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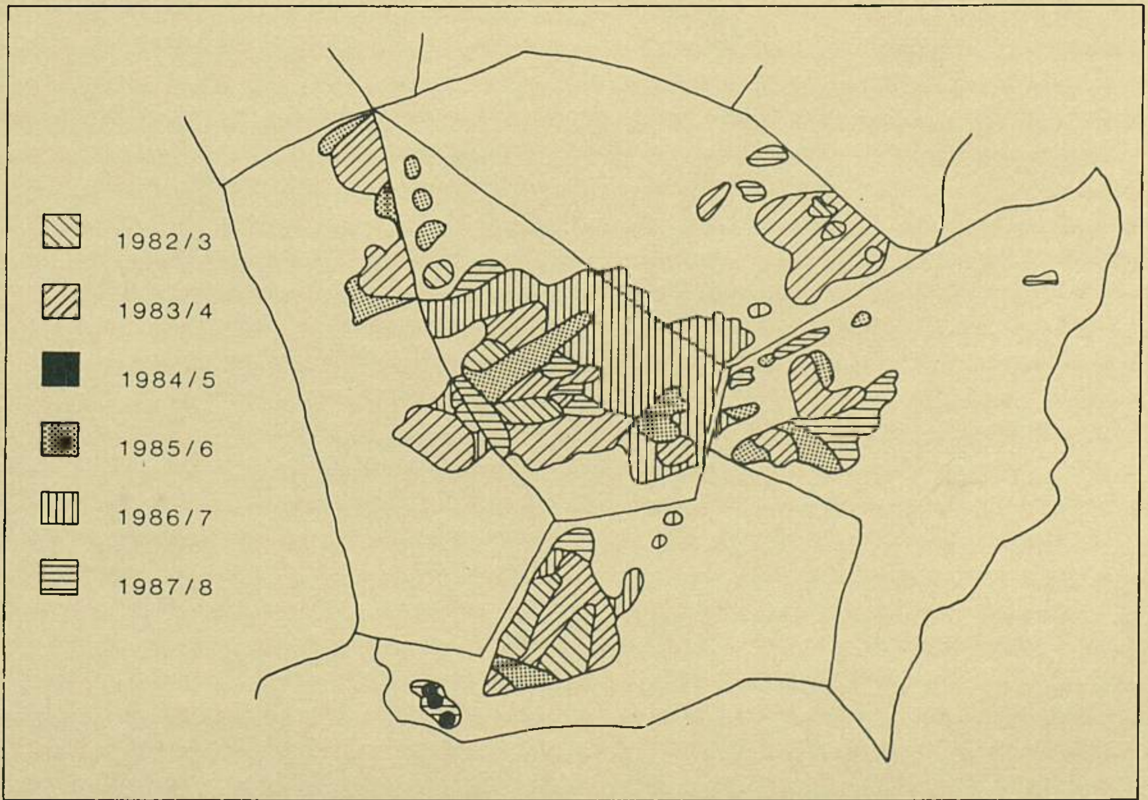
A New Series of Windthrow Monitoring Areas in Upland Britain

C.P. Quine and B.R. Reynard



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A NEW SERIES OF WINDTHROW MONITORING AREAS IN UPLAND BRITAIN

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Forestry Commission, Edinburgh

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by C.P. Quine and B.R. Reynard
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Abstract

A network of eight windthrow monitoring areas together with reference anemometers and wind vanes has recently been established in forests in remote upland areas of Britain. The sites chosen will allow study of the onset and progression of windthrow in productive plantations. Details of the associated wind climate will also be obtained. The data gathered will be used to validate, refine and extend the Windthrow Hazard Classification.

Background

Wind damage to forests, particularly extensive windthrow well before normal economic rotation, is a serious problem for the British forest manager. Land-use policies have meant that much of the expansion of coniferous forest since 1919 has taken place on wet gley soils in exposed upland areas. Rooting of the trees is largely restricted to the top 25-45 cm of the soil by waterlogging, and anchorage of the trees can prove inadequate in strong winds.

Research work on tree stability is currently targeted at predicting the likelihood of damage based on site, crop and wind climate characteristics, and also at improving our understanding of the interaction between trees and airflow (Gardiner, 1989) and the relationship between topography and airflow. The influence of cultivation type and planting position on root architecture is also studied (Quine *et al.*, 1990; Miller and Coutts, 1986).

At present a simple predictive model, the Windthrow Hazard Classification (Booth, 1977; Miller, 1985), is used to calculate the risk of windthrow by combining scores for soil type and site windiness — the latter is determined on the basis of region, elevation and geomorphic shelter. The relative importance of these components of site windiness has been derived from extensive surveys of site exposure using 'tatter' flags (Lines and Howell, 1963; Miller *et al.*, 1987), while the soil scoring is based on tree-pulling work, extensive observations of rooting behaviour, and studies of soil hydrology.

It is now recognised that observations of the development of forest damage during recorded wind events are important to validate and improve the predictive model. Past monitoring of Bowland Forest, South Lakes Forest District, gave valuable insights into the progression of windthrow and stressed the event-specific nature of much of the progression. The rate of progression of damage within compartments proved to be irregular from year to year, and to be strongly linked with the variability in the wind climate (Figures 1 and 2). In some compartments damage was observed to spread from 10% to 40% windthrown during a single winter. Such progression is obviously of great significance to the forest manager. However, detailed analysis was hampered by the programme of clearfelling within the forest and by the lack of wind data relevant to the area; the nearest anemometer sites for which data were available were 40, 53 and 64 km away. The experience gained from the Bowland study has now been used to establish a new series of monitoring sites.

