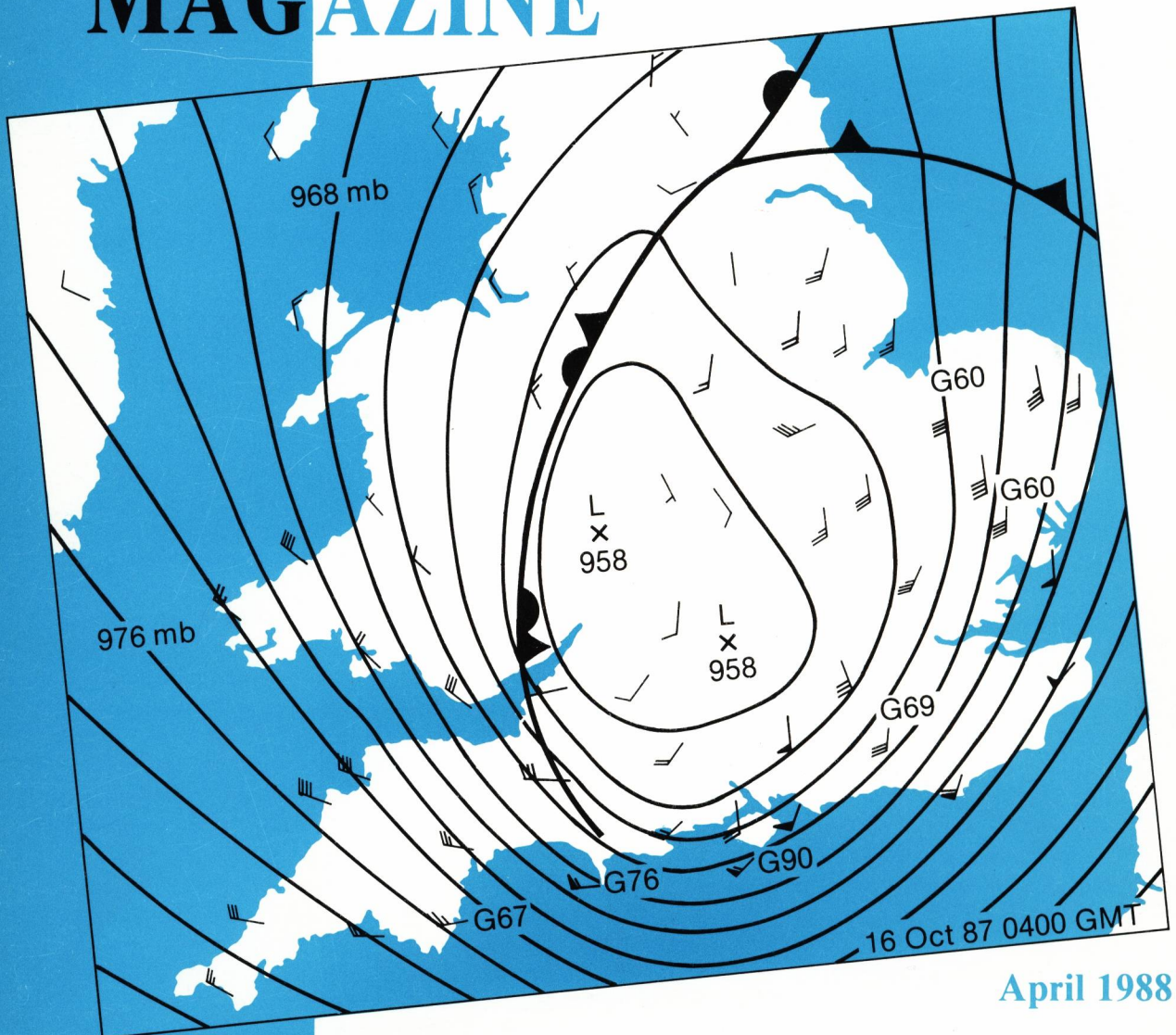


Report on the storm of 15/16 October 1987

THE METEOROLOGICAL MAGAZINE



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The Meteorological Office report on the storm of 15/16 October 1987

On the 15/16 October 1987 a severe storm crossed the southern part of England and Wales, and caused much damage and disruption. In the press and media there were some criticisms of the forecasts and warnings issued by the Meteorological Office; consequently the Director-General of the Meteorological Office, Dr J.T. Houghton, set up an internal enquiry. The Secretary of State for Defence, Mr G. Younger, decided that Sir Peter Swinnerton-Dyer (Chairman of the Meteorological Committee) and Prof. R.P. Pearce (University of Reading) should consider the findings of the enquiry and report their conclusions to him. The executive summary of the report prepared by the Office is given below, and this is followed by shortened versions of the papers which appear in the report.

Executive summary

1. The situation leading to the storm of 15/16 October 1987 has been studied in considerable detail. It is clear that several discrete low centres ran north-east over Biscay before the arrival of the final low which developed into the major storm centre. Statistically the falls of pressure in front of the storm were not unusual, but the rise in pressure behind the front was exceptional, with rises of over 20 mb in three hours in places. The belt of southerly gales over land was also exceptional for the south-east in October with expected return periods of over 100 years in some areas.

2. The output from a number of relevant Numerical Weather Prediction (NWP) models was available to the Senior Forecaster in the Central Forecasting Office in Bracknell. Useful NWP guidance was given in the medium range (3–6 days) but as the time before midnight on 15/16 October became shorter the various models gave diverging guidance. The 36-hour forecasts from the European Centre for Medium-range Weather Forecasts (ECMWF), the United States and the UK global coarse-mesh model, and the equivalent 24-hour UK fine-mesh forecast, differed substantially; consequently the Senior Forecasters' guidance depended upon a compromise based on his subjective experience. In the event the emphasis was incorrectly placed on the rain and flooding problems rather than on the possibility of severe gales overland. Thus, although the guidance in the Synoptic Reviews did include gale warnings for exposed parts of southern and eastern England, the main area of severe gales was forecast for the Channel and the southern North Sea and the extreme south-east.

3. In the scientific investigations that have been carried out in the Meteorological Office following the storm, the main problems of interpretation have arisen from the paucity of data coverage, especially over the ocean areas to the south and west of the United Kingdom. The observations available during 15 October left the actual position of the storm uncertain and fell far short of providing an adequate description of the atmospheric structure in its vicinity. The prerequisites for a really accurate prediction were therefore absent. Although the general synoptic situation at the time of the storm showed conditions that strongly favoured cyclonic development, no features have been identified which would have enabled the quite exceptional character of the storm to be recognized at an early stage. Further, it was the lack of the inclusion of certain observations, which were not available at the time of the run of the fine-mesh model following 0000 GMT on 15 October, that caused that model's prediction to differ from that deduced from the run of the global model following closely after that of the fine-mesh model. The reasons for the poor predictions 12 hours in advance from the numerical model runs at 1200 GMT on 15 October have been more difficult to establish. Nevertheless, by introducing features of numerical forecasting systems at an advanced stage of development in the Meteorological Office, it has been possible to obtain good predictions of the track and intensity of the storm by selecting values of the adjustable parameters beginning from 0000, 0600 and 1200 GMT on 15 October.

4. The forecasts and warnings concerning the storm given to the public via the media began the previous Sunday (11 October) when the summary chart of the week's weather on the BBC 1 TV programme 'Weather for farmers' included a caption 'becoming very windy late in the week'. On Thursday 15 October from 0630 GMT the shipping forecasts for the Channel and southern North Sea included gale and severe gale warnings. Further warnings of severe weather were given to various authorities from 1730 GMT that evening culminating in a general FLASH message of severe gales at 0120 GMT on 16 October. Customers who could take immediate action on receipt of a warning during the night (e.g. civil and military aviation) received sufficient notice to minimize any damage that might have been sustained in severe storm conditions. Although strong winds were mentioned especially for the coastal regions in the south and south-east, the media forecasts on Thursday 15 October emphasized the rain predictions rather than the wind. No forecasts issued by the French, Belgian and Dutch weather services covered the United Kingdom; they were in line with the UK predictions as far as the Channel and the European mainland were concerned.

5. The reaction of the media in the period following the storm mostly centred on the question 'Why weren't we warned?' Press articles, based on a mistaken interpretation of remarks made to journalists both in the United Kingdom and abroad, were highly critical because they believed incorrectly that other forecasting services 'had got it right'. The TV weathermen (and the Director-General of the Meteorological Office) were put in the spotlight over the weekend, and it was only after the Press Conference given by the Director-General and his Directors on the Monday following the storm that this view subsided, giving way to the more soundly based realization that the damage to trees and property could not have been avoided however accurate the forecasts might have been. Some of the press confusion revolved around the use of the word 'hurricane' (meteorologically a 'hurricane' is a tropical revolving cyclone); the use of the word by one of the TV weathermen was particularly unfortunate, since it was picked up and exploited by the media as part of their criticisms.

Summary of weather pattern developments of the storm of 15/16 October 1987

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Summary

A descriptive account is given of the development of the storm of 15/16 October 1987, incorporating analyses of the surface pressure pattern prepared 'after the event' using all available data. The analyses reveal a complex evolution with a series of relatively innocuous low centres running north-eastwards across Biscay before the arrival of the final low which developed into the major storm

1. Introduction

The sequence of developments of the storm of 15/16 October 1987 will be described by a series of mean-sea-level pressure analyses. These analyses have been constructed using all sources of information, some of which were not available to the forecasters at the time — they will be referred to as the finalized analyses. The operational mean-sea-level pressure analyses produced by the Central Forecasting Office (CFO), that is those charts drawn within 3 hours of the time of origin of the data, constitute a second series of charts which will be referred to where significant differences are apparent when compared to the finalized analyses.

2. 0000–0600 GMT on 15 October

Fig. 1, which is almost identical with the CFO operational analysis, shows a complex area of low pressure at 0000 GMT on 15 October extending over several hundred miles to the west of Corunna. There were few ship reports to fix the details of the pressure pattern precisely; the analysis therefore depended heavily on the Meteosat imagery and a single ship report giving a northerly wind near 44° N, 13° W.

The Meteosat imagery indicated rapid eastward movement of the main cloud features during the next 6 hours. The finalized surface analysis for 0600 GMT (Fig. 2(a)) shows the forward low centre near Bordeaux (having degenerated into a minor feature) with a more substantial centre just to the north-

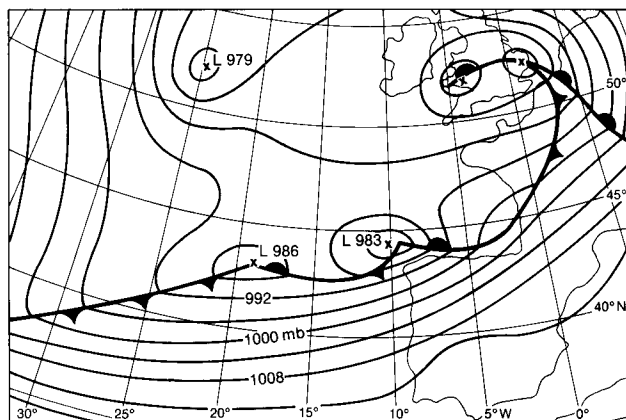


Figure 1. Finalized surface analysis for 0000 GMT on 15 October 1987.

west of Corunna. The corresponding CFO operational analysis (Fig. 2(b)) at first sight appears similar but omits the forward feature, implying only very slow eastward movement of the two low centres. Satellite imagery also suggested a further wave developing on the trailing cold front near 17° W but, with no ship reports in the vicinity, details of this feature cannot be determined with any precision.

3. 1200 GMT on 15 October

At 1200 GMT on 15 October (Fig. 3(a)), the position of the surface trough just to the south-west of Brittany was fixed reasonably well by ship reports available at the time of the operational analysis but further west the position and depth of the individual low centres were not determined very precisely. However, both the satellite imagery and the complete set of ship reports suggest that the main low centre was probably north-west of Corunna, estimated depth 968 mb, but the exact details of the analysis to the west of the centre were unclear. Comparison with the CFO operational analysis (Fig. 3(b)) reveals minor differences, the latter analysing an elongated low centre slightly further north-east, central pressure 970 mb. Pressure gradients were very strong on the south-eastern flank of this low and ahead of the trailing cold front, consistent with several reports of winds of 45–55 kn in that sector. The Meteosat imagery also showed signs of a further low pressure centre on the cold front near 42° N, 15° W; by following the imagery through it appears that this feature ran rapidly north-east and was associated with the development of the storm centre.

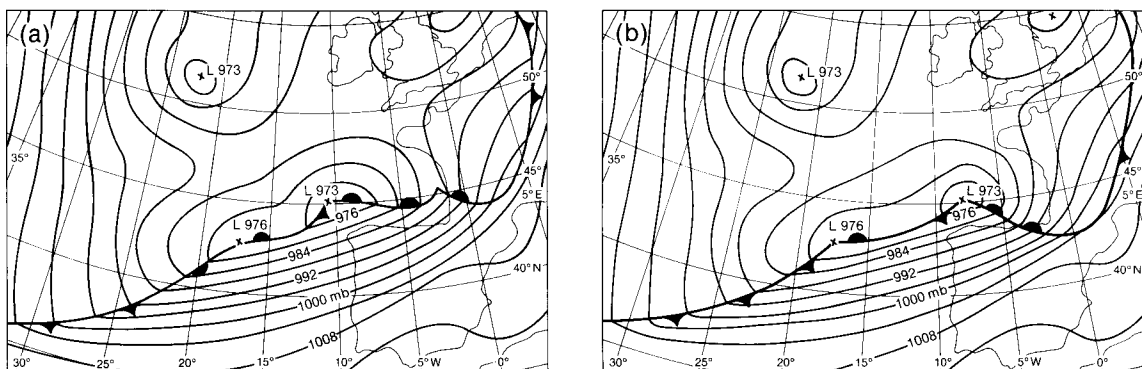


Figure 2. (a) Finalized and (b) CFO operational surface analyses for 0600 GMT on 15 October 1987.

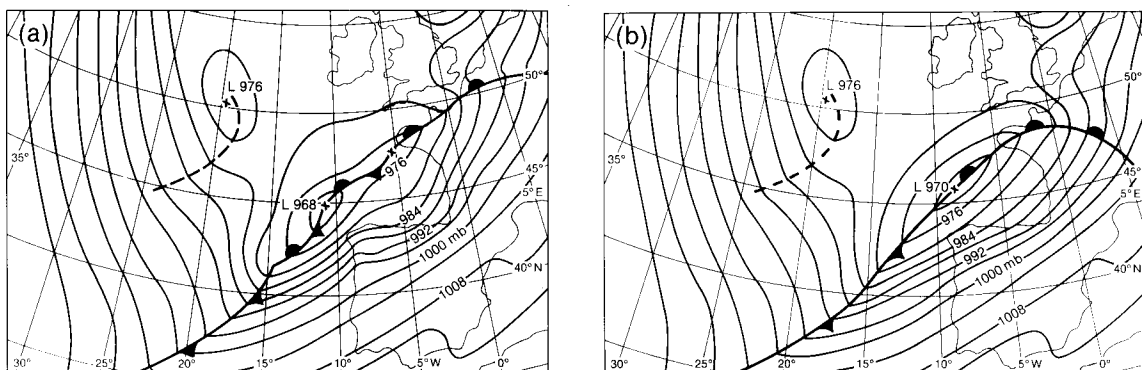


Figure 3. As Fig. 2 but for 1200 GMT on 15 October 1987.

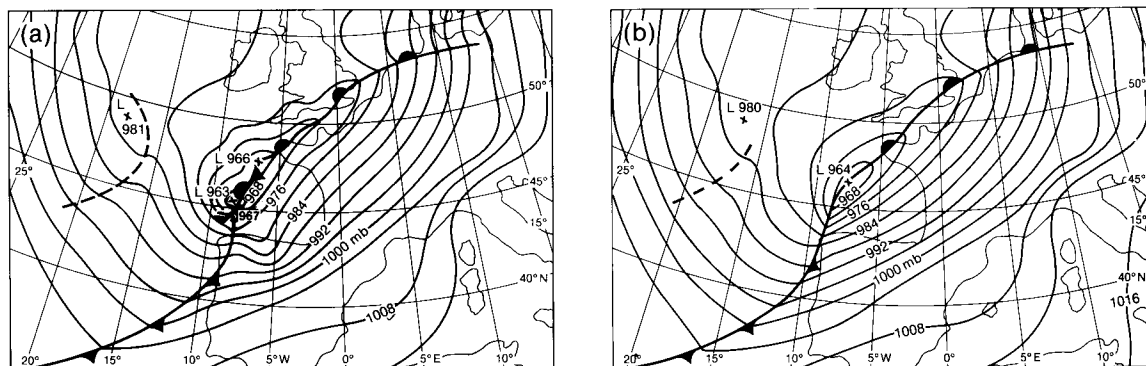


Figure 4. As Fig. 2 but for 1800 GMT on 15 October 1987. A selected ship's pressure (mb) and wind are plotted.

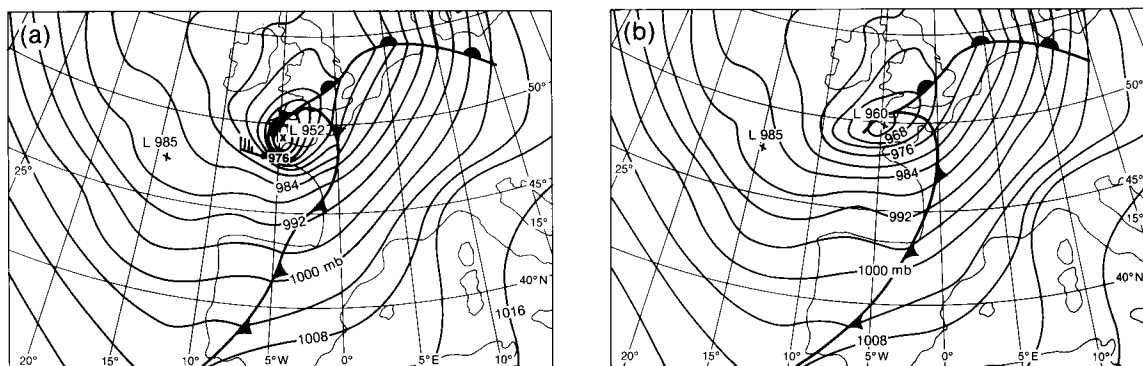


Figure 5. As Fig. 2 but for 0000 GMT on 16 October 1987. A selected ship is plotted as in Fig. 4.

