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The storms of January and February 1990

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Summary

A synoptic review is undertaken of the windy period that affected the United Kingdom and much of northern Europe from late January to the end of February 1990 and an attempt made at classification of the cyclogenesis events.

1. Introduction

The 1990 winter period of intense storminess over the United Kingdom and north-west Europe began with the Burns' Day storm on 25 January (McCallum 1990) and ended soon after the major low of 26 February . In this article the general characteristics of the separate storm events will be assessed and a tentative classification proposed. A rather more detailed study will be made of the 26 February event and some comparisons drawn with the Burns' Day storm. An attempt will be made to put the period in some perspective in terms of the broad-scale atmospheric anomalies and a review will be made of some of the numerical guidance available during the period. The role of the forecasters in their interpretation and tuning of this guidance will be stressed.

2. Setting the scene — early winter in the North Atlantic

In the early part of the winter (Nov./Dec. 1989) much of northern Europe had already experienced stormy interludes and some exceptionally deep lows had developed over the Atlantic. The Atlantic jet stream was unusually strong and had become displaced further south than normal during December with an area of exceptional cold (large negative) 1000–500 mb thickness anomaly (hereafter referred to as thickness anomaly) extending across north-eastern USA, eastern Canada and Newfoundland. Early January saw a transition to a more zonal regime and a recovery of thickness values over much of the USA but it remained anomalously cold over Labrador and to the north-east of Newfoundland, maintaining the exceptionally strong baroclinic zone well to the south of its normal latitude. Whether through atmospheric coupling or some other mechanism, sea surface temperatures (SSTs) were abnormally cold to the east of Newfoundland while further to the south values were actually a little above normal. Thus the SST gradient between the Gulf Stream and Newfoundland was even stronger than usual (Fig. 1).

Past studies have indicated that the distribution of SST may have a significant influence on the development of depressions. For example Sanders and Gyakum (1980) noted a significant association between rapid

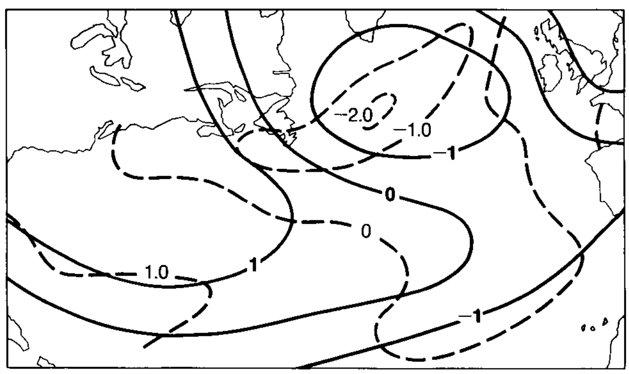


Figure 1. Anomalies of normalized 1000–500 mb thickness (standard deviations, January 1990) (solid lines) and sea surface temperatures (°C, 1–25 January) (dashed lines) for the period preceding the stormy period.

deepening and SST gradient, with a preference for the initiation of explosive deepening over or just to north of the mean winter position of the Gulf Stream. They suggested that the exchange of sensible and latent heat between cold continental air and a relatively warm sea surface is an important contributor to cyclogenesis and should be most marked where cold air moves rapidly across a strong SST gradient towards warmer water. The importance of latent heat in intense cyclogenesis has been demonstrated in a number of numerical model studies; Hoskins (1980), for instance, described a case in which latent heat processes accounted for more than 60% of the forecast deepening of a Pacific low.

Namias (1987, 1989) has also drawn attention to the concurrence of warm SST anomalies south of Newfoundland with negative geopotential anomalies further north in the periods preceding both the record Atlantic low of December 1986 (Burt 1987) and the October 1987 'Great storm' and suggests that such combinations are always likely to foreshadow extreme cyclogenesis during the following weeks. Fig. 1 emphasizes that anomalously strong gradients of both SST and thickness existed in the first few weeks of 1990; the antecedents for a stormy interlude had been established.

It is of interest to note that the continued cyclogenesis during February served to amplify the pre-existing temperature anomalies. Indeed, in mid Atlantic the negative thickness anomaly for the month exceeded 15 dam (3 standard deviations from normal) and the pressure of the mean Iceland low was more than 30 mb (3.5 standard deviations) below normal; both figures the largest recorded anomaly since records began in 1873.

3. The cyclogenesis events of the period

3.1 Some characteristics of the lows

The period from 24 January to 28 February 1990 was notable for the succession of storms that battered the United Kingdom and north-west Europe, attracting a high level of media attention. The period opened with the Burns' Day storm on 25 January when winds were of a magnitude comparable with those of the Great Storm of October 1987. It ended with the deep low and following wave depression on 26–28 February. The significance of the windiness of the period in a historical context is discussed elsewhere (Hammond 1990), though it is worth noting that many sites in southern England recorded their highest ever maximum wind speeds for the months of January and February. For example London (Heathrow) Airport recorded a gust of 76 kn on 25 January (compared with 66 kn in October 1987) and its highest ever maximum wind in February with a gust to 61 kn on the 7th. It was extreme gusts such as these that were largely responsible for the extensive damage and loss of some 80 lives.

The high frequency of the stormy spells was memorable; despite a week of anticyclonic regime in the middle of February, 15 major lows passed close to or over the British Isles during the 5-week period.

The separate tracks of the 15 lows are shown at Fig. 2. They are labelled in order of their occurrence from A to O and their positions marked at 6-hourly intervals. The position of each of the lows at the start of the period of maximum 24-hour deepening is indicated by a bold dot. Each low was steered quickly east-north-east across the

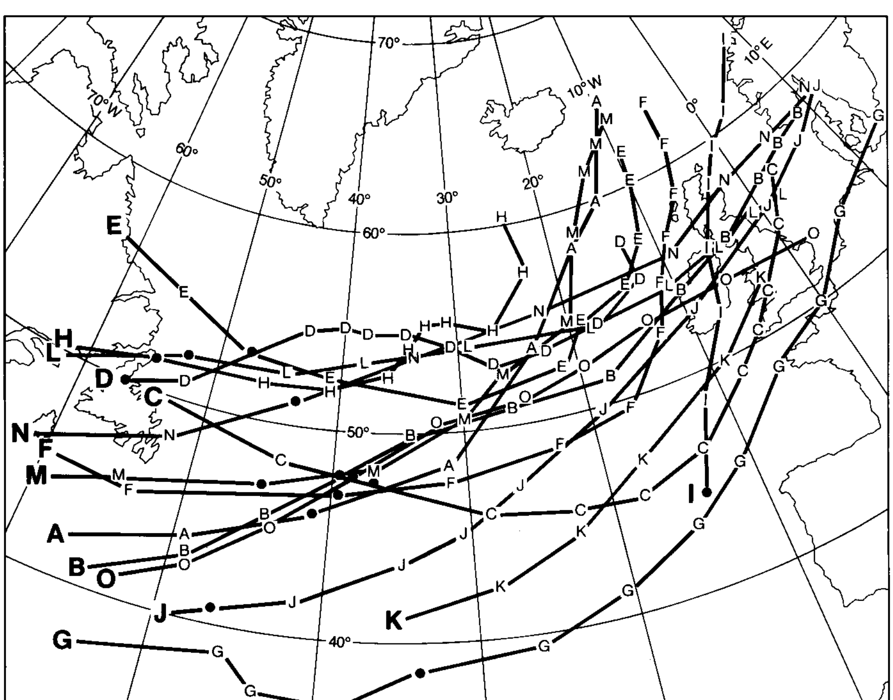


Figure 2. Tracks of the 15 lows. Positions of centres shown at 6-hour intervals, marked by identifying letter. Bold dots mark the start of period of maximum 24-hour deepening.

Atlantic and most deepened rapidly as they approached Europe. All were the result of baroclinic instability.

No two lows behaved in quite the same way; each had unique characteristics dictated by subtle differences in the dynamic forcing. It is beyond the scope of this article to examine each one in detail but it is possible to identify certain recurring patterns of behaviour which suggest a tentative classification into archetypes. A more detailed analysis is reserved for the two major lows of the period on 25 January and 26 February (described in section 4).

Table I provides details of the individual lows and their relationship with the 250 mb long-wave pattern. Sanders and Gyakum coined the term 'bomb' for lows in which the 24-hour fall in central pressure equalled or exceeded a latitude-dependent critical value, which ranges between 18 mb at latitude 40° N and 24 mb at 60° N. It will be seen that 11 of the depressions considered here can be classified as explosive deepeners or 'bombs'. Perhaps significantly, each of the bombs developed over or to north of the Grand Banks of Newfoundland: the other four developed south of 45° N.

The table also emphasizes the strong winds at jet levels above each centre — an indication of the marked baroclinicity and the reason for the rapid movement of each system. The 'standard textbook' idea that many baroclinic disturbances begin life (relative to the jet) as right entrance features or embedded in the jet axis itself and end their deepening phase in the left exit region is borne out by 13 of the 15 depressions. This simplistic idea belies the complexity of the dynamics and feedback mechanisms involved as developing surface low and propagating jet evolve, but is nonetheless a useful forecasters' rule of thumb.

3.2 A classification into archetypes

In Fig. 3 a tentative classification of the lows is suggested in which five basic archetypes are identified according to their relationship to the major 250 mb trough. This is similar to the scheme adopted in the new *Forecasters' imagery interpretation manual* (currently being co-ordinated by the Meteorological Office — due for publication 1991) and resembles a classification proposed by McClennan and Neil (1988) for identifying cyclogenesis in the Pacific Ocean. In the period considered here, there are examples of all five archetypes.

3.2.1 Type I — Mobile, flat, confluent trough

Many of these lows were associated with a short-wave trigger or jet streak which moved around the flat, confluent, upper trough although in each case they remained in close association with the long-wave pattern. This was a typical pattern for rapid cyclogenesis found by Young (1989) and was the most common configuration here with eight examples, including five 'bombs' moving east-north-east from the Grand Banks area (A,B,F,O,M), a modest deepener that approached from the Azores (G) and the non-deepening couplet that formed near 40° N (J,K). Three of the lows (A,F,M) turned to the left to pass to the north-west of Scotland bringing gales to the far north-west of the British Isles. Low G passed through the English Channel bringing widespread storm damage to northern France and the

Table I. Relationship of surface low centres to certain features of flow patterns at 250 mb. (a) at start of period of maximum 24-hour deepening, and (b) 24 hours later.