Purpose of windthrow monitoring areas

The Windthrow Hazard Classification is widely used by managers to predict probable rotation lengths for forest stands and thus assist production forecasting and investment appraisal. It is also used to determine whether thinning is a valid option for a particular site. It is important that the Classification is applicable to the wide variety of crop, terrain, soil and cultivation types represented in forests in upland Britain.

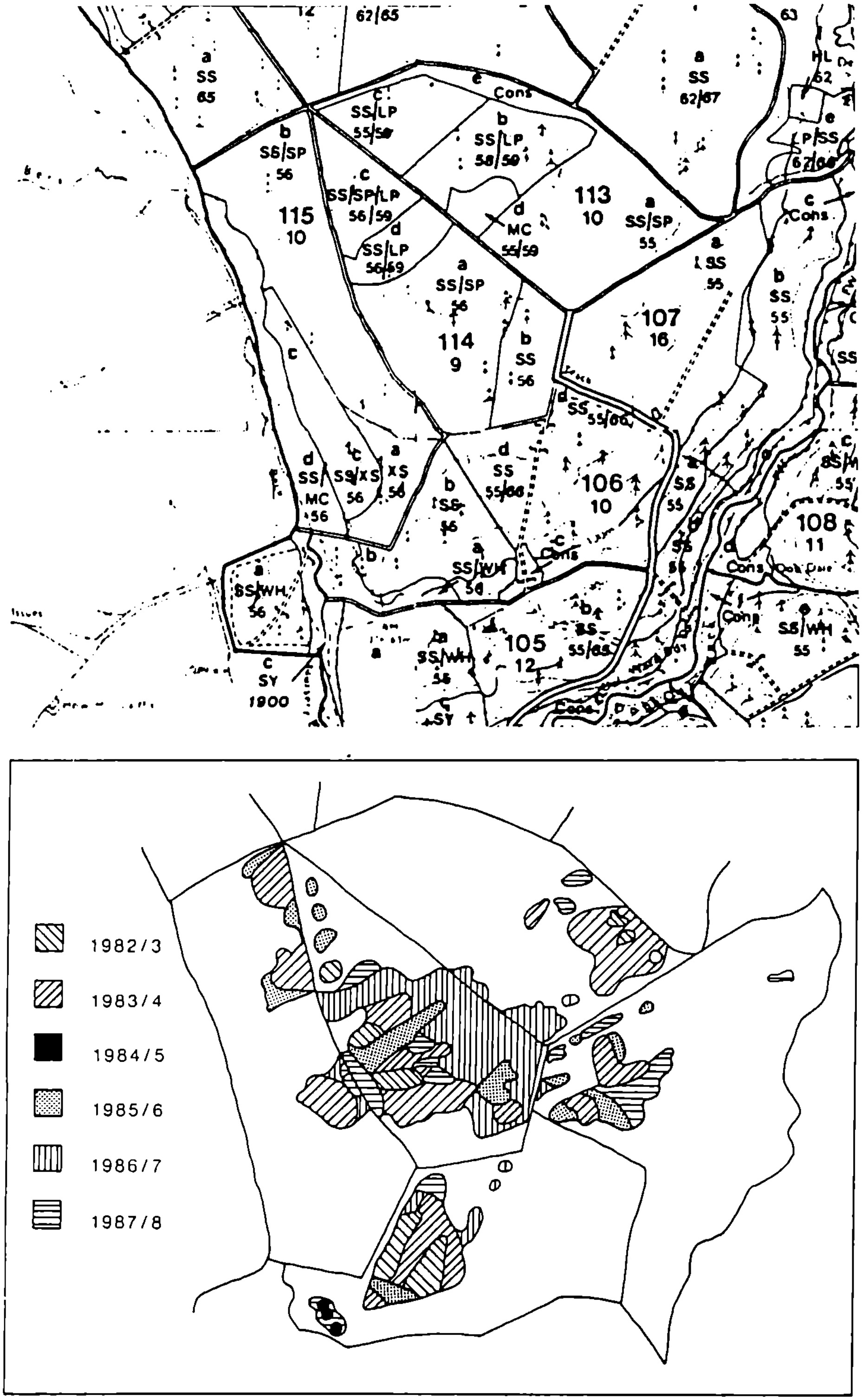

Figure 1. a) Stock map, and b) Damage map, of part of Bowland Forest, South Lakes Forest District, illustrating the spread of windthrow over a period of 6 years in crops in Windthrow Hazard Class 6.