4. 1800 GMT on 15 October

By 1800 GMT (Fig. 4(a)), the surface observations indicated that the low pressure centre was developing into a vigorous feature near 45° N, 8° W with winds of 60 kn ahead of the cold front. The CFO operational analysis (Fig. 4(b)) did not define the two separate centres over Biscay but again showed a single elongated centre, probably the best that can be expected given the time available for the analysis and the scale of the charts. Nevertheless the very strong gradients ahead of the cold front were well represented in the drawing.

A selected ship which was also near 45° N, 8° W at 1800 GMT has subsequently provided evidence confirming the position of the cold front deduced from satellite imagery. Although the surface pressure reports from the vessel consistently appear about 3 mb too high in relation to surrounding data, the barograph trace received well after the event shows a marked pressure minimum at 1800 GMT with a fall of about 12 mb in the preceding 3 hours. All the evidence suggests that the low pressure centre passed just north-west of the ship at that time. It should also be noted that there is evidence, from the various wind reports, of a marked trough developing in the cold air behind the front.

Although there are no ship observations in Biscay to help with the analysis at 2100 GMT, the sequence of Meteosat images shows a marked circulation developing in the cold air to the south-west of Brittany

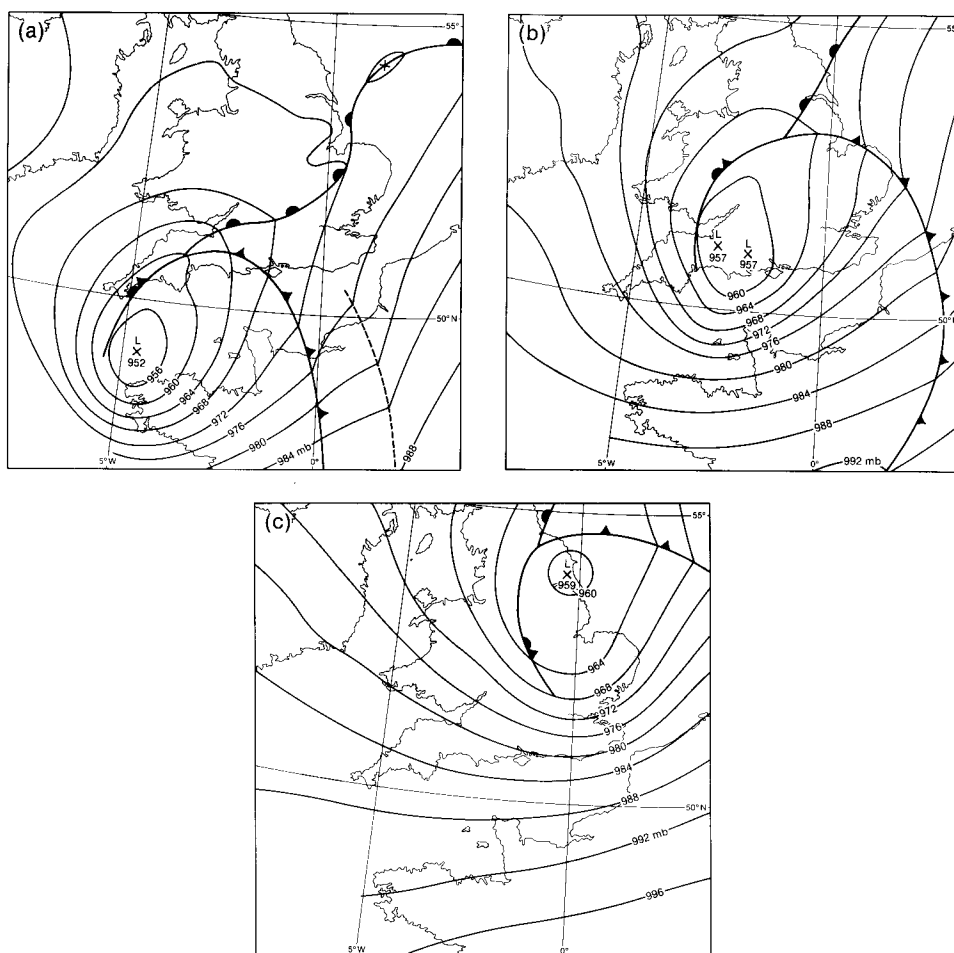


Figure 6. UK surface analysis for (a) 0000 GMT, (b) 0300 GMT and (c) 0600 GMT on 16 October 1987.

at this time with strong gusts of 72 kn being reported over Brittany ahead of the approaching cold front. Thus, although a forward low centre was evident over the western English Channel, as depicted in the UK surface analysis at the time, the main storm centre was still south-west of Brest.

5. 0000 GMT on 16 October

The finalized surface analysis for 0000 GMT on 16 October is shown in Fig. 5(a), the storm centre now being analysed in the south of sea area Plymouth, estimated depth 952 mb. This is slightly further south and 8 mb deeper than the CFO operational analysis (Fig. 5(b)), the difference arising because the crucial observations from Ushant and Ile de Batz were not received in CFO for the operational analysis. Observations at this time indicated that winds had reached 45–55 kn in the western and southern sectors of the depression and there were reports of 45–50 kn also along the English Channel to the east of the centre. Winds reached gale force along parts of the south coast at about this time. However, the lack of observations from Brittany meant that the forecasters were unaware of the exceptional gust of 95 kn recorded on the north French coast at that time.

A notable feature of the analysis in Fig. 5(a) is the exceptional pressure gradient drawn to the south of the centre with geostrophic gradients exceeding 300 kn in the strongest zone. This analysis hinges on the report from the ship at 48° N, 6° W. Although the pressure characteristic is clearly wrong (a rise of 13 mb would fit with the 2100 GMT analysis) the ship does not appear on the CFO list of unreliable ships. Later observations from the ship appeared satisfactory and with geostrophic gradients of well over 200 kn evident in the English Channel a few hours later, it seems likely that the drawing is not too far from the truth.

6. Detailed surface analyses

The detailed surface analyses (Fig. 6) over southern Britain and the English Channel show that, as the storm approached the English coast, two separate centres became apparent with relatively light winds in the vicinity of these centres and to the north of them. The very strong winds lay in a belt through the eastern, southern and western quarters, the highest and most damaging gusts being experienced around 0500 GMT some 200 miles or so to the south-east of the centre. The crux of the forecasting problem was the prediction of the location and severity of this belt of very strong winds and that problem had exercised the forecasters' minds from Sunday 11 October onwards.

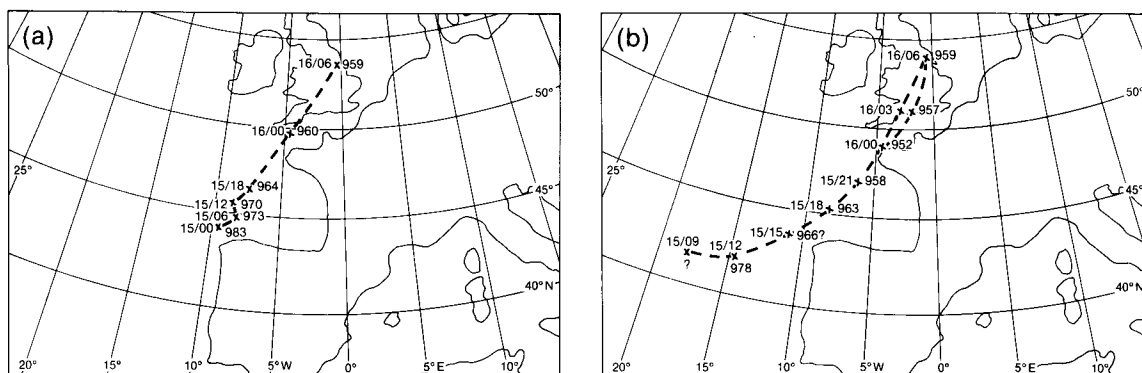


Figure 7. (a) Operational analysis and (b) finalized analysis of the storm track.

7. Conclusions

A detailed 'after the event' appraisal of all the data and satellite imagery indicates that several discrete low centres ran rapidly north-east over Biscay before the arrival of the final low which was associated with the major storm development. Tracking of the centre depicted on the CFO operational analyses (Fig. 7(a)) suggests slow north-eastward transference of the low across southern Biscay up to 1800 GMT on 15 October, followed by a rapid acceleration towards the United Kingdom. In reality it was different low centres which were being followed and this explains the inconsistent movement. In contrast the deduced track and depth of the developing low centre present a very coherent pattern (Fig. 7(b)), the chart revealing relatively steady deepening of the centre as it tracked from west of Iberia to the western English Channel. However, it must be recognized that, even now, some doubt still exists concerning the precise details of the analyses, depending as they do on subjective interpretation of the satellite imagery and the assessment of the reliability of the various ship reports.

Acknowledgement

The author would like to thank B.A. Hall of the Central Forecasting Office, Bracknell for his assistance in the preparation of the analyses.

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A detailed description of wind and weather during the passage of the storm of 15/16 October 1987 across southern England

Advisory Services Branch

Meteorological Office, Bracknell

Summary

A violent storm with mean winds to hurricane force for a while in some, mainly coastal, areas, crossed southern areas of Great Britain on 16 October 1987, leaving a trail of destruction in its wake. A detailed description of the wind, pressure and temperature experienced at individual locations in southern England during the passage of the storm is given. The extreme values of wind and pressure experienced are also put into perspective by comparison with historical events.

1. Introduction

The passage of the depression on 15/16 October 1987, accompanied by violent storm force winds and heavy rain over southern England, caused chaos. An estimated 4 million cubic metres of timber were lost, many trees crashed into power lines, bringing them down and many fell across roads and railway lines, leaving a large part of southern England with no electricity, and no services on many parts of British Rail and the London Underground system. Damage and disruption caused by the high winds was reported from Dorset to Essex and travellers were advised to stay at home unless their journey was really necessary. The damage to power lines resulted in widespread loss of electricity. Seventeen deaths were reported as a result of the storm, mostly caused by falling trees or masonry. Structural damage was widespread and severe, including many chimneys and, sometimes, complete roofs destroyed. At Folkestone a Sealink ferry was grounded, at Dover a container ship capsized in the mouth of the harbour, and light aircraft in many places were moved about or overturned by the force of the wind. A detailed description of the wind, pressure and temperature experienced at individual locations in southern England during the passage of the storm on the night of 15/16 October 1987 is given.

2. Temperature

On the evening of 15 October a frontal zone was moving across south-east England. To the south of the frontal zone the air was mild, with temperatures between 14 and 17 °C, and the wind direction southerly to south-westerly. To the north of the frontal zone the air was much cooler, between 5 and 7 °C, and the winds were blowing from the north-east.

As the warm air advanced across the country there were large changes in temperature, with rises of about 5 °C at Plymouth just before midnight and rises of about 10 °C farther to the east. The temperature changes are clearly illustrated by the thermogram given in Fig. 1(a). An analysis of the rates of changes of air temperature over various time-scales based on 15 years of data* gives extreme hourly changes in one hour of 5.6 °C in London on 13 April 1969, in a showery airstream and 6.6 °C at Boscombe Down on 16 March 1972, with a ridge of high pressure across the country, the temperature rise occurring after a clear night. The rises in temperature in the early hours of 16 October 1987 greatly exceeded these previous extremes and were unusual in that they were associated with a front.

Between 0100 and 0200 GMT the temperature at Heathrow rose by over 7 °C compared with the previous highest rise in 1 hour, taken from hourly observations over 37 years of record, of 6.7 °C; this

* Laing, J.; Rates of change of air temperature in the United Kingdom in time-scales of between 1 and 6 hours, *Climatol Mem, Meteorol Off*, No. 111, 1980.

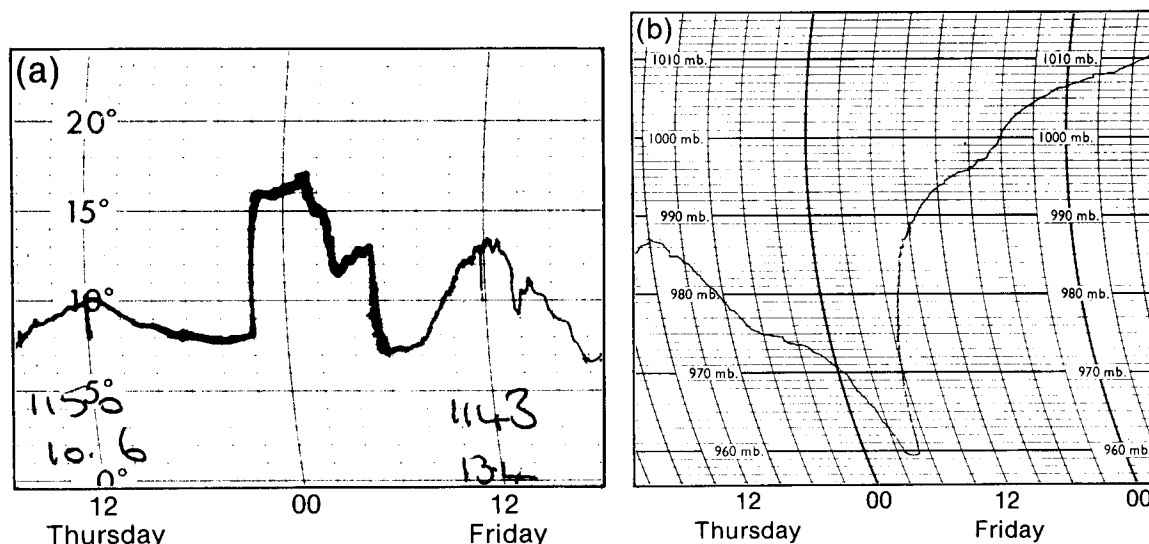


Figure 1. Autographic records of (a) temperature and (b) pressure from Bracknell for 15/16 October 1987.

was associated with strong solar heating on 26 March 1963. The previous highest frontal rise was 6.1 °C on 9 October 1951, 16 October 1952 and 7 November 1956. A preliminary study of previous rises shows that a rise of over 7 °C in 1 hour at Heathrow is a very rare occurrence.

3. Pressure changes

The hourly pressure changes in south-west England at the start of the storm show that the falls of pressure, before the front went through and ahead of the storm centre, were by no means unusually steep and looked no different on the barograph from many other pressure falls preceding strong gale or storm force winds. In fact, in the south-west the pressure fall on the previous day (0900–2200 GMT on 14 October) was greater than the fall on 15 October and more rapid. However, the rise in pressure after the passage of the front was phenomenal, with around 20 mb rises in 3 hours in a number of places. Fig. 1(b) shows a typical barograph trace in southern England.

The highest and steepest rises in the three hours to 0600 GMT were in parts of central southern England, ranging from 19.5 mb at Bristol to 25.4 mb at Portland which is believed to be the greatest rise of pressure in three hours on record for the British Isles. The rises in the three hours to 0900 GMT in more easterly parts of England were steep, but not quite as steep as in southern areas, although in most of East Anglia pressure rose more than 19.2 mb, the highest rise being 20.0 mb at Wittering at 0900 GMT.

4. Surface winds

For most weather forecasting purposes the wind is reported at hourly intervals usually using indicating-dial anemometers. The observer takes at least two readings of mean wind speed (each reading being over 15 seconds) within the overall period of the observation (approximately 10 minutes) and should report the average of these readings. A wind thus reported is usually referred to as a 10-minute wind.

Stations equipped with anemometers and a dial also report the highest gust in the previous hour using an anemograph trace if available. At main (0000, 0600, 1200, 1800 GMT) or intermediate (0300, 0900,

1500, 2100 GMT) hours the highest gust in the previous 6 or 3 hours respectively is reported in the routine synoptic report.

Details of the surface winds as reported by observing sites are shown in Fig. 2. These reports form part of the full weather observation made in the 10 minutes or so before the nominal hour of observation shown on the charts. Therefore the mean wind direction and speed refer to a 10-minute period preceding the time shown.

At 2100 GMT on 15 October most of southern England except the coasts of Kent and Sussex was covered by light to moderate north-easterly winds. Observers around the coasts of Kent and Sussex were already reporting stronger winds from the south or south-west.

By 0000 GMT the stronger winds had spread quickly northwards over southern England, backing to south-south-east to south. Gusts to more than 40 kn were reported over some inland areas and gusts to over 70 kn occurred at a number of coastal stations.

Between 0200 and 0600 GMT, most areas experienced their strongest winds. Particularly noteworthy are the gusts of 80–90 kn shown on the charts for the hours ending 0400 to 0600 GMT over the area south of an approximate line from London to the Isle of Wight. Gusts to 82 kn were recorded in London between 0200 and 0300 GMT, but stations along the coast and in the Thames estuary recorded gusts exceeding 90 kn at times, especially between 0300 and 0500 GMT.

By 0600 GMT most of England south of a line from Bristol to The Wash was covered by a broad belt of very strong winds. The wind direction had veered to south-west or west by this time as the depression moved away across Humberside. By 0900 GMT the winds had moderated over most areas except northern parts of East Anglia.