Low designator (see text)		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
		January						February								
Date/time (UTC)	(a)	22/00	24/06	26/06	27/12	29/12	31/12	02/00	02/12	05/18	06/00	06/00	10/06	18/00	25/06	27/06
Position Lat. (° N)	(a)	46	47.5	47.5	50	53	46.5	38.5	51	44	41	41	51.5	46.5	51	47.5
Long. (° W)	(a)	41	39	37	56	47	39	34	55	14	35	47	52.5	45	43	39
24-hour pressure fall (mb)		62	46	29	46	27	36	17	38	15	−5	10	26	34	27	23
24-hour average speed (kn)		55	48	41	29	47	46	47	32	42	50	42	52	45	60	42
250 mb																
Distance from trough (n mile)	(a)	720	600	−1200	360	250	350	240	150	420	950	540	860	880	950	600
	(b)	540	460	0	0	250	300	240	0	250	960	420	>1200	920	>1200	540
Trough character	(a)	C	C	C	C	D	C	C	D	C	C	C	C	C	C	C
	(b)	C	C	D	C	D	C	C	S	C	C	C	C	C	C	C
24-hour maximum jet speed (kn)		210	170	210	170	210	140	140	140	140	165	165	180	180	180	210
Overhead maximum wind speed (kn)	(a)	140	120	100	140	90	120	100	65	60	100	125	90	120	150	130
	(b)	70	100	50	20	35	50	110	35	100	100	125	100	70	120	140
Jet-stream sector	(a)	R O	R E	L X	R E	J X	J O	J E	L X	R E	R X	R O	J X	J X	R O	R E
	(b)	L X	L X	L X	L X	L X	L X	R E	L X	J E	J X	L O	L X	L X	L X	R O
Low archetype		I	I	V	III	IV	I	I	IV	III	I	I	II	I	II	I

Key: R,L,J = to right of, to left of, and at, jet axis. E = entrance, X = exit, O = mid jet, C = confluent, D = diffluent, S = symmetrical

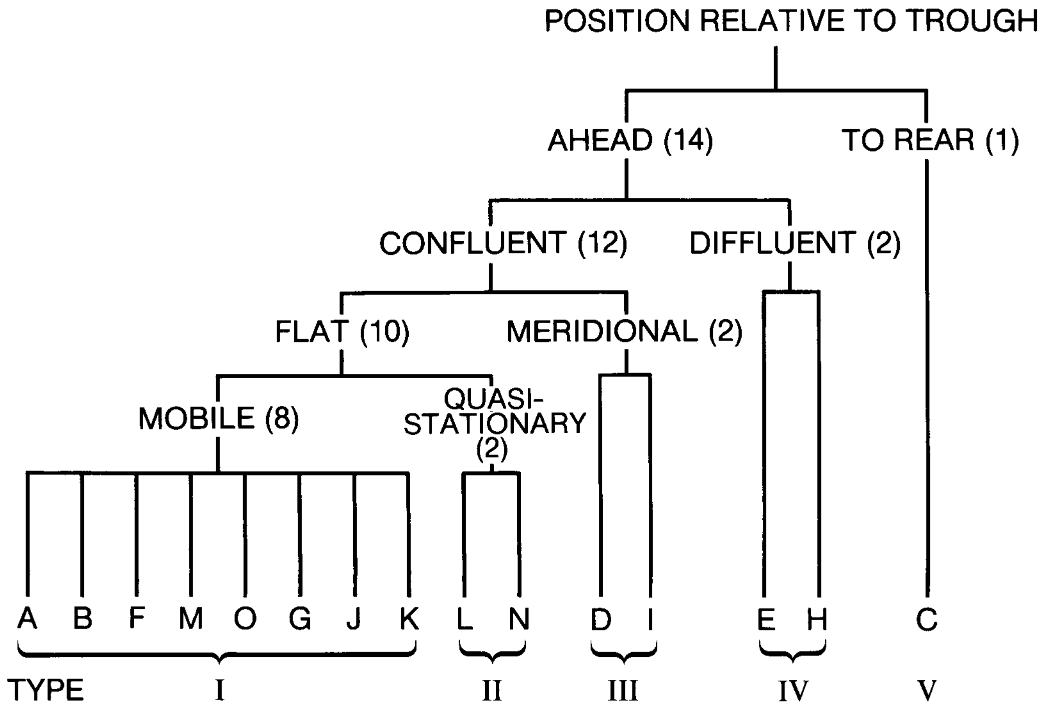


Figure 3. Tentative classification of lows into archetypes, based upon their relation to major troughs at 250 mb.

other four (B,K,J,O) crossed some part of the United Kingdom bringing gusts to at least 80 kn. The Burns' Day Storm (B) was one of these, bringing the highest gust of 93 kn (see section 4). A general schematic of this type is shown in Fig. 4; in particular the position of the jet stream relative to the low centre early in its life cycle (Fig. 4(a)) and as a mature system (Fig. 4(b)), with superimposed typical significant cloud distribution shown shaded.

A characteristic feature of those type I lows was the surge of pressure that followed in the wake of the centre (due to marked subsidence, which typically occurs immediately behind the confluent upper trough), leading to very strong winds on their western and southern flanks. Low G which brought storms to northern France was a particularly striking example of this marked anticyclogenesis with pressure rises of over 20 mb per 3 h to the rear of the centre although it was not an explosive deepener itself (see Young 1990).

Except for the warm front wave (K) all of this group exhibited characteristic cyclogenetic signatures on satellite imagery; notably the baroclinic leaf and dry slot (Weldon 1979, Monk and Bader 1988). However, although some showed these characteristics before the rapid deepening phase, others did not develop a good cloud head until the explosive deepening was well under way.

3.2.2 Type II — Quasi-stationary, flat, confluent trough

Lows L and N developed ahead of a slow-moving 250 mb trough. Each progressed very rapidly east-north-east with little curvature of track, moving well to poleward of the main baroclinic zone and driven by a shallow, fast-moving, short-wave perturbation near the left exit region of a propagating polar-jet streak. The developing centres were associated with an area of local diffluence and moved away from the slower moving long-wave, confluent, upper trough. In neither case was there marked anticyclogenesis following the passage of the centre due to the diffluent nature of the associated short-wave upper trough. One of this pair, the 26 February low N gave a highest gust of 87 kn over the United Kingdom and is discussed in more detail in section 4 below.

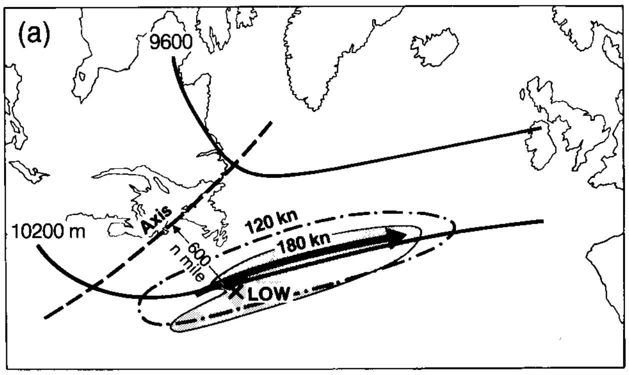
Satellite imagery showed some degree of the classical dry-slot and baroclinic-leaf signatures but these were generally less organized than in type I storms.

3.2.3 Type III — Meridional confluent trough

Two lows (D,I) developed on the forward side of large-amplitude, 250 mb troughs (i.e. trough amplitude ≈ half the wavelength). Low D deepened as it moved seaward from Newfoundland in association with a disrupting upper trough. Its subsequent movement was dictated by progression of the closed upper circulation. Low I ran quickly north-east across Britain in the entrance region of a jet ahead of a relaxing 500 mb trough.

3.2.4 Type IV — Diffluent trough

Two lows (E,H) deepened ahead of a diffluent, long-wave, upper trough. Both were well to poleward of the main jet and already under a closed 500 mb contour pattern on moving east from Labrador. As with the type III low mentioned above, subsequent progress was controlled by the upper vortex. Both lows passed to the north-west of Scotland as mature systems with no exceptional wind speeds.



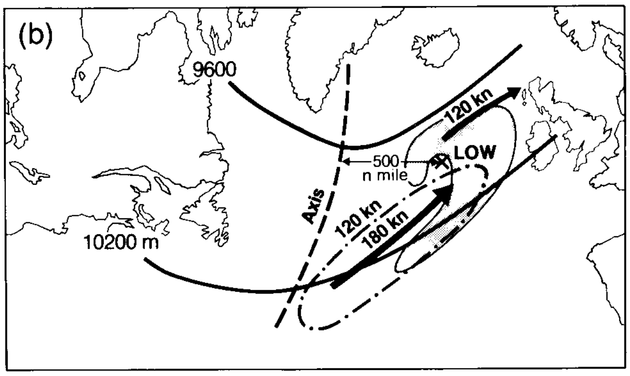


Figure 4. Schematic of low development ahead of a broad, mobile, confluent 250 mb trough. Disposition of surface centre relative to 250 mb pattern (a) at time of onset of rapid deepening, and (b) 24 hours later. Main cloud bands are stippled.

3.2.5 Type V — Development to rear of trough

Low C was the only low to develop in the north-westerly flow to the rear of a long-wave upper trough. It developed in the left exit of a propagating and veering polar jet with a developing short-wave feature in close association. Cyclogenesis occurred in conjunction with this short-wave perturbation although the classical cloud head and dry-slot signatures were not apparent on imagery until the development was well under way.

3.3 Summary of types

The following general conclusions emerge from this study:

(a) Marked anticyclogenesis to rear of the surface centre is a potent generator of strong winds and appears to be a characteristic of lows developing in, or advancing to, a position ahead of a mobile, flat, confluent 250 mb trough.

(b) Such a surge of pressure is not a feature of lows ahead of a diffluent trough, nor of the important type II lows which run rapidly ahead of, and away from, a quasi-stationary, long-wave, upper trough.

(c) There is no simple correlation between severity of surface wind gusts and amount of deepening. Low G was one of the most damaging but was a comparatively modest deepener. The warm front wave (K) did not deepen at all yet produced gusts of 80 kn.

(d) Satellite imagery is often invaluable in drawing attention to the onset of major deepening but it is not always useful as a predictor of such events. Cyclogenetic signatures evident on imagery are helpful in determining the conceptual type. However, the waxing and waning of cloud features and changing cloud-top temperatures as witnessed on satellite movie-loops give a more useful insight into development.

4. Dynamical evolution on 26 February — comparison 25 January 1990

To understand a little more of some of the dynamics involved with two major storms during the period, the depression of 26 February is compared here with the Burns' Day storm of 25-January. It was the severe gales from these two lows that attracted most media attention and heralded the commencement and end of the windy period.

The embryonic storm of 26 February, as did the other, formed as a minor perturbation on the main baroclinic zone over the eastern USA. A closed isobaric circulation first developed over New England around midnight on 24 February. Embedded in a powerful westerly jet (maximum speed 180 kn), it moved rapidly east-north-east in association with a minor, short-wave, upper trough developing on the western flank of the main baroclinic zone.

The low began to deepen soon after moving east of Newfoundland early on 25 February. Satellite pictures at this time indicated the typical signature seen on many of the cyclogenesis events during this period with the appearance of a double baroclinic zone, emphasized by two parallel cloud bands. Deepening was to continue for more than 48 hours, by which time the centre had reached the Gulf of Bothnia and the central pressure fallen by 42 mb.

At midnight on the 26th, the low was centred in sea area Malin and the dynamics of the system are well represented by diagnostic output from the Meteorological Office fine-mesh regional model for that time (Fig. 5). Marked vertical motion well ahead of the low was mainly due to the substantial maximum in the warm advection field, with rapid ascent over the centre itself due to differential vorticity advection ahead of the fast moving, slightly diffluent, short-wave, upper trough. Behind the upper trough axis, marked subsidence resulted from a combination of cold advection and negative vorticity advection. This symmetrical pattern of warm and cold advection emphasized the translatory nature of the system while the ascent over the centre of the low explains the continuing fall in central pressure, features identified in the study of the October 1987 storm by Morris (1988). The pressure rises behind the system were of a similar order to the falls ahead and were modest by comparison with the Burns' Day storm which exhibited rises of more than 20 mb in 3 hours. This

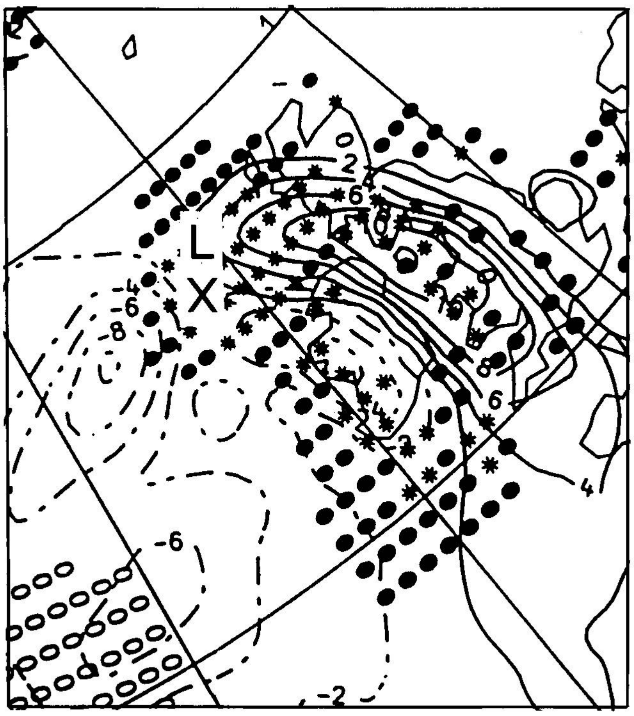


Figure 5. Diagnostic output from the Meteorological Office fine-mesh model for 0001 UTC on 26 February 1990.

reflected the slightly diffluent shape to the associated upper trough, as opposed to the confluent nature of the Burns' Day storm, where marked anticyclogenesis behind the centre contributed to the greater pressure surge.