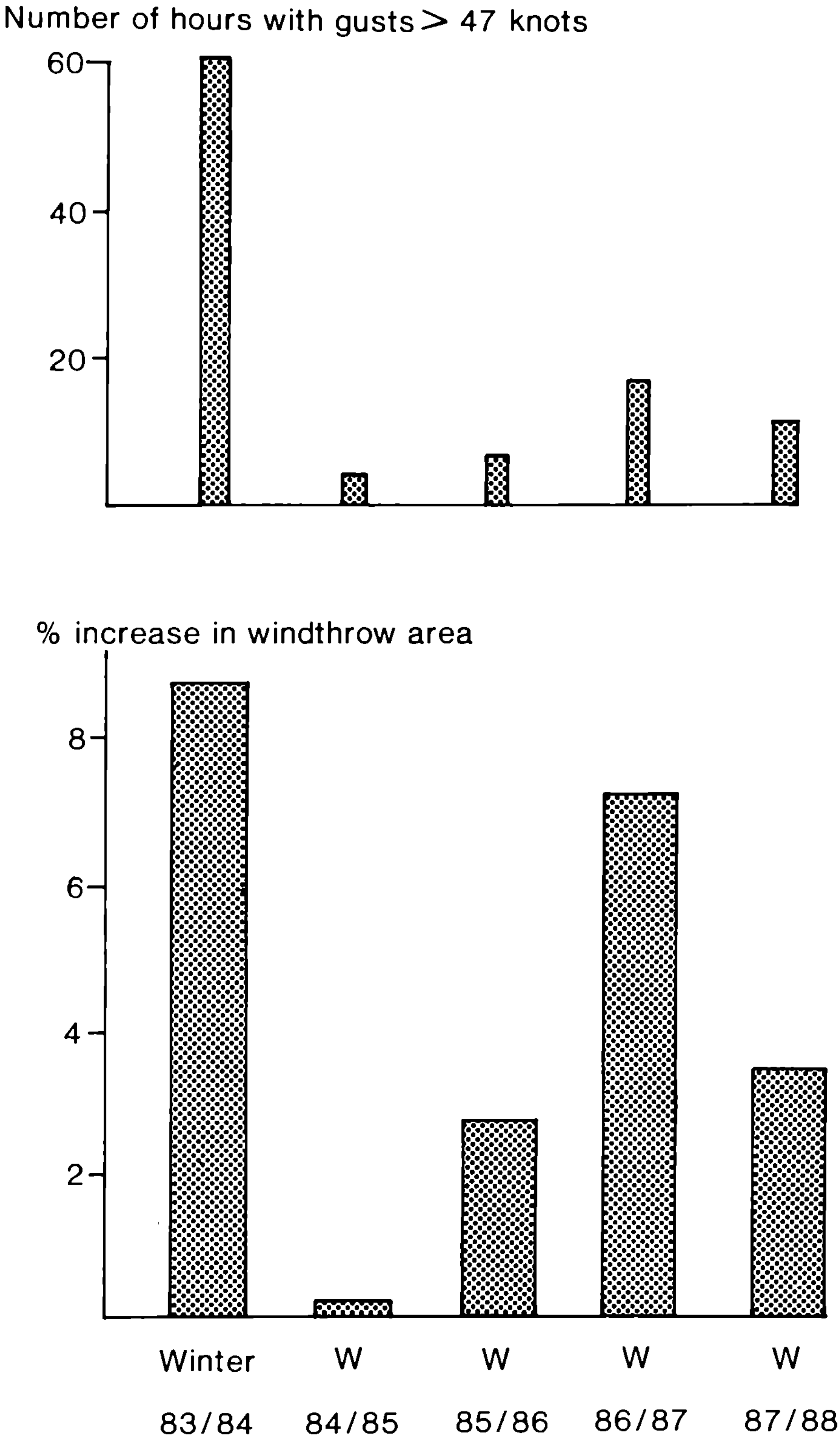

Figure 2. Annual percentage increase in windthrown area for the compartments shown in Figure 1 together with the variation in occurrence of strong winds (derived from published Meteorological Office data for Wilsden, 40 km south-east of Bowland).