In the region of most damage, roughly south of a line from Southampton to Ipswich, maximum gusts occurred about 0300 and 0600 GMT. Gusts of 70 kn or more were reported for three or four consecutive hours during which time the mean wind veered from 180 to 230°. To the north-west there were two periods of high gust speed separated by a clear drop in wind speed. The first peak was associated with mean winds from between 170 and 190°, the second with a direction of around 230°. Strongest gusts were mostly in the southerlies between 0200 GMT (over central southern England) and 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 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 ratio of the maximum gust to the hourly mean speed at the hour in which the gust occurred is used as an index of the gustiness of the wind. At an inland rural site, free from obstruction and at 10 m above the ground, a typical value of the gust ratio in strong winds is about 1.6 with a standard deviation of 0.10. In the storm of 16 October a number of much higher values of the gust ratio were noted (see Table I), but in general the ratios were within the range of ratios for the relevant sectors.

Table I. *Highest mean wind and gusts, and the gust ratio, at anemograph stations with the highest gust ratio on 16 October 1987 (Bristol's gust was very isolated and may have been a freak effect, Southampton and Ashford have non-standard exposures, and Ashford's wind speed was estimated)*

Station	Highest mean (degrees/kn)	Time (GMT)	Highest gust (degrees/kn)	Time (GMT)	Gust ratio
Bristol	270/23	0500	270/66	0530	2.9
Southampton	170/30	0200	170/75	0215	2.5
Gatwick	210/34	0400	210/86	0430	2.5
Ashford (Kent)	190/38	0400	—/92	0440	2.4

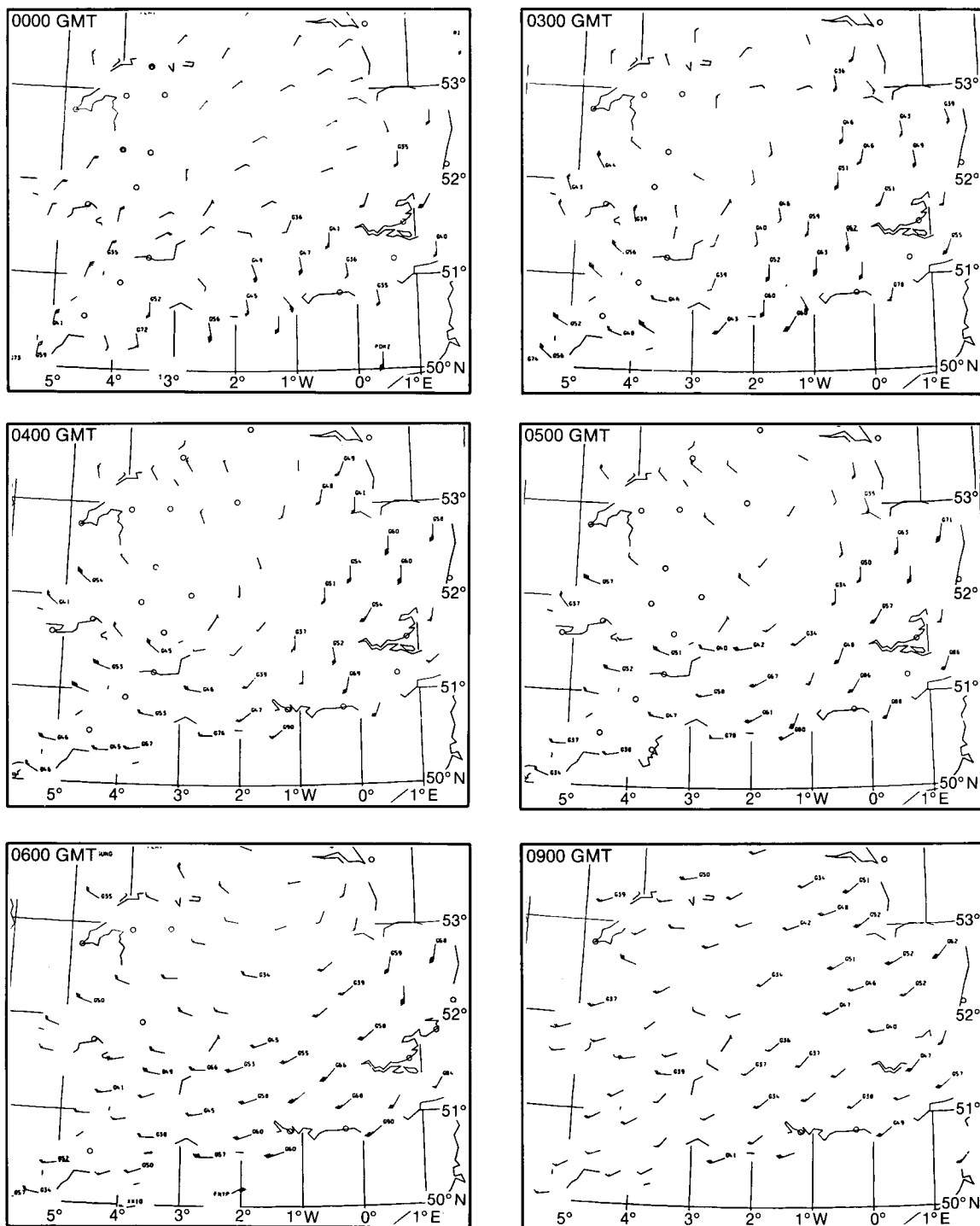


Figure 2. Mean wind speeds and maximum gusts reported on 16 October at the times shown.

5. Frequency of occurrence of wind speeds

An assessment of how unusual were the wind speeds recorded on 16 October 1987 may be reached using extreme value analyses of the past records from anemograph stations. Estimates of the average frequencies of occurrence ('return periods') of the maximum gust and maximum hourly wind speeds were made for a selection of stations within and bordering on the areas most severely affected. To enable the most reliable estimates to be made, the choice of stations should be restricted to those with long records. However, in order to improve the spatial coverage, it has been necessary to use data from some stations having less than 30 years of record. Any changes in the exposure of the anemographs during the period of analysis were accounted for by correcting all the annual maximum wind speeds used to a common effective height. The results are shown in Fig. 3. The analysis periods used were principally those ending in 1986, but further analyses were carried out for six of the stations using the maximum speeds on 16 October 1987; the influence of the speeds on 16 October resulted in relatively small decreases in return period. The following conclusions may be drawn.

- (a) At several stations, including Shoeburyness where continuous records span over 60 years, wind speeds on 16 October exceeded the previous highest recorded.
- (b) To the south-east of a line from the coast of East Anglia through southern London to Southampton Water, the return periods of both the maximum gust and the maximum hourly mean speed exceed 200 years.
- (c) There is a marked gradient in the distribution of return periods, corresponding to the line mentioned earlier from East Anglia to Southampton, so that to the north-west of London the speeds were much less exceptional, with return periods generally less than 10 years.

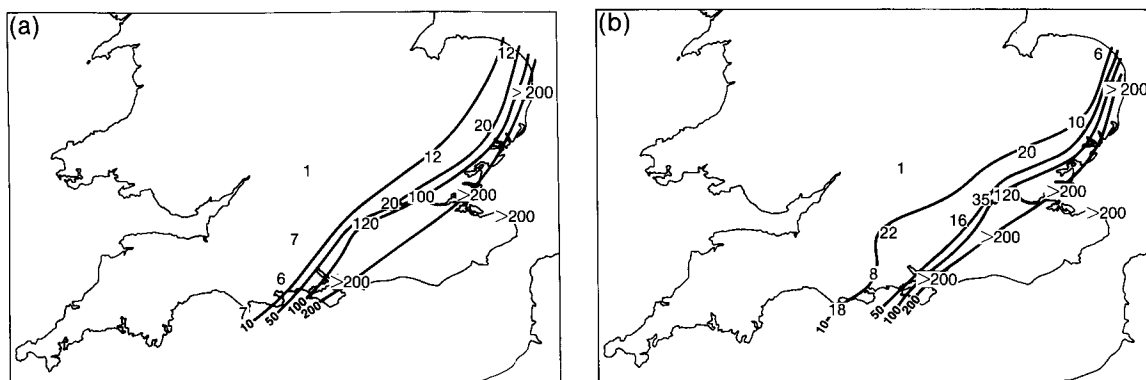


Figure 3. Estimated return periods (years) of (a) highest mean winds and (b) highest gusts on 16 October 1987.

6. Seasonal and directional factors affecting the frequency

In view of some of the damage caused to trees in leaf, it is of interest to assess the frequency with which such wind speeds occur in October. It is not statistically sound to analyse the highest speed recorded each October to produce return periods, since there are insufficient data for the analysis techniques used, but some indication of the rarity of the speeds on 16 October may be gained from a ranking of these with previous Octobers. This is done for a selection of stations in Table II. At almost all stations the speeds on 16 October were the highest ever recorded in October. The exception is Jersey, where there were localized very strong winds on 9 October 1964.

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 (24 October 1945). Dover recorded

Table II. *Highest wind speeds (kn) recorded in October*

Station	Year of first record	Hourly mean speed			Gust speed		
		16 Oct.	Previous highest and year		16 Oct.	Previous highest and year	
Boscombe Down	1932	39	38	1967	70	70	1945
Gatwick	1960	34	32	1967	86	56	1971
Gorleston	1913*	68	41	1926, 1955	106	68	1976
Heathrow	1959	39	34	1959	66	52	1959
Jersey	1958	55	68	1964	85	94	1964
London Weather Centre	1965	42	30	1971, 1983	82	57	1981
Manston	1967	58	42	1967	86	64	1967
Shoeburyness	1913	56	49	1967	87	74	1949

* There are gaps in the records for this station

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 1964 did not affect southern England.

Since the strongest winds in the United Kingdom are usually associated with directions from about 230 to 280°, the occurrence of high hourly mean winds and gusts from directions 170 to 190° appears to be unusual. However, this is not easy to check, since no long records are available of the highest speed per year, analysed for individual wind directions. Hourly records of wind speed and direction have only been held on a computer archive since 1970. Using these data it is found that during the period 1971–83 at Heathrow, the hourly mean speed never exceeded 27 kn whilst the mean wind direction was in the sector 170–190°. On 16 October 1987 the hourly mean speed was at least 36 kn for 3 hours for a direction of 170°.

Analyses of periods of strong winds at 50 places in the United Kingdom carried out by the Building Research Establishment suggest that, for a given return period:

- the ratio of the extreme in October to that for all the year is generally 0.82, with ratios for December and January close to unity (i.e. the annual maximum wind speeds normally occur in these months), and
- the ratio of the extreme for sector 170–190° to that for all wind directions is generally 0.85, with ratios for 30° sectors centred on 240 and 270° close to unity, i.e. the strongest winds normally occur in these sectors.

Thus, when either the seasonal or the directional feature of the storm on 16 October 1987 is taken into account, the likelihood of having winds of this strength from these directions in October is very much rarer than the return periods of Fig. 3 might suggest.

7. Concluding remarks

There have been many severe storms over the United Kingdom causing extensive damage and with wind strengths comparable to those on 15/16 October 1987. However, winds of the reported strength are extremely rare over south-east England. Furthermore, October is not normally a month of very extreme winds, nor do extreme winds normally occur with directions between 170 and 220°. While return periods, considered on an annual basis, may have been as high as 200 years or more (e.g. Gorleston and Shoeburyness), the probability of winds of these strengths from these directions during October is a considerably rarer (and unquantifiably so) event.

Guidance available at Bracknell for the storm of 15/16 October 1987, and the forecasters' conclusions at the time

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Summary

The numerical weather prediction guidance available to forecasters at Bracknell during the period leading up to the storm is reviewed. The steps by which the forecasters reached their conclusions are explained.

1. Introduction

Forecasters in the Central Forecasting Office (CFO) at Bracknell are provided routinely with guidance from the following numerical weather prediction (NWP) models:

- (a) The UK fine-mesh regional model.
- (b) The UK global model.
- (c) The ECMWF model.
- (d) The US global model.

The two UK models are run on the Cyber 205 computer within the COSMOS computing complex at Bracknell. The European Centre for Medium-range Weather Forecasts (ECMWF) model is run on a Cray X-MP/48 computer at Reading. The US global model is used in two runs, one denoted by AVN (aviation) and the other by MRF (medium-range forecast), on Cyber 205 computers in Washington.

Certain important characteristics of the NWP guidance are summarized in Table I. The information is given separately for guidance based on 0000 and 1200 GMT starting conditions, and includes the *length* of the numerical forecast in days, the *cut-off* time for observations used to establish the starting conditions, and the time at which the numerical products become *available* in CFO.

Table I. *Characteristics of the NWP guidance routinely available at Bracknell*

Model	Guidance from 0000 GMT			Guidance from 1200 GMT		
	Length (days)	Cut-off (GMT)	Available (GMT)	Length (days)	Cut-off (GMT)	Available (GMT)
UK fine mesh	1.5	0200	0300	1.5	1400	1500
UK global	6	0320	0500	6	1520	1700
ECMWF	—	—	—	10	1930	0200–0500
US AVN	3	0345	0830–1000	3	1545	2030–2200
US MRF	10	0600	1200	—	—	—

Numerical products could also be made available from NWP models run in France and the Federal Republic of Germany. These are not used routinely at present, but some comments on guidance from the French model are included below.

During the period leading up to the storm of 15/16 October 1987, the routine NWP guidance was

available without any significant delays, and the operational work on COSMOS was run according to schedule. Some delays did occur in the early hours of Friday 16 October as a result of disturbances in the power supplies to the computers, but of course these did not affect the production of guidance in advance of the storm. Fortunately these delays were not prolonged, and did not impair the forecasters' ability to provide accurate advice during the immediate aftermath, as the storm moved away.

2. Medium-range NWP guidance

The medium range of forecasting is defined by the World Meteorological Organization as 'more than 72 hours ahead and up to 10 days'. The ECMWF and the US MRF numerical forecasts are designed specifically for this purpose. Hence they need to be run only once daily, and they use later data cut-off times to ensure that important observations are not missed. The UK global numerical forecasts are designed primarily for short-range forecasting purposes. Hence, like the US AVN forecasts, they are run twice daily with a relatively early cut-off. The UK global forecasts are, however, extended to 6 days ahead to provide additional guidance for the early medium range.

The medium-range NWP guidance for the onset of the storm was generally good. It must be borne in mind that precision is not attainable in the medium range, so the guidance is judged according to whether or not it indicates the correct general weather conditions. For example, a numerical forecast may give the wrong relative emphasis to two or more depressions moving in rapid sequence along similar tracks; this will lead to modest timing errors, but the quality of the medium-range guidance remains good.

Although it is the sequence of forecast guidance from each model run that is important in practice, attention is focused on numerical forecasts valid at 0000 GMT on 16 October. At this time the storm was fully developed with a central pressure of 952 mb in the English Channel, and the onset over southern England was imminent.

Fig 1 shows the forecast locations of the storm at 0000 GMT on 16 October and tabulates the values of mean-sea-level pressure at the storm centre according to the numerical forecasts from the UK global model, the ECMWF model and the US global model. For convenience the complete sets of forecasts, including the short-range forecasts, are given in these figures.

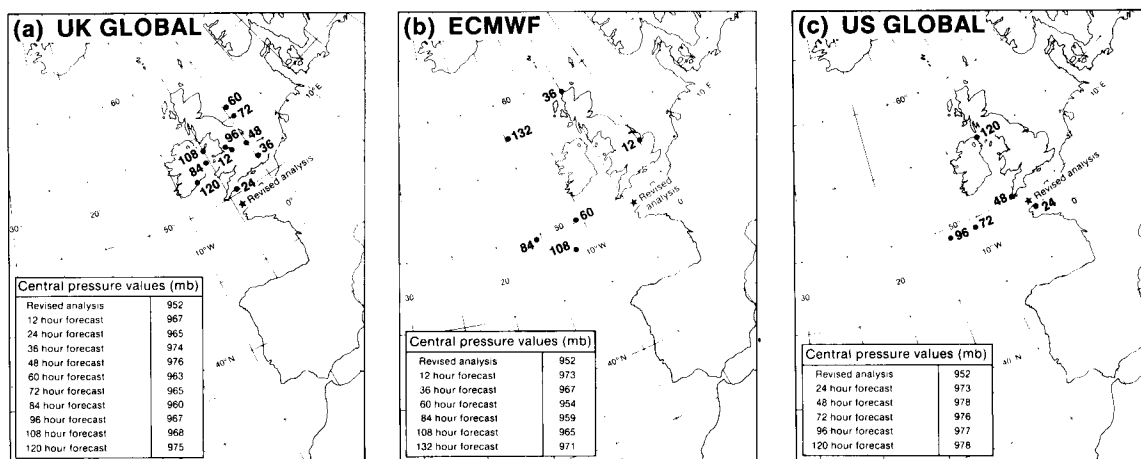


Figure 1. Locations and pressures of the storm at 0000 GMT on 16 October 1987 forecast for (a) the UK global model (b) the ECMWF model and (c) the US global model. The locations are indicated by •, and the associated numbers are the forecast periods in hours. The analysed position of the storm using all available data is indicated by ★.

The medium-range guidance from the UK global model was more consistent than that from either of the other two models. It was also more accurate, particularly with regard to the track of the storm, though it showed a slight systematic error in moving the storm across the British Isles a few hours too early.

These points are brought out by the NWP guidance from the three models available in CFO during the evening of Sunday 11 October and the morning of Monday 12 October. The two UK forecasts (108 and 96 hours ahead) are consistent in showing a deep depression, 968 mb (centred over the Irish Sea) and 967 mb (centred over Lancashire) respectively, with very strong winds implied by the pressure gradients over southern and eastern England. The corresponding ECMWF (108 hours ahead) and US (96 hours ahead) forecasts both keep the storm well south and west of Ireland at this stage. As a consequence they retain an older low as a separate feature north of Scotland, whereas in the UK forecasts this has merged with the storm circulation leaving only troughing of the pattern. The ECMWF forecast shows a vigorous low, with a central pressure of 965 mb, but the US forecast has the added disadvantage of indicating a less intense system, with central pressure 977 mb.

The medium-range forecasters in CFO accepted the NWP guidance, leaning towards the UK model in view of its consistency at 12-hourly intervals, with the result that forecasts issued from Sunday 11 October onwards emphasized the expected storm, timing its arrival for late on Thursday 15 October.