Satellite pictures during the early deepening phase (Fig. 6) showed some signs of the baroclinic leaf structure and dry slot; features normally associated with rapid cyclogenesis, but the signature was less pronounced than in the Burns' Day storm which exhibited a larger cloud head (compare with Fig. 7).

Tightest gradients were on the western and southern flanks of the low, and by 0600 UTC on the 26th covered a large part of the United Kingdom (Fig. 8) with some of the strongest winds associated with the surface cold front. This distribution of wind and the rapid movement of the system were important features identified in the Burns' Day storm (McCallum 1990). Highest mean speeds were again at western and southern coastal sites with 40–50 kn fairly common. However, it was the powerful gusts that were important factors in the widespread damage and loss of life; factors which, along with the severe flooding in North Wales, attracted much media attention. It was a very windy day nation-wide

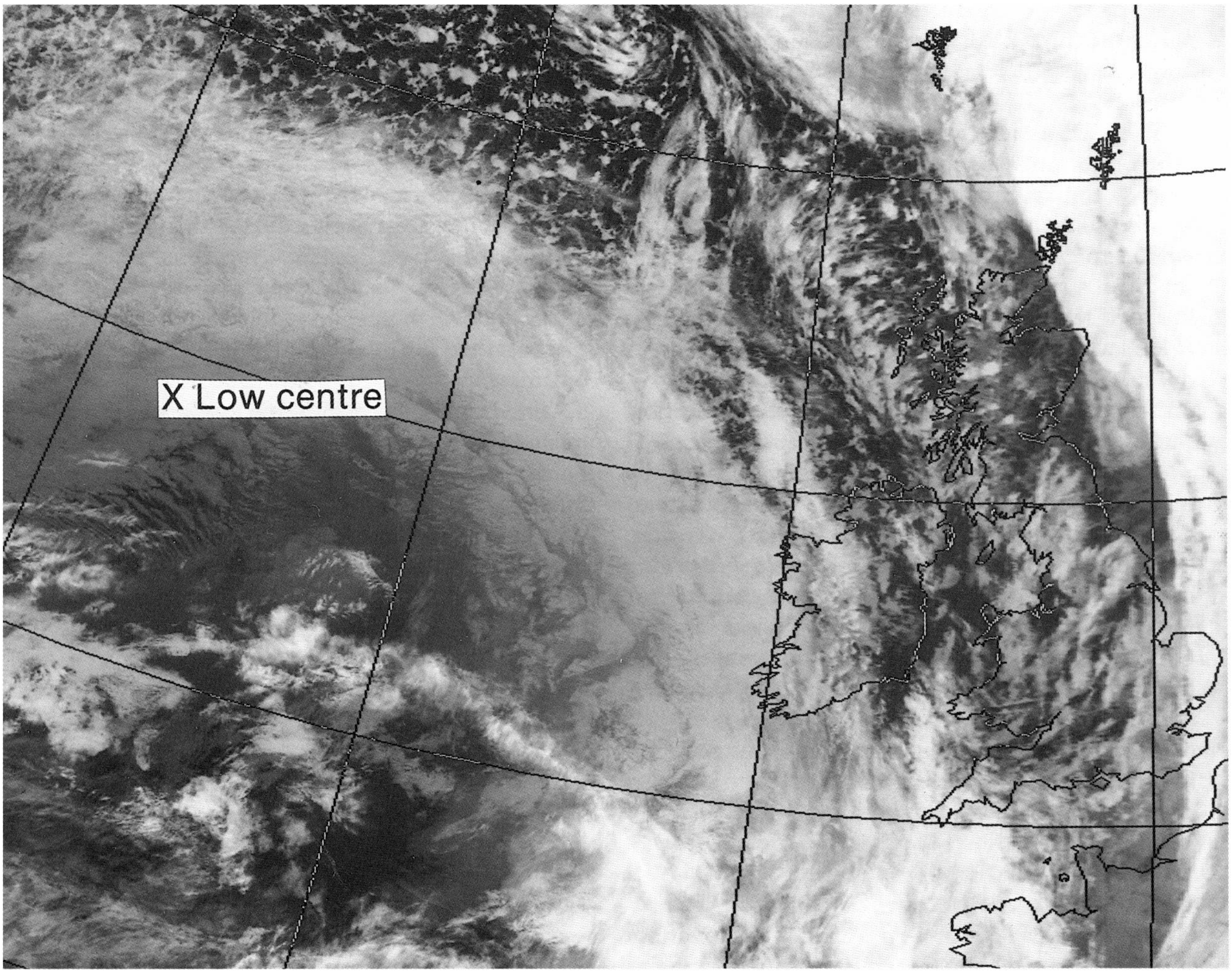


Figure 6. NOAA-11 infra-red image for 1435 UTC on 25 February 1990.

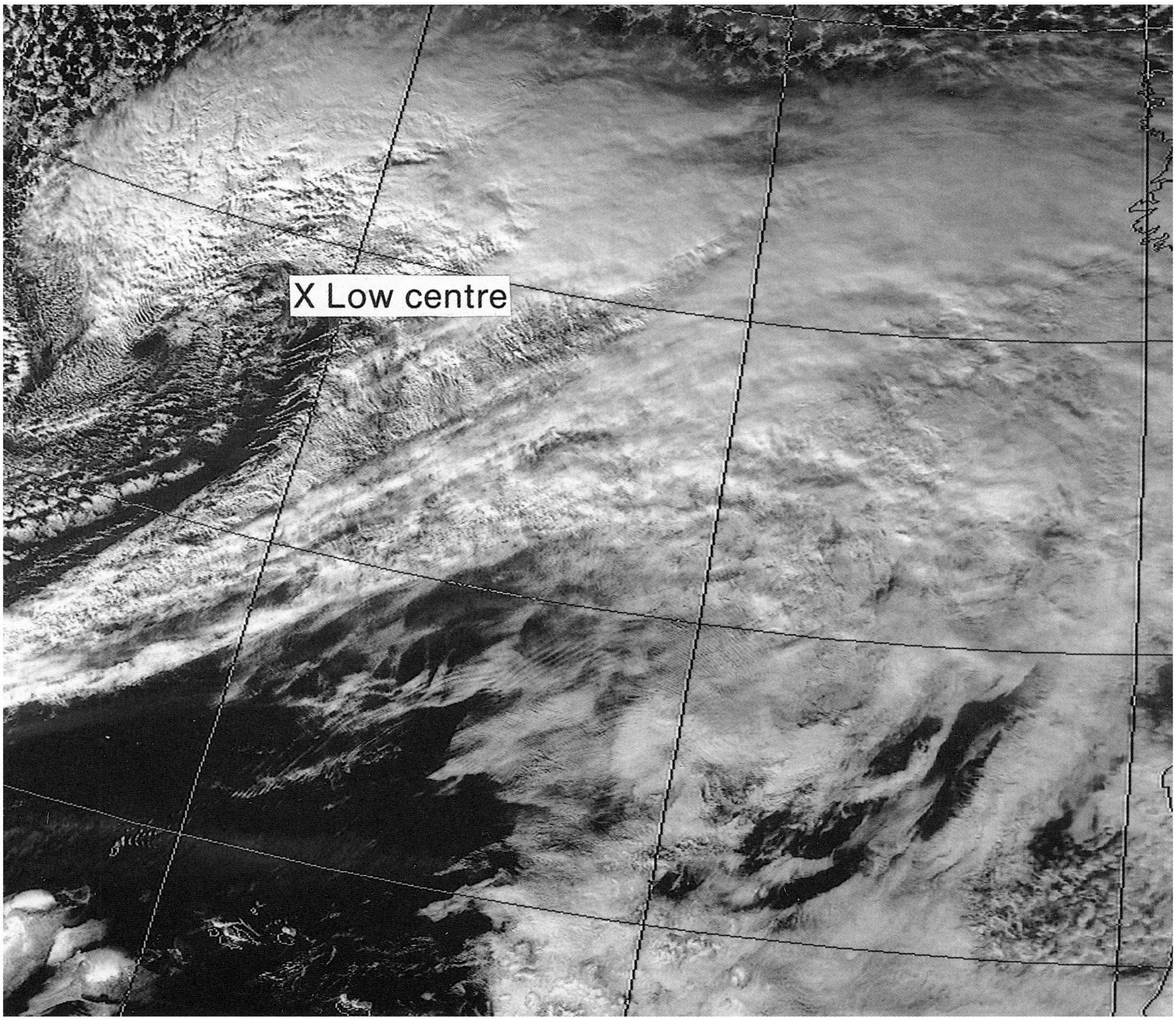


Figure 7. NOAA-11 visible image for 1518 UTC on 24 January 1990.

but the maximum gusts were generally less than those observed on the Burns' Day storm, except for the north of England which had its windiest day of the winter.

5. How well were the cyclogenesis events forecast?

The current generation of operational NWP models shows considerable skill in handling major cyclogenesis events, and the Meteorological Office's 15-level model is widely regarded as a leader in this field. The global (coarse-mesh) version of this model was useful in giving advance warning of potential storms up to 6 days ahead. Accurate notice of the (Thursday) Burns' Day storm was first given in the television farming forecast on the previous Sunday. For the finer detail that was necessary for the framing of warnings for the media the regional (fine-mesh) version was useful in giving detailed guidance up to 36 hours ahead. Gadd *et al.* (1990) have shown that the regional model is capable of realistic representation of explosive deepening. A similar study by Hall (personal communication) for this present period is presented at Fig. 9. Cases included are those in which a pressure fall of at least 24 mb was forecast by the regional model or was observed to occur in a period of 24 hours commencing at 0000 or 1200 UTC. There appears to be a slight bias towards larger falls than forecast, which was not apparent in the longer analysis of Gadd *et al.* Of particular note, though, is that the two poorest forecasts relate to the major storms of the period, those of 25 January and 26 February.

Handling of these two lows highlighted the crucial role of the forecaster in overcoming the occasional major deficiencies in numerical guidance that occur from time to time.

The deficiency in the Burns' Day case is an example of the 'rogue run' where the model lapses into a weak or non-developmental mode after a consistent and clear signal for marked cyclogenesis. Such lapses have been noted by Woodroffe (1990) and by Reed *et al.* (1988) and if followed may prompt a downgrading of a previous

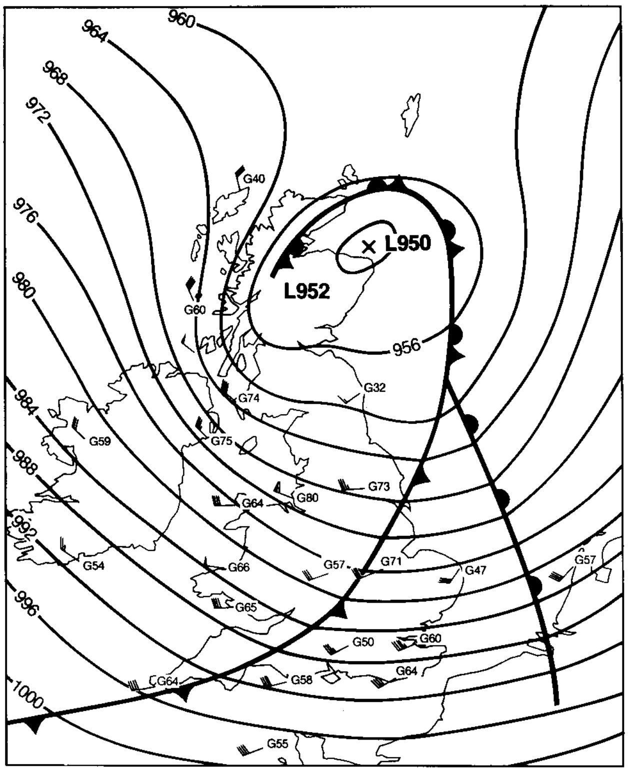


Figure 8. Mean-sea-level pressure pattern and fronts at 0600 UTC on 26 February 1990, with winds and gusts shown conventionally at selected stations.