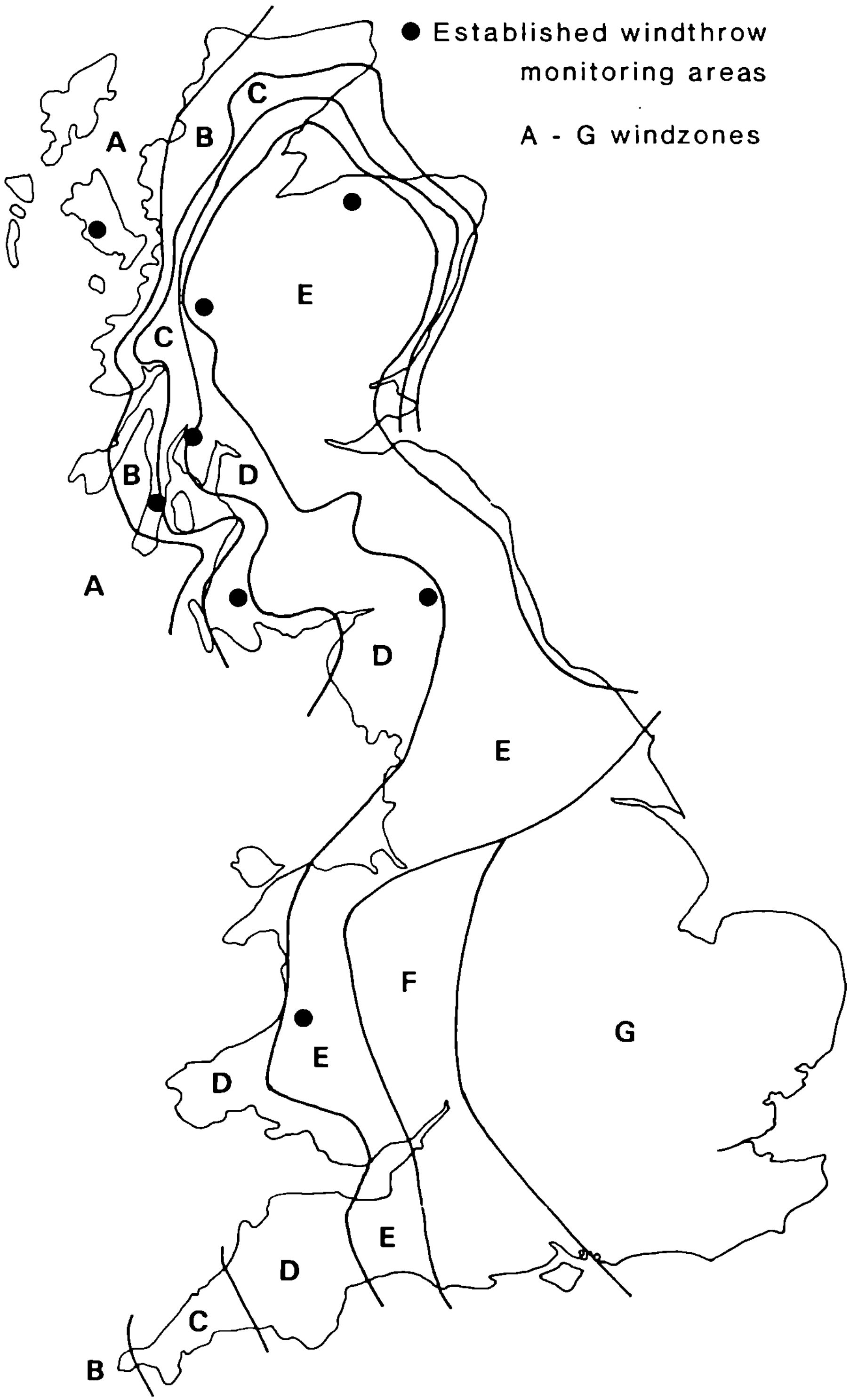

Figure 3. Location of the new series of windthrow monitoring areas within the current regional wind zonation of Britain used in the Windthrow Hazard Classification.

Quality data are required to enable researchers to validate and, where necessary, refine and amend the current Windthrow Hazard Classification. A particular aim is to provide a more flexible system of determining damage progression rather than reliance on defined critical (3% damage) and terminal (40% damage) heights.

Unfortunately, there is no suitable single objective data source within the material routinely collected by managers, although data from crop assessment and harvesting records can give useful indications. Monitoring of selected areas of forest will provide the necessary objective data for research purposes. Agreement has been obtained to protect the monitoring sites from clearfelling for the next 5 years at least.

Monitoring of windthrow

The eight main established windthrow monitoring areas have been selected to be representative of different regions within upland Britain (Figure 3), thereby reflecting different topographic forms, soil and crop types, cultivation practices and regional wind climate. The boundaries of the sites have been chosen to give wide variation of species, soil type, aspect, elevation and exposure within an area of 100-600 ha. Summary details of the sites are given in Table 1.

There are a number of sub-sites within the eight main sites to take into account additional variation. For example, the monitoring area at Kielder comprises two blocks, one of which will be restructured during the course of the study while the other will remain free of harvesting activities.

All the sites contain crops that have either low levels of damage already or are close to predicted critical height.

Work is now underway to record the site and stand characteristics of selected compartments within the monitoring areas. This is being achieved by a detailed ground survey which will record variation in top height, basal area, ground preparation and soil type. Although this survey will provide data on windthrow occurrence, such ground-based methods are impractical when damage reaches moderate levels. Extensive use will therefore be made of annual large scale colour aerial photography to monitor the initiation and progression of wind damage.

Table 1

Forest District	% Area pure Sitka spruce	Wind zone	Elevation range (m)	Topex range	% Estimated occurrence of soil types giving rooting depth of		
					>45 cm	25-45 cm	<25 cm *
Wester Ross	42	A	0-274	23-86	—	29	71
Kintyre	61	B/C	60-355	0-62	—	—	100
Newton Stewart	61	C	150-550	8-57	6	18	76
Cowal	75	D	30-430	14-137	41	14	45
Kielder	72	D	210-460	3-42	—	—	100
Lochaber	59	E	50-380	26-57	7	82	11
Moray	34	E	190-355	2-38	19	2	79
Llandovery	77	E	300-484	1-70	19	46	35

* i.e. scores of 0 5 10
in Windthrow Hazard Classification

Monitoring of wind climate

The importance of wind climate variability from year to year was well illustrated at Bowland but also applies on a wider geographic scale. The mid 1980s were relatively free of damaging winds, with 1985 and 1987 being particularly quiet in northern and western Britain (Figure 4). Such variation can affect damage levels and their