3. NWP guidance 72–48 hours ahead

The 72- and 60-hour numerical forecasts from the UK global model had slightly larger timing errors than the longer period UK forecasts, and took the centre out over the North Sea by 0000 GMT on 16 October. The 48-hour UK forecast for this time gave a more accurate location, but unfortunately the central pressure was 976 mb compared with a range 960–968 mb for the previous five UK forecasts (see Fig. 1(a)).

The ECMWF 60-hour forecast persisted with a location south and west of Ireland. However, it improved on earlier guidance by taking the central pressure down to 954 mb (see Fig. 1(b)).

The US 72-hour forecast gave a location only slightly more accurate than the US 96-hour forecast, but the location from the US 48-hour forecast was considerably better and the most accurate produced up to that stage. Both the 72- and 48-hour US forecasts continued to underplay the intensity of the low, with central pressures of 976 and 978 mb respectively (see Fig. 1(c)).

The NWP guidance during this period did not give a clear message, and the forecasters were left uncertain as to the likely track, timing and intensity of the low pressure system. The UK model had switched its story towards a shallower feature, tracking further east, and the threat of very strong winds over UK land areas seemed to have diminished somewhat.

4. NWP guidance up to 36 hours ahead

During the final 36 hours leading up to the onset of the storm, additional NWP guidance became available from the UK fine-mesh model. Senior Forecasters in CFO rely heavily on this model when preparing 24-hour prognostic charts, which they do at 6-hourly intervals, though the results from the UK global model are also available in time to be considered.

The NWP guidance for 0000 GMT on 16 October from 36-, 24- and 12-hour forecasts is shown in Figs 2, 3 and 4 respectively. The 36- and 12-hour forecasts from the ECMWF model are included for interest, though of course they are not available in time to be directly useful for short-range forecasting.

All three 36-hour forecasts are poor. The UK fine-mesh model and the ECMWF model both completely failed to develop a storm, and the main centre shown in both forecasts is the older low near the north of Scotland. The fine-mesh model has run a shallow feature (977 mb) forward over the North Sea. The ECMWF model has a very weak secondary centre (985 mb) near Brest. This is close to the

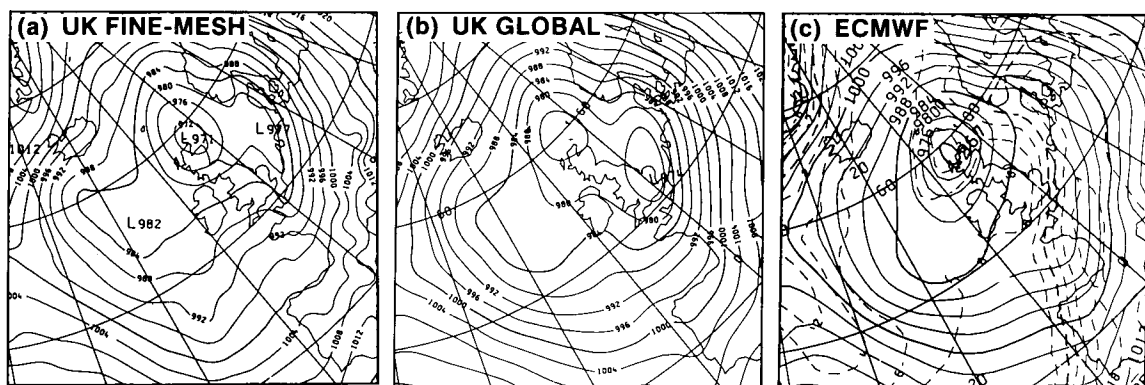


Figure 2. 36-hour numerical forecasts valid at 0000 GMT on 16 October 1987 from (a) the UK fine-mesh model (b) the UK global model and (c) the ECMWF model.

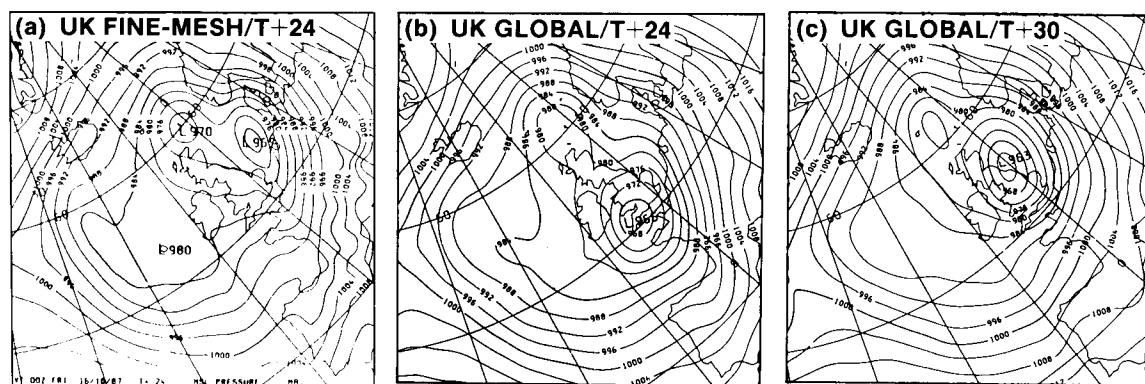


Figure 3. 24-hour numerical forecasts valid at 0000 GMT on 16 October 1987 from (a) the UK fine-mesh model and (b) the UK global model, and (c) the 30-hour numerical forecast valid at 0600 GMT on 16 October 1987 from the UK global model.

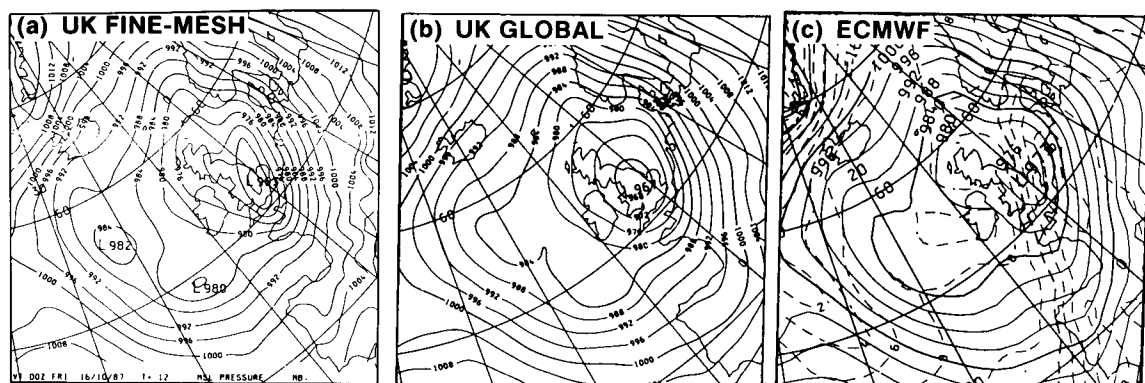


Figure 4. 12-hour numerical forecasts valid at 0000 GMT on 16 October 1987 from (a) the UK fine-mesh model (b) the UK global model and (c) the ECMWF model.

position of the storm, but with errors in excess of 30 mb the implied winds are very light (around 10 kn) over the English Channel, southern England and northern France.

The 36-hour forecast from the UK global model is only a little better, with a 974 mb centre over East Anglia. This advantage is sufficient, however, to retain strong pressure gradients and implied strong winds over northern France and the Low Countries.

The 24-hour fine-mesh forecast maintains the idea of a low centre crossing south-east England to a position over the North Sea, but the feature is now considerably deeper (967 mb) than in the 36-hour forecast. The particular track and timing are quite similar to those of the low that preceded the storm itself. A possible interpretation, then, is that this run of the fine-mesh model handled the first low well but completely missed the next baroclinic wave that developed into the storm. The accurate handling of the first low may have tended to confirm the perceived accuracy of this fine-mesh evolution as a whole, since the crucial wave developed in a data-sparse area and remained undetected for a time.

The 24-hour forecast from the UK global model stands out from all the previous guidance and places a 965 mb centre (i.e. 13 mb in error) near the south Devon coast. This proved to be the first NWP guidance that was reasonably accurate for *both* the location and the intensity of the storm. The 30-hour forecast from the same run (included in Fig. 3) is also accurate, showing the storm centre positioned just off the east coast of England by 0600 GMT on 16 October.

Comparing the global and fine-mesh 24-hour forecasts, and continuing the line of interpretation suggested above, it is probable that this run of the global model failed to capture the first low. Certainly the forecast shows no sign of the troughing into the North Sea that should be present at 0000 GMT on 16 October. More significantly as it turned out, the run seems to have succeeded in developing a baroclinic wave rapidly in about the right position to give accurate guidance on the storm onset.

Disappointingly, none of the 12-hour forecasts are as accurate as the 24-hour forecast from the global model. All three models moved centres along reasonably accurate tracks but with timing errors of around 4 hours in 12. The fine-mesh model was the most successful of the three, with a centre of 963 mb.

It is noteworthy that all of the 24- and 12-hour forecasts, despite other faults to varying degrees, maintain the belt of strong pressure gradients and implied strong winds across northern France and the Low Countries, and over adjacent sea areas.

5. The forecasters' conclusions regarding the NWP guidance on 15 October 1987

The NWP guidance for this particular event displayed characteristics that forecasters have to contend with most of the time. There are variations in the NWP advice from run to run and between different models. Quite frequently a later run proves to be less accurate than an earlier one. Small errors in track, timing or intensity of weather systems in the NWP guidance can have major consequences for the weather conditions to be expected at particular locations. Often there is the difficulty of determining whether a weather system emphasized by a numerical forecast can be identified with the system that becomes important in the real atmosphere, or whether it is merely a near neighbour that may evolve differently.

Up to about 0500 GMT on Thursday 15 October the forecasters in CFO could justifiably feel confident of the guidance offered by the morning's fine-mesh numerical forecast. This run was consistent with the guidance from the previous cycle in tracking a low centre across south-east England during the 15th and keeping the very strong winds away from UK land areas. The guidance had been supported by the ECMWF forecast, from 1200 GMT on 14 October initial conditions, that had arrived a little before the fine-mesh run.

When the UK global model guidance arrived it offered a markedly different solution with an earlier deepening, a slower movement and a track further to the west, crossing south-west England and the Midlands.

The fine-mesh model has established a reputation among National Meteorological Services throughout Europe for its ability to handle intense low pressure systems. Case studies have shown that its higher horizontal resolution sometimes permits it to represent dynamical processes that are missed by the global model. On the other hand the fine-mesh model, requiring only a regional coverage of observations, is run with an early data cut-off time. This procedure has important advantages, but it carries the known risk that on rare occasions there will be crucial late observations that miss the fine-mesh cut-off but are used by the global model, which then provides the more accurate forecast as a result.

These factors had to be weighed on the morning of the 15th. The latest observations and satellite imagery were examined for clues as to which solution was the more accurate (see next section). In the event the forecasters elected to compromise between the fine-mesh and the global-model guidance. The subjectively drawn 24-hour prognosis for 0600 GMT on 16 October, issued at 0955 GMT on 15 October, is reproduced in Fig. 5 and may be compared with the global-model evolution in Fig. 3. Compared with the fine-mesh guidance, the storm has been deepened, its movement slowed, and its track moved west, all reflecting the influence of the global-model guidance.

The next NWP advice to become available was the afternoon fine-mesh run at around 1500 GMT. This turned out to be in remarkably close agreement with the earlier subjective prognosis. The afternoon run of the global model, available around 1700 GMT, predicted a similar track and rate of movement, though it relaxed the pressure gradients around the storm a little (Fig. 4).

The story portrayed in Fig. 5, formulated after the two morning runs and confirmed by the afternoon fine-mesh run, was used as a basis for the issue of forecasts and warnings until observations finally revealed its errors just a few hours before the onset of the storm over southern England. The errors were as follows:

- (a) The expected intensification of the low was only 12 mb as it moved from Biscay (973 mb) across England and out over the North Sea (961 mb). In reality the storm had already deepened to 952 mb as it crossed the English Channel. Consequently the surface wind speeds over south-east England were significantly underforecast.
- (b) The predicted track of the low was still too far to the east as it crossed the English Channel. This had the effect of confining the expectation of strong winds over land to a too-small part of south-east England.
- (c) The expected movement of the low centre along its track was too rapid, with the result that the strong winds were predicted to arrive over south-east England about 4 hours too early.

6. Synoptic reviews issued by CFO on 15/16 October 1987

The Senior Forecaster in CFO is responsible for the issue of centralized guidance to all public service forecast offices throughout the country. These responsibilities include providing advice to the shipping forecaster, who is also located in CFO, on the issue of gale warnings for all sea areas around the UK continental shelf. The Senior Forecaster in turn receives advice from a number of other forecasters, including a colleague of equal rank who is responsible for monitoring and fine-tuning the numerical model analysis before the forecasts are made.

In association with the subjectively drawn 24-hour surface forecast chart referred to above, the Senior Forecaster issues a descriptive textual guidance routinely four times daily, although updates and amendments can be issued at any time. Each issue of the guidance, which is termed a 'synoptic review', is put into two or three parts (three parts for the early morning and afternoon issues, i.e. approximately 0400 and 1600 GMT). The guidance is designed to add value to selected numerical model products which are received by the outstations direct from Bracknell as well as containing the definitive guidance on the forecast to be followed by all regional offices.

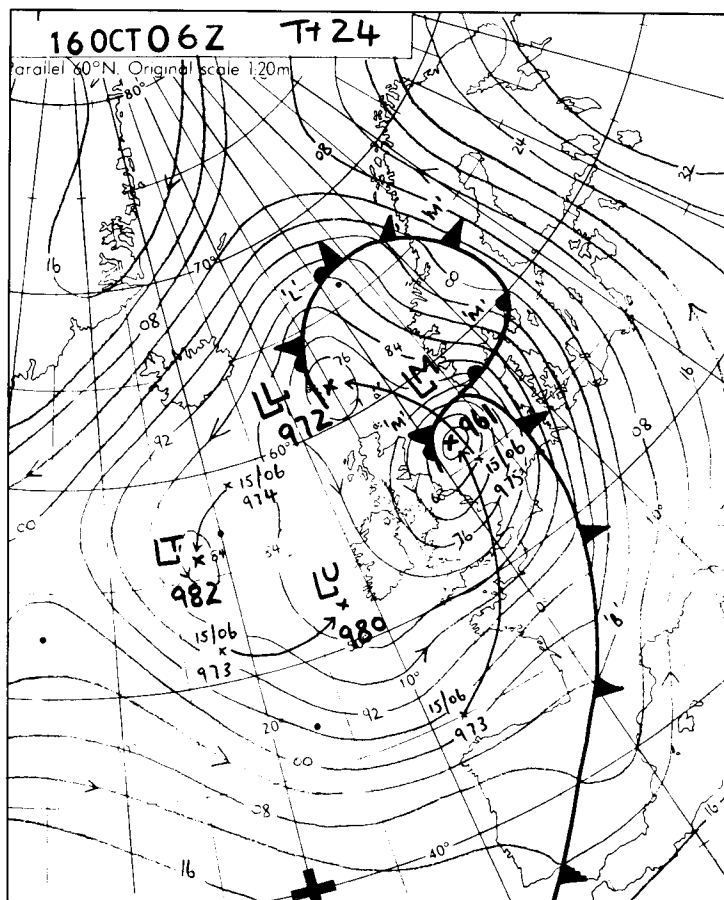


Figure 5. Subjectively drawn prognostic chart for 0600 GMT on 16 October 1987, issued at 0955 GMT on 15 October 1987.

Although outstations are required to follow the central guidance, the procedures involved in formulating the guidance include conferences and discussions with all the regional main meteorological offices at least twice daily and more frequently with the national television and radio presenters.

The early morning synoptic reviews were chiefly concerned with the likelihood of heavy rain in the south in view of recent flooding. The Part 1 (issued at 0345 GMT on 15 October) mentioned the possibility of winds reaching gale force in exposed locations especially in south-east England during the second half of the day. (At this stage, the timing of the evolution was following the latest fine-mesh guidance which proved in the event to be significantly too rapid.) The Part 3 (issued at 0550 GMT on 15 October) expressed concern about the different model solutions in a rapid developmental situation, concluding that the fine-mesh solution was preferred because of a marginally better initial state. The late morning Part 1 (issued at 1010 GMT on 15 October) included a land-gale warning for exposed parts of southern and eastern England. The Part 2 (issued at 1040 GMT on 15 October) suggested a compromise solution between the coarse mesh and the fine mesh for the position and track of the centre. This was because the available observations suggested that the fine-mesh forecast had the better pressure field

over France for 0600 GMT on the 15th, whilst on the other hand there was a suspicion that it was not developing the low quickly enough.

The Senior Forecaster was also considering yet another solution throughout the day. Satellite imagery to the south-west of the United Kingdom showed a possible 'baroclinic leaf' structure which often precedes rapid cyclogenesis and the formation of an 'instant' occlusion around a development in the cold air. This was yet another compromise solution between the coarse mesh and the fine mesh in which both models would be right to some degree, the first wave running north-east as the fine mesh predicted with the main development following in the cold air. By mid afternoon the details of the analysis (both surface and upper air) in the critical region were still unclear. The forecaster judged that the main thrust of storm force winds in the moist south-westerly flow was likely to extend over north France but the east Channel and extreme south-east England could be at risk from severe gales. There was also the possibility of severe gales around the development in the cold air, if it occurred.

The fine-mesh solution based on 1200 GMT data showed the expected slight changes of track and speed of the wave, but there was no sign of rapid development or of the formation of an occlusion. The mid-afternoon synoptic review (issued at 1535 GMT on 15 October) included a land-gale warning stating that the gales would become confined to Scotland tomorrow. This was amended at 1640 GMT in Part 2 to mention severe gale force at times in exposed coastal districts during the evening in the extreme south-east, especially in a southerly flow on the eastern flank of the depression. During the late afternoon the wave was approaching the Brest area but pressures were not as low as the fine-mesh forecast. The forecaster considered that rapid cyclogenesis could already be occurring further to the south-west or would shortly occur there; this would steer the low further north for a time but increasing north-westerly flow on the western flank would tend to recurve the low back onto a more easterly track and the strongest winds in the cold air would probably be confined to the English Channel coasts and the extreme south-east.