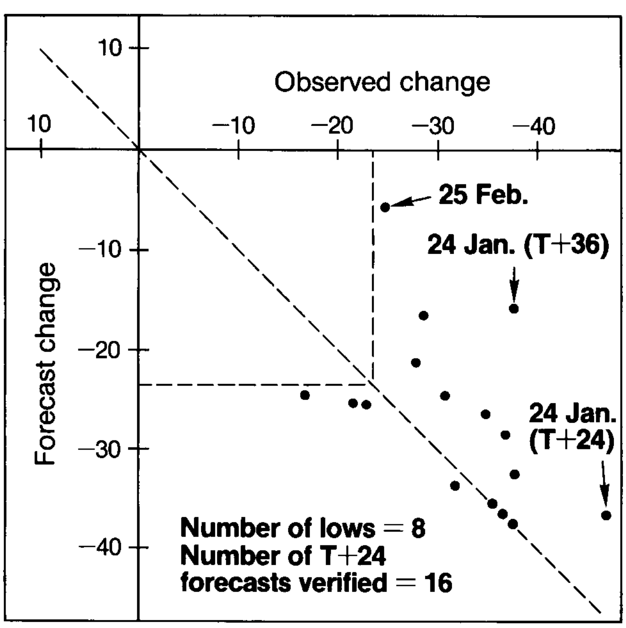


Figure 9. Observed 24-hour change in central pressure (mb) of rapidly deepening lows in the North Atlantic compared with values forecast by the fine-mesh model during period 22 January–28 February 1990. Only cases where observed or forecast change exceeded 24 mb are shown.

warning of severe weather. Fig. 10 shows forecasts from two consecutive runs for verifying time of 1200 UTC on the 25th. The 36-hour forecast (T+36) shown in Fig. 10(a) typifies the non-developmental mode and can be contrasted with the much better 24-hour forecast shown at Fig. 10(b). Fortunately, forecasters were alert to the problem and warnings were issued on the strength of the overall signal from an ensemble of solutions. Clearly, confidence was also increased by the marked cyclogenesis of the latest run although it should be emphasized that this is not always the case and indeed this particular forecast was greatly improved by the

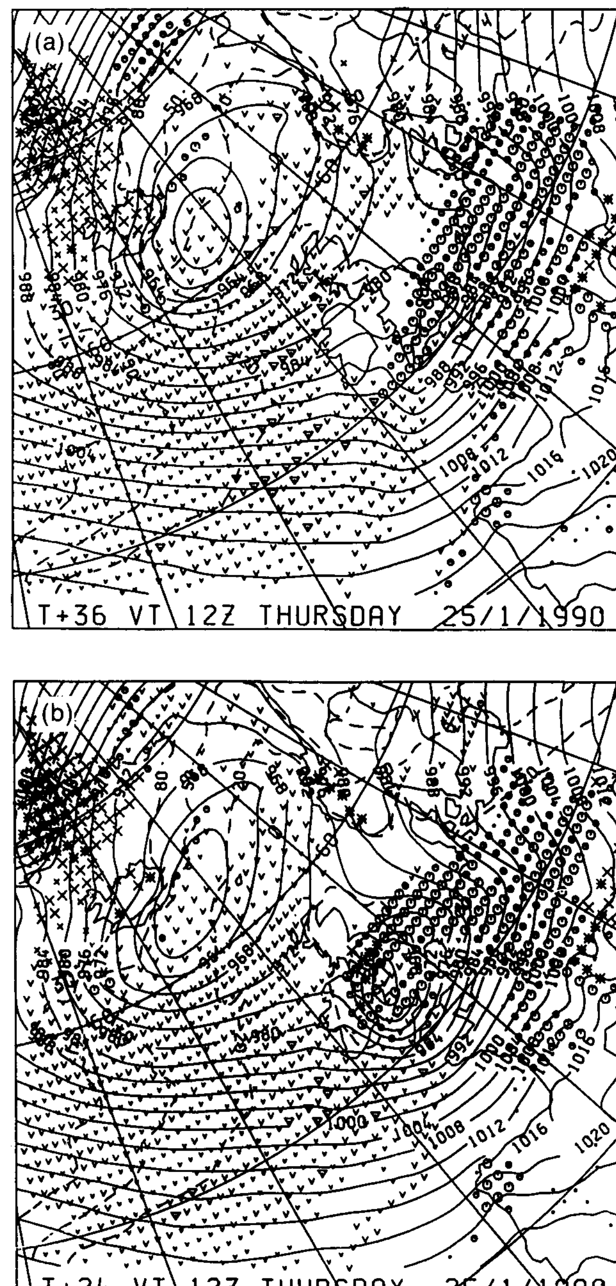


Figure 10. Fine-mesh model output from consecutive runs, both verifying at 1200 UTC on 25 January 1990. (a) T+36 forecast from data time 0001 UTC on 24 January 1990 and (b) T+24 forecast from data time 1200 UTC on 24 January 1990.

observations from two ships near the low centre (Heming 1990).

The second problem identified during the period was the tendency to 'nudge' towards the correct solution (of intense development) from run to run rather than a sudden change to explosive cyclogenesis. This again was highlighted by Woodroffe (1990) and was particularly manifest in the 26 February storm. Fig. 11 shows a set of tracks from a succession of 6-hourly fine-mesh runs for this event; note the trend to more development and a more northerly track for each forecast. This trend is symptomatic of greater distortion of the steering flow (hence change of track) caused by feedback effects from the more intense circulation. How well the forecaster pre-empted this trend is shown by the 24-hour forecast for 26 February at 0600 UTC (Fig. 12). In reality this extrapolation erred on the conservative side as the depression took an even more northerly track through the Great Glen in northern Scotland, a deviation that was covered by a subsequent amendment.

These examples emphasize that, although the overall numerical guidance was good, there were some very important occasions when the forecaster added significantly to the accuracy of the warnings issued to the media and population at large.

6. Conclusions and forecaster guidelines

The period from 25 January to 28 February 1990 was unusually windy over the United Kingdom and much of northern Europe and was associated with the lowest pressure anomaly since records began. This stormy spell was preceded by a protracted spell of abnormal cold over Canada and the northern North Atlantic and by anomalously high SST south of Newfoundland. These are the very antecedent conditions which Namias (1987, 1989) considers to predispose the atmosphere to the occurrence of one or more extreme cyclogenetic events in the North Atlantic.

Many of the 15 baroclinic disturbances identified were explosive deepeners or 'bombs' with latent-heat processes an important contributory factor in the intensity of the development. Eight of the lows were associated with a highly mobile, flat, slightly confluent, upper trough and exhibited baroclinic leaf and dry-slot characteristics on satellite imagery and marked pressure rise behind the centre.

Numerical guidance was useful in predicting overall developments on the majority of occasions but the lows of 25 January and 26 February low are a reminder that the forecaster must not have blind, unquestioning, dependence upon numerical weather prediction (NWP)

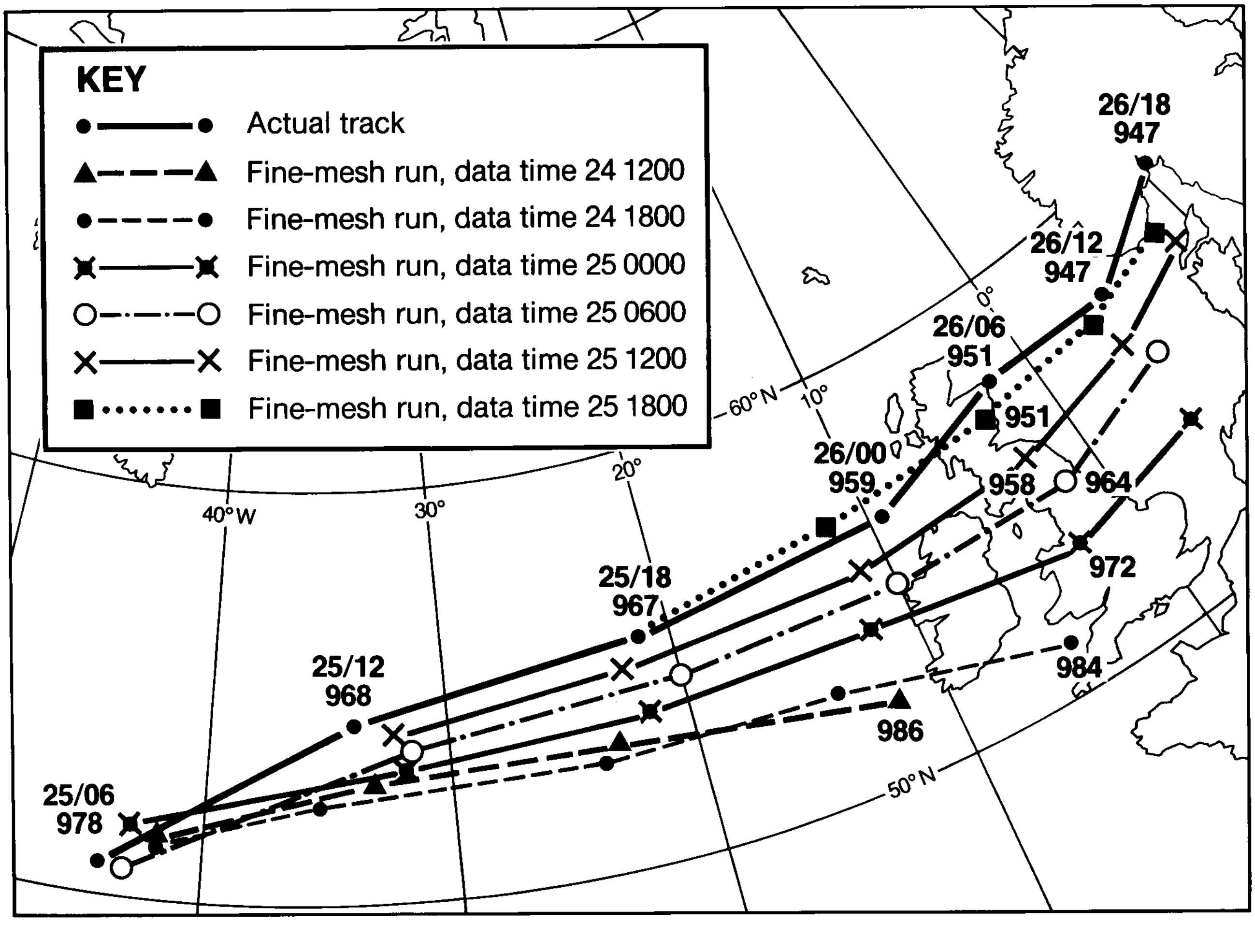


Figure 11. Tracks of low of 26 February 1990. A comparison between its actual track and successive forecast tracks is distinguished in the key) from the fine-mesh model. Central pressure (mb) is shown where feasible.

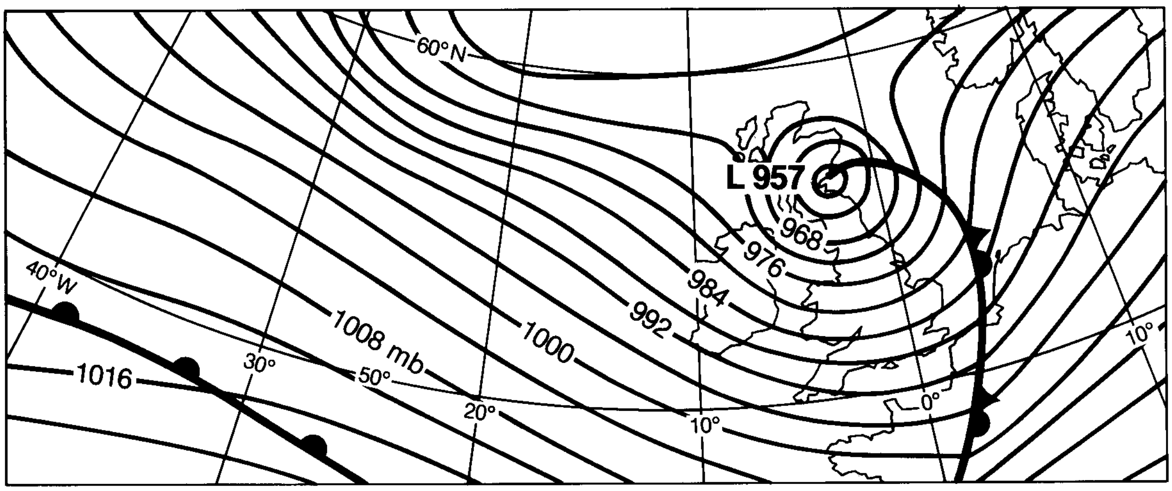


Figure 12. Meteorological Office 24-hour forecast for 0600 UTC on 26 February 1990.

products. In consideration of this, and other cases from the period, the following guidelines emerge for forecasters when interpreting NWP products on occasions of possible cyclogenesis.