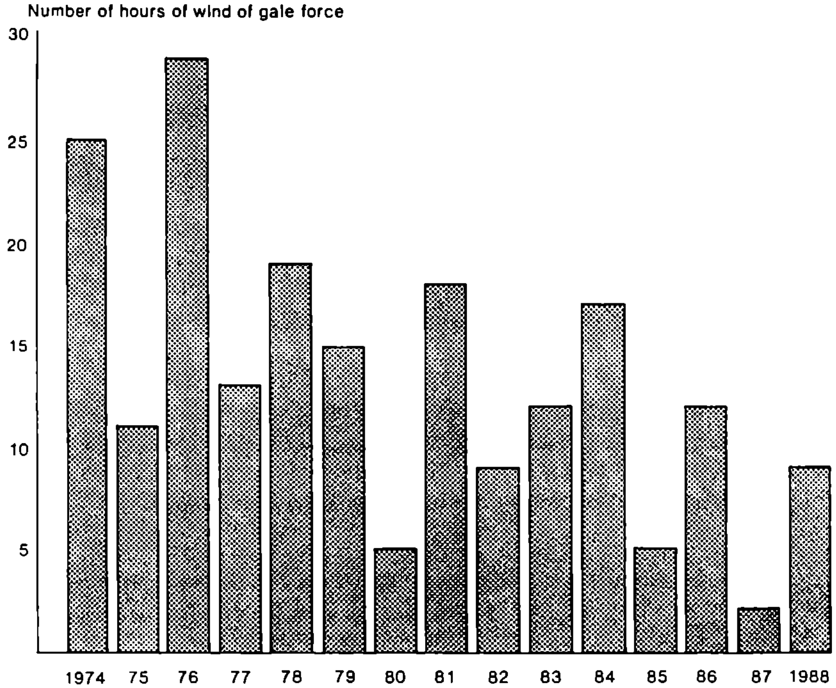

Figure 4. An index of windiness for northern and western Britain showing the variation in occurrence of winds of gale force (hours with mean windspeed greater than 34 knots (39 m.p.h., 17 m s^{-1}). Index derived from Meteorological Office data for 1974 to 1988 for stations at Wick (Highland), Dyce (Grampian), Dunstaffnage and Prestwick (Strathclyde), Eskdalemuir (Dumfries and Galloway), and Brawdy (Dyfed).

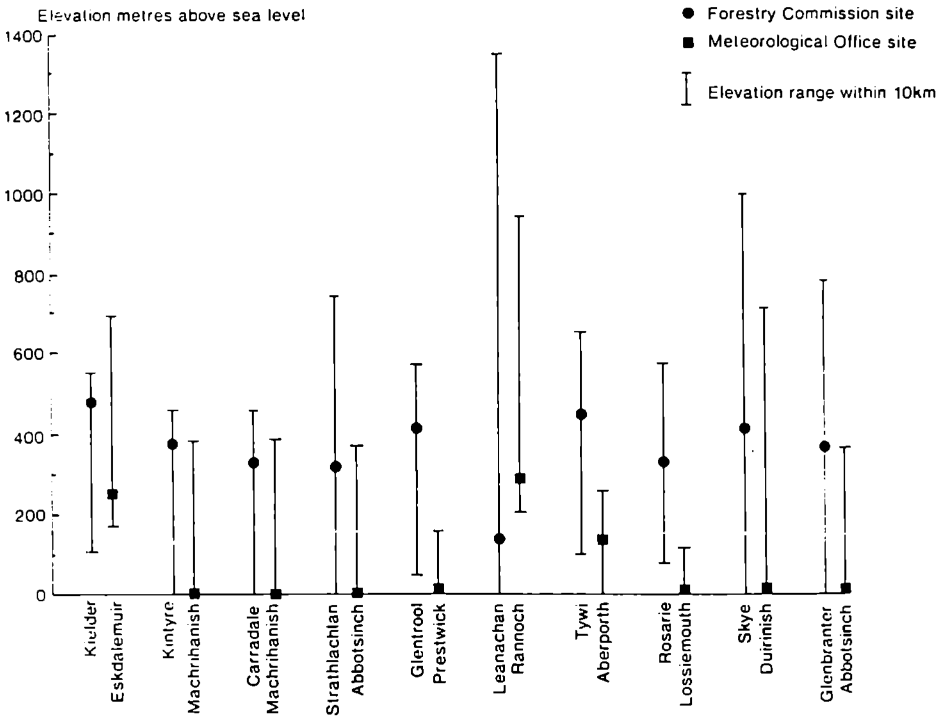

Figure 5. Elevation of reference anemometers and elevational range of terrain in the surrounding 10 km, compared with that for the nearest Meteorological Office network site.

progression in stands following thinning and in those approaching terminal height; it may also influence managers' perceptions of the performance of the Windthrow Hazard Classification. Relating stand behaviour to details of the spatial and temporal variation in the wind climate as recorded by on-site anemometers will be crucial if any refined estimates of damage progression are to be derived.

The development of data-recording equipment able to operate in remote sites at low cost has now enabled the research to progress to detailed measurements of windspeed and direction at each windthrow monitoring area, where formerly only tatter flag surveys were practicable.

We already know that winds gusting in excess of 30 m s^{-1} (67 m.p.h., 58 knots) can cause sporadic damage within forests and that winds gusting in excess of 40 m s^{-1} (90 m.p.h., 78 knots) can result in widespread damage (Quine, 1989). However, the frequency with which these winds affect large parts of upland Britain is unknown and the shelter obtained in complex terrain is ill-defined. The network established to date will act as reference sites. Further equipment will be deployed on additional sites around the monitoring areas for shorter periods and this will allow us to determine the scale of area adequately represented by the reference sites and also the topographic influences on wind climate.

The wind recording sites range from 140 m above sea level (a.s.l.) to 479 m a.s.l., with nine located above 300 m a.s.l. (Table 2). The surrounding terrain varies from rolling hills and low plateau to more mountainous terrain — including Ben Nevis (1344 m a.s.l.) (Figure 5). Considerable care has been taken in locating the instrument arrays to ensure that they are well exposed and that the site is representative of the local area.

The data gathered from the reference sites will be compared with computer predictions from airflow models (Jackson and Hunt, 1975) and also information from the network of anemographs maintained by the British Meteorological Office for which long-term records are available. Unfortunately, most of these sites are located at low elevations near to ports or airports (Figure 5 shows the position of those closest to the monitoring areas); 38 of the 44 official anemograph stations in Scotland are located at sites less than 200 m a.s.l. It is difficult to assess their applicability to upland areas, hence the reason for the establishment of these new sites.

The equipment installed at each site consists of a Vector Instruments anemometer and windvane and a Holtech datalogger with 32K memory cards. The anemometer and windvane have been mounted on guyed light steel masts at the standard reference height of 10 m. The datalogger was initially programmed to take readings of mean windspeed and direction every 16 seconds and form histograms of 24 windspeed categories (each 2 m s^{-1} wide) and 16 wind direction categories; every hour the information was transferred to the removable memory card. The datalogger has now been upgraded to sample every 8 seconds, form histograms every half hour, and accommodate 40 windspeed categories (each 2 m s^{-1} wide); this will permit accurate recording of the very high gusts encountered on these exposed sites. The memory card has sufficient capacity to hold 34 days data and the system is powered by standard alkaline manganese batteries which will keep the datalogger running for up to 2 months. The combination of low power requirement and removable memory makes the datalogger ideal for operating in remote sites, requiring only a monthly visit. The discrete recording of data for each hour or half hour is a major advance on other basic logging equipment which merely accumulate the data between visits, and will allow better statistical interpretation to be made of the wind climate of upland Britain. Tatter flags are being run at each of the anemometer sites to allow further work on correlating windspeed and tatter (Jack and Savill, 1973).

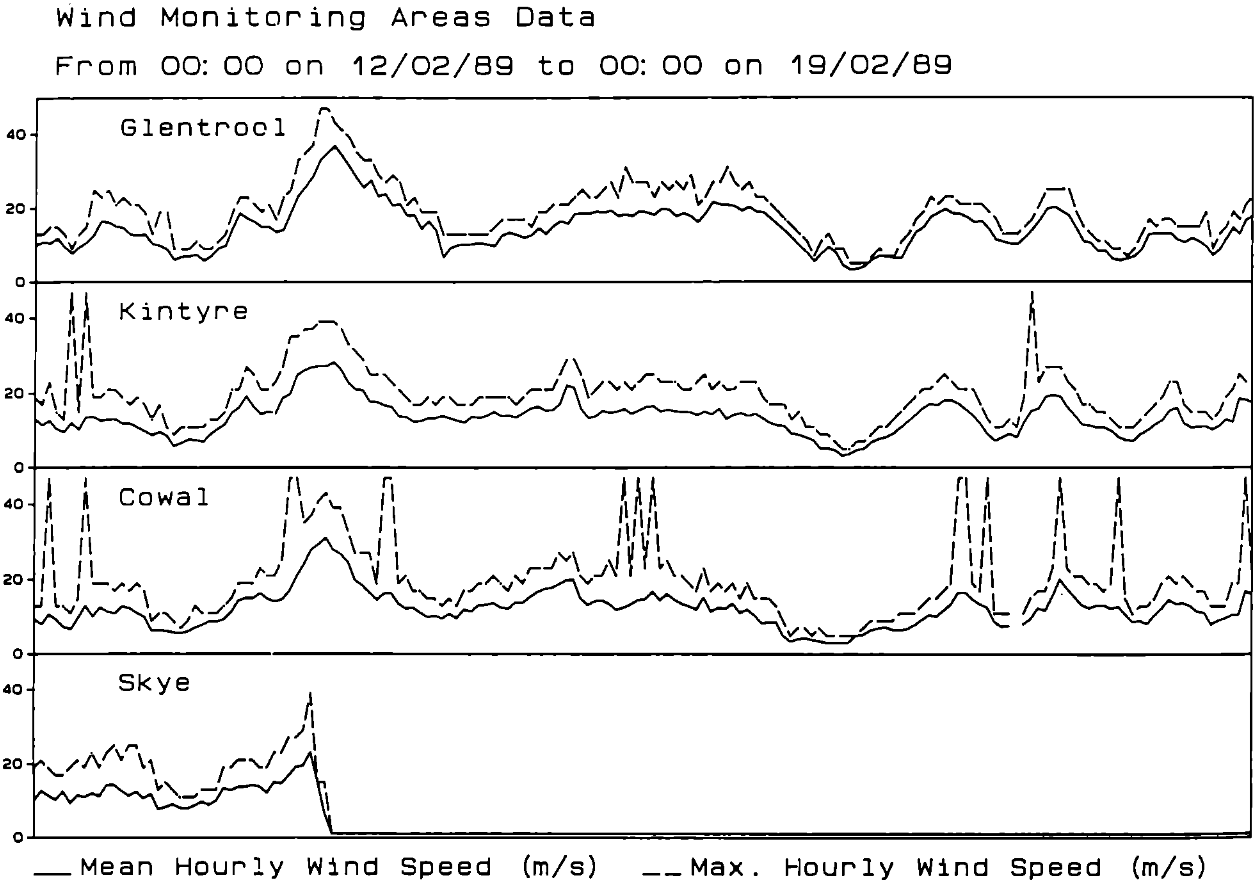

Figure 6. Hourly mean and maximum windspeed (m s^{-1}) for four stations in northern Britain for the week with the strongest winds of the 1988/1989 winter. The sharp peaks observable at Cowal (Strathlachlan) and Kintyre (Meall Buidhe) may be the result of convective downbursts.