Part 3 (issued at 1750 GMT on 15 October) mentioned the possibility of rapid deepening of the surface circulation in the next few hours but with no specific mention of winds. The 2225 GMT synoptic review mentioned gales, even severe gales, over exposed areas of the south-east with Part 2, issued at 2235 GMT, stating that southerly gales over land could extend further westwards across southern Britain than thought earlier. The 0345 GMT synoptic review said that there would be severe land gales across much of England and Wales during the first part of the day.

The complexity of the developments which exercised the Senior Forecasters' minds throughout the 15th are well revealed in the full text of the synoptic reviews.

Numerical forecast studies of the October 1987 storm over southern England

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Summary

The dynamical structure of the storm is described with the aid of numerical analyses and forecasts. Causes of differences between operational forecasts are investigated. Excellent 24-hour forecasts with the fine-mesh model were obtained in experiments using observations which arrived after the operational cut-off. There were insufficient observations to define the detailed structure of the developing system at 1200 GMT on 15 October. However, an excellent forecast from this time was obtained using a new assimilation scheme designed to cause less disruption to the forecast model's structure.

1. Introduction

This article presents the results of investigations aimed at clarifying the reasons for the deficiencies in the numerical guidance presented to forecasters concerning the storm of 15/16 October 1987.

In section 2, the dynamical characteristics of the genesis and evolution of the storm are examined, within the limits of the evidence available, to see if they were highly exceptional. Sections 3 and 4 are concerned with the shortcomings of the operational numerical forecasts, particularly those originating from 0000 and 1200 GMT on 15 October. The objective is to determine how observations, analysis procedures or the forecast models themselves contributed to the errors. Section 5 describes the potential usefulness of systems now being developed. Some conclusions are given in section 6.

2. Dynamical structure of storm

To understand the processes which led to the development of the storm on 15/16 October it is necessary to consider the wider atmospheric conditions over the Atlantic and during the preceding days. At 0000 GMT on 14 October (48 hours before the storm affected the United Kingdom), the flow at upper levels over the Atlantic consisted of a strong, broad, westerly airstream between latitudes 40 and 50° N (Fig. 1(a)). This is fairly far south for the time of year, but not unusual. The temperature contrast between polar and tropical air was largely confined to the same latitude belt. At the surface, the depression of interest was near 40° W, with a central pressure of 1003 mb (Fig. 1(b)), well ahead of the upper trough. During the next 24 hours the depression deepened and moved quickly eastwards. In the operational computer analysis of mean-sea-level pressure for 0000 GMT on the 15th (Fig. 1(d)) there is some uncertainty because of the sparsity of observational data. Its indication of three distinct low pressure centres is probably correct, but there is some doubt over their relative intensities. The upper trough also moved quickly eastwards, but it was still to the west of the surface depression (Fig. 1(c)).

During the period 0000 to 1200 GMT on 15 October, the amplifying upper trough with its associated strong winds crossed the region in which there were surface pressure centres, and where the low-level baroclinicity and thermal contrasts were large. These conditions are especially favourable for the development of depressions, especially if the upper trough 'phase-locks' with a surface centre.

Small-scale jet streaks (areas of local intensification) may be embedded within the broad jet-stream flow, and influence the nature and intensity of subsequent surface development. This may have been important on this occasion.

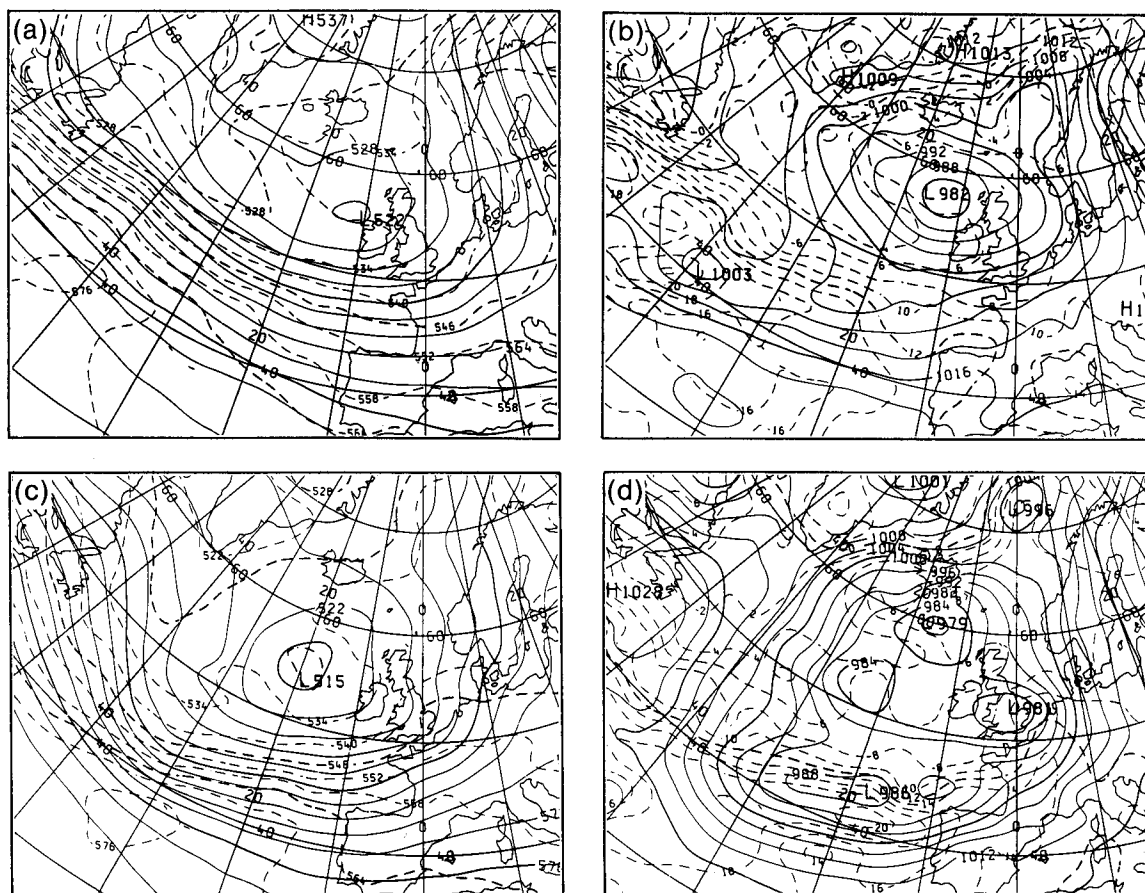


Figure 1. Operational global assimilation analyses of (a) 500 mb height (solid lines, contour interval 6 dam) and 1000–500 mb thickness (dashed lines, contour interval 6 dam) and (b) sea-level pressure (solid lines, contour interval 4 mb) and 850 mb wet-bulb potential temperature (dashed lines, contour interval 2 °C) for 0000 GMT on 14 October. (c) and (d) are as (a) and (b) but for 0000 GMT on 15 October.

In studies of a storm which developed explosively off the eastern seaboard of the USA, Uccellini *et al.* (1984, 1985) showed that a key feature was a polar jet streak which propagated, with associated stratospheric air, down to mid-tropospheric levels. Conclusive observational evidence for a similar feature is lacking, but satellite images for the UK storm indicate that a dry slot (cloud-free zone) was visible in the cloud images and more clearly in the water vapour imagery. This may have been associated with a deep stratospheric intrusion. The imagery during 15 October is essential for fixing the position of the frontal zone and the waves on the front because of the lack of surface observations. The satellite pictures also show a number of other features (for instance a cloud head) which are believed to be linked to strong cyclogenesis (Böttger *et al.* 1975). However, these qualitative observations by themselves do not provide sufficient information to enable the precise nature of the evolution of the low to be predicted.

During the mature phase, on 16 October, the depression, as represented in the most successful fine-mesh forecast (see section 3.1), had a pronounced warm core below 5 km between two zones of high baroclinicity (Fig. 2). The existence of such a feature is supported by surface observations. The

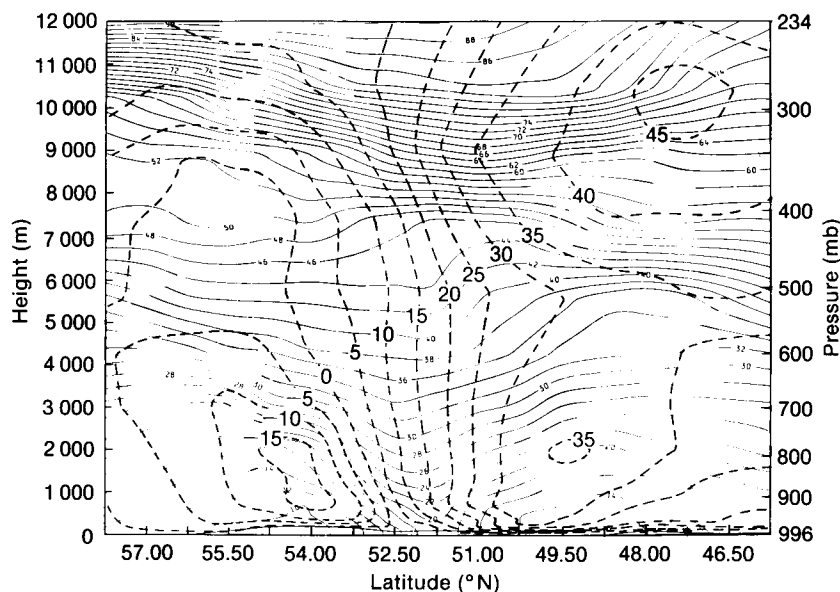


Figure 2. Cross-section of potential temperature (solid line, contour interval 2°C) and northerly component of wind (dashed line, contour interval 5 m s^{-1}) along 1.87°W at 0300 GMT on 16 October from a forecast using the fine-mesh model from the best available rerun fine-mesh analysis for 0000 GMT on 15 October.

hydrostatic relationship and geostrophy gives the thermal wind relationship between horizontal temperature gradients and vertical wind shears. The warm core in Fig. 2 is related to low-level maxima in the winds; the model's northerly components are shown. There was also observational evidence for this low-level jet maximum.

Many intense extratropical cyclones have been observed to have warm cores, the origin of which is the subject of scientific debate at present. One possibility is that in the occluding phase of a depression some of the warm air gets extruded from the warm sector and remains trapped at low levels in the depression, whilst the rest moves upwards and ahead of the storm. Bergeron (1928) identified such a process and termed it 'seclusion'. Another explanation is that vigorous convective ascent in the vicinity of the centre of a developing depression causes compensating subsidence outside the convective areas which leads to adiabatic warming. Although there were some reports of thunderstorms from stations on the Welsh coast during 16 October, there is little evidence that convection was sufficiently widespread to contribute significantly to this process. A third possible explanation for the relative warmth is that large fluxes of sensible and latent heat entered the storm over Biscay in association with the pre-existing strong winds. Whatever the actual process is, the fine-mesh model seems capable of representing it. Further studies of these dynamical mechanisms and their role in the formation of such storms are needed to establish the nature of the mechanisms more precisely.

In summary, though the general atmospheric conditions strongly favoured cyclonic development, no features have been identified that would have enabled the quite exceptional character of the storm to be identified at an early stage.

3 Forecasts from 0000 GMT on 15 October

The Meteorological Office's fine-mesh model has an excellent record in forecasting rapid developments up to 36 hours ahead. As a result forecasters have come to put more weight on its guidance

than on the global model. Thus its failure to predict the storm's development correctly in the forecast run with data received by 0200 GMT on 15 October was unusual, and a major factor influencing the forecasts that were issued. On the other hand the global model, run with data received by 0320 GMT, gave reasonable guidance for the storm's track and intensity over England.

3.1 *Forecasts from different analyses*

The obvious most likely reasons for differences in the models' forecasts are that the analyses were significantly different. This was examined by running the fine-mesh forecast model from an interpolated global model analysis. Fig. 3 compares the 12-hour operational forecasts from the global and fine-mesh models, and from the fine-mesh forecast using the interpolated global analysis and the best available rerun fine-mesh analysis. The corresponding 24-hour forecasts are shown in Fig. 4.

The run of the fine-mesh model starting from an interpolated global model analysis differs little from the global model forecast except in the central pressure of the storm, implying that the operational

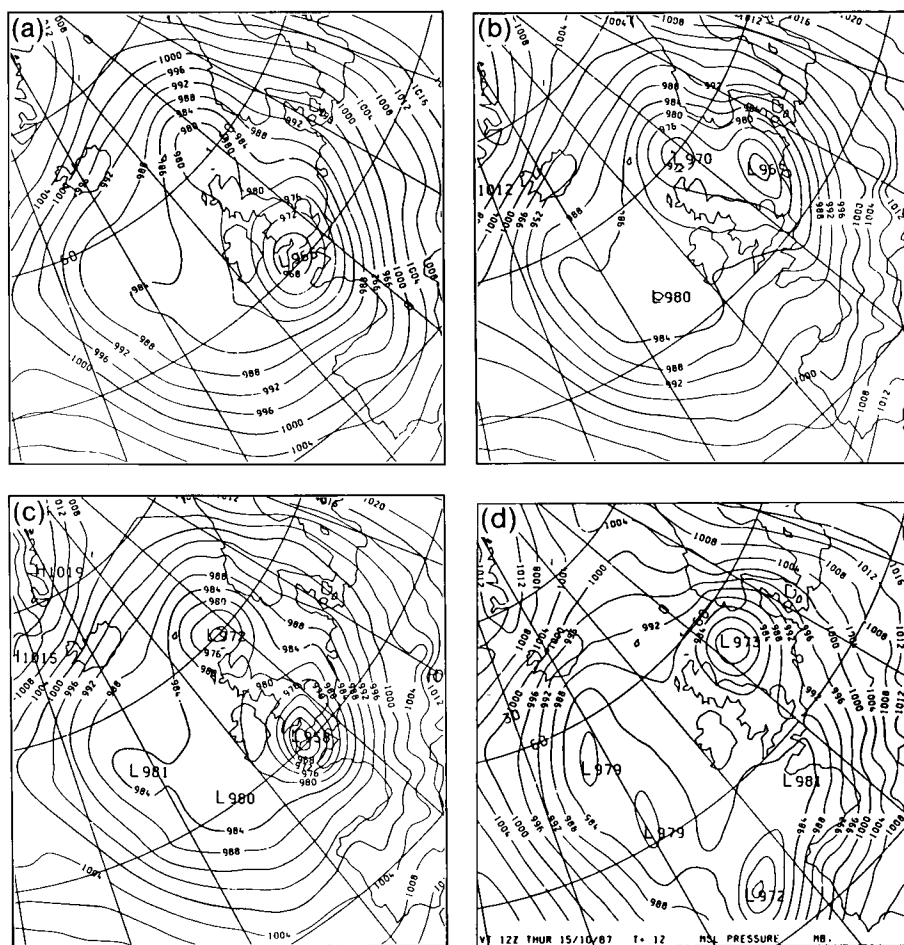


Figure 3. 12-hour forecast of mean-sea-level pressure (mb) valid at 1200 GMT on 15 October from (a) operational global model, (b) operational fine-mesh model, (c) fine-mesh model using an interpolated global analysis and (d) fine-mesh model using the best available rerun fine-mesh analysis.

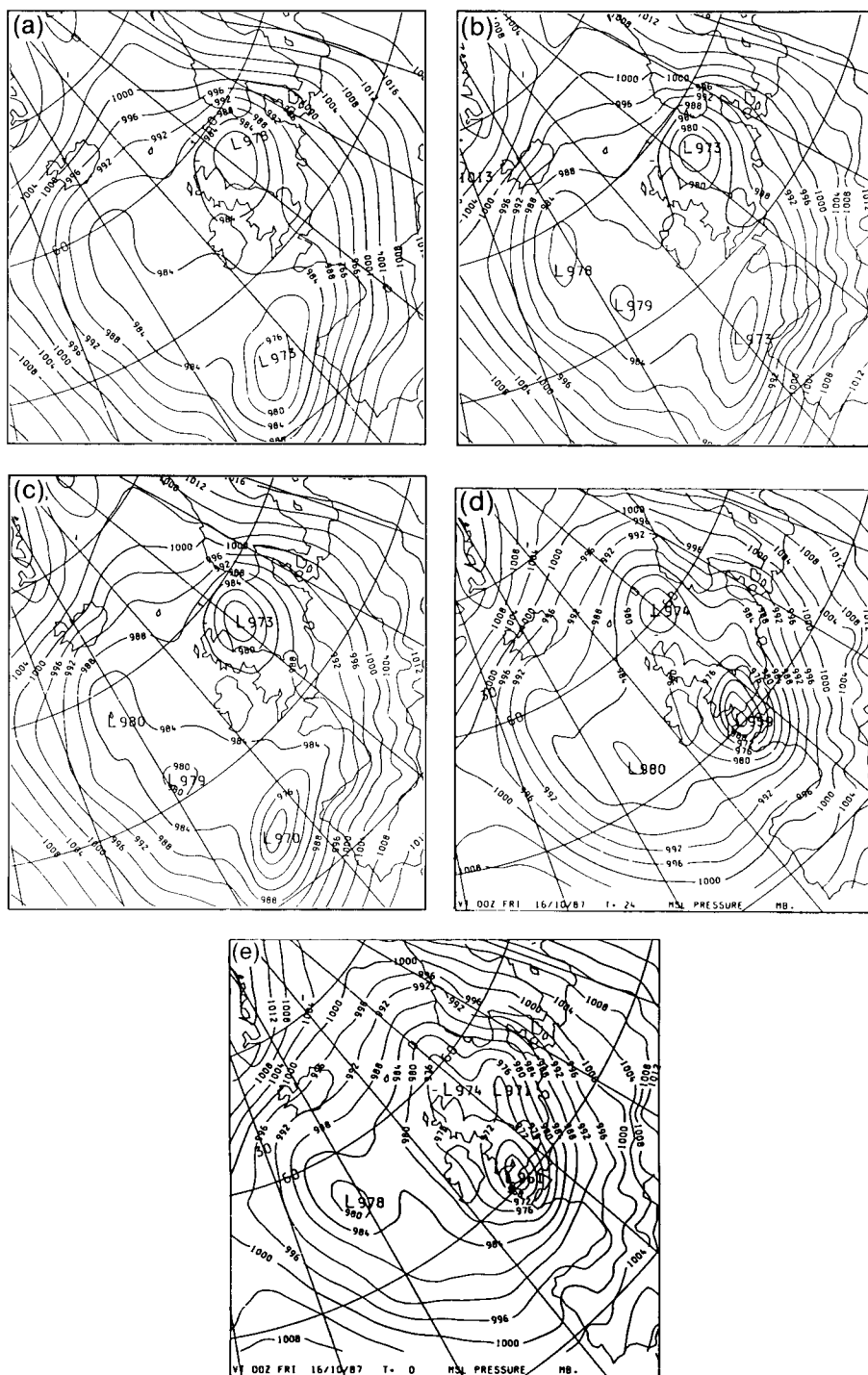


Figure 4. As Fig. 3 but for the 24-hour forecasts valid at 0000 GMT on 16 October, but with (e) the verifying analysis.

forecast errors in the track and timing of the system were caused by features in the fine-mesh analysis.

