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The First GARP Global Experiment

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For a number of years now we have been hearing about GATE, the international experiment conducted in the eastern tropical Atlantic during the summer of 1974. The contents of current scientific journals are evidence of the degree to which the initial aims of the experiment are being achieved for they contain a growing volume of research that is clarifying many of the most significant problems in tropical meteorology. Hard upon the heels of GATE comes a new experiment and a new acronym—this time it is FGGE, the First GARP Global Experiment. What is it all about and what does the Meteorological Office hope to get out of it?

Scientifically, interest in a Global Atmospheric Research Program stemmed from two technological developments—satellites and computers. The former brought the ability to monitor the global atmosphere continuously within grasp, and computers provided the means for digesting the colossal amounts of information involved and for using them for prediction. A global atmospheric program to exploit the scientific possibilities was attractive politically because it called for co-operation between nations for peaceful purposes to achieve worthwhile shared scientific aims. The potential benefits that might accrue from improved forecasts and better understanding of the atmosphere's general circulation were enormous and they would be available to all nations, not merely to those with advanced scientific capabilities.

As early as 1961, the General Assembly of the United Nations adopted the following resolution: 'Noting with gratification the progress for meteorological science and technology opened up by the advances in outer space and convinced of the world-wide benefits to be derived from international co-operation in weather research and analysis recommends . . . the early and comprehensive study of measures: (a) to advance the state of atmospheric science and technology . . . (b) to develop existing weather forecasting capabilities . . .'. In 1962, following a report submitted to it by WMO as a result of this resolution, the General Assembly recommended that the WMO should develop a more detailed plan for an expanded program in consultation with other United Nations Agencies and governmental and non-governmental organizations. In 1964, a WMO Advisory Committee and an ICSU/IUGG

Committee on Atmospheric Sciences were established in response to the UN action and they began the task of marshalling an international scientific effort aimed at solving some of the most pressing problems in meteorology. In 1966, the WMO Commission for Atmospheric Sciences recommended that 1972 should be designated a twelve-month period for intensive international study and analysis of the global circulation of the troposphere. They also proposed a series of supplementary studies aimed at understanding particular parts of the atmospheric system: these included studies in the tropics, the calculation of radiative transfers in the atmosphere and the investigation of air/earth exchange processes. The whole was to be called the Global Atmospheric Research Program or GARP.

It was soon evident that 1972 was a hopelessly optimistic date for a venture as large and novel as a global experiment. It would require careful planning and development of appropriate observing systems over a number of years, and furthermore there were good reasons why some of the supplementary investigations, particularly those concerning the nature of atmospheric developments in the tropics, should be completed before the main experiment. The methodology for preparing for the main FGGE was devolved to a Joint Co-ordinating Committee (JOC) for GARP, which was established in 1967 as a result of a formal agreement between WMO and ICSU. The Global Atmospheric Research Program was to be a program for studying those processes in the troposphere and stratosphere that are essential for an understanding of: (a) the transient behaviour of the atmosphere as manifested in the large-scale fluctuations which control changes of weather . . . and (b) the factors that determine the statistical properties of the general circulation of the atmosphere which would lead to a better understanding of the physical basis of climate. From the outset, the JOC has been active in promoting international co-operation in meteorology and in encouraging large-scale experiments to probe the outstanding problems which limit our understanding of the atmosphere. It saw clearly at an early date that one of its main aims must be the setting up of a global experiment, since so many of the questions concerning the predictability of the atmosphere required an input of observations on the global scale. As early as the second meeting proposals were put forward for a global experiment in 1974–75, but the need for tests of the proposed observing systems and further consideration of the detailed logistics have led to postponements to the present firm dates for the First GARP Global Experiment in 1979.

FGGE will involve the deployment of special observing systems to supplement the normal World Weather Watch. In addition to five geostationary satellites providing continuous cover of the whole of the Earth equatorwards of about 50–55° latitude and four polar orbiting satellites, special efforts are being made to supplement the observational data for a number of areas where the network is otherwise inadequate. Over the tropical oceans for example, ships (Tropical Wind Observing Ships, TWOS) and aircraft will be deployed to try to make good large blank areas in the conventional coverage. They will concentrate on the Special Observing Periods when it is expected that 40 or 50 ships and 5 or 6 aircraft flights will provide substantial additional data each day. In the tropics also, constant level balloons (TCLBs), up to 300 in number, will be released to float at about 46 000 ft. Their positions will be monitored, using satellites for communications, and winds will be derived. In the southern hemisphere, the great need is for observations over the southern oceans that will provide more surface observations to supplement the upper-air data obtained from satellites. In this instance, floating buoys, capable of transmitting surface pressure and temperature values back to satellites will be deployed. About 300 will be launched, and with a reasonable life-time, many may still be operating at the end of FGGE to feed additional data into the World Weather Watch network for some time thereafter. Special emphasis is being given to the program to collect as much information as possible from commercial aircraft flights. For example, arrangements have been made to use the Aircraft Integrated Data Systems (AIDS) in over 80 aircraft.

The opportunity to experiment with enhanced amounts of data on a global scale is one for which the Meteorological Office has been preparing for a number of years. There are, in particular, three questions we shall be endeavouring to answer:

(1) What analysis system should be used to make the optimum use of the data available?

(2) What is the operational benefit of each of the observing systems and, in particular, can we use FGGE to indicate what is the best mixture of observing systems to plan for in the future?

(3) What can we learn about the predictability of the atmosphere, and how can we use the information to improve forecasts for the British Isles?

The analysis procedures now used in CFO were designed a number of years ago and were suited to the observing systems that were then in operation. For analysis of upper-air charts, the methods assumed that the data came primarily from radiosonde observations, which take soundings through the atmosphere at fixed times and places. The number of soundings is comparatively small, and some areas, especially over the oceans, are thinly covered, but the observations are reliable and have rather small errors. An analysis system could therefore concentrate on providing the best possible fit to the synoptic observations for 00 GMT and 12 GMT. Also the system was based on an analysis of contour heights, winds being derived using the geostrophic or similar relation. It was not well suited to the incorporation of wind reports, especially when they were not accompanied by height information, nor did it aim to deal with tropical areas.

The assumptions on which the analysis system were based are becoming less and less valid. Nowadays there are a large number of observations-of-opportunity which are made as and when the particular observing system happens to be available. For example, there are more wind observations from aircraft which, with modern navigation and recording instruments, are more accurate than they were some years ago. Polar orbiting satellites give information about clouds and temperatures as and when they pass over the area concerned. On the other hand the number of radiosonde observations has decreased in some regions. Over and around the North Atlantic they are fewer and there may be difficulties in the future in maintaining even the present network. Both because the Meteorological Office is involved in supplying winds for long flights into or crossing the tropics and because we are aiming to provide forecasts for the British Isles for longer periods ahead our analyses need to cope with tropical conditions. A system that is partly based on geostrophic assumptions is clearly inappropriate for this.

The growing part played by aircraft, satellites and new observing devices in the observational system has led to a larger total volume of information about the atmosphere, but its characteristics are changing from those of a well-ordered, synoptic, rather accurate system to a more continuous but heterogeneous flow which is in general less accurate and less internally consistent. The data show more clustering in space around specific altitudes and geographical locations and can apply with more-or-less equal probability to any time of day. To deal with this situation requires a new approach to analysis, and poses difficult problems of interpretation which for the volume of data concerned can probably only be solved by systematic computer methods.

In the Meteorological Office an objective analysis scheme has been developed for use during FGGE. If it proves sufficiently successful it may indicate how the operational analysis system must also change in the future. Its characteristics can be summarized as follows:

(a) All observations of upper-air parameters, surface pressure and surface wind over the sea from whatever source can be made use of, irrespective of the method of observation or of the time of day at which they are made.

(b) Observations are, however, not treated equally. They are allocated weights depending on their likely statistically determined errors. For example, temperatures from radiosonde ascents are assumed to be more accurate in the troposphere than values derived from the inversion of satellite radiance measurements. The former are therefore given substantially more weight than the latter, but in areas where more accurate information is lacking satellite observations of temperature can nevertheless have a substantial impact.

(c) The observations are inserted into the forecast model during a forward integration, with a weight that starts from a small value $1\frac{1}{2}$ hours before the observation time, increases to a relative value of 1·0 at that time and decreases again to zero after $1\frac{1}{2}$ hours. In this way the model has time to adjust gradually to the data and there are hopes that this will eliminate the need for special initialization procedures such as have to be followed with the present operational model.

(d) The process of inserting observations leads to an immediate alteration in model values at a group of points surrounding the observation both vertically and horizontally. For instance, an observation of wind at one level causes consistent changes determined in a statistically optimum way at other levels and within a specified horizontal radius of influence. During the forward integration the influence of the observation spreads wider afield, and therefore during the three hour period of assimilation it is capable of influencing a substantial surrounding area.

The whole process can be envisaged as one in which at successive time-steps the model is nudged towards the observed values, but at no stage is it forced to fit them precisely. However, if the values are consistent among themselves and with the structures that the model can handle, the resulting analysis will be a good representation of them; if, on the other hand, the observations are in some way inconsistent the model will adjust to the nearest probable state and a certain amount of noise, which the model has to be capable of dealing with, will be created.

A test of this system on a global scale took place in CFO for one week during October 1978. Preliminary results are encouraging, and there is every reason to expect that the analysis scheme will be suitable for carrying out the further experiments that are planned for FGGE. Whether it can be adapted for operational purposes and so become the basis for a future system in CFO depends on the outcome of these experiments.

The availability of an advanced and flexible analysis scheme that can deal with all kinds of observations is a prerequisite for investigating the second main topic. The analysis scheme has been developed from one that was originally produced for the purpose of carrying out a series of Observation System Simulation Experiments (OSSEs) which were asked for by the JOC to help in their planning of FGGE. The idea was that one could use the results of a general circulation integration as though it represented the real atmosphere, and a second different model as though it were a forecasting model. By deriving 'observations' from the first model and feeding them into the second, run in forecast–analysis mode, one could then see how closely the second model could be persuaded to follow the developments in the first. By changing the assumptions about the observations available, a number of possible global observing systems could be simulated, and some idea obtained about what observations are required to reach any specified error level. The advantage in comparison with similar experiments involving the real atmosphere is that for the general circulation model, we know what is happening at every point and are not frustrated in our attempts to determine the adequacy of an observing system by a lack of knowledge. Before FGGE the experiments were carried out using an 11-layer model with a 220 km grid to represent the real atmosphere and a 5-layer model with a 330 km grid to represent the forecasting model. During FGGE itself, the OSSEs will become Observation System Experiments, in which the general principle will be the same but the roles of the 11- and 5-layer models will be taken over by, respectively, the real atmosphere and the 11-layer model. This will enable us to examine the utility of particular kinds of observation. For example, it will be possible to remove temperature soundings from satellites and repeat the analyses and forecasts to determine by how much they are degraded. The question of estimating the importance of weather ships or aircraft in the global observing systems is another that might be usefully looked at in this way. What is proposed therefore is a natural extension of the work that was carried out before FGGE and one of the aims will be to see how well the information that was given to the JOC then stands up to critical evaluation. This in turn will provide us with useful data about the performance of the general circulation models that have been developed over the last decade or so.

The third question is concerned with improving the numerical forecasts used within the Meteorological Office and is of course part of a continuing commitment that occupies a substantial part of the effort of the Operational Computer Analysis and Forecasting section and the Forecasting Research Branch (Met O 2b and Met O 11). The particular questions that one hopes will be helped particularly by the enhanced observing systems available during FGGE are those that arise regarding the area the operational forecast model should cover to serve the Office requirements as well as possible. It is already clear, for example, that the area of the 10-level operational forecasting model is too small for some purposes. With a boundary at around 15°N, it fails to cope with some of the long flights now being undertaken by large aircraft. Also we are aware that there are occasions when the influence of motions near or outside the boundaries substantially influence middle latitudes within a few days and certainly within the period for which we wish to produce numerical forecasts. There is therefore a real need to deal with a larger area, but how large should it be? Experiments have shown that it is not advisable to place the boundary at or near the equator since then the Hadley cell which is driven by low-latitude heating is grossly distorted; also at most times of the year there are substantial cross-equatorial flows which may extend into subtropical latitudes. There are probably good reasons therefore if we wish to have a forecast that is valid over the northern hemisphere why the boundary should be placed well into the southern hemisphere, probably at a latitude which can be considered from a meteorological point of view to be quiet at most times of the year. A global coverage of data will enable us to consider these matters more effectively than in the past, in order to reach a decision taking account both of the scientific advantages of extending the area and of the computational disadvantage of so doing.

In the longer term there are other investigations that will use FGGE data. Concerning predictability, for example, it is well known that the present level of forecast success is well below that indicated as possible by theoretical experiments. Why this is so is undoubtedly a very complex matter involving a number of factors. The shortcomings in the models themselves is certainly one of the most significant. However, it is important to try to find out how the level of forecast achievement is affected by uncertainties in the initial state of the atmosphere, and while FGGE will certainly not resolve this problem completely it will provide the best data yet available for investigating the question.

Two other areas of activity within the Meteorological Office that will greatly benefit from the intense observational activity during FGGE are the study of the general circulation of the atmosphere, and the verification of the simulations of climate. Concerning the first, the data available for describing the atmospheric circulation in the greater part of the northern hemisphere are, despite some shortcomings, reasonably complete, but in the tropics and in the southern hemisphere, they are far from adequate. The possibility of examining the southern hemispheric motions and of comparing the hemispheres in greater detail will be a most valuable opportunity for increasing our understanding of the global atmospheric system.

It is not at first obvious that FGGE has much to do with climate or climatic change. However, considering that within the annual cycle and over the surface of the globe a very wide range of climates is represented and further that what we are most interested in is a physical description of how these climates are created (rather than a descriptive account of what they are, though this of course is a necessary preliminary) it is evident that the potential of FGGE for improving our knowledge of climate and of the factors that might cause climatic change is substantial. Investigations to exploit the FGGE data for this purpose are likely to be an important part of the work on climate in the Dynamical Climatology Branch (Met O 20) for some years.

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The northerly gales of 11–12 January 1978

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Summary
Synoptic reports and anemograph records of the gales were analysed. None of the recorded gust speeds exceeded the values currently used in building design. Mean wind speeds were recorded which are likely to be exceeded only once in 50 years. The strongest northerly winds occurred in eastern England, especially on and near the coast.

Introduction

The storm of 11–12 January 1978 was immediately recognized as a rare event by people in east coast districts whose homes were inundated by the sea. The northerly gale that accompanied the flooding also caused a good deal of structural damage in inland districts, and it was the wind damage that led to this examination of the gales. The main object was to find out how the wind speeds that occurred were related to the existing published values of extreme wind speed which are used by architects and engineers in the design of buildings and other structures.

1. Synoptic situation

A low centred near Lincolnshire in the early morning of 11 January 1978 moved across the North Sea and was over the Continent by midnight (Figure 1). Strong south-westerly winds associated with the deepening of this depression during the night 10th–11th affected Wales, south-west England and the English Channel. By early morning on the 11th these south-westerly winds had decreased, and northerly gales had already started in Shetland. After 03 GMT the surface pressure rose by 7–8 mb each three hours in the Hebrides until 15 GMT, and this large and sustained pressure rise resulted in a very strong geostrophic wind from about 030°, with little curvature of the isobars (Figure 2). East Scotland, north-east England, much of southern England, and south-east England were in turn affected, as the greatest pressure rises migrated south-eastwards across south-west Scotland and the Irish Sea to southern England. Geostrophic winds measured 90–100 knots over north-east England from 15 to 21 GMT, over central southern England at 18 GMT and over south-east England at midnight and 03 GMT on the 12th.

With the continuing rise of pressure in the north-west, the horizontal gradient of surface pressure was increasing quickly, so that the geostrophic approximation was not valid, and the so-called isallobaric wind—the ageostrophic term which quantifies the effect of the changing pressure pattern—could not be ignored. The isallobaric wind was calculated as 30–35 kn from 310–340° over extensive areas south-east of a line Lincoln–Bournemouth from 15 to 21 GMT (Figure 3). While isallobaric winds over 30 kn are not particularly unusual it seems probable that only rarely would they occur over such large areas. If an isallobaric wind of 335° 35 kn is added as a vector to a geostrophic measurement of 030° 100 kn (for example, north of London at 18 GMT) the resultant is 015° 125 kn, and this may be the best estimate of the strongest winds in the free air over south-east England that evening. However, the isallobaric vector as a component of the upper wind has not been confirmed, either in the original work on isallobaric effects (Brunt and Douglas, 1928) or subsequently. In this instance also, the reality of the 125 kn estimate cannot be verified. The only independent evaluation of the free air movement is that obtained by radar-following of balloon-borne reflectors, and these

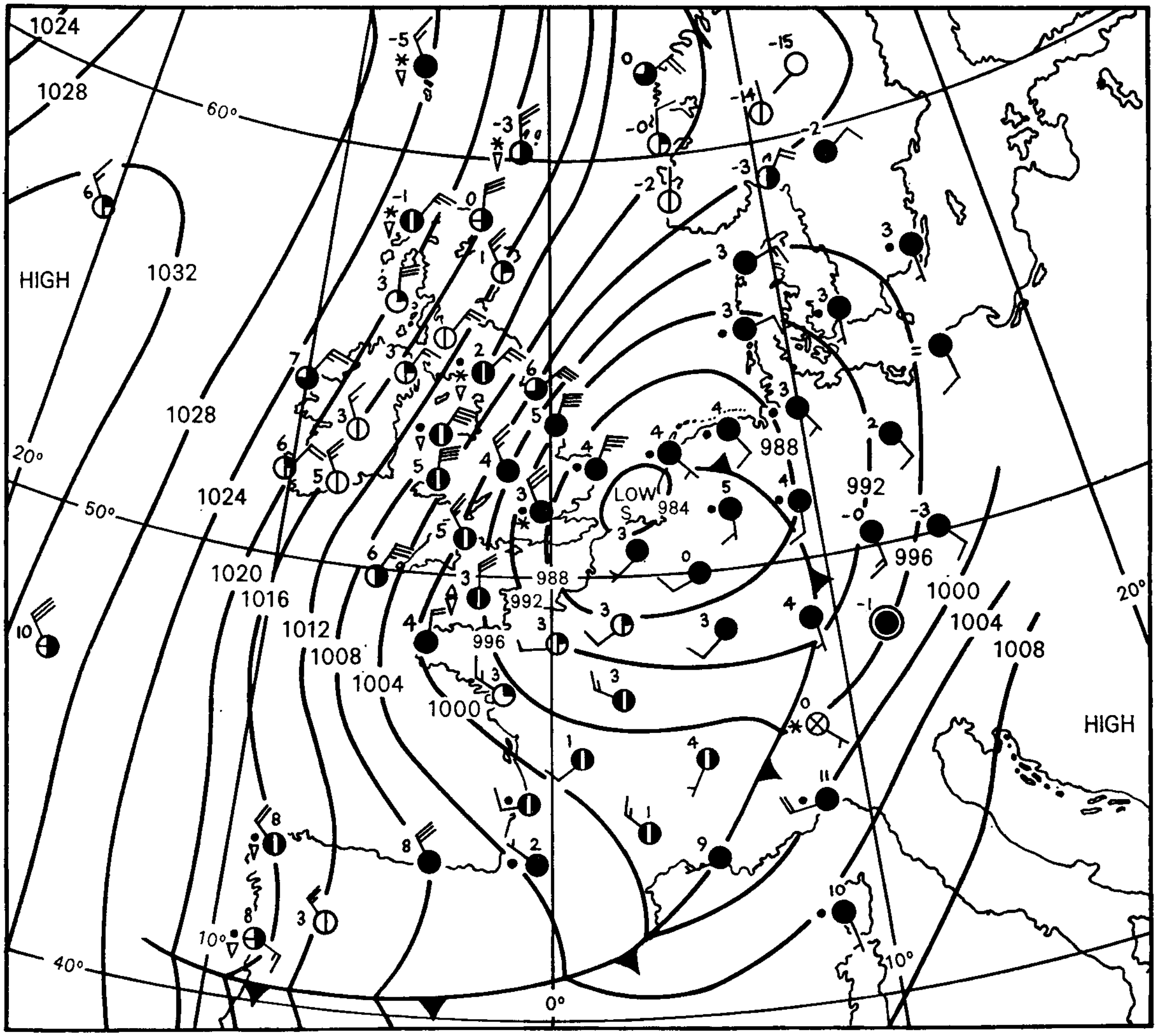

Figure 1. Synoptic situation at 18 GMT on 11 January 1978.

routine radar measurements did not coincide with the strongest geostrophic wind measurements. Disregarding the possible isallobaric contribution, therefore, it is presumed that the free air winds are indicated by the geostrophic measurements, and these were over 100 kn in some places.

2. Synoptic reports

In synoptic reports from hourly charts, very strong northerly winds (nominally 10-minute mean speeds) were reported extensively over the North Sea and the Channel. Mean winds over 57 kn were reported at Ballycastle (Co. Antrim), Gorleston (Norfolk), St Abbs Head (Borders) and The Needles

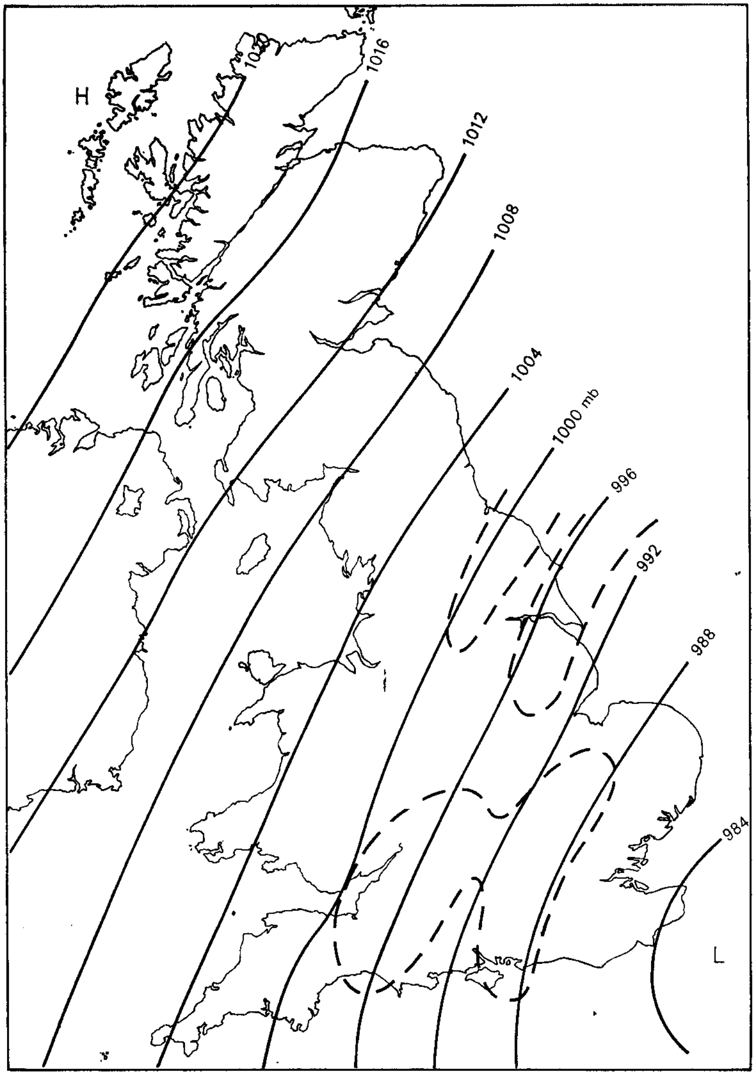

Figure 2. Mean-sea-level pressure at 18 GMT on 11 January 1978.
Dashed lines are isotachs of the 90 knot geostrophic wind.

(Isle of Wight). Mean winds over 47 kn were reported for 11 hours at Flamborough Head (Humberside) and 12 hours at St Margaret's (Kent); these two sets of measurements were obtained with hand-held anemometers, the other stations having permanently installed eye-reading cup anemometers or (at Gorleston) an anemograph.

Synoptic reports from inland stations included measurements of 40 kn at Yeovilton (Somerset), Binbrook (Lincs.), Cardington (Beds.), Wyton (Cambs.) and Wattisham (Suffolk). Inland stations reporting 30 kn or more were mostly east of a line Newcastle upon Tyne–Exeter, and these strong winds persisted for 12 hours in some places, especially in the more eastern counties.

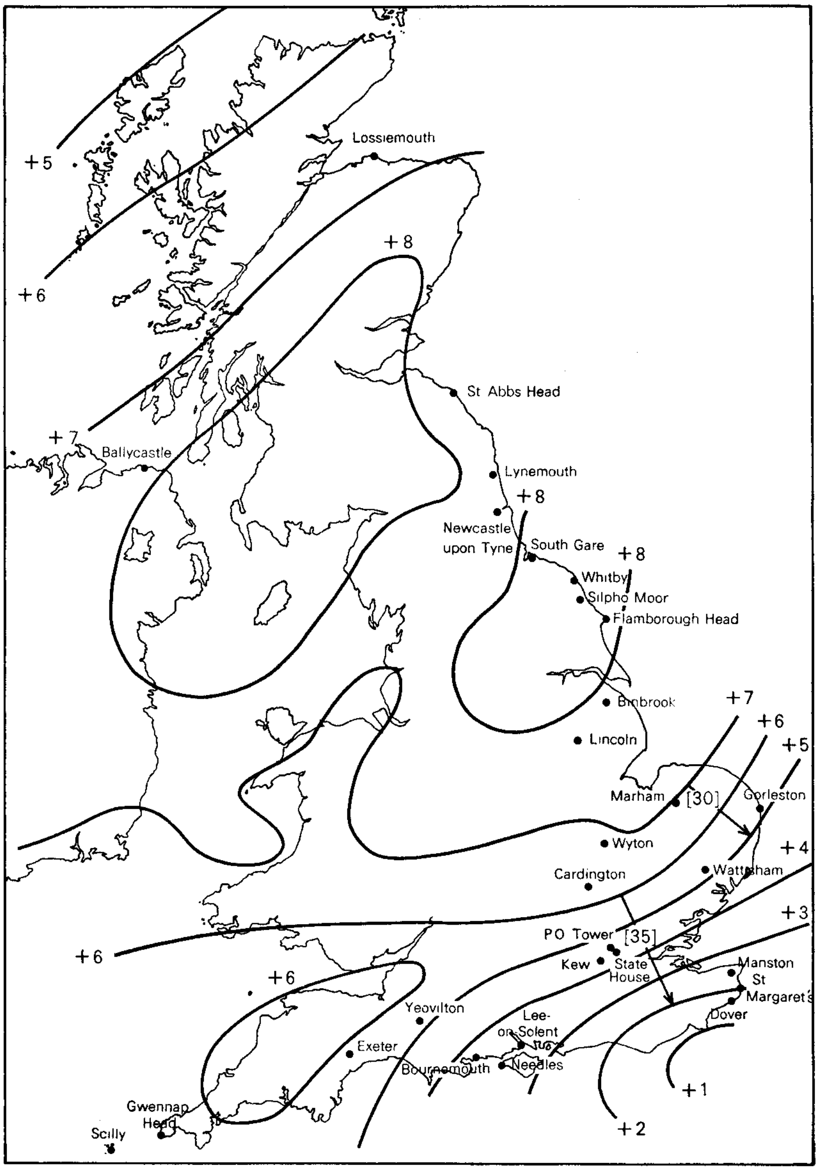

Figure 3. Isallobars at 18 GMT on 11 January 1978. Isopleths show pressure changes in millibars between 15 and 18 GMT. The arrowed lines with figures in square brackets indicate the isallobaric wind in knots.

Too much reliance should not be placed on mean wind speeds in synoptic reports because they are often only eye estimates made from a fluctuating pointer of a wind speed indicator, and tend to err on the high side. A gust speed is often included in the synoptic report and this is usually the highest instantaneous reading of a wind-speed dial; if the dial is not under observation when the highest gust occurs the true maximum gust speed will be higher than the gust speed reported. This does not apply, of course, to a station which has the benefit of an anemograph. Some coastal stations experience wind flows that may be considerably accelerated by a cliff or exposed hill: gusts of 82 kn reported at Whitby and St Abbs Head probably fall into this category. The extreme mean and gust speeds at any station may of course have occurred in the breaks between the synoptic reports. However, even with all these inadequacies it is clear from the synoptic reports that the main impact of the gales was felt in the east and south-east of the country.

3. Anemograph records

The only continuous wind records are from the anemograph charts. Special reports for 11–12 January were received from 136 anemograph stations in the United Kingdom. In north-east Scotland the strongest gusts occurred before midday whereas in central southern England they came about 12 hours later.

Gust speeds of 60 kn or more were recorded at points on the coast (predominantly the east coast) from Lossiemouth to Scilly (Figure 4) and at some places inland in south Scotland, north-east England, Lincolnshire, East Anglia and London. Gusts of 70 kn or more were recorded at Lynemouth (Northumberland), South Gare (Cleveland), Silpho Moor (North Yorks.), Gorleston, Manston (Kent), Dover, and Gwennap Head (near Land's End), all on the coast; the only inland stations to record 70 kn gusts were Kew, London Weather Centre (State House) and the Post Office Tower.

Hourly mean speeds of 40 kn or more were recorded at points on the coast from Orkney to Land's End, again predominantly in the east (Figure 5). The highest hourly mean speed recorded, 53 kn, was at Gorleston.

Even in the areas of strongest winds, however, many places had speeds no greater than would occur in the normal run of winter gales; at Heathrow Airport, only 10 km from Kew, for instance, the highest gust was 54 knots.

4. Return periods

One measure of the severity of a gale is the 'return period' of the wind speed recorded. This is the statistically estimated number of years in which a given speed will be equalled or exceeded only once. In reality it may be equalled or exceeded more than once or not at all, but once is the most probable outcome. The speeds (at 10 m) which have a return period of 10, 20, 50, 100 or 120 years have been calculated (Hardman, Helliwell and Hopkins, 1973) for 142 anemograph stations and are listed in Climatological Memorandum No. 50A (CM 50A). Those stations which on 11–12 January recorded speeds within a few knots of their 50-year-return-period value are shown in Table I, and the return periods of these speeds, inferred from CM 50A, are given. Stations not listed in CM 50A were compared with stations in the same region for which CM 50A does give details. The anemometers are at different effective heights, and for the comparison the recorded speeds were reduced to a common effective height of 10 m, using the usual relationship

$$\frac{V}{V_{10}} = \left(\frac{h}{10}\right)^{\alpha},$$

the exponent α being taken as 0·17 for mean speeds and 0·085 for gust speeds.

The return periods estimated from station data in CM 50A confirm that the gales were more significant on the east and south-east coasts and in the London area than elsewhere. As is emphasized in CM 50A, the computed extremes for individual stations should be used with caution; since the

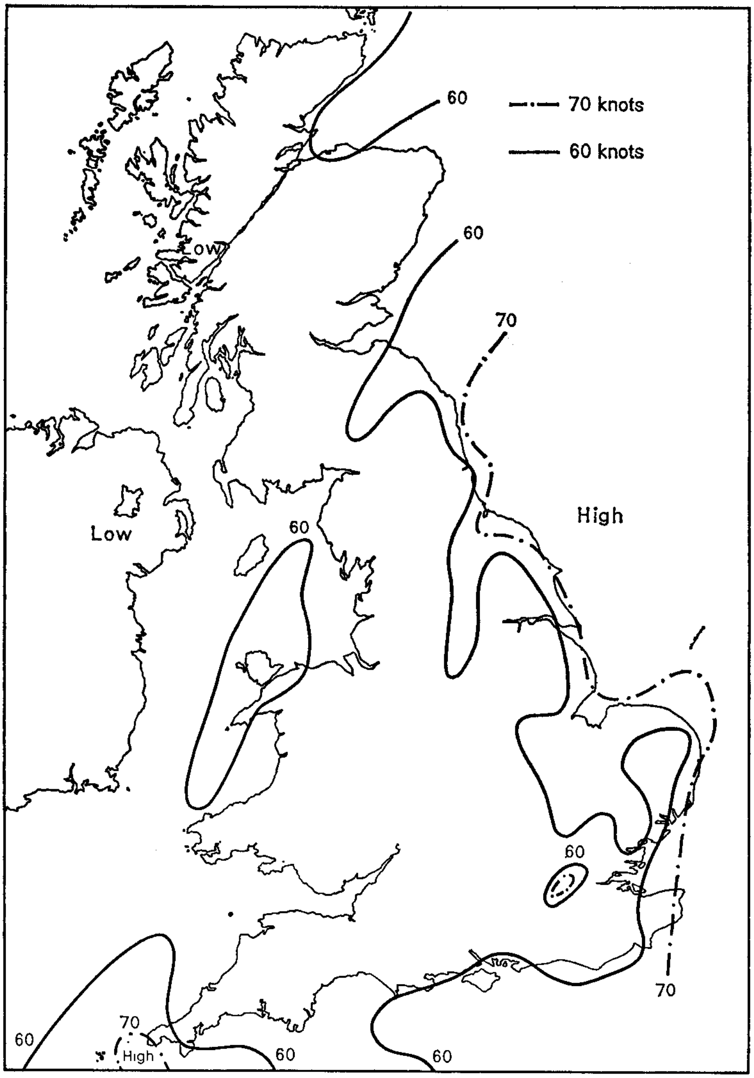

Figure 4. Maximum gust speeds for 11–12 January 1978 deduced from anemograph records.

difference between a once-in-20-years speed and a once-in-50-years speed is often only 2 kn, a rather wide tolerance must be accorded to any return period estimated from an individual station's records.

The outstanding return period for gust speed is that for **Kew**; using CM 50A the 70-kn gust would have been estimated as a once-in-70-years event but it is now estimated to be a once-in-35-years event (see Appendix). In central London a gust of 71 kn was recorded at **State House** (effective height 38 m) and this is estimated as a once-in-30-years event (see Appendix).

At **Gorleston** a gust of 74 kn was recorded. By comparison with CM 50A this would have a return period of 20–50 years. However, a 74 kn gust occurred in 1976 also, after the CM 50A table

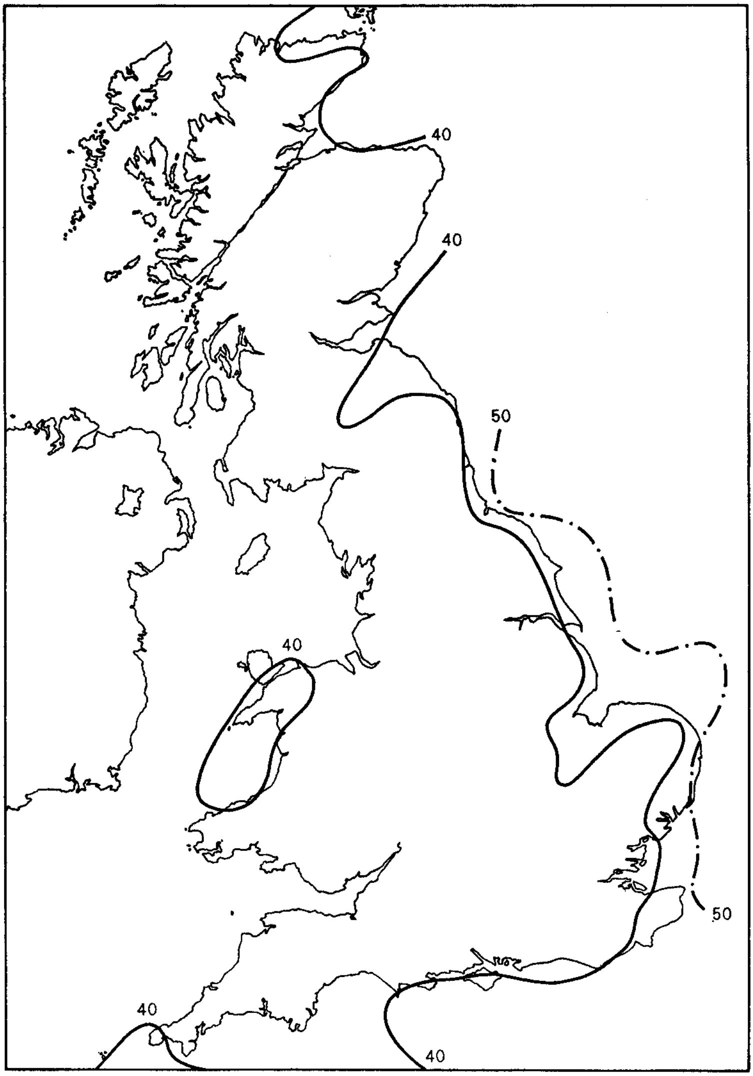

Figure 5. Maximum hourly mean wind speeds (knots) for 11–12 January 1978 deduced from anemograph records.

was compiled. It is not possible to make a reliable new estimate, as was done for Kew, because of numerous breaks in the long-period record, but it would seem prudent to regard this 74 kn event as having a return period close to 20 years.

The sustained very high speeds, rather than the gust speeds, were the main feature of this storm. The outstanding return periods for hourly mean speed were 100 years at State House (estimated from 13 years' annual maxima by comparing them with Kew's long-period record, as described in the Appendix), and 100 years at Gorleston (from records spanning 50 years but with some breaks). Return periods of 50 years were estimated for Marham (Norfolk), Manston and Dover. Furthermore, strong winds from the northerly quadrant are several times less common than strong winds from the south and west. An extreme-value analysis of winds at Kew from different directions based on the 20 years 1957–76 shows a 30 kn hourly wind speed to have a return period of 85 years for northerly winds (Figure 6), 80 years for easterlies, 20 years for westerlies and 10 years for southerlies. This is consistent with the all-directions return period of <10 years obtained from CM 50A.

Table I. *Anemograph stations—high values*

	Effective height *metres*	Maximum gust speed Obs. *knots*	Reduced to 10 m *knots*	Return period *years*	Maximum hourly mean speed Obs. *knots*	Reduced to 10 m *knots*	Return period *years*
Lynemouth	10	71	71	15	33	33	<10
South Gare	15	72	70	10	51	48	15
Silpho Moor	9	71	71	15	27	27	<10
Marham	10	61	61	<10	38	38	50
Gorleston	13	74	72	20	53	51	100
Wattisham	10	66	66	10	39	39	10
Cardington	41	67	59	<10	46	36	<10
Manston	18	72	68	10	48	43	50
Dover	18	71	68	10	47	43	50
Lee-on-Solent	12	64	63	10	36	35	<10
London							
State House	38	71	63	30	41	33	100
Kew	15	70	68	35	30	28	<10*

* N.B. Return period of *northerly* winds with mean hourly speed 30 kn at Kew is 85 years.

5. Design winds

All the gust speeds recorded on 11–12 January fall below the Basic Wind Speed for design purposes obtained from the map in the British Standards Institution Code of Practice C.P.3; that is to say, all the gusts recorded were less than the 50-year return period values on which the map is based. Hence no change in the design values in the map or in Table I of the Code of Practice is called for by this later knowledge. The map value of 37 m/s (72 kn) for the Kew area, apparently a rather high value when set against the Kew records up to 1971, is justified by the more recent events.

6. Conclusion

The northerly gales of 11–12 January 1978 were not of special significance in the north and west of the United Kingdom; their greatest effect was in the counties bordering the North Sea from Northumberland to Kent and in part of the London area.

Mean winds or gusts of exceptional strength occurred in several places on the east coast and in a narrow belt across the London area. Generally the hourly mean speeds were statistically more significant than the gusts, and at Gorleston and London Weather Centre the hourly mean wind reached speeds likely to be exceeded only once in 100 years. Probably at many more places the speeds recorded were unusually strong for a northerly wind, as was the case at Kew.

The long-term frequency of strong gusts at Kew (all directions) has been reassessed. No amendments are required in the wind-loading Code of Practice, however.

Winds in the free air at times exceeded 100 knots, and may have reached 125 knots in one or two places in south and east England.

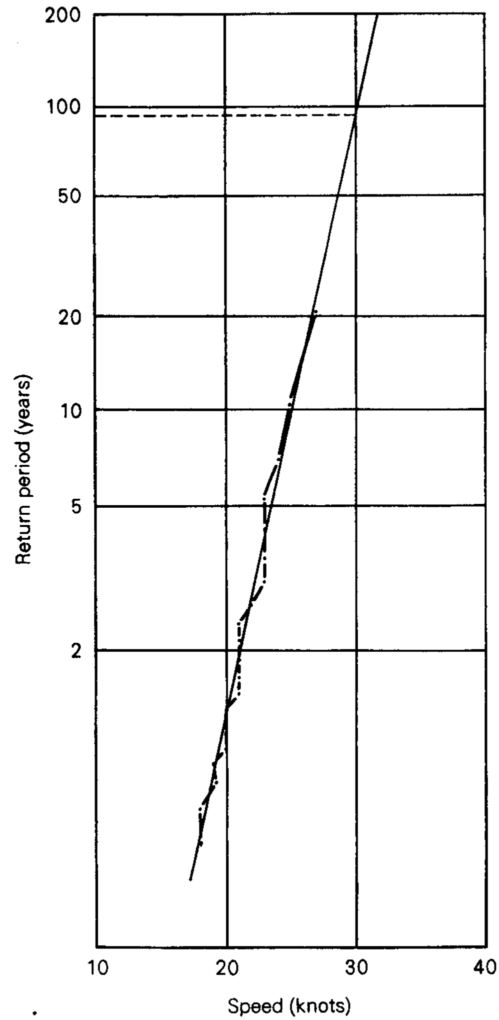

Figure 6. Maximum annual hourly wind speed at Kew (northerly winds, quadrant 320°–040°) at effective height of 15 metres, 1957–76.

Acknowledgements

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References

British Standards Institution — 1972 — Code of basic data for the design of buildings, Chapter V, Part 2: Wind Loads.

Brunt, Sir David and Douglas, C. K. M. — 1928 — The modification of the strophic balance for changing pressure distribution and its effect on rainfall. *Mem R Meteorol Soc*, **3**, No. 22.

Hardman, Carol E., Helliwell, N. C. and Hopkins, J. S. — 1973 — Extreme winds over the United Kingdom for periods ending 1971. London, Meteorological Office, *Climatological Memorandum* No. 50A.

APPENDIX

Return periods of strong winds at Kew and State House

The pressure-tube anemograph at Kew Observatory recorded a gust of 70 knots at 1809 GMT on the 11th. This station has now had a continuous high-quality record in a 'suburban' situation with no local changes of exposure or instrument for 47 years. The return periods quoted in Climatological Memorandum No. 50A (when a 41 years' record was to hand) should therefore have been a very close approach to reality, and the strongest gust in the 41 years up to 1971 was 63 kn in 1947 (Figure A1, *A*). Since 1971, however, four large annual maxima have occurred:

1974	78 kn
1976	69 kn
1977	66 kn
and now 1978	70 kn (Figure A2).

This sequence of extreme gust speeds is unique to Kew: no other station in these years experienced so many or such large departures from its historical pattern. With this later information a 70 kn gust (at 15 m effective height) at Kew can no longer be taken as a once-in-70-years event. A new estimate of return period has been made by the Gumbel procedure using all data now available, including the 70 kn gust of 11 January 1978. In the initial analysis the 78 kn value of 1974 produced a distortion in the plot of speed versus probability (Figure A1, *B*), but a very good fit was obtained by excluding this extreme figure and analysing the remaining years (Figure A1, *C*). The 78 kn gust then appeared as a once-in-200-years event. The autographic record and a verbal description of this 78 kn gust suggested a tornado as the cause, and this would in fact be an exceedingly rare occurrence at any one place. In Table A1 are the revised values for Kew reduced to effective height 10 m for comparison with the CM 50A values: the new once-in-50-years gust speed is 69 kn. The revised estimate of return period for a 70 kn gust at 15 m (equivalent to 68 kn at 10 m) is 35 years.

The electrical anemograph at State House in High Holborn recorded a 71 kn gust at 1809 GMT. A Gumbel analysis of the 13 years' data now available gives an estimated return period of 17 years, but these 13 years include the noticeably windier years (at Kew) 1974 and 1976. A preferred alternative approach was to compare the 1965–77 period at State House (38 m) with Kew (15 m), but excluding 1974 as before. The total of annual maximum gust speeds at State House was expressed as a percentage of the total of annual maximum gust speeds at Kew, and this percentage was then applied to the speeds in a revised frequency table for Kew (15 m) to obtain speeds (at 38 m) for State House for various return periods: these are in Table A2. This would give an estimated return period of 30 years for a 71 kn gust. Knowledge of wind flows over cities is scanty, so that these speeds and return periods can only be tentative, and no equivalent speeds for 10 m above ground can be given.

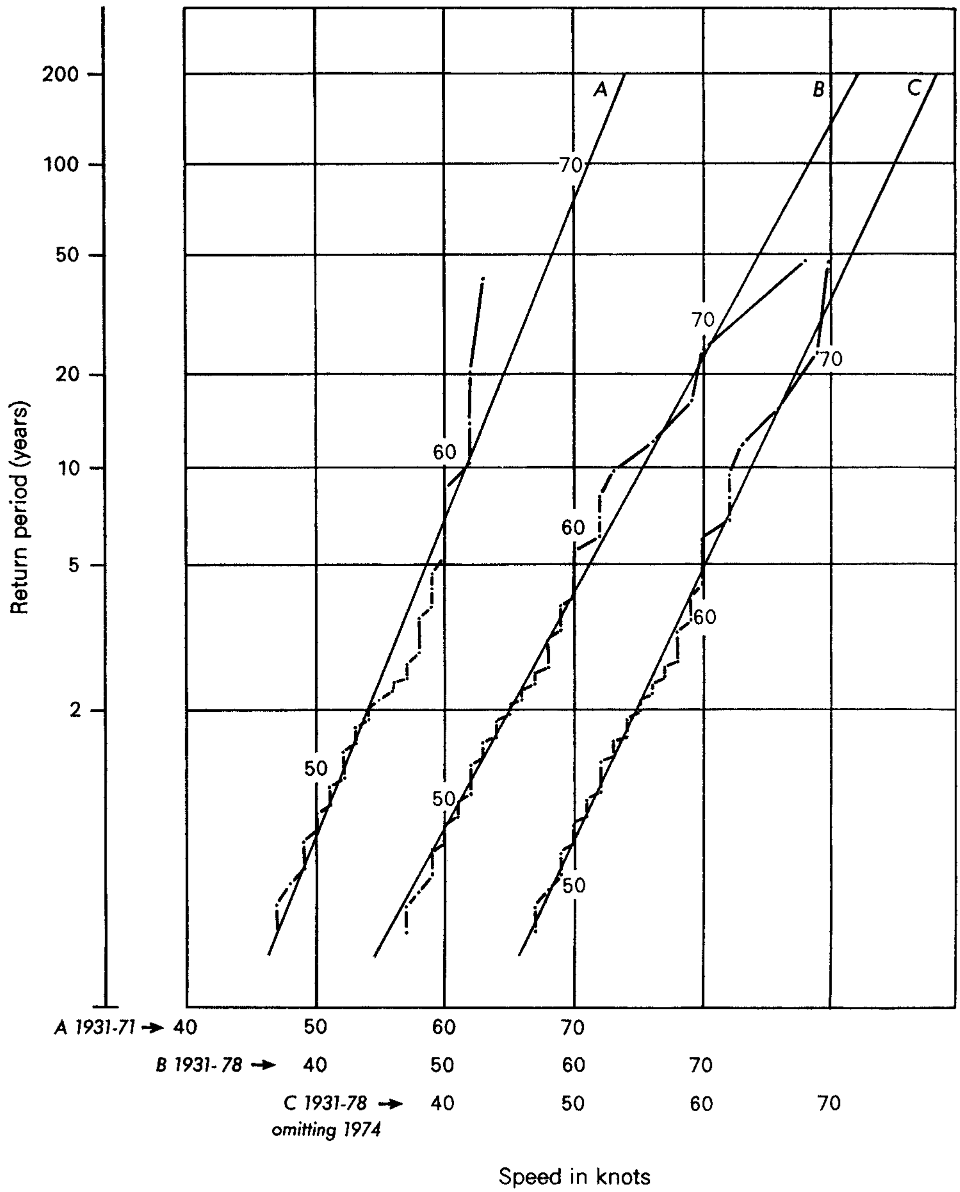

Figure A1. Annual maximum gusts at Kew at effective height of 15 metres.

Table A1. *Variation of gust speed with return period at KEW**

Return period (years)	1†	10	20	50	100	120
			knots			
Gust speed (revised)	53·7	62	65	69	72	73
Gust speed (from CM 50A)	52·8	60	62	66	70	72

* At standardized height of 10 m.
† Corresponds to average annual maximum.

Table A2. *Variation of gust speed with return period at STATE HOUSE, LONDON**

Return period (years)	1†	10	20	50	100	120
Gust speed (knots)	57·4	66	69	74	77	78

* At effective height 38 m: reduction to 10 m standard height not practicable, see Appendix to CM 50A.
† Corresponds to average annual maximum.

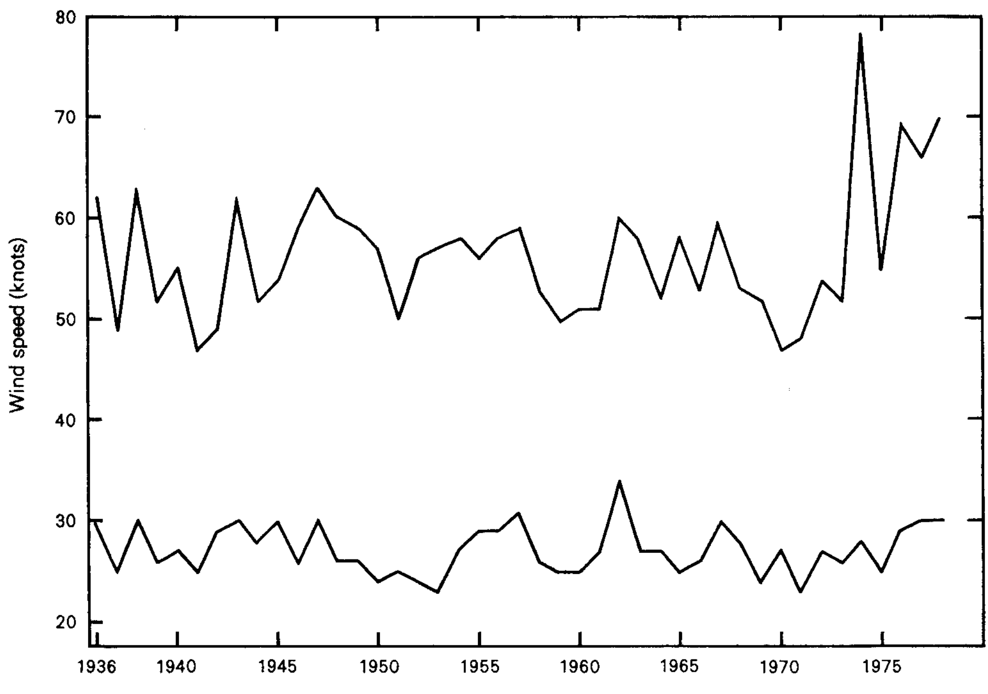

Figure A2. Annual maximum gusts and maximum hourly mean wind speeds at Kew.

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The storm surge of 11–12 January 1978

By Lt Cdr J. Townsend
(Storm Tide Warning Service, Meteorological Office, Bracknell)

Summary
An account is given of the storm surge of 11–12 January 1978, the worst since that of January 1953. The meteorological situation is described and the actual tidal residuals are compared with the forecasts made by the Storm Tide Warning Service. Forecasts were very satisfactory at four of the five 'reference ports'.

Introduction

The storm surge of 11–12 January 1978 has been described as the worst since 1953, and that with some justification: tidal levels on the north-east coast of England near the Humber Estuary were higher than those of 31 January 1953, approximating to the very high levels of 28 September 1969, and while levels in the Thames Estuary were not as great as in 1953, they equalled those of 10 December 1965, the last occasion on which flooding occurred in central London.

The following table compares the levels reached on this occasion at the five East Coast ports used as 'reference ports' for tidal warnings, with the levels reached with other major tides since 1953. Tidal heights are given in metres above Ordnance Datum (Newlyn).

Reference port	31 Jan.–1 Feb. 1953	28–29 Sept. 1969	3 Jan. 1976	11–12 Jan. 1978
North Shields	3·57 m	3·57 m	3·43 m	3·50 m
Immingham	4·51 m	4·69 m	4·60 m	4·67 m
Lowestoft	3·35 m	2·56 m	2·73 m	2·37 m
Walton*	3·99 m (Harwich)	2·96 m (Harwich)	3·08 m	—
Southend	4·60 m	3·60 m	3·50 m	4·18 m

The towns worst affected by the tide of 11–12 January 1978 were Cleethorpes on Humberside, King's Lynn and Wisbech near the Wash, and Deal in Kent.

At Cleethorpes the number of houses affected by flooding was variously reported as 500 to 1000, and 20 families were evacuated from their homes. The railway line from Grimsby to Cleethorpes was damaged. An audience of 150 people, which included aged, disabled, and children, who had been watching a performance of a pