East Anglia right up to Lincolnshire. Literally thousands of roads, and dozens of railway lines, were blocked by fallen trees and debris, and much of southern and south-eastern England was brought to a halt for the best part of a day. Schools, shops and businesses remained closed as people heeded the advice of the emergency services – “Don’t travel unless it’s absolutely necessary”. At sea, conditions overnight were described as ‘murderous’: ports and harbours were closed and ships were battered as they ran for cover. Hundreds of yachts and other pleasure craft were washed away or pounded to pieces at their moorings all along the south and east coasts. Nearly 800 passengers spent what must have been an unenviable night on two Sealink ferries, 650 on the *St Nicholas* from Holland which was unable to enter Harwich, and 150 on the cross-Channel *St Christopher* which could not get into Dover.

British Rail suffered badly, as much from staff not being able to get to work as from fallen trees. There was no service into or out of Fenchurch Street or Liverpool Street (British Rail Eastern Region) on 16 or 17 October: on a 5 km stretch between Romford and Upminster there were 20 fallen trees and 1500 metres of overhead wires brought down. In all, there were power supply problems at 160 places. Barriers had been blown away from ten level crossings in the Colchester area. Almost no trains were running on Southern Region or Network SouthEast lines during the morning: at one time there were 90 trees down across a 5 km length of railway between Haywards Heath and Balcombe (West Sussex). On Friday night, from Charing Cross trains were running only as

far as Kidbrooke and Orpington: from Victoria and London Bridge lines to the south coast were open only as far as Purley. London Midland Region had no trains running south of Rugby during the morning. Western Region escaped relatively lightly, and after initial problems were able to run a near-normal service. For those drivers who ventured onto the road, the elevated section of the M4 motorway in western London was closed at one stage during the morning because of the high winds. Sections of the M25 London Orbital Motorway were closed due to debris on the carriageways: the M23 remained closed for two days. More than a hundred flights were cancelled from Heathrow and Gatwick airports.

#### *Electricity and telephone services*

Almost the whole of south-east England (including much of London) was without power between about 0300 and 0930 GMT: London was blacked out for the first time since the Blitz. Problems started before 0300 in southern England as cables began to crash into each other, trees fell onto power lines and wind-borne debris caused short-circuits, disrupting safety mechanisms. A domino effect throughout the region caused alarms to be generated at the Central Electricity Generating Board’s national grid control centre in south London. Engineers were forced to disconnect supplies to safeguard substations and transformers: very shortly afterwards a succession of power stations in the Thames estuary and Dungeness A nuclear power station in Kent were taken out of service after they were cut off from the grid by transmission failures. The cross-Channel link also ceased to function. After 0430 GMT the stations were gradually brought back ‘on-line’ after engineers had switched power from northern plants – a shut-down power station itself needs electricity to start up again – but London continued to lose power as the 275 kV and 400 kV transmission lines continued to trip out until the wind died down: power was restored to most of the capital by mid-morning. Army helicopters were drafted in to aid identification of fallen power lines. Urgent warnings were put out to the public to beware of unattended live cables. Hundreds of thousands of homes were still without power on Friday night: even two weeks later some 2000 homes were still without electricity. Telephone services were also affected, but since more of the supply lines are underground, effects were less and most lines were soon back in working order.