There is some uncertainty as to the correct surface pressure analysis for verifying the forecasts in Fig. 3. For instance, the fine-mesh analyses shown in Fig. 5 differ in places by over 5 mb, and various careful human analyses differed in the depth, position, and even the number of low centres. There is no doubt, however, about the existence of the elongated trough stretching approximately south-west from Brest, probably with one low centre (which did not subsequently develop) approaching Brest, and one or two others further west (one near 14° W which developed into the storm). Neither of the forecasts from the global analysis reproduce the pressure centre approaching Brest; instead they concentrate on the centre which actually did develop into the main storm. As the horizontal separation between the centres is about 400 km, and variations on this scale cannot be adequately represented in the global model with a grid length of about 150 km, the absence of detailed structure in the forecast surface pressure field is not surprising. The operational fine-mesh forecast (Fig. 3(b)) predicted a low with troughing towards Brest, in better agreement with many aspects of the actual field than the forecasts from the global analysis. However, it went on to develop this feature, moving it forward rapidly and giving a misleading forecast (Fig. 4(b)). This highlights the difficulties of reaching correct decisions on the day.

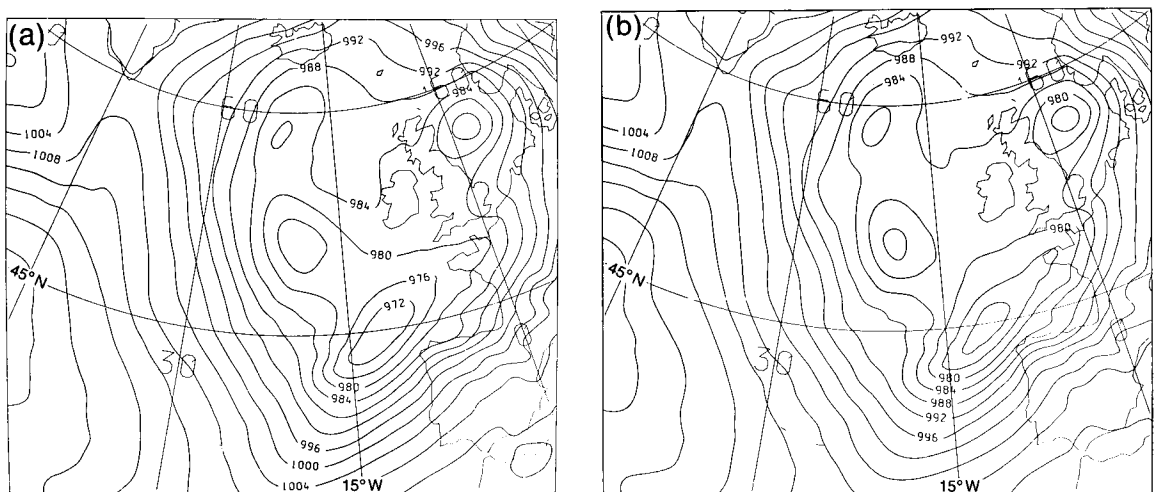


Figure 5. Mean-sea-level pressure (mb) at 1200 GMT on 15 October from (a) the test fine-mesh analysis and (b) the operational fine-mesh analysis.

A series of experiments, described below, culminated in a fine-mesh assimilation and forecast which was excellent in its prediction of the track and intensity of the storm over England. Its cloud fields were in good agreement with significant features inferred such as the dry slot and cloud head in the satellite imagery, and detailed diagnostics from it, such as Fig. 2, give a consistent picture of the dynamics of the storm. The forecasts of mean-sea-level pressure are shown in Figs 3(d) and 4(d). Like runs from the global analysis, the forecast concentrated development on the last centre though it did have significant troughing forward towards Brest, and in this aspect is superior to them. There are more substantial differences in the upper winds. The best forecast shows a series of jet streaks propagating around the upper trough, and there is no sign of the area of weakness over the Bay of Biscay which was a feature of forecasts from the global analysis.

3.2 *The observations*

The fine-mesh data assimilation cycle (Bell 1986) consists of four 3-hour assimilation periods starting from interpolated global model fields every 12 hours. For each cycle, data are accepted if they are within a time-window ± 90 minutes from the nominal analysis time. In contrast, the global model has a 6-hour cycle and a ± 180 -minute time-window.

The good forecast from the 0000 GMT 15 October global analysis seems to be due to observations in its last time-window; a forecast from its earlier 1800 GMT analysis had only a weak low pressure centre of 982 mb near the Dutch coast at 0000 GMT on the 16th. This window corresponds approximately to that of the last two cycles of the fine-mesh assimilation. However, most observations are nominally valid for the main synoptic hours, so Table I lists the volumes of data available to the 0000 GMT cycle of the global and fine-mesh assimilations. For the former, it consists of all observations made within the period 2100 GMT on the 14th to 0300 GMT on the 15th and received before 0320 GMT on the 15th; the equivalent period and time for the fine-mesh model are 2230 GMT on the 14th to 0130 GMT on the 15th and received before 0200 GMT on the 15th.

Table I. *Number of observations available operationally within the fine-mesh area for the 0000 GMT cycle on 15 October*

	Fine-mesh assimilation	Global assimilation
SATEMs (500 km)	4	25
SATEMs (250 km)	0	98
Ships	139	163
AIREPs	34	99
DRIBUs	8	10
SATOBs	21	41
Radiosondes	153	169

The table and an examination of the locations of observations indicate that more satellite data, and more aircraft and ship reports, were available to the global assimilation in areas where they might have affected developments in the Bay of Biscay. By deleting the SATEM data, and the AIREP reports successively, it was established that only the latter had a significant effect on this occasion. Without the benefit of the additional aircraft data, the 24-hour global forecast for 0000 GMT on the 16th was considerably less realistic.

Almost all the additional AIREPs were for the period 0130 to 0300 GMT and, importantly, they were in the strong wind belt between 30 and 40° W. (The majority of commercial transatlantic flights leave North America to arrive in Europe in the early morning, and try to fly in the westerly jet.) Additional SATEMs on the other hand were from an orbit with an overpass time of approximately 2200 GMT at 40° W. They were outside the ± 90 minute time-window of the 0000 GMT fine-mesh analysis, but they arrived too late to be included in the 2100 GMT cycle of the operational run. In order to ensure that the additional AIREPs were included in a revised fine-mesh forecast, as well as the additional SATEMs, the observation time-window of its 0000 GMT cycle was increased to match that of the global assimilation. The result was an improvement on the operational fine-mesh forecast for the storm over England but it was still inferior to the run from the interpolated global analysis.

Observations made before 0300 GMT continue to arrive at Bracknell after 0320 GMT. Table II shows the data volumes which were eventually available for repeat fine-mesh assimilations at 2100 GMT on the 14th and 0000 GMT on the 15th, as well as the volumes operationally available.

Table II. *Number of observations available within the fine-mesh area for the 2100 and 0000 GMT cycles on 14/15 October*

	Operational fine-mesh assimilation	Rerun assimilation with late data
1930–2230 GMT		
SATEMs (500 km)	20	33
SATEMs (250 km)	59	150
Ships	76	77
AIREPs	23	23
DRIBUs	11	11
SATOBs	0	24
2230–0130 GMT		
SATEMs (500 km)	4	4
SATEMs (250 km)	0	69
Ships	139	244
AIREPs	34	43 (127)
DRIBUs	8	9
SATOBs	21	123
Radiosondes	153	177

As already noted, potentially useful satellite data were missing from the 2100 GMT assimilation. At 0000 GMT, the extra satellite data were at 60° W and are probably not relevant. Additional ships' observations were received because many ships wait until morning to transmit their night-time reports. The increase in aircraft reports within the fine-mesh time-window is 9, but 93 if the window is expanded to 0300 GMT. A relatively large number of SATOBs (cloud motion vectors derived from satellite images) were received; however, it is recognized that care must be exercised if they are used operationally as they sometimes underestimate the strength of upper-level jet streams.

Various combinations of these data were tested. The best, which included all of them, gave a result close to the run from the interpolated global analysis.

Several experiments were performed to test the effect of various parameters in the fine-mesh data assimilation scheme. They showed that, in this case, a 40% increase in the weight given to the observations was beneficial. An analysis made using all the observations, and this increased weight, gave the forecasts shown in Fig. 3(d) and Fig. 4(d).

4. Forecasts from 1200 GMT on 15 October

Both the global and fine-mesh models from 1200 GMT failed to deepen the low sufficiently in the early stages, and moved it on too rapidly, leading to unhelpful forecasts. A fine-mesh forecast from the global analysis did not correct this deficiency, nor did the ECMWF forecast from an analysis with an even later data cut-off.

The forecast from the global model analysis at 0000 GMT was good, whereas that from 1200 GMT was not. It is important to find out why.

Experiments were undertaken with the fine-mesh system to establish which data contributed most to the change. The fine-mesh assimilation was started from an interpolated global analysis for 0000 GMT on 15 October, which was known to give a good forecast. Forecasts were run from intermediate analyses (data times 0600 and 0900 GMT). That from 0600 GMT gave an excellent position both at 0000 and at 0600 GMT on the 16th, with the low 2 mb shallower than the run from the 0000 GMT global analysis. In the forecast from 0900 GMT the low moved too quickly, but not as fast as in the 1200 GMT run. The

progressive worsening of the forecast from the 0600, to 0900 to 1200 GMT analyses, indicates that a single observational cause is unlikely. This was verified by other experiments.

As varying the observations available was not helpful, an alternative approach was to use manually generated 'bogus' observations. The best 12-hour forecast from 0000 GMT was used as a guide in generating them, and they were assimilated along with the actual observations. It was found that in none of the 'bogusing' experiments were the position and depth of the depression at 0000 GMT on the 16th correctly forecast.

In contrast to the experiments using the operational scheme, a test version of a modified assimilation scheme, which is being developed and is described in section 5.4, gave a fine-mesh analysis for 1200 GMT on 15 October which led to a very good forecast for the storm. The test scheme was run for two 3-hour cycles, starting from the operational fine-mesh analysis for 0600 GMT on 15 October, and using the same observations as were available operationally. The sea-level pressure from the test is shown in Fig. 5(a), which can be compared with the operational analysis given in Fig. 5(b). The test scheme gives a 969 mb low at 13° W compared to the operational scheme's 971 mb low at 11° W. The test analysis places greater emphasis on a trough near 44° N, 15° W; its pressure here is 5 mb lower. The test scheme's pattern in this region is more similar to the best forecast from 0000 GMT (Fig. 4(d)), and less similar to an independent subjective re-analysis, than is the operational scheme's pattern. However, there are very few observations and some doubt about their reliability, so the true analysis is uncertain.

Sea-level pressure forecasts obtained from the test scheme's analysis are shown in Fig. 6. The track of the forecast from the test analysis is very slightly to the north of the actual track, but the guidance which this forecast would have given a forecaster was excellent.

As the model humidities agree with the satellite cloud positions, and the computer analyses are consistent with available observations, the location of a depression near 44° N, 14° W at 1200 GMT on 15 October may indeed be correct. Despite the success of the forecast, it should be noted that in root-mean-square terms the test analysis fitted the available observations less closely than the operational analysis. It therefore cannot be concluded that the forecast was accurate in all respects, and the safer conclusion at this stage is that in the development of the storm there was a very large sensitivity to the details of the three-dimensional atmospheric structure, which were not resolved by the available observations.

5. Effect of systems currently under development

The Meteorological Office is developing improvements to its forecasting system. This case has been, and will continue to be, used to test them. In this section early tests of systems currently under development are briefly reviewed in order to give some idea of potential future improvements. It must be emphasized that the results are preliminary; considerable further work is needed before some of the systems can become operational.

5.1 Mesoscale model

The mesoscale model is for use in preparing forecasts up to 18 hours ahead, the aim being to provide guidance to local forecasters on surface temperature and wind, low cloud, precipitation and visibility. It is currently run twice a day using boundary conditions derived from the fine-mesh model forecasts starting at noon and midnight. Its horizontal resolution is 15 km and it has 5 levels in the lowest kilometre, permitting some detail in the treatment of boundary-layer structure. Fig. 7 shows the 12-hour forecast for 0000 GMT on 16 October at full resolution. As expected the general evolution follows the fine-mesh model forecast. However, the wind speeds predicted over land compare well with the general level of mean speeds reported at the height of the storm. It does not reproduce the highest speeds, but since the storm an algorithm to predict the maximum gust has been added to the model.

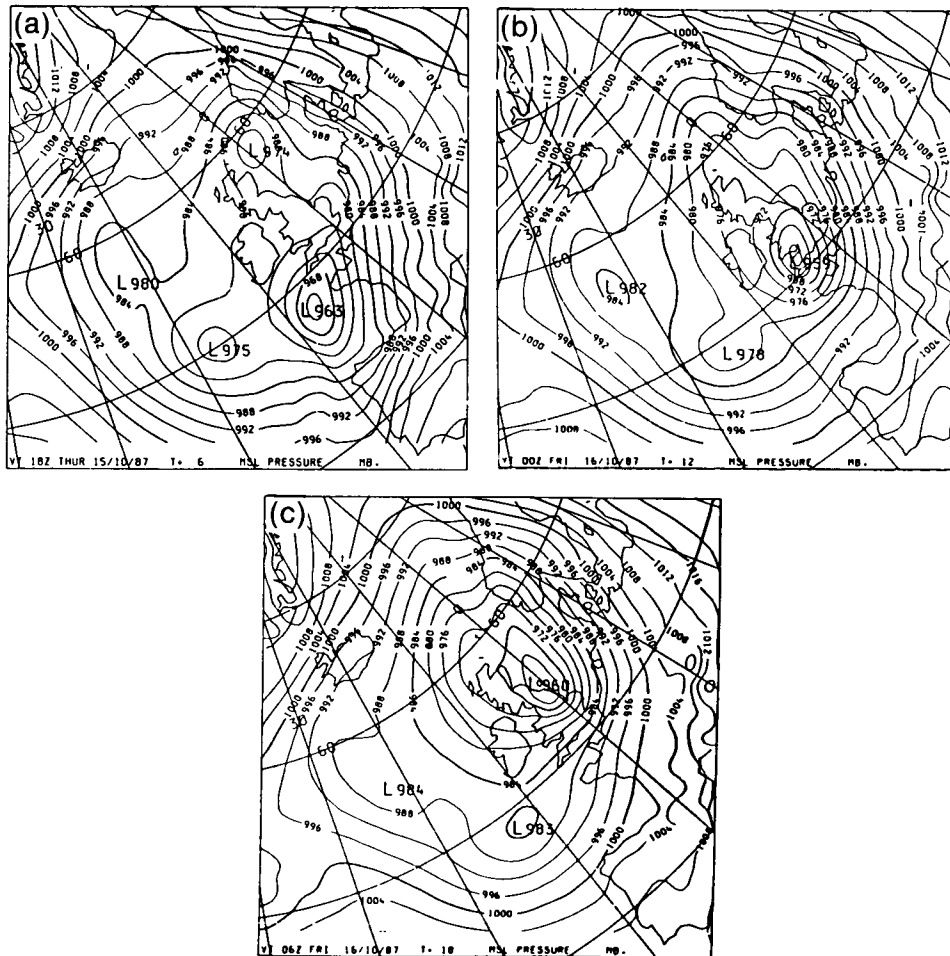


Figure 6. 6-, 12- and 18-hour mean-sea-level pressure (mb) forecasts using the fine-mesh model with the test fine-mesh analysis for 1200 GMT on 15 October.

5.2 Higher-resolution fine-mesh model

A higher-resolution version of the fine-mesh model is expected to become operational in 1988. Higher resolution should allow a more accurate description of frontal processes, and therefore the main improvement is expected to be in forecasts of precipitation. Where topographic forcing is significant, or when frontal processes contribute significantly to the dynamical evolution, improved wind forecasts should also be obtained. No data assimilation scheme is yet available for the model, so initial conditions are obtained by interpolation from the global analysis.

Forecasts were made from data times 0000 and 1200 GMT on 15 October with a horizontal grid length of 40 km, i.e. just over half that of the operational fine-mesh model. As expected, the evolutions of these forecasts were similar to those with the operational fine-mesh model using the global analysis, and with the operational global forecast; however, there is extra detail in the wind fields from the higher-resolution forecast (Fig. 8), and the depression is made more intense.

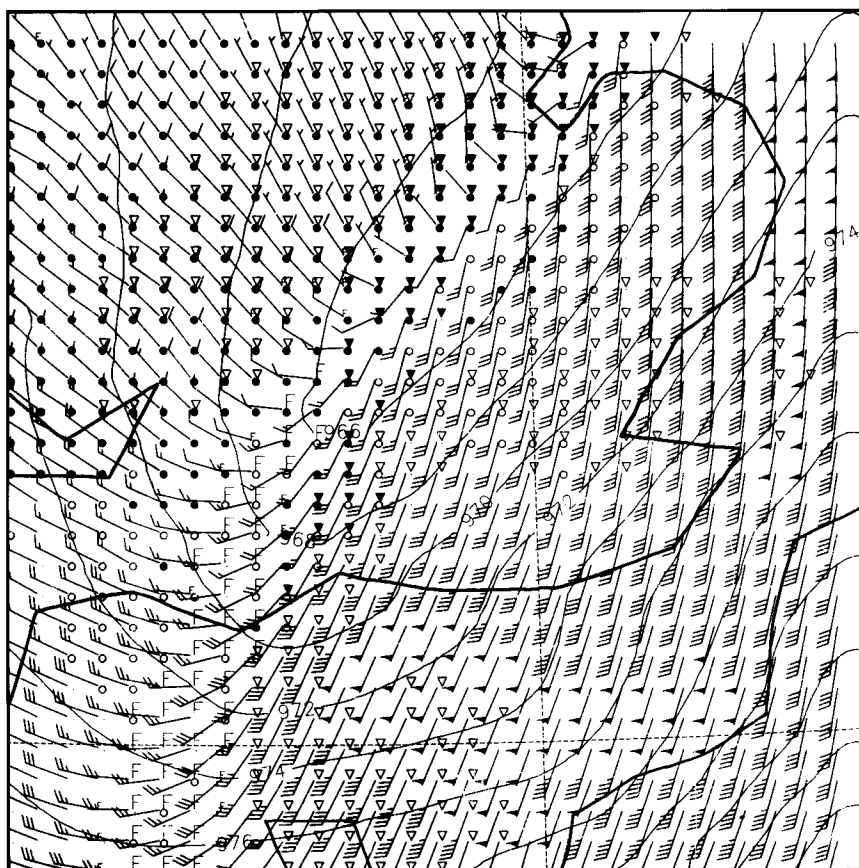


Figure 7. 12-hour mesoscale model forecast of pressure, wind and weather over south-eastern Britain from data time 1200 GMT on 15 October. Pressure in millibars, winds in knots, and weather by circles indicating precipitation from layer cloud (greater than 0.5 mm h^{-1} if solid) and triangles indicating showers (greater than 0.5 mm h^{-1} if solid). F indicates very low cloud.

5.3 Local Area Sounding System

TIROS satellite data for orbits near the United Kingdom are picked up by the receiving station at Lasham. By processing the Local Area Sounding System (LASS), higher resolution and more timely soundings can be produced than are available over the Global Telecommunication System as SATEM reports. Two processing methods are available. The first, based on techniques developed in the USA for processing TIROS data, but with locally derived calibration coefficients and other modifications, uses a statistical method and a first-guess profile based on a sample of radiosonde soundings. The second uses a physically based method with a first guess taken from a fine-mesh model forecast.

The impacts of both sets of retrievals were tested on the fine-mesh assimilation leading to the 1200 GMT 15 October analysis, but for the present case the retrievals were not helpful. Because of their high resolution, these data are potentially of great value, but improvements in methods of using them are needed.

5.4 Analysis Correction assimilation system

A new assimilation scheme, known as the Analysis Correction scheme, is being developed. Its basic

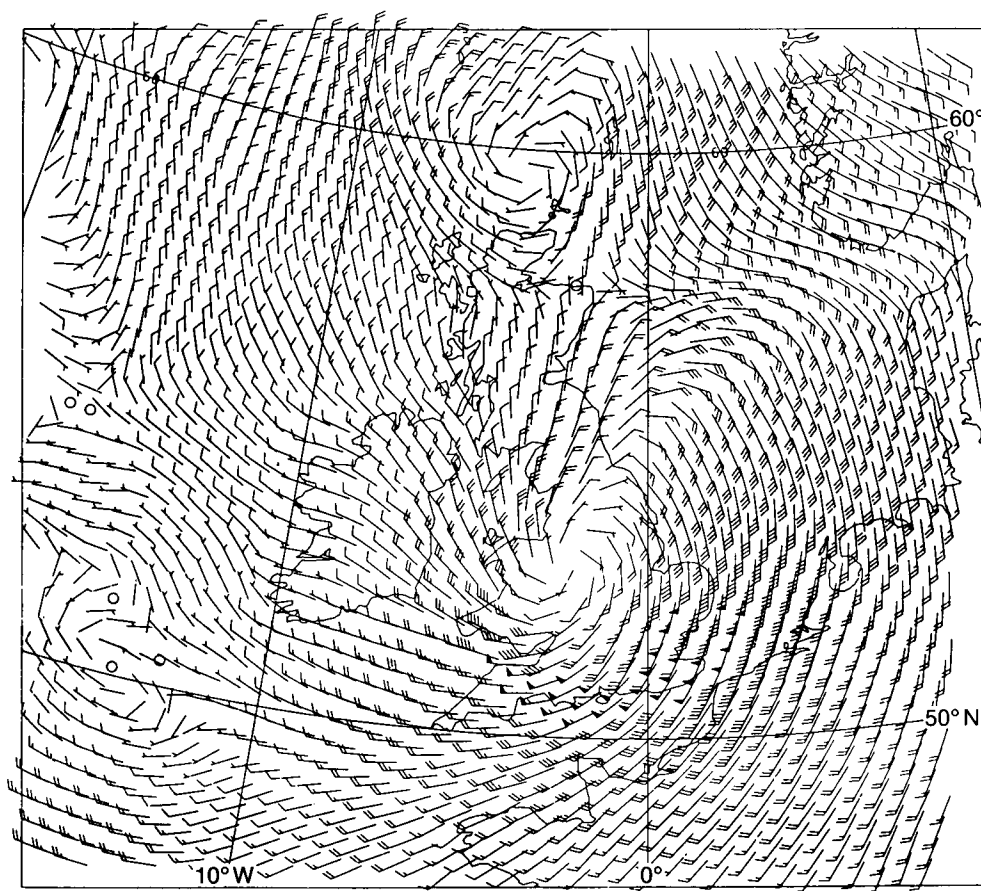


Figure 8. High-resolution fine-mesh forecast of 10 m mean winds (kn) at 0600 GMT on 16 October, run from the global analysis for 0000 GMT on 15 October.

structure is similar to that of the operational scheme, but its weighting and spreading of data are different. These differences are important in:

- (a) the handling of off-time data such as AIREPs, which are processed at their valid time rather than the nominal analysis time, and
- (b) the treatment of sparse data which should be fitted with less disruption to the detail in the forecast background.

New techniques for using the LASS retrievals discussed above are being developed as part of this scheme, but are not yet ready for testing.

A two-cycle rerun of the global version, like the operational global scheme, gave a good forecast from 0000 GMT. A fine-mesh version of the scheme which is being developed was tested on the assimilation leading to 0000 GMT on the 15th. Results were slightly worse than the corresponding run with the operational assimilation. The test of the fine-mesh version of the assimilation for 1200 GMT on 15 October has already been described in section 4. It gave the only analysis so far obtained for that time which leads to a good forecast of the storm.

6. Conclusions

The storm which crossed the south of England during the night of 15/16 October 1987 developed when an upper-level trough caught up with a strong frontal zone on 15 October. The existence of this development region was well forecast by numerical models several days in advance. Details of the features within this large-scale situation were crucial for determining the track, timing and intensity of the storm, and they were less consistently forecast. In contrast with the global model, the fine-mesh forecast from 0000 GMT on 15 October did not give a good prediction of the storm's track and intensity over England because of incorrect details in its initial conditions. Aircraft reports from the Atlantic between 0130 and 0300 GMT, which were too late for the operational analysis, would have provided much of the necessary detail; more would have come from satellite temperature soundings which arrived too late for the previous 2100 GMT analysis. A forecast based on the 0600 GMT analysis, which incorporated these late data as well as the 0600 GMT observations, would have provided excellent guidance to the development of the storm.

Neither of the two operational model forecasts from 1200 GMT predicted the storm adequately, but a fine-mesh forecast from a new assimilation scheme which is being developed did; the reasons for this are still being resolved. In the development of the storm there was a very large sensitivity to the details of the three-dimensional atmospheric structure which were not resolved by the available observations.

High-resolution models gave a better prediction of the local severity of the storm.

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Public forecasts and warnings of the storm of 15/16 October 1987

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Summary

The various forecasts and warnings issued for the storm of October 15/16 are described and the procedures in operation for warning the public and emergency authorities are discussed.

1. Introduction

Forecasts and warnings in the public sector are issued on a regional basis by the network of Weather Centres. These forecasts are based on guidance provided regularly by the Central Forecasting Office (CFO) in Bracknell. Presentations on national television and radio are carried out by London Weather Centre staff and there are routine telephone conferences with CFO to ensure that the forecast is up to date and consistent with the Senior Forecaster's views.

As regards the storm, forecasts were issued from as early as the previous Sunday and a fairly consistent picture was maintained during the week. This was reflected in the warnings issued on Thursday the 15th though the exceptional severity of the wind was not foreseen until late on Thursday evening. Many warnings were then updated a few hours before the onset of the storm. The Weather Centres at London, Norwich and Southampton were most heavily involved and several night duty staff stayed on in the morning to cover for those delayed getting into work. All in all it was a very busy period for all concerned.

2. Medium-range (2 to 6 day) forecasts

Useful forecast guidance for the 15/16 October began with the forecasts issued on Sunday 11 October.

There was mention of 'rather wet and windy weather right at the end of the week' on the BBC 1 television programme 'Weather for Farmers' broadcast on Sunday 11 October at 1258 (all times are BST unless indicated otherwise). The caption map displayed at the end of the broadcast included 'becoming very windy late in the week'. Many of the BBC television and radio forecasts from Monday to Wednesday highlighted the stormy weather expected later in the week. On the BBC 1 Wednesday broadcast at lunch-time for example, instead of opening with today's weather as is usual, the weatherman spoke of a low pressure system which 'is going to deepen like mad and head up and give us an angry spell of weather, wet and windy' on Thursday and Friday.

An example of the service that was provided to specialist users is the series of weather forecasts issued during the week to the Automobile Association. On Monday, the forecast for Thursday for south-east England was 'becoming windy, gales in places'. On Tuesday, the summary spoke of 'a major storm, crossing Britain from the south-west during Thursday and Friday'. The forecast for south-east England for Thursday was 'becoming very windy with gales or storm-force winds developing'. For Friday, the forecast was 'stormy at first, then slowly becoming less windy'.

Finally, the Meteorological Office issues forecasts for three to five days ahead on the pre-recorded telephone service, Weathercall; the relevant forecasts from Monday to Wednesday all referred to the expected exceptional strength of the wind.

3. Media forecasts issued on Thursday 15 October 1987

On the day before the storm, CFO did not anticipate the full severity of the winds. The forecasts highlighted the deep depression moving up from the south-west but concentrated on the heavy rain which was expected as a result. This was reflected in the wording used in the public forecasts issued that day. Part of the reason for the emphasis on rain lay in the weather of the previous week. There had already been copious amounts of rainfall during October, and over the previous several days there had been widespread flooding, especially in the south and east. This concern was clearly dominant in the forecasters' minds — for example, a message from Norwich Weather Centre to London Weather Centre on the afternoon of the 15th expressed the Water Authorities' serious concern at the risk of widespread flooding should the rain expected that night in their area occur.

The BBC 1 television weather forecasts at 1325, 1833 and 2128 all mentioned the likely wind in the south and east, but gave it less emphasis than the rain. Nevertheless, the wind symbols on the charts for both the early-evening and mid-evening broadcasts (symbol charts identical) showed winds of 50 m.p.h. (43 kn) for 'tonight' off the east coast and in the eastern English Channel. Note that the symbols represent mean wind speeds, not gusts.

The early evening broadcasts on BBC East and BBC South, given by staff from Norwich and Southampton Weather Centres, emphasized the wind rather more than the national forecast had done — as one would expect from a local forecast covering an area with extensive coastlines — but the national and local basic products were entirely consistent with each other.

On BBC Radio 4, the 1755 broadcast spoke in the introduction of 'an intense low pressure centre' moving across the Midlands overnight bringing 'strong winds'. The main body of the forecast for south-east England referred to expected conditions as 'quite windy with southerly winds touching gale force near south-eastern coasts for a while'.

The local radio scripts written at London, Southampton and Norwich Weather Centres, and those scripts written for the 24-hour forecast service on Weathercall for the affected areas, dealt with the situation in a similar way, tending to emphasize the unsettled nature of the weather and the rain, and making less of the wind. This was particularly the case with the forecasts for inland areas as opposed to those for coastal areas.

By midnight, however, rather more was being made of the expected winds. The live 0020 Radio 4 broadcast emphasized the severe weather to occur that night; part of it said 'just to re-emphasize, some dirty, wet weather to come, especially for England and Wales, as a really nasty depression sweeps up from Biscay, ... so some really unpleasant conditions if you are out and about on the roads and motorways tonight, some torrential rain, stormy winds eventually, especially on the Channel coast, and there will be inland gales as well'.

Finally, two television broadcasts are relevant in considering the wider area affected by the strong winds. In the BBC 2 'Weatherview' programme (pre-recorded at 2030, as usual, for broadcast at 2305), much was made of the strong winds over the sea areas and the near continent. Earlier in the day, the 1355 broadcast for the European satellite television Superchannel, which is presented by the weatherman at the BBC Television Centre, had opened with 'It's a case of batten down the hatches I think for some parts of Europe; some very, very stormy weather on the way indeed'. There was a subsequent reference to likely gales in France and the Low Countries and, later, in Scandinavia.

4. Warnings

Before going into details about the warnings issued to various authorities, it is necessary to describe the arrangements by which such warnings are given. The Meteorological Office, through its Weather Centres, gives notification of conditions expected to exceed given thresholds to those authorities requesting them. The thresholds are defined by the customer according to their operational needs.

Of particular relevance on this occasion are the arrangements by which the Meteorological Office warns emergency authorities. The London Fire Brigade has arranged to receive warnings if winds are expected to be more than 26 kn (30 m.p.h.); this is because winds of this strength curtail their use of long ladders. The London Fire Brigade has not asked to be warned of any other hazardous weather conditions, or of any wind strengths greater than the threshold. No other fire brigade has asked for warnings of any nature to be given and there are no national arrangements.

There is a national arrangement for warning police forces of fog on motorways, but all other arrangements for issuing warnings to the police are organized on a local basis. In the south-east, the local police forces receive warnings of snow, icy roads and heavy rain as well as fog, but there are no arrangements for the issue of strong wind warnings. In East Anglia, however, police forces do receive warnings of mean winds greater than 30 kn. Medical authorities only receive warnings by request and arrangement; in the south-east of England there are no such arrangements.

The Meteorological Office has organized a FLASH weather service by which the public can be warned via radio and television of the occurrence of severe weather which may cause considerable inconvenience to a large number of people and/or present a danger to life. These warnings are only issued when there is a virtual certainty of occurrence (usually based on actual weather observations) and the aim is to give immediate warnings of the onset of severe weather. The FLASH message system is important during the day since avoiding action, particularly by those intending to travel, can be taken. It is clearly much less effective at night when most people are in bed asleep, but they are not then exposed to weather hazards to the same extent. Weather FLASH messages are still issued at night, however.

FLASH warnings may be issued in cases of dense fog, heavy rain, heavy snow, widespread icy roads and severe inland gales and blizzards. They cover the 18 major urban areas of the United Kingdom (with the exception of blizzards which can refer to any area). Arrangements have been made for warnings to be broadcast through the BBC on national radio and television, and on those independent television and radio companies which agree to carry them.

Apart from receiving copies of FLASH warnings, the BBC Motoring Unit receives warnings of hazardous weather for broadcast on the BBC radio network. The criteria for these messages are less severe than for the FLASH messages; in the case of strong winds, the threshold is a mean speed of greater than 30 kn.

Warnings of exceptionally severe weather, which may call for military aid to be provided to the civil community, are issued to the Ministry of Defence at any time throughout the 24 hours. Forecasts are required when the following phenomena are anticipated:

- (a) Severe inland gales with mean wind speed of 43 kn (50 m.p.h.) or more; 'inland' means anywhere over inhabited parts of the United Kingdom.
- (b) Heavy and prolonged rain.
- (c) Snowfall likely to reach a level depth of 1 ft or more.

The Meteorological Office also issues warnings of high winds to British Rail because of problems in windy conditions with overhead lines. The requested threshold is a mean speed of 34 kn (i.e. gale force) or gusts over 60 kn. Warnings are only provided to those parts of the British Rail network where there are overhead lines; Southern Region is not covered.

On this occasion, the relevant warnings were issued at the following times:

Recipient	Time (GMT) 15/16 October
1. British Rail (Eastern Region)	1730
2. London Fire Brigade	2150
3. East Anglian Police Forces	2305
4. BBC Motoring Unit	2315
5. FLASH message of severe gales	0120
6. MOD for and to civil community	0135
7. London Fire Brigade	0140
8. All Police Forces in south-east	0145

Note that the warning to the London Fire Brigade at 0140 GMT was on the initiative of the London Weather Centre forecasters — there is no arrangement for this. Similarly the warning to the police in the south-east was beyond any agreement in respect of strong winds.

5. Forecasts for specialist purposes

5.1 *Forecasts for sea areas*

As early as 0630 GMT on 15 October, gale warnings were already in operation for all parts of the English Channel. At 1030 GMT on the same day warnings of severe gale force 9 'soon' were issued for the whole Channel except for sea area Plymouth ('soon' implies a time of validity between 6 and 12 hours after time of issue of the warning). These warnings were reaffirmed at 1710 GMT, except that it was anticipated that the gales in Portland would decrease to force 8 during the night.