1. Do not accept model guidance at face value without first trying to understand (qualitatively at least) the dynamical logic behind the model predictions.
2. Consider a sequence of runs for the same verifying time. The most recent run is not always the best — it may be a 'rogue'. The degree of consistency from run to run will determine the confidence with which a solution can be reached. Also when successive forecast runs show a continuing and consistent trend, be prepared to anticipate the likely outcome by extrapolation.

Although not specifically highlighted in the cases discussed above the following points are also important when utilizing numerical products.

3. Look at an ensemble of solutions from different models. Some may have a particular sensitivity to certain initial conditions.
4. The broad-scale upper pattern will reveal the potential for cyclogenesis but its precise timing and location will usually (perhaps always) depend upon the timely intervention of a 'trigger', some small-scale perturbation or jet streak. This is most likely to be picked up from close scrutiny of satellite imagery. A single frame 'snapshot' may, fortuitously, capture the crucial moment of initiation, but a movie-loop is likely to be more revealing.

Acknowledgements

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The strong winds experienced during the late winter of 1989/90 over the United Kingdom: Historical perspectives

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Summary

The persistently windy period of late January and February 1990 included three widespread and damaging gales. Using a variety of statistical and graphical techniques, this period is assessed in a long-term context to judge how unusual it was. The question arises as to whether changes in the wind-climate mean that this type of weather is recurring more often.

1. Background

A period of particularly sustained windiness affected the United Kingdom during the late winter of 1989/90. The period was punctuated by three especially stormy events.

The first and most damaging event, on 25 January, was confined largely to southern and eastern parts of the United Kingdom. Gusts of 70–90 kn in this region were comparable with those of the 'Great Storm' of October 1987. However, because the strongest winds occurred during the day, and over a wider area, the more recent event caused a greater loss of life (McCallum 1990). Damage to buildings and trees occurred widely, with dislocation of power and transport causing major inconvenience. Many places reported their highest gust on record. Boscombe Down (near Salisbury), for example, recorded 79 kn, the strongest wind since the station opened in 1933. Fig. 1 shows the return periods of the maximum gusts recorded at a selection of

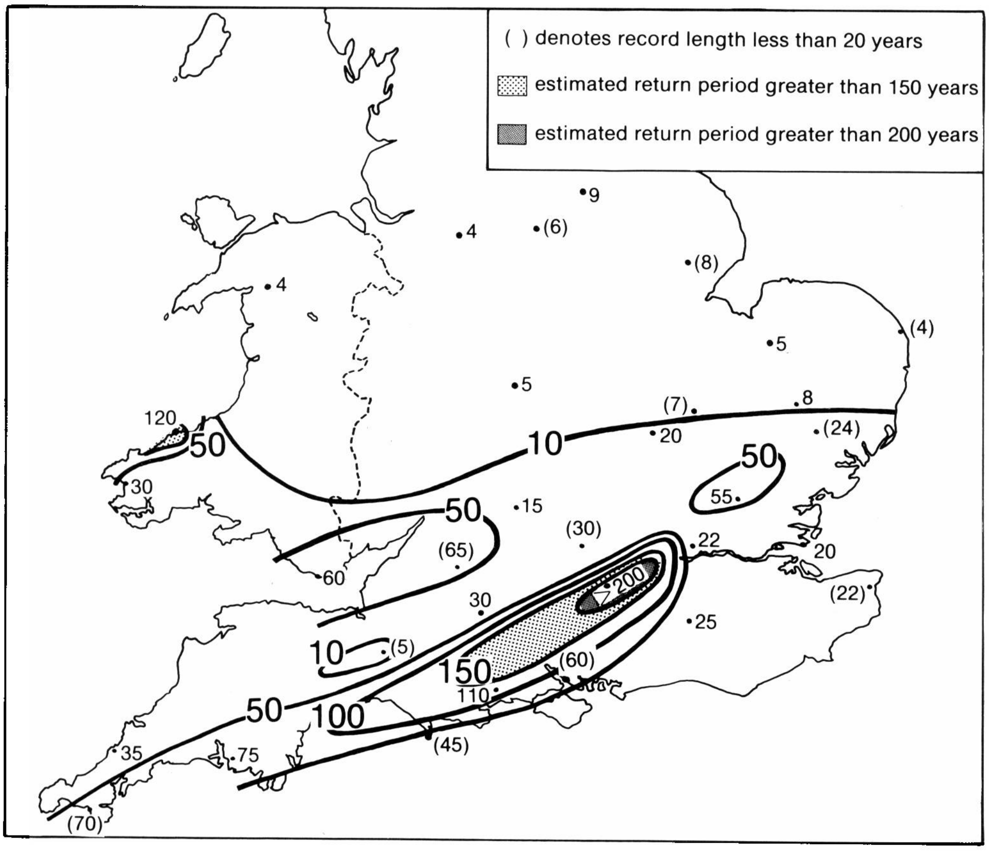

Figure 1. Return periods (years) for maximum gusts recorded on 25 January 1990.

anemograph stations in southern parts of the United Kingdom. The most exceptional gusts were concentrated in a densely populated band from Dorset north-eastwards to London.

The second bout of especially strong winds occurred during 7 and 8 February, and the most exceptional gusts were again in southern parts of the United Kingdom. Gusts of 50–70 kn were reported widely in this area, London (Heathrow) Airport having its highest February gust on record with 61 kn.

In contrast, the strong winds between 26 and 28 February were spread throughout the United Kingdom. Mean speeds in excess of 40 kn were common, with gusts above 80 kn in northern England.

Indeed, although the gusts of February did not reach the damaging levels of 25 January in the south, February 1990 over the whole of the United Kingdom was persistently windy, all the more unusual because it is often the least windy month of the winter.

2. Is it getting windier?

The evolving wind climate affects a diversity of activities. Each has its own sensitivity to change on different temporal and spatial scales, which the climate is constantly undergoing. Where incidents of unusually high wind speed are isolated occurrences within an essentially stationary long-term distribution, the impact may be restricted to personal inconvenience, temporary disruption to industrial activity, or sporadic building damage. More serious difficulties arise where such variations are associated with prolonged trends in the mean wind regime; or alternatively, where a change in variability produces a greater frequency of extreme events. For example, Palutikof *et al.* (1987) have sought to show that long-term variability in the wind field is sufficient to be a matter of concern to the wind energy industry. Building design is another sector which should be wary of relying on existing long-term averages, which may not reflect adequately the wind climate's inherent potential to change.

To help answer the question 'Is it getting windier?' a long-term view of the windy period of the winter of 1989/90 needs to be taken. To do this satisfactorily requires different scales of analysis. Injudicious selection of the wrong scale of analysis could bias unfairly the prominence of one spell compared with another; a combination of techniques will best reveal how the windy period of last winter appears in the long-term context.

3. Data sources

3.1 Anemograph data

Hourly mean and gust speeds are recorded routinely at over 100 anemograph stations around the United Kingdom. These records are archived on computer for 1970 onwards (Collingbourne 1978). Manuscript records exist further back for a number of stations; but due to site, exposure or instrument changes, there are only a handful of stations for which long-period hourly wind speed data can be analysed as an homogeneous time-series. Six stations currently operating have records extending back to before the First World War.

3.2 Spot-wind data

A further network of about 50 synoptic sites record routinely the 'spot' wind each hour. This is the mean wind over the 10 minutes before the hour, and is archived on computer typically from the mid-to-late 1950s onwards. It is therefore a longer, computer-based archive, but is less representative of the entire hour than anemograph data.

Both anemograph and spot-wind data, when averaged monthly, seasonally or annually, can be used for assessing long-term trends in the mean wind climate.

3.3 Windiness indices

Smith (1982) used homogeneous anemograph records for the period 1965–80 to devise an index based on monthly mean winds, and so assess the relative windiness of a particular month compared to the same month through the rest of the record. These indices can be averaged into seasonal or annual values, regionally or nationally. Also, using surface pressure gradients between six grid-points around the British Isles, Smith obtained national estimates of the monthly windiness index from 1881 onwards. Using a synthesis of the two techniques, monthly indices can be produced from January 1881 onwards.

3.4 Spell analysis

Series based on monthly means can often disguise individual windy periods of varying length, and the especially stormy events within them. Anemograph or spot-wind data held on computer can be processed easily, this allows flexible analysis of monthly or annual averages and, in particular, enables individual spells of *any* chosen time period to be studied and compared.

3.5 Storm analysis

3.5.1 Maximum gusts

As it is maximum gusts that usually cause the most damage within any one storm event, they are often more appropriate to use in assessing the changing frequency of extreme winds (for example, in terms of return periods), and in comparing the severity of individual storm events.

3.5.2 Subjective assessment

Another, and more subjective, analysis of the changing frequency of individual windy events is to identify qualitatively the 'notable incidences of widespread gales'. A selection of gales was made by Harris (1970) from the period 1920–70. However, not only do different gales exhibit differing characteristics in terms of duration, mean wind speed, and strength and frequency of gusts, but they vary crucially in terms of timing and areal extent. Selection can therefore often be a haphazard procedure, based partly on personal memory or inconsistent media exposure. Complicating conditions such as high tides, prolonged rainfall and heavy snowfall, make comparison of different gales still more difficult.

4. February 1990 — how unusual?

4.1 Comparison with previous Februarys

4.1.1 Monthly mean winds

Fig. 2 shows how February 1990 compares nationally with other Februarys since 1970. These national averages have been calculated using data from 17 anemograph stations, divided into three regions as follows:

North: Leuchars, Kinloss, Kirkwall, Fort Augustus, Benbecula, Prestwick,
Central: Aldergrove, Valley, South Shields, Waddington, Leeming, Fleetwood, and
South: Boscombe Down, Plymouth, Honington, Aberporth, Avonmouth.

Nationally, monthly mean speeds in February have fluctuated generally between 8 and 13 kn up until 1988. However, 1989 was windier, with an average of 13.7 kn, while February 1990 was by far the windiest, with an average hourly wind speed of 17.2 kn. The pattern is somewhat confused when the data are broken down into the three regions, but in each case the last three Februarys have shown increasing windiness, with February 1990 having the maximum monthly wind speed by a clear margin, especially in the South region, where the average speed was 18.8 kn.

4.1.2 Monthly windiness index

The use of the Smith (1982) windiness index allows the difference between the mean speed for an individual month and the 1970–89 averages for that month to be determined and expressed as a proportion of the standard deviation. So for each month a standardized anomaly is obtained.

For 15 of the 17 stations listed in section 4.1.1, the February 1990 index values are shown in Fig. 3. Fleetwood and Fort Augustus indices could not be calculated because data were missing or incomplete for February 1990. The index values shown are the highest (most unusually windy) since 1970 at all of the stations in the South and Central regions, with the exception of South Shields. In the North region, all stations except Kirkwall recorded their highest index.