Table 2 Reference anemometer stations for windthrow monitoring areas (as at 1 November 1989). See also Figure 5.

Forest District	Anemometer site	Grid reference	Elevation	Topex
Wester Ross	Skye, Beinn Staic*	NG399237	411	7
Kintyre	S Kintyre, Meall Buidhe	NR735325	374	0
	Carradale, Deucheran	NR762442	329	1
Newton Stewart	Glentrool, Mid Hill	NX288895	411	9
Cowal	Strathlachlan, Sron Cruaich	NS052962	317	14
	Glenbranter, Bernice	NS116922	370	110
Kielder	Kielder, Caplestone	NY590875	479	0
Lochaber	Leanachan, Leanachan bog	NN187786	140	31
Moray	Rosarie, Hill of Newton	NJ335448	330	2
Llandovery	Tywi, Cefn Fannog	SN824505	448	5

*Not the site referred to as Skye in Figure 6

Initial results

The winter of 1988/1989 was the first for which the network was operational. The strongest winds of the winter were experienced in northern Britain in the period 12-14 February 1989. Considerable forest damage occurred in north-east Scotland, particularly around the Moray Firth and on the Black Isle, and also in parts of west Scotland; over 300 000 tonnes of timber were windthrown. The winds were associated with the passage of a deep depression between north Scotland and the Faroes. In this period four of the reference station sites recorded maximum mean hourly windspeeds in excess of 25 m s^{-1} (see Figure 6), with the highest being 34.9 m s^{-1} (79 m.p.h.) at Glentrool, a hilltop site in Newton Stewart Forest District, south-west Scotland. These four stations also recorded gusts in excess of 39 m s^{-1}, with the maximum, at Glentrool, being in excess of 47 m s^{-1} (105 m.p.h.). The mast at Skye (a pneumatic model not used at other sites) failed during the storm — hence the abrupt end to the data displayed in Figure 6.

Initial comparisons have been made between sites. So far the site at Glentrool has given the highest mean hourly windspeeds. There is close agreement in timing and magnitude between the windspeeds measured at Glentrool and those measured at the site at Mealle Buidhe, Kintyre (see Figure 7a) approximately 70 km away but also sited on a hilltop close to the western seaboard. In contrast, comparisons between Glentrool and the site at Kielder, some 130 km away to the east, indicate that these two sites are not so well coupled and that the windspeeds are less at the site further inland (Figure 7b).