### *Effects upon the landscape*

Cottages and cathedrals, city parks and country estates all suffered in the storm. Over southern England more trees were lost in one night than in a decade of Dutch Elm Disease. All over southern and eastern England, parks were devastated, forests flattened, historic gardens rendered unrecognisable and familiar landmarks disappeared. Trees that had grown up over generations were felled within a couple of hours. Kew Gardens was badly affected with one-third of its trees down: some had stood for hundreds of years. A number of buildings were also damaged. Ian Beyer, deputy curator, was quoted in *The Times* as saying "This is the worst day in the entire history of Kew. It is impossible to put any kind of financial estimate on the damage; literally hundreds of trees, many of them 200 years old, have been devastated". Others spoke of lifetimes of work wasted in a few hours. A spokeswoman said "The face of the gardens will never be the same again. The whole landscape will have to be re-shaped". Many of the 500-plus trees brought down were of great scientific or historical interest: oaks planted by Queen Charlotte 200 years ago were felled, as was a rare black walnut planted by Queen Elizabeth in 1959. Kew's only specimen of *Ulmus villosa*, a huge and promising elm resistant to Dutch Elm disease, did not survive the night. Dozens of poplars, limes and mulberries were blown down. All 100-year old turkey oaks around the Palm House were felled. Much of the palm collection was not expected to survive after a large plane tree crashed through the roof of the temporary palm house, smashing glass and letting in killing cold air (perhaps fortunately, the main building was being repaired at the time and there was no glass in the framework). The gardens remained closed for 12 days until emergency safety work was complete, but it was estimated that clearing-up would take most of the winter (for an article on the future of Kew's shattered landscapes, see Mabey (1987)). At the Royal Botanical Gardens second site, Wakehurst Place near East Grinstead in Sussex, 50 per cent of the collection was lost. Hundreds of rare butterflies, birds and insects escaped when a large tree crashed through the roof of the London Butterfly House at Syon Park; many were tropical or sub-tropical species and were not expected to survive for more than a few hours. London's Royal Parks together lost some 5000 trees; Hampton Court and Bushey Park accounted for 1000, 150-200 in Kensington Gardens and 200 mature trees were blown down in Hyde Park. The superintendent at Hyde Park said, "It's going to be another 100 years before Hyde Park looks as it did on Thursday". A similar story of

destruction was evident on the Embankment and at the Tower of London, where many plane trees were blown down. The Tower remained closed for the first full day since 1945 because of the danger from unsafe trees. Hampstead Heath was badly affected. The situation in London was said to be particularly grave since many of the capital's trees were mature with few younger trees to replace them. The National Trust launched an appeal for funds to replace trees after huge losses at 11 major properties; one report spoke of 750000 trees uprooted or badly damaged on Trust property alone. Worst hit was Scotney House in Kent where 80 per cent of the trees in the garden were blown down. In Norfolk, Blickling Hall lost several hundred exotic and indigenous trees for which the garden was famous, and at Clandon House in Surrey a double avenue of trees up to the house was felled. At Cliveden in Buckinghamshire the garden walls were crushed by toppling trees, while the house itself was damaged by falling scaffolding. Petworth in Sussex used to boast six 'champion' trees, the tallest of their kind in the country - a sweet chestnut, a sycamore, a Catalpa, a magnolia kobus, an oriental beech and a birch *albosinensis septentrionalis*. On that Friday morning, only the beech remained: the others were amongst the 613 casualties of the storm at Petworth. The sweet chestnut (probably 255 years old) was 40m high, the tallest chestnut tree recorded since the species was introduced by the Romans 2000 years ago.

In Windsor Great Park, there was a fallen tree every 200 metres in the Long Walk. Woodland beyond Windsor looked 'as if a giant comb had been run haphazardly through the trees'. The damage to trees was worst amongst those with shallow roots and amongst older, top-heavy deciduous trees (oak and beech in particular) but was often surprisingly variable within short distances - from only a missing branch or two to near-total destruction.

### *Effects upon the population*

As far as is known, 18 people lost their lives as a result of the storm. Many millions were terrified by the combination of unexpectedly strong winds, structural damage and power failures. Some of the more significant events of the storm are listed below, on a county basis.

Three fishing boats sank at Topsham in Devon. Three Royal Navy airmen were rescued from the sea off Porthleven, Cornwall, after their Wessex helicopter was forced to ditch during an exercise. In the Channel Islands, hundreds of greenhouses on Guernsey were flattened by the wind, and a large quantity of crops destroyed. On Jersey all 29 schools



## PHOTOGRAPHS FROM SURREY



Photos by courtesy of Heather Angel, FBIPP, FRPS

*(Upper) Some of the fallen beech trees which blocked the Hog's Back road (A.31) between Guildford and Farnham for two days after the storm*  
*(Lower) Blue spruce (Picea pungens glauca) at the Royal Horticultural Gardens, Wisley, beheaded by the storm*



## PHOTOGRAPHS FROM ESSEX



Photos by M. Doherty\*

*(Upper) Damage to a house, particularly to its windows, in Cliff Parade, Leigh-on-Sea*  
*(Lower) Masonry from a damaged church in Southend-on-Sea fell on a parked taxi*

\* The LYNN TAIT GALLERY (85a Chalkwell Esplanade, Westcliff-on-Sea, SS0 8JJ) specialises in coloured postcards reflecting the history of the area around Southend-on-Sea: Series 15, comprising 12 postcards, from which two are reproduced here, were quickly printed to present details of the storm damage.



remained closed. The first fatalities of the storm occurred in **Dorset**, when two firemen died as a 25m oak tree crashed onto their tender as they returned from an emergency call at Highcliffe. Seventy-two children had to be evacuated from a caravan site on the coast after fears of their safety, and the Weymouth lifeboat, with support from the destroyer *Birmingham*, rescued six people from a catamaran off Portland. In **Wiltshire** a man was killed on the Amesbury to Salisbury road when his car hit a fallen tree. The coastal ship *Union Mars* was badly damaged off the **Isle of Wight**: two lifeboats stood by to attend, because it was felt that conditions were too severe for a single boat. A 200-metre section of 98-year old Shanklin Pier, including the pier-end amusement arcade, was washed away in the storm. About half of the schools on the Island suffered structural damage. The Island was cut off from the mainland until lunchtime.

Troops based in **Hampshire** were called out to clear roads and railway lines of fallen trees and abandoned vehicles. A block of flats at Fareham collapsed, trapping the residents. Regional television and radio stations were blacked out as transmitter masts were damaged. A man died when his car was hit by a falling tree at Nursted, on the Chichester to Petersfield road. In Portsmouth there was damage to both the Anglican and Roman Catholic cathedrals. Caravan parks paid dearly for an uninterrupted view of the sea: one at Hayling Island was totally wrecked. Most schools in **Berkshire** remained closed, some for several days. A woman was killed when a chimney fell through the roof of a hotel in Windsor. Most roads in **Surrey** were closed: it was 16 days after the storm before the last tree had been cleared from minor roads in the Mole Valley district. A guest in a hotel at Horley had a lucky escape when a 25m lime tree crashed through the roof, flattening the spare bed in his room. Four people died as a result of the storm in **West** and **East Sussex**. An elderly man was killed when a chimney-stack smashed through the roof and four floors of a hotel in Hastings: a fisherman died when struck by a beach hut swept up by the gale, also in Hastings; a pensioner died at Rottingdean while trying to repair storm damage to his garage; and in Hove a woman was killed as a chimney-stack fell through her roof. Sea defences were breached in several areas, resulting in cliff slides: the harbour walls at Hastings and Rye suffered damage. Twenty residents of a block of flats in Brighton were evacuated when the building began to collapse. Also in Brighton, a minaret weighing three tonnes from the newly-restored Music Room in the Royal Pavilion caused tens of thousands of pounds worth of damage as it crashed through the roof. A spokesman for the West Sussex

National Farmers Union stated that millions of pounds worth of damage had been caused to the horticultural industry, much of it in the thousands of square metres of glasshouses flattened between Worthing and Chichester. Chichester Cathedral suffered considerable damage when one of the pinnacles on the cathedral's tower was dislodged by the wind and fell through the roof. Several stained-glass windows along the 900-year old building's west side were also blown in. At Selsey, more than 100 people were evacuated from a caravan site just before the caravans were overturned and wrecked in the wind, while at Shoreham Airport 27 aircraft were damaged, many of them written off. All 280 schools in East Sussex were closed: more than 50 suffered severe structural damage.