To put February 1990 in the longer context of Smith's 1881–1980 windiness index record, the nationally averaged January 1970–February 1990 index values

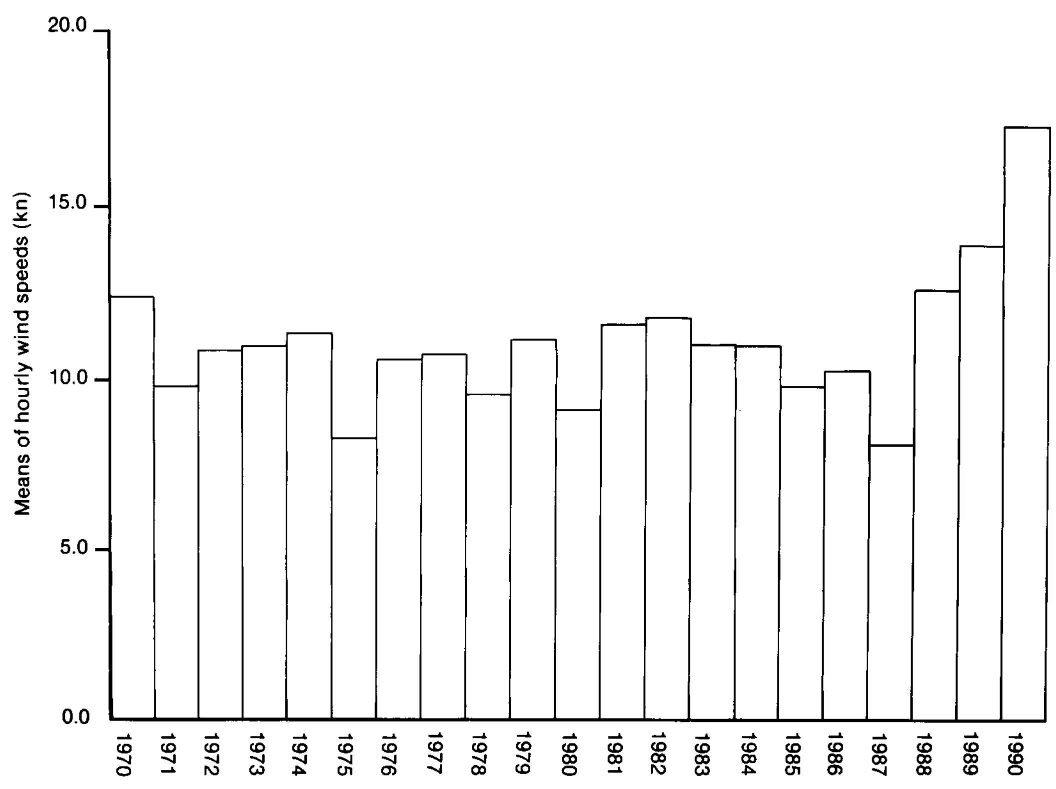

Figure 2. Mean wind speed (kn) for Februarys, averaged from 17 anemograph stations for the period 1970–90.

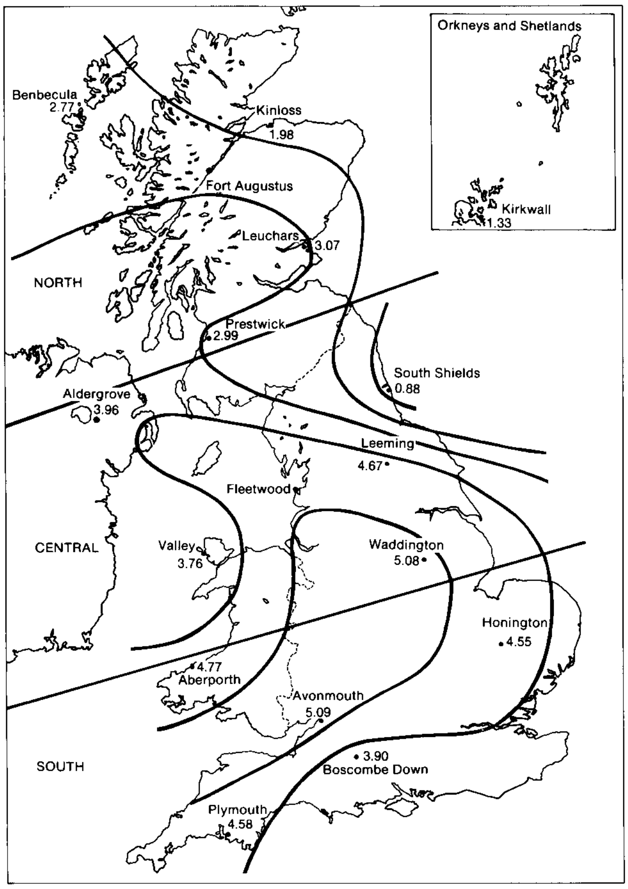

Figure 3. Windiness index for February 1990, see text for derivation.

were calculated and corrected to compensate for differing averaging periods and stations used, after Crummay (1987), (see Table I).

Fig. 4 shows the entire series from 1881–1990. February 1990 does appear to have been the most windy since before 1881, the index of 3.6 exceeding marginally the February 1903 value of 3.5. The time series as a whole is very 'noisy' with no obvious trends in the raw data. The smoothed graph, however, reveals a steady decline in indices from around 1960 until the 1980s. Indeed the February index fell as low as −1.4 in 1987, prior to the increasingly windy last 3 years.

When looked at in the long-term context then, the last 3 years cannot be interpreted as a clear signal of a sustained tendency towards windier Februarys; indeed February 1990 was an anomalous month compared with the long-term trend of previous Februarys.

4.2 Comparison with all months of the year

4.2.1 Monthly mean winds

The anomalous windiness of February 1990 is confirmed when monthly mean winds are compared for all months of the year. Fig. 5 shows nationally averaged monthly mean wind speeds since January 1970, for the same 17 anemograph stations. February 1990 had the highest mean (17.2 kn) of any month, with December 1974 and January 1983 the next two highest with 15.8 kn and 16.3 kn respectively. February 1990 stands out particularly because there had not been any notably high means since January 1983.

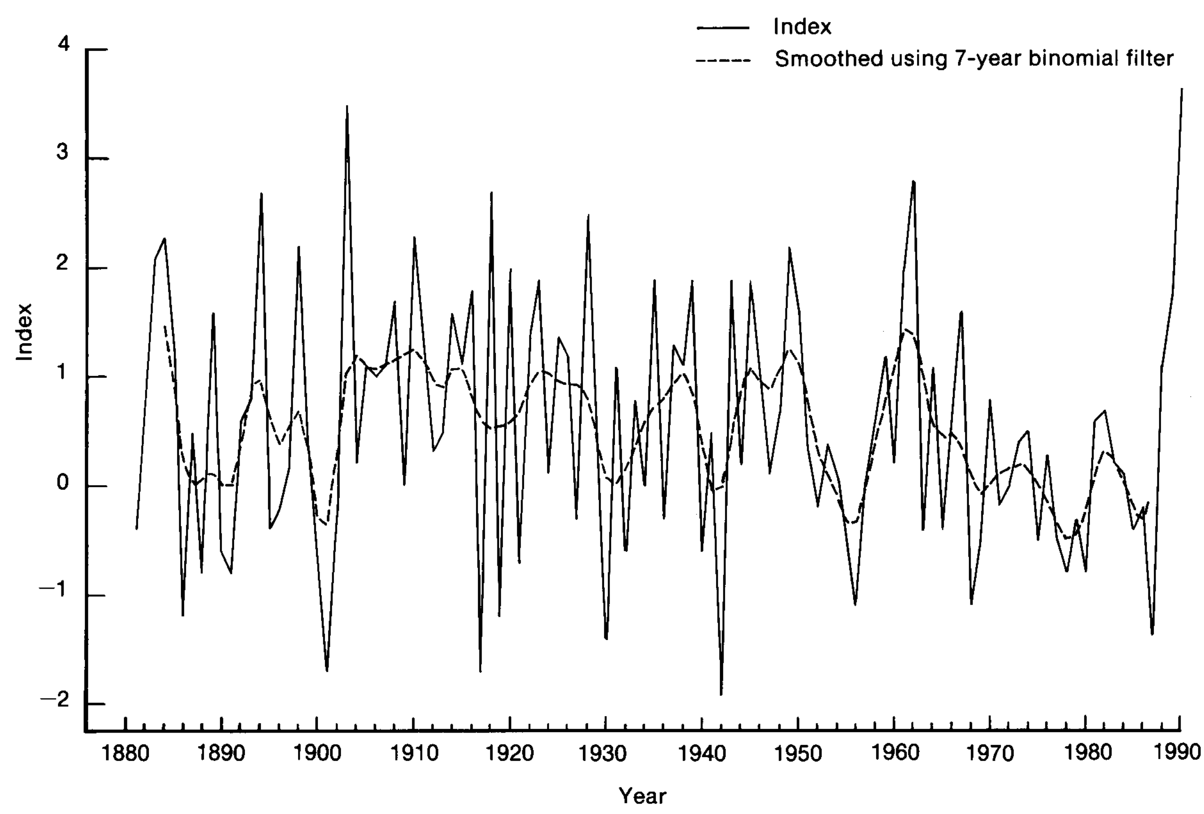

Figure 4. Windiness index for Februarys for the period 1881–1990.

Table I. Monthly indices averaged over the three regions for January 1980–February 1990 (values for 1881–1980 can be found in Smith (1982))

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1980	−1.2	−0.8	−0.3	−0.3	−0.3	0.7	0.7	0.9	0.7	0.9	0.6	0.9
1981	0.1	0.6	0.6	−0.6	0.3	1.2	0.4	−0.7	0.2	0.7	0.5	−0.6
1982	−0.3	0.7	0.4	−0.8	−0.4	−0.9	−0.8	1.6	0.2	0.4	0.6	−0.1
1983	1.9	0.2	0.1	−0.9	−0.6	−0.4	−1.8	−1.1	1.0	1.4	−1.6	0.1
1984	1.0	0.1	−1.5	−1.3	−1.7	−0.5	−1.1	−1.2	−0.2	0.5	−0.4	−0.8
1985	−1.4	−0.4	−0.9	0.2	−1.1	−0.8	−0.2	1.9	−0.5	−1.3	−0.9	0.1
1986	0.6	−0.2	0.5	−0.4	1.5	−0.1	−0.1	0.0	−0.9	0.3	0.6	0.6
1987	−1.3	−1.4	−0.1	−1.3	−0.2	−1.1	−0.4	−0.2	−0.3	−0.9	−1.1	−1.1
1988	−0.2	1.1	−0.4	−1.5	−0.8	−1.6	0.6	0.5	−0.5	−0.3	−1.7	−0.2
1989	0.0	1.7	0.2	−1.2	−0.9	−0.8	−0.7	0.9	−0.6	0.2	−1.4	−1.4
1990	0.8	3.6	—	—	—	—	—	—	—	—	—	—

4.2.2 Monthly windiness index

As well as being windy in absolute terms, the unusual occurrence of high mean wind speeds in February is emphasized by the fact that apart from South Shields, Kirkwall, Leuchars and Kinloss, all the other stations (with February 1990 data) recorded their highest Smith's windiness index value of all months since before January 1970.

5. Analysis of 35-day spells

5.1 24 January–27 February 1990 — unusually persistent windiness?

To see just how unusual the entire windy spell of late January and February 1990 was, requires greater flexibility of analysis. The strong winds of that period were not conveniently contained within one month, but lasted some 35 days. While February was arguably unprecedented, what of the windy period as a whole?

Again, using the same anemograph stations, the average hourly mean wind speeds through all 35-day periods from January 1970 to March 1990 were compared. As Table II shows, 24 January–27 February had an average hourly mean wind speed higher than any other 35-day period at all stations in the Central and South regions — with the exception of Fleetwood (no data available), Valley and South Shields.

For stations which make synoptic reports this analysis can be extended back to include earlier spells, typically from the late 1950s, using spot-wind data. Fort Augustus, Fleetwood, South Shields and Avonmouth are not synoptic stations. Of the remainder, the 35-day period from 24 January to 27 February again figures prominently. As Table II shows, this was the windiest 35-day period on the synoptic record at Aberporth, Plymouth and Waddington.

5.2 Other windy spells

Other comparable windy spells have occurred in recent decades. Table III ranks periods according to the position of their most windy 35-day spell. So here we are not considering just one 35-day spell (as with 24 January–27 February 1990), but any within the three periods noted.