Acknowledgements

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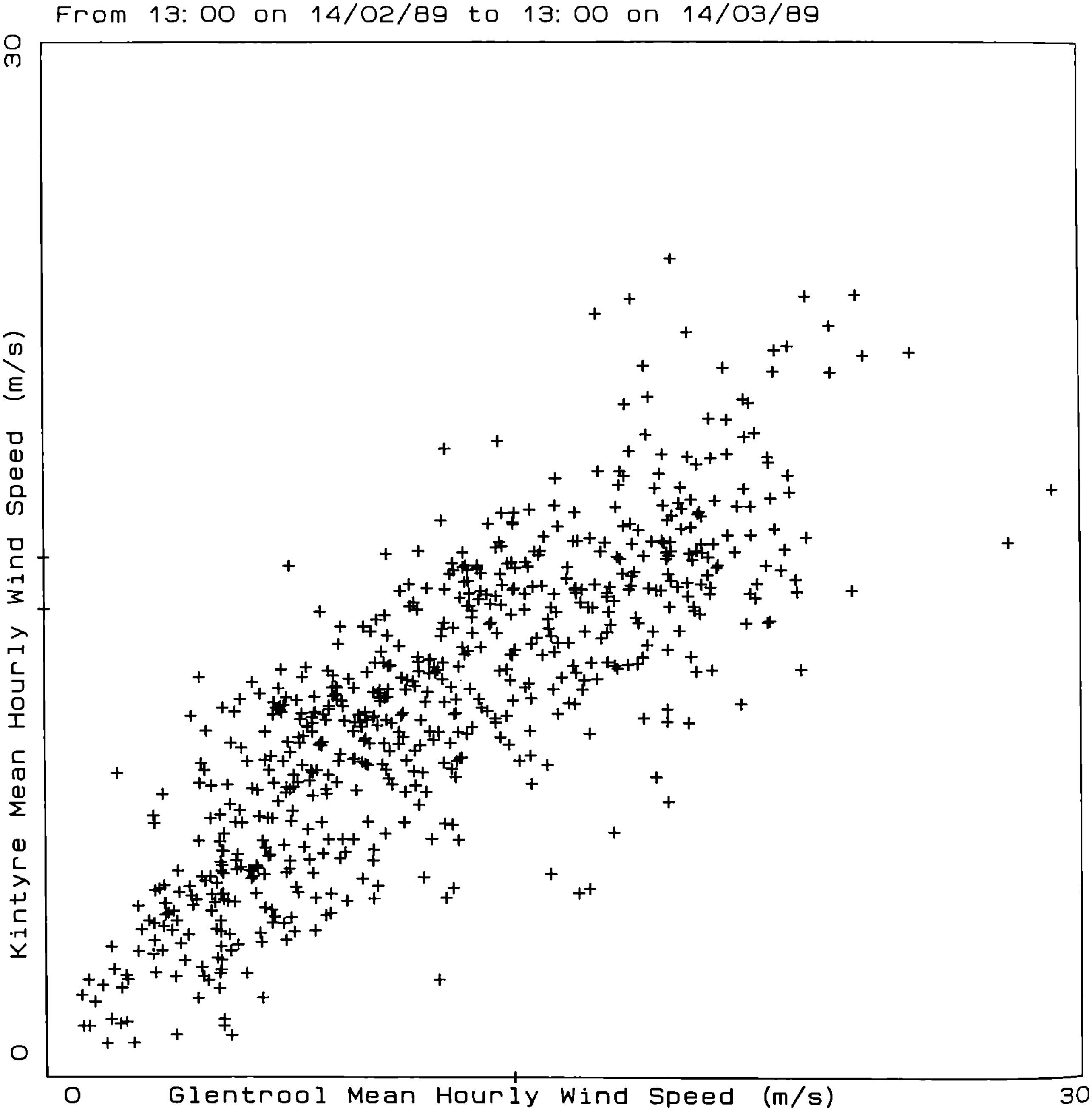
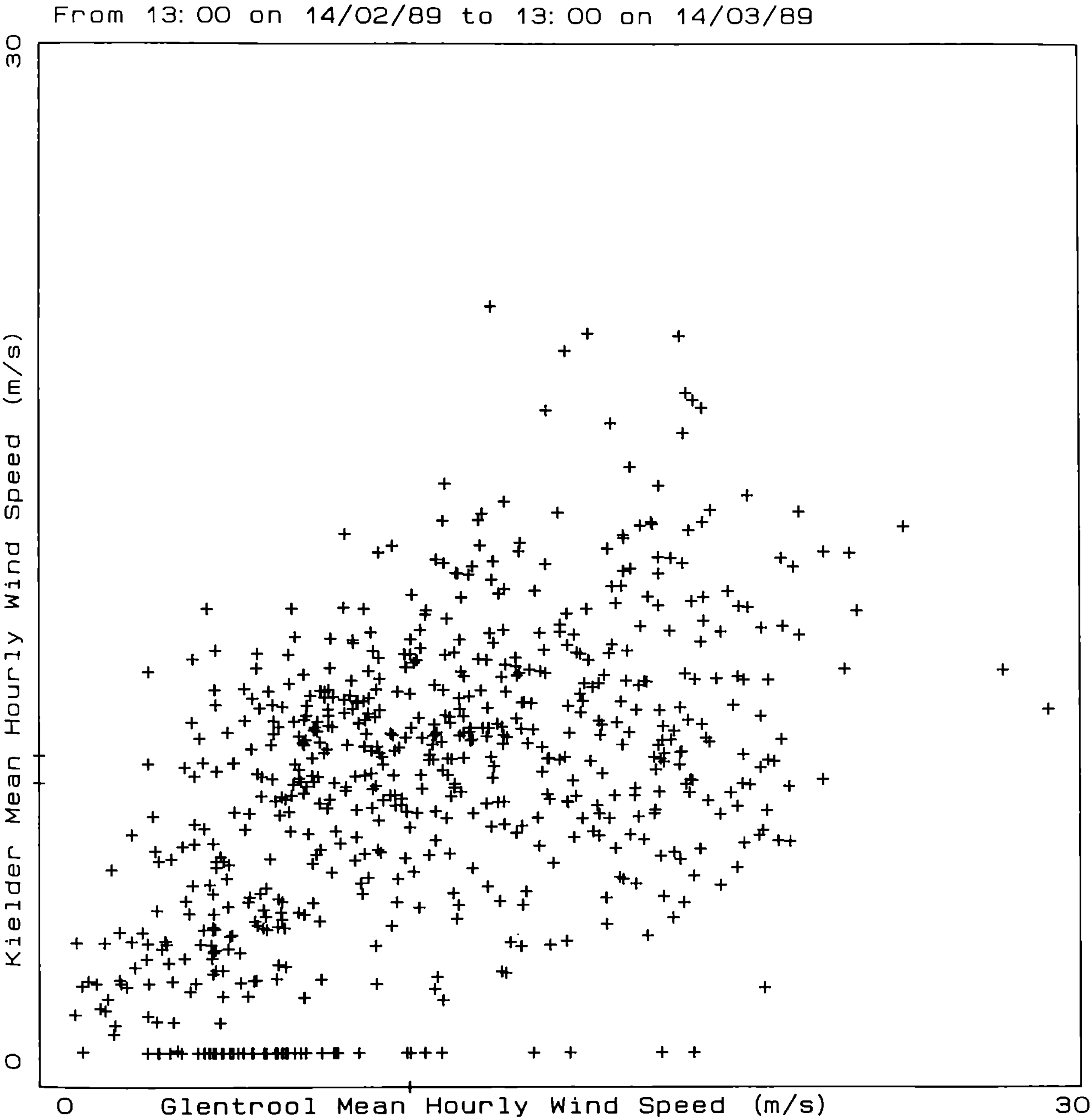


Figure 7. Scatter plots of simultaneous hourly mean windspeed (m s^{-1}) for two stations for the period 14 February 1989 to 14 March 1989. a) Glentrool v. Kintyre (Meall Buidhe), b) Glentrool v. Kielder.



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