In **Kent**, Dover (Britain's busiest port) was closed for the first time ever in peacetime. Two seamen were lost when the bulk carrier *Sumneo* capsized just outside Dover harbour; four others were rescued by Dover lifeboat. Twenty-two crew members had to be rescued by breeches-buoy from the Sealink ferry *Hengist* which ran aground off Folkestone. There were three other fatalities in the county as a result of the storm: a woman died in Walderslade, near Chatham, as a tree crashed through the roof of her home, a motorist died when his car hit a tree on Detling Hill, Maidstone and a man was killed when a house collapsed at Biddenden after two chimney-stacks had crashed through the roof. Almost 90 per cent of all the county's roads were impassable, including a major section of the A2 from Strood to Dartford, and all 700 schools were shut. A row of cottages was blown down at Tyler's Hill, near Canterbury, and a caravan was blown 30 metres at Chatham. Two leopards escaped from a zoo near Canterbury; one was recaptured immediately, the other returned (thinner and hungrier) of its own accord a few days later. Six of the seven oak trees that gave their name to Sevenoaks were blown down (see p. 66), and dozens of hectares of orchards were destroyed during the night.

The **London** Fire Brigade alone dealt with a record 6000 emergency calls in 24 hours (two-thirds of those between 8 a.m. and noon, one per second at the peak). This was nearly twice their previous highest daily value (a normal day averages only 350 calls). Commuters faced (or, in many cases, wisely chose to avoid) a difficult struggle to work, with most of the Underground out of action, buses delayed by fallen trees or dangerous buildings and little or no rail services. A man died, and his family were seriously injured, when their car was hit by a tree in Croydon. The Stock Exchange suspended trading for the first time since 1974 because of power and telephone outages and a



lack of staff. The Bank of England and many of the clearing banks also remained closed. A vagrant was killed by a falling wall in Lincoln Inn's Fields. In Kennington over 200 people had to be evacuated from a 18-storey block of flats after exterior walls were stripped from the 14th floor by the force of the wind. Parts of St Bartholomew's Hospital, a Grade I listed building, were damaged by falling plane trees. Several shops in Oxford Street were damaged: Selfridge's lost several plate glass windows. Windows were broken at the top of St Paul's Cathedral, causing glass to fall 85 metres to the floor beneath the dome.

A prison ship with about 50 people on board broke free from its moorings at Harwich in Essex and drifted helplessly for two hours, almost running aground in the Stour estuary. Troops were called in to help at a mobile home site near Clacton, where 110 caravans had been blown over. Near Chelmsford, 17000 birds were killed or injured when a poultry farm lost its roof during the storm. In Suffolk Lowestoft's dock had to be cleared when a vessel carrying explosives began to sink, while Felixstowe was closed for some time after a barge sank at the mouth of the River Orwell, blocking the main shipping channel into the port. All 360 schools in the county were closed; 30 were damaged by falling trees. A man died on the A10 near King's Lynn in Norfolk after

crashing into an articulated lorry while swerving to avoid a fallen tree. Perhaps the luckiest escape of all occurred in the southern North Sea, some 65 km off the Norfolk coast. A major alert was triggered in the area after the *Smit Lloyd One*, a semi-submersible diving vessel, lost all power and steering and began to endanger oil and gas rigs in the area. The 79 crew and six divers, four undergoing decompression, remained on board as rescue vessels braved mountainous seas to keep the vessel from two rigs: forty crewmen had to be evacuated by helicopter from one. Norfolk coastguards said that "A most terrible accident could have resulted". Finally, on the other side of the country, a motorcyclist was killed when a gust swept him into the central reservation on the M62 at Prescott in Merseyside.

#### *And on the Continent . . .*

Four people were killed, and at least 15 injured, in France. At Caen, the bell tower of the famous Abbaye des Hommes (built in 1066) was blown down, crushing four cars below. Fire services were called out to attend 5300 emergencies in 18 hours in three areas on the Channel coast. Severe damage was caused to buildings in several parts of Brittany, and a number of sailing boats broke their moorings. A number of ships were reported in trouble but none was lost.

## **DAMAGE TO TREES AND WOODLANDS IN THE STORM OF 15-16 OCTOBER 1987**

By C. P. QUINE

*Forestry Commission, Northern Research Station, Roslin*

**T**HE storm of 15-16 October 1987 caused widespread damage to woodland and non-woodland trees in the south-east corner of England. Trees of great scientific and aesthetic value were blown over or broken as strong winds crossed an area rich in botanic gardens, stately homes and scientific collections. Damage to trees in collections such as Kew, Wakehurst, Ventnor and Bedebury was severe. Orchards, particularly in Kent and Essex, were also devastated. Public appeals have been launched by, for example, Kew and the National Trust to assist in repairing the damage, and the Government has introduced special replanting grants for fruit growers.

Large areas of productive woodlands, valued for their timber production and contribution to the landscape, were also seriously affected. Preliminary figures produced by the Forestry Commission and the specially convened Forest Windblow Action Committee, indicate the scale of the destruction as outlined in Table 1. These windblown trees represent a significant proportion of the growing stock in the affected counties (Table 2) and the volume of timber is considerable even in national terms. Approximately 15 million trees are believed to have been blown over during the storm. The volume of coniferous wood involved is equivalent to around 5 months total UK

production, while the broadleaved timber represents approximately 2 years UK production.

TABLE 1 Approximate volumes of windthrown timber (in thousands m<sup>3</sup>)

	Suffolk	Essex	Kent	East Sussex	West Sussex	Surrey	Hampshire	Other	Total
Woodland conifers	510	10	230	380	350	110	90	230	1910
Woodland broadleaves	200	90	310	360	450	160	110	150	1830
Non-woodland (conifers and broadleaves)	30	10	20	10	30	20	10	40	170
Total	740	110	560	750	830	290	210	420	
Grand total									3910

TABLE 2 Approximate percentage of original standing volume blown down

	Suffolk	Essex	Kent	E. Sussex	W. Sussex	Surrey	Hampshire
Woodland	13	4	18	24	19	6	2
Non-woodland	3	2	4	6	5	3	2

Destruction of woodlands on a lesser though equally dramatic scale has occurred in Britain on three other occasions since 1945. Foresters term these as 'catastrophic' events – a definition dependent upon the coincidence of strong winds and heavily forested areas rather than related to a particular windspeed. Table 3 lists their salient features and Fig. 1 shows their location and representative wind records.

TABLE 3 Summary of catastrophic wind damage to British forests since 1945

Date	Region	Volume (in millions m <sup>3</sup> )		
		Conifers	Broadleaves	Total
31 January 1953	North-east Scotland	1.53	0.27	1.80
15 January 1968	Central Scotland	1.53	0.11	1.64
2/3 January 1976	Mid-Wales, Midlands and East Anglia	0.93	0.03	0.96
15/16 October 1987	South-east England	1.93	1.98	3.91

On each occasion the widespread damage was associated with winds gusting in excess of 80 knots, but undoubtedly the duration of the event and frequency of the high gusts had an important role.

The volume of timber thrown in the last storm is considerably greater than that of previous events, and the proportion of broadleaved timber is dramatically different. Although it is tempting to ascribe the latter in particular to the fact that many broadleaved trees were still in leaf, it is important to be aware of the differences in woodland character between the affected regions. The comparison is most readily made between the 1953 and 1987 storms using data from Forestry Commission censuses of woodlands in 1947–49 and 1979–82 (Forestry Commission 1952; Locke 1987). Effects of woodland age distribution are masked by the differences in species composition and by the format of available data. The data on woodland composition in Table 4 has been derived in each case from the four counties most seriously affected – in 1953 these were Aberdeen, Banff, Kincardine and Moray, and in 1987 these were West Sussex, East Sussex, Kent and Suffolk.