The forecasts for the Channel sea areas were not revised until 2235 GMT on the 15th when warnings of storm force 10 were issued for all areas. These warnings were issued after an assessment of the 1800 GMT mean-sea-level pressure analysis. At 0135 GMT on the 16th the forecasts were increased to violent storm force 11 'imminent' (i.e. within 6 hours) for all parts of the Channel.

In addition, some forecasts for inshore waters are prepared for broadcast by local radio stations. The forecast for the inshore area from the Pool of London to North Foreland to Dungeness, issued to Radio Essex at 1631 on the 15th covering the period 1800 to 0600 on the 16th, was for winds increasing to between force 7 and severe gale 9 (30 to 45 kn) with gusts over 50 kn likely.

London Weather Centre issues many routine forecasts to the offshore industry operating in the North Sea. It is interesting to study a series of forecasts for a location off the coast of Norfolk issued between Monday 12 October and 0130 on 16 October. Apart from the high quality of the forecast early in the period, of particular relevance is the forecast issued on the afternoon of the 15th predicting winds overnight of 40 to 50 kn with gusts higher.

Generally the forecasts issued during 15 October for coastal or offshore areas, where wind is of course an important feature at all times, did include very strong winds. In particular, one major offshore contract actually began at midnight on the night of 15th/16th! Warnings issued were much appreciated by the operational staff offshore and proved to be very accurate.

5.2 *Forecasts for civil aviation*

The Senior Forecaster at London/Heathrow Airport is responsible for the forecasts for civil aviation but there are regular discussions with the Senior Forecaster in CFO. A strong wind warning was issued to 35 airfields in south-east England at 1328 GMT on the 15th valid up to midnight, forecasting wind speeds of 15 to 20 kn and gusts of 35 to 40 kn. A second strong wind warning was issued at 2300 GMT, followed at 0100 GMT on the 16th by a gale warning for wind speeds of 30 kn and gusts to 50 kn. This was quickly superseded by a storm warning issued at 0130 GMT forecasting a wind speed of 35 to 40 kn

and gusts of 55 to 65 kn. At 0450 GMT a further storm warning was issued giving wind speeds of 35 to 40 kn and gusts to 80 kn. Subsequent warnings were for gale and strong wind (depending on location) gradually moderating.

The warnings proved sufficient for most operational purposes and although damage is known to have occurred, no complaints have been received about the service provided.

5.3 Forecasts for military airfields

The Principal Forecasting Office (PFO) at Headquarters Strike Command is responsible for the forecasts issued for military airfields. The PFO produces its own forecast charts and for 0600 GMT on 16 October it forecast a depression of 959 mb near 55° N, 00° W, little different from the 0600 GMT forecast produced earlier by CFO.

Strong wind warnings were subsequently issued for military airfields south-east of the line Lincolnshire–Cornwall. Warnings of severe gales were issued during the evening, which preceded the onset of the gale at 6 stations by 3 hours or more, and at a further 5 stations by 8 hours. These warnings enabled the military authorities to take appropriate action and, apart from one aircraft parked inside a hangar which suffered superficial damage from a falling glass roof panel, no damage to aircraft has been notified.

5.4 Forecasts from other countries

A number of forecasts issued by the French National Weather Service have been obtained. It should be noted that forecasts covering the United Kingdom are not issued. For northern France, where very strong winds had always seemed likely, good warning was given. On the 14th, a message of severe weather was issued to various addresses, including the French railways, the Water Board, the Electricity Board, the national press and television stations. The message forecast winds of 43–54 kn for Thursday over some coastal areas and the English Channel, with extreme gusts of 80 kn. Sea-area forecasts and gale warnings issued by the French National Weather Service were generally similar to those issued by CFO.

6. Discussion

The medium-range forecasts issued (from the Sunday to the Wednesday) were generally very good though there is always uncertainty at this stage about the track of a depression and its intensity. Within 24 hours, the expectation is to produce a much more detailed forecast. On this occasion there was mention of strong winds in most of the forecasts, but the extreme severity of the wind was not anticipated until late on Thursday evening.

Nearly all the users of the specialized forecasts produced by the Meteorological Office were satisfied with the service provided; some, in the offshore industry for example, were very grateful. It should be noted, however, that actions are geared to wind speeds which are not as extreme as those that occurred (for example, a gale force wind of 34 kn or greater). Further, when the notice of a very severe event is given, such action as can be taken in the circumstances may often be carried out at relatively short notice and there are staff available throughout the 24 hours. The general public is not in this position and while the short period FLASH weather warning system is effective by day, it is inevitably less so at night (although messages are still issued). Further ahead, warnings to the public may be put out via the standard radio and television presentations (both national and local). On national BBC television there have been increases (in recent years) in both the number of broadcasts and the time allotted. Nevertheless, there may be scope for further action here.

One area where there will be changes of procedure concerns the warnings provided to the emergency

authorities. The warnings required by the Ministry of Defence, in cases which may call for military aid to be provided to the civil community, are well defined. These go to a single point in the Ministry of Defence and work well, even though warning of exceptional conditions is usually given with only a few hours notice. A similar arrangement with police and other emergency authorities may prove to be necessary. This will be discussed, at the initiative of the Meteorological Office, with the bodies concerned. At the same time it would be useful to review the wider requirements the emergency services have for weather information. Current procedures, with the police for example, have developed over many years, mainly on a local basis. One exception to this is the arrangement for issuing warnings of dense fog to the police; this was set up in 1965 by the then Minister of Transport following a series of crashes on motorways in foggy conditions. Although on 15/16 October warnings were passed to emergency authorities in accordance with arrangements made (in some cases exceeding the agreed requirements), extension of this nationally organized scheme may well be needed. Information would still be provided on a regional basis by the Weather Centre most closely in touch with the local weather; ideally it would be issued to a few key national and regional centres for onward distribution within the organization.

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Media reaction to the storm of 15/16 October 1987

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Summary

The media reacted strongly to the storm, and in particular to the supposed failure of the forecast. This article summarizes the main points made and the response of the general public.

1. Introduction

During the period following the storm, there was an unprecedented level of interest from TV, radio and the press, most of it centred on the question 'Why did the forecasters get it wrong?', though there were many subsidiary issues. The majority of items were critical of the Office, some extremely so, but about a quarter provided a more or less balanced view of the situation. As time progressed there was a growing body of press opinion (though never in the majority) which expressed a more sympathetic view. An increasing proportion recognized that the south-east of England could not have escaped the damage, however accurate the forecasts might have been. Many letters were received from members of the public; the vast majority expressed support for the Meteorological Office in the face of what was perceived as undue criticism in the press.

2. Survey of reports and interviews

A survey has been conducted to ascertain the reactions of the media both before and after the storm. A major source of data for the survey was the set of press articles extracted routinely from the national daily and Sunday newspapers. Weather Centres in the south of England have supplied copies of items that have come to their attention in the other national and local papers. The other major source of data has been a series of transcripts of radio and TV programmes, supplied by an agency.

Every item available has been examined, but it must be stressed that there are gaps in the coverage — notably many of the local papers and the *Daily Mirror*. It is also rather unlikely that no comments on the subject were included in any of the weekend radio or TV programmes, as stated by the agency. However, it is felt that, given the repetitive nature of much reportage, the points mentioned are likely to be a good representation of most of those made even in the areas not examined in the survey.

3. Summary of reactions of the media

3.1 *Before the storm*

During the weekend prior to the storm, much media attention had been given to the widespread flooding which had occurred in the south-east of England following a period of very heavy rainfall. Reports of 'torrential rain' were quoted, and photographs of flood damage appeared under front-page headlines in many national newspapers on Monday 12 October. Meteorological Office spokesmen were quoted as saying that the worst of the rain had passed. There were no reports recorded in the media concerning the gales forecast for the end of the week.

3.2 *Friday 16 October*

By daybreak on Friday 16 October, the majority of TV and radio services were in chaos. Breakfast-time television and radio were disrupted, with only skeleton services being transmitted. These transmissions almost exclusively reported facts as they became available, together with warnings and guidance for householders, travellers, schoolchildren, etc.

As the morning progressed, services were re-established, and attention began to shift towards forecasts issued the previous day. At 11 a.m. Nigel Gait of London Weather Centre was being faced on the 'Jimmy Young' programme (BBC Radio 2) with such statements as 'I don't recall being told in advance to expect weather like this'.

During the day, radio and TV picked up many of the issues that were to be expanded and reiterated later:

- An assertion that the ambulance services did not receive a warning.
- An assertion that the London Fire Brigade was paying for a warnings service.
- A comment by Michael Fish on his BBC TV lunch-time forecast that there would not be a hurricane. Subsequently, this term was used in virtually all media reports and articles to describe the event.
- Bill Giles's BBC 2 TV presentation pre-recorded at 8.30 p.m., broadcast at closedown on the 15th, in which, pointing to tight isobars with 50 m.p.h., he said 'it will be very breezy up through the Channel and on the eastern side of the country'. (Note that this comment was followed by a description of very strong winds to be expected. Subsequent viewing of the transmission makes it clear that this was intended to be conveyed as a deliberate understatement.)
- The opinion that the Meteorological Office and the weathermen might be sued for negligence. This was particularly highlighted in the BBC Radio 4 programme 'PM' at 5 p.m.
- Opinions that the warnings came 'too late, no effective warning.'
- The view that meteorology needs more upper-air stations and weather ships.
- The view that the Office was only as good as its forecasts of extreme events.

3.3 *Saturday 17 October*

The Saturday papers were emblazoned with reports concerning the storm. The typical front page headline was something like 'Why weren't we warned?' The *Times* printed a report that the Meteorological Office had disregarded information from ECMWF, and that the French and Dutch had got the forecast right. This point was subsequently taken up by many newspapers as a key issue.

3.4 *Sunday 18 October*

By now, many newspapers were seeking stories which concentrated on the personalities involved. The Director-General of the Meteorological Office and the TV weathermen — notably Michael Fish — were besieged at their homes by reporters and cameramen. In addition, the BBC TV Centre was inundated with press enquiries concerning the weather and the forecasts broadcast prior to the storm.

The *Sunday Telegraph* reported the Environment Secretary as condemning an 'unbelievable failure to get it right'. Most papers concentrated on the French/Dutch/ECMWF forecasts. There was a complaint from one private meteorological consultant that the distribution of ECMWF forecasts was unfairly controlled by the Office, and a statement from another that he used forecasts from the Office, ECMWF and Offenbach!

3.5 *Monday 19 October*

Monday's papers produced a number of new points:

- A virulent attack on the Cyber supercomputer (*The Guardian*).
- The possibility of privatization (*The Daily Telegraph*).
- The view that power officials 'could have coped if we'd been warned' (*The Daily Telegraph*).
- Bengtsson's (ECMWF) comments: '(the Met Office) trying to be too exact' (*The Daily Telegraph*).
- The *Sun* called for the Director-General's resignation. Reports of interviews with the Director-General in the *Daily Mail* and *Financial Times* tempered the acidity a little.

The evening TV and radio carried reports and reactions to the Director-General's Press Conference, the views of ITN's 'News at Ten' being particularly condemnatory despite broadcasting an interview with the Director-General. The whole issue was trivialized in the TVS 'Question' programme ('Weathermen always forecast for the part of the country you're not interested in').

3.6 *Tuesday 20 October*

On Tuesday 20th most of the papers gave full accounts of the Director-General's Press Conference, some with later interviews, and the whole tone was very considerably changed for the better, although the *Guardian* still talked of the Office as 'top of everyone's list of duffers'. The evening TV and radio were also by this time coming down to a very low key, with most references being to the setting up of an enquiry. In the course of the 'Tuesday Call' programme (BBC Radio 4) the head of the Dutch company, Meteocast, agreed that reports that they had forecast with greater precision were misleading.

3.7 *Wednesday 21 October*

On Wednesday the papers produced a variety of views. The *Daily Express* had some irate language — 'complete, shameful devastation of the credibility of those smugly useless TV weather people', and most papers reported details of the Swinnerton-Dyer-Pearce inquiry, but the real interest lay in the letters. These ranged from the first mention of 'What could we have done even if the forecast had been correct?' to 'Do without them!'. There was a more supportive air generally, with letters from Brian

Hoskins and Ian James (both from the Department of Meteorology, University of Reading) suggesting probabilistic forecasting, and Norman Lynagh (Noble Denton Weather Service) saying that it could not have been forecast in detail more than a few hours before. His letter, however, went on to ask why the warnings had not been issued until after midnight. Several other letters backed probabilistic forecasting, usually by suggesting the use of 'may', 'could', 'might', etc. as well as 'will'.

Media interest was revived at this stage as severe flooding occurred in South Wales and the south of England. Merton Council was reported as complaining of the Meteorological Office's supposed inadequate warnings, to be rebutted by an interview with Roger Hunt (London Weather Centre) on 'Thames TV News' later in the day. There was a fair amount of further TV coverage, mainly on ITV. During the morning Norman Lynagh was interviewed on the 'Jimmy Young' programme.

3.8 *Thursday 22 October*

In Thursday's papers there were fewer articles but more interest. John Gribbin in the *Daily Mail* blamed it all on the greenhouse effect, Arthur Blackham in the *Independent* celebrated 'dead silence from the frog-spawn watchers' and recommended the Noble Denton Weather Service method of giving confidence levels. An article in the *Sun* was headed 'Twenty things you didn't know about Weather Wally Fish'.

On television, Professor Pearce in the 'Breakfast Time' interview was fair but neutral despite rather leading questions from the interviewer. In the evening 'Tomorrow's World' produced an 'explanation' of the forecast failure based on a theory that the 0.2 °C global rise over the last ten years had been greater over the oceans than the land.

3.9 *Friday 23 October*

In Friday's *Daily Telegraph* an article concluded that if it were not for the Ministry of Defence the Office could be the next to be privatized and rationalized. The other papers only carried letters of interest, among which was one from Hugh Cumming (spokesman for the Institution of Professional Civil Servants) and another demanding more weather ships, a comment that was to be repeated fairly often. There was little on TV.

3.10 *Saturday 24 October and afterwards*

On Saturday 24th the *Times* third leader was asking why the Office should be in the Ministry of Defence, suggesting that the Office was being asked to do too much, highlighting conflict between the Office's role as a National Meteorological Service and its commercial roles, and hinting that we penalized the airlines in comparison with the shippers.

The *Sunday Times* went back through all the early comments without adding anything significant.

Tuesday's *Guardian* carried a blatant advertisement in the guise of an article about Metecast (Europe's satellite-TV weather channel) saying that it was better than the BBC forecasts or teletext because it was continually updated.

On Friday 30th it was discovered that BBC's Ceefax had been carrying a highly critical article entitled 'MEGA-BLOOMER' for a period of at least a week.

On Saturday 31st an article by Brian Hoskins and Ian James (Department of Meteorology, University of Reading) appeared in the *Guardian*, giving some very good background and making more clearly than anyone else the point that a 300 km wide storm can easily be missed by an upper-air observing network that has an average spacing of 270 km only over the land.

Thereafter the issue dropped out of the limelight, in the wake of continuing problems in the Stock Market.

4. Interviews, News Releases and Press Conferences

Many interviews were given by members of staff to the media. Also, during the period, two News Releases were issued by the Press Office:

- (a) Friday 16 October at 3 p.m. issued from Bracknell. This gave a very brief summary of the key facts known at the time.
- (b) Saturday 17 October at 3 p.m. issued from London Weather Centre. This concerned responsibility for Meteorological Office public service forecasts, and also stated that an internal inquiry on the storm was to be held.

On Monday 19 October, a Press Conference was held at London Weather Centre at 5 p.m., with the Director-General and senior members of the Directorate in attendance.

5. Reactions of the general public and customers

Not surprisingly, there was a considerable volume (several hundred) of letters and telephone calls from members of the public, as well as a smaller number from customers and representatives of various organizations.

The overwhelming majority expressed support for the Office and appreciation of its services. Many correspondents believed that the Office had been unduly criticized by the press.

Among the commercial customers, there has been hardly any negative reaction. Two customers for medium-range forecasts complained about the failure to predict the intensity of the storm although, as stated earlier, the forecasts issued a few days before the event were in fact very good; the situation has been explained to these customers. The Office also received a complaint from the BBC who said that the lack of warning of the storm given in the TV forecasts reflected upon their own credibility.

6. Summary of principal issues in the media

Many comments and criticisms appeared in the media, notably in the press. There was a mixture of informed and uninformed opinion, as well as perceptions which in retrospect seem distorted. The central issues were:

- Whether the forecasts had been 'wrong'.
- Whether other meteorological agencies, particularly those in The Netherlands and France, had issued more accurate forecasts. At present, no meteorological agency is claiming this; indeed there have been public assertions by such agencies to the contrary.
- Whether there had been any negligence, and whether any information (e.g. from ECMWF) had been disregarded.
- The comments made during TV forecasts during the previous day. The interpretation of these comments is a matter for judgement. Clearly, they were intended to be part of the style of delivery of the forecasts, aimed at making them more interesting rather than a dry repetition of the facts.
- Whether warnings had been too late.
- Whether emergency services had been given adequate warning.
- Whether commercial customers had received a better service than the general public.
- Whether there are sufficient upper-air stations and weather ships.
- Whether the Meteorological Office should be privatized.
- Whether anything could have been done had there been more warning.
- The difficulties of forecasting such extreme events and weather systems of such small size.

Meteorological Magazine

GUIDE TO AUTHORS

Content

Articles on all aspects of meteorology are welcomed, particularly those which describe the results of research in applied meteorology or the development of practical forecasting techniques.

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Spelling should conform to the preferred spelling in the *Concise Oxford Dictionary*.

References should be made using the Harvard system (author, date) and full details should be given at the end of the text. If a document referred to is unpublished, details must be given of the library where it may be seen. Documents which are not available to enquirers must not be referred to.

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April 1988

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