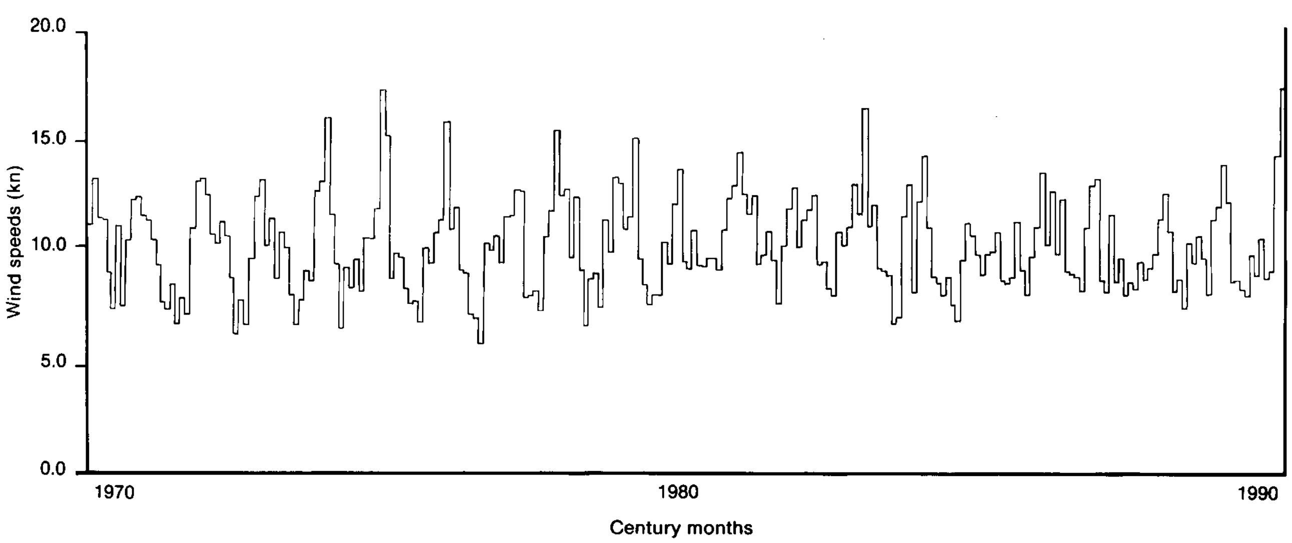

Figure 5. Monthly mean wind speeds averaged from 17 anemograph stations for the period January 1970–February 1990.

Table II Stations where the 35-day period 24 January–27 February had the highest mean speed (kn) on record using either anemograph (A) or spot wind (S) data

Station	Data used	Mean wind speed during period	Previous highest 35-day	
			Mean speed	Dates
South Region				
Avonmouth	A	18.9	16.8	25.11.74–29.12.74
Honington	A	15.4	14.8	25.11.74–29.12.74
Boscombe Down	A	16.7	15.9	8.1.74–11.2.74
Plymouth	A,S	20.2	19.6	8.1.74–11.2.74
Aberporth	S	25.4	21.1	3.1.84–6.2.84
Central Region				
Waddington	A,S	16.4	14.9	24.11.54–28.12.54
Aldergrove	A	15.2	14.8	29.12.73–1.2.74
Leeming	A	15.2	14.7	2.12.80–5.1.81

5.2.1 The late winter/spring of 1967

Several spells during February, March and April 1967 were as windy as, or in some cases windier than, those during the 1989/90 winter.

As Table III shows, at Benbecula, Prestwick, Aldergrove, Valley, Waddington, Honington and Boscombe Down, at least one 35-day spell during the late winter and early spring of 1967 has a mean within the top four on record; while at Leuchars, Kinloss, Kirkwall and Leeming, 35-day mean speeds are the highest on record.

Reference to synoptic charts reveals that the end of February and beginning of March 1967, in particular, were characterized by a series of intense depressions passing, in general, but not entirely, just to the north of the United Kingdom. Hence the rankings of 35-day mean speeds show greatest prominence at the more northern stations. The weather from mid February until early April was particularly disturbed, usually with a strong zonal pressure gradient.

5.2.2 The winter of 1974/75

Although the winter of 1974/75 was on the whole windy, the mid to latter parts of December and January featured some especially strong zonal gradients, within which deep depressions formed. Honington recorded its highest 35-day mean wind on record between 25 November and 29 December.

5.2.3 The winter of 1982/83

Thirty-five-day spells during the winter of 1982/83 rank prominently in the analysis, especially over Scotland, where at Benbecula and Prestwick the highest average 35-day wind speeds on record occurred. Unlike 1967, this period was not as continuously windy throughout, but did include a number of deep depressions passing over, or just to the north of the United Kingdom, in a mobile west or north-westerly airstream. This pattern was especially prevalent in early December, early January, and again in late January and early February.

Apart from the above examples, very few 35-day spells compare with the period from 24 January to 27 February 1990 in terms of (hourly or spot) mean wind speed. Indeed, only the late winter of 1967, arguably, contains spells of comparable or greater mean windiness over a wide area, in recent decades.

6. Annual trends — increasingly windy?

6.1 Annual mean winds

Fluctuations in the windiness of individual months and spells can be compared to broader trends using long-term records of annual mean winds.

Palutikof *et al.* (1987) studied annual mean winds at Southport from 1895 to 1955. They observed that annual mean wind speeds were about 5.7 m s^{-1} at the end of the nineteenth century increasing rapidly (to over 6.5 m s^{-1}) in the 1910s, and subsequently falling back (to under 6.0 m s^{-1}) in the late 1920s; remaining at about that level to the end of the record. Using a dense network of stations for the period 1956–82, they detected a rapid decrease in wind speeds around 1970, after a trend of increasing windiness through the 1960s.

6.2 Annual windiness indices

Fig. 6 shows the 1881–1989 annually averaged national indices. The smoothed graph shows a decline from the early 1950s until the mid 1980s, with minor increases in the early 1960s and around 1980.

It should be emphasized that this series does not simply reflect the monthly average wind speeds recorded over each station each year, but is also a function of how *unusually* windy the mean speeds in any particular month were, averaged over the year.

Table III Rank of other notable periods containing high 35-day mean speeds. The ranking is according to the position of each period's highest 35-day mean speed.

Station		Data used	Late winter/ spring 1967	Winter 1974/75	Winter 1982/83
North Region					
Leuchars		S	1	5	2
		A	*	3	1
Kinloss		S	1	5	3
		A	*	4	2
Kirkwall		S	1	4	2
		A	*	4	1
Benbecula		S	2	2	1
		A	*	3	1
Fort Augustus		S	*	*	*
		A	*	*	*
Prestwick		S	3	2	1
		A	*	2	1
Central Region					
Leeming		S	1	3	5
	(1)	A	*	4	3
Valley		S	3	—	—
		A	*	—	4
Aldergrove		S	2	4	5
	(1)	A	*	3	4
Waddington	(1)	S	4	5	3
	(1)	A	*	4	3
Fleetwood		S	*	*	*
		A	*	*	*
South Shields		S	*	*	*
		A	*	3	1
South Region					
Plymouth	(1)	S	—	—	—
	(1)	A	*	—	—
Boscombe Down		S	2	3	4
	(1)	A	*	3	4
Aberporth	(1)	S	—	—	3
		A	*	—	2
Honington		S	3	1	*
	(1)	A	*	2	3
Avonmouth		S	*	*	*
	(1)	A	*	2	4

Key: S = Spot (10-minute) mean; A = Anemograph (hourly) mean; — denotes rank >5; * denotes no available data; (1) shows where 24 January–27 February 1990 mean was highest.

However, the background of a general decline of index values in recent decades suggests that February 1990 is not symptomatic of a long-term trend in overall monthly mean wind strength, but is, at this stage, to be treated as a 'random' fluctuation.

7. Incidence of severe winds

To look simply at winds averaged over months, spells or years conceals other facets that determine the impact of the wind. What made the recent winds seem so unusual were the severity of gusts and the close succession of three widespread gales.

7.1 Gusts

We have already seen how unusual the gusts of 25 January were in terms of return periods (see Fig. 1). To emphasize this point Fig. 7 shows the annual maximum gust recorded at one station, Boscombe Down, since records began in 1933. Whereas the 1990 gust (79 kn on 25 January) was the highest on record, gusts recorded in the persistently windy spells during 1967, 1974/75 and 1982/83 were not nearly so exceptional. In other words, these windy spells did not contain extreme gust conditions, and so, arguably, had less of a damaging impact at the time.

The graph would show a similar peak in early 1990 for other central and southern locations, but for some stations, especially the more northern ones, recent peak gusts were not so unusual. Certainly, overall there is no indication of a sustained trend towards higher peak gusts over the years.

7.2 Recurrence of gales

The type of analysis shown in Fig. 7 does not, however, show the distribution of high gusts within any one year, a close succession of damaging gust events being more likely to have greater impact (perhaps because repairs to damaged structures have not been completed before further damage is caused by the next storm). How unusual this scenario is can be gauged by comparing historically the frequency of notable windy events.

Fig. 8 shows notable incidents of widespread gales, updated to include the storms up to January and February 1990, after Harris (1970), who produced the series from 1920 to 1970. Although far from an objective representation of the length, severity or spatial extent of windy events, it does give an indication of their distribution through time.

The three stormy events of 25 January, 7/8 February and 26/27 February 1990 do indeed seem to be unusual in terms of their closeness of occurrence. Note again that the windy periods of 1967, 1974/75 and 1982/83 do not appear to have had widespread gusts or mean speeds, of exceptional strength — the criteria by which the gales are selected. While these spells contained widespread and persistently strong winds, the windy period of the winter of 1989/90 had far greater impact because, additionally, it featured a successive recurrence of storms with damaging gusts.

8. Conclusions

In trying to answer the question 'Is the weather getting windier?', a number of different techniques have been used in placing a single windy spell in a long-term context.

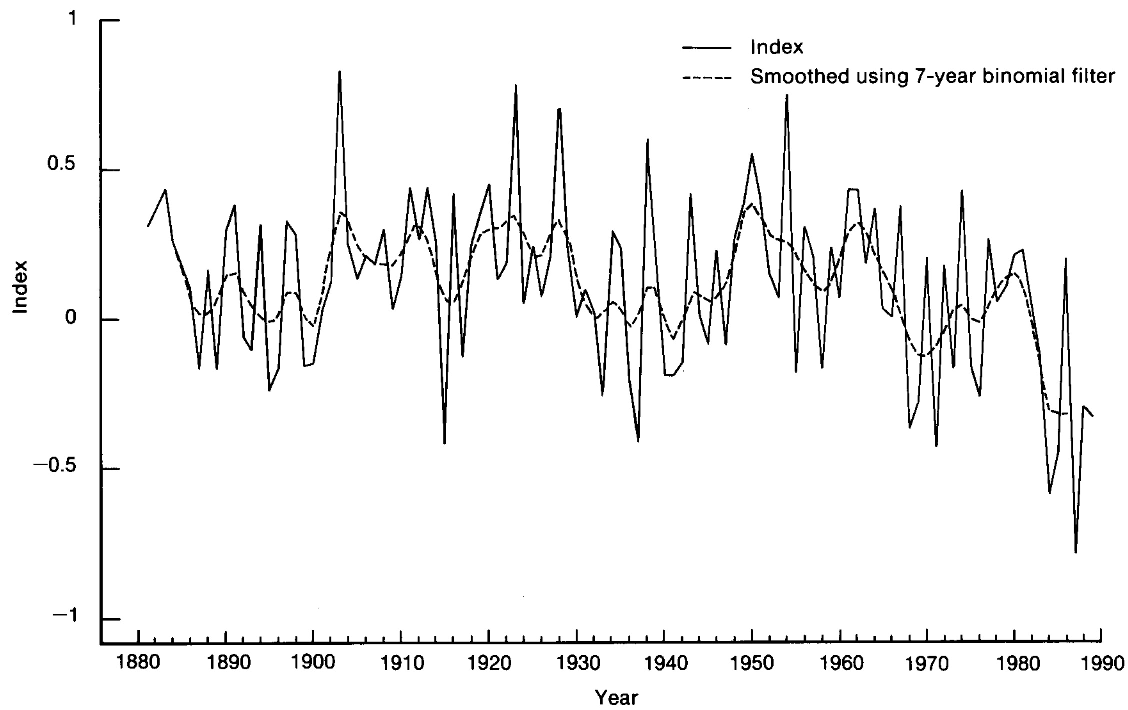

Figure 6. Annual windiness index 1881–1989.

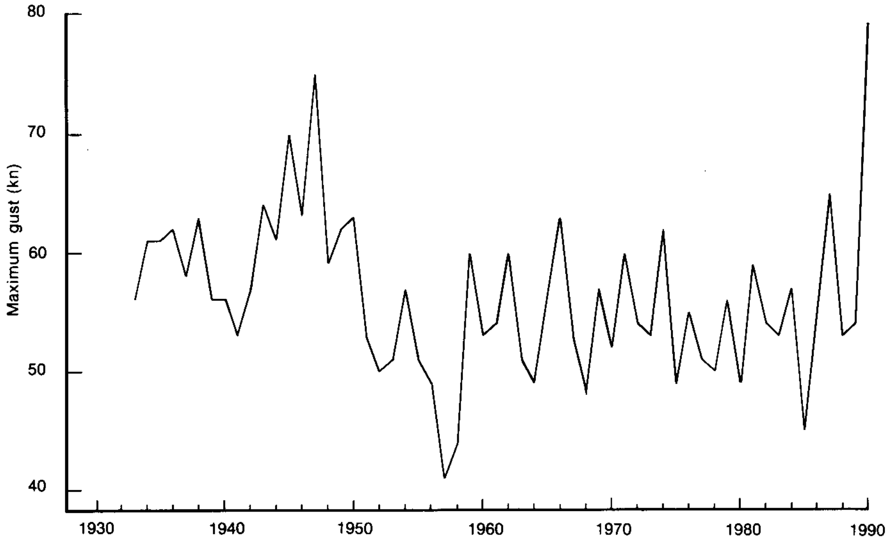

Figure 7. Annual maximum gusts at Boscombe Down for the period January 1933–June 1990.

Was the period from late January to the end of February 1990 a symptom of a more variable wind climate in which peak gusts become more extreme? Return-period analysis has demonstrated that the winds of 25 January in particular were exceptionally strong over parts of southern England. However, they did not in general exceed those of 16 October 1987, and long-term analysis of annual maximum gusts shows no sign of a sustained upward trend.

Does the closeness of those individual storm events over the United Kingdom indicate more frequent recurrence, nowadays, of periods of damaging gales? Although their grouping was indeed rare, the incidence of the three storms in close succession during late January and February 1990 is not proven to be part of a longer-term tendency for a more frequent recurrence or clustering of storm events.

As a sustained period of strong winds, how uncommon was the recent spell and is it indicative of increasing levels of mean winds either during February or over the year as a whole? The 35-day mean wind speeds between 24 January and 27 February 1990 were almost unpreced-

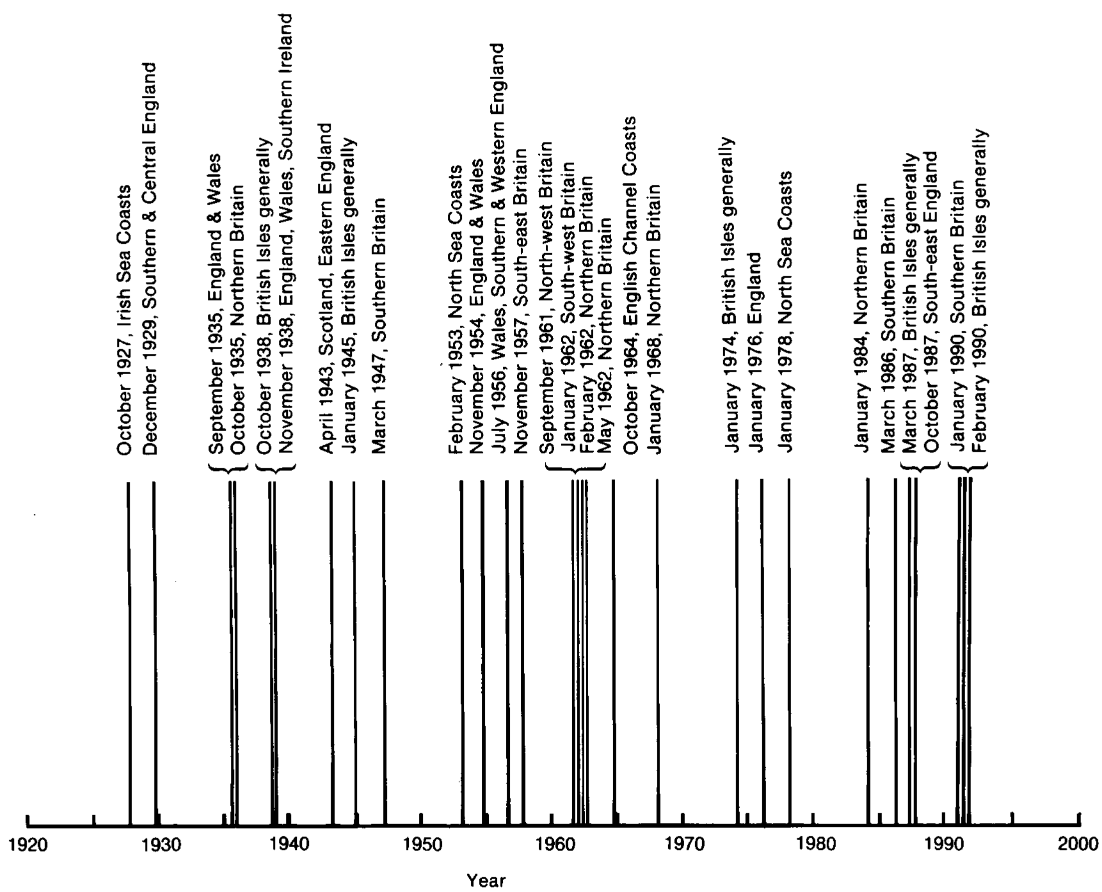

Figure 8. Notable gales affecting at least part of the United Kingdom for the period 1920–90, after Harris (1970).

ented in recent decades especially over central and southern districts, although a number of comparable windy spells have occurred during that time over the British Isles.

When February alone is analysed, the last 3 years have shown an increasing tendency towards higher mean winds, Smith's windiness index indicating that February 1990 was the most windy nationally, since before 1881; yet the recent February winds would not, arguably, appear so unusual had not the 1970s and much of the 1980s, in particular, been so anomalously quiet.

Using windiness indices averaged over the year, the general trend in recent decades is for wind anomalies to decline since the early 1950s.

Returning to the original question posed, it depends on the scale being considered, but as yet any changes in the wind climate of the United Kingdom which can be detected are 'wanderings' in the long-term mean speed, and these do not support the hypothesis of an increasingly windy United Kingdom. The exceptional features of the last windy spell do not show significantly an increasing frequency of persistent windy periods, or more frequent or extreme storm events, but are part of the 'random' fluctuations to be expected in the long-term wind climate of the United Kingdom.

Yet we should be vigilant, because if rises either in long-term mean winds or in the frequency of short-term extreme events should start to accelerate, the resilience of modern social and industrial activities to a non-stationary climate will be tested. Prudent advance measures will help ameliorate the impacts of future wind conditions.

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Satellite photograph — 30 June 1990 at 1347 UTC

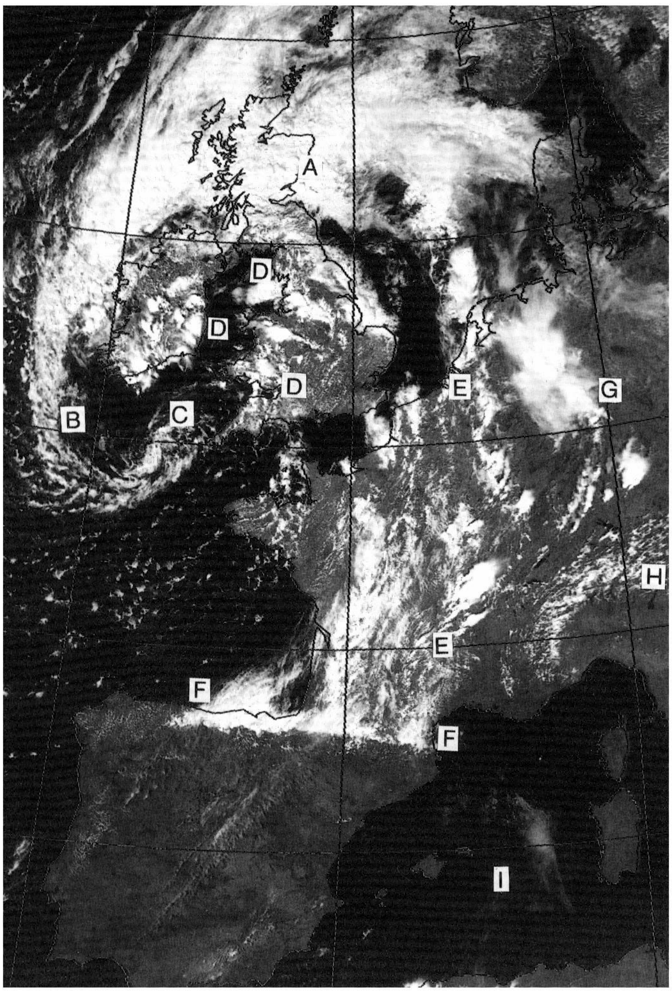

Figure 1. NOAA-11 AVHRR visible image on 30 June 1990 at 1347 UTC, the labelling A–I is referenced in the text.

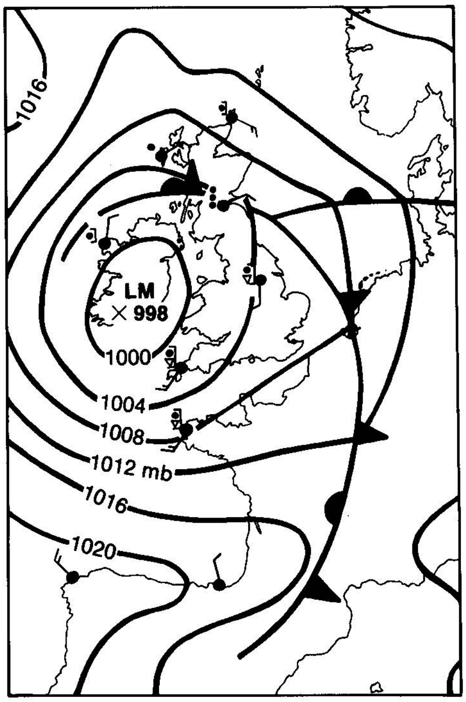

Figure 2. Surface analysis on 30 June 1990 at 1200 UTC. Present weather symbols are shown conventionally.

The NOAA-11 visible image in Fig. 1, covering part of western Europe, shows cloud features associated with the fronts and circulation of an Atlantic depression. The synoptic situation is shown in Fig. 2. Corresponding upper-air charts (not shown) reveal an upper low over Ireland, a trough extending to north-west Spain and a south-westerly jet over France.

The occlusion over the northern United Kingdom can be clearly identified on the image. Embedded convective elements are evident, especially over central Scotland (A). A tail of mostly shallow convective cloud (B) curls round towards south-west England. Some deeper convective elements can be seen near (C). Deep convective cloud can also be identified at several locations (D) where heavy showers and thunderstorms occurred.

The cold front fragmented and weakened as it moved over the near continent, becoming difficult to locate on the synoptic chart. On the image it is marked by a broken line of convective cloud extending from The Netherlands to southern France (E–E).

An interesting feature on the image is the cloud that appears to be streaming away from the mountains of northern Spain and the Pyrenees (F). Relevant upper-air ascents (not shown) and surface observations suggest that most of this cloud is cumulus and stratocumulus with tops around 6000 ft. Some of this may be the remnants of cloud associated with the weak cold front trapped against the mountains. The marked surface ridge in this area (see Fig. 2) was a shallow boundary-layer feature, with cloud above this level advecting north-eastwards in the upper flow.

Other features shown include a convective complex (G) over Germany, shallow convective cloud (H) outlining the Alps and an area of fog and / or low stratus (I) to the west of Sardinia.

D. Ratcliff

GUIDE TO AUTHORS

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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 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, except by 'personal communication'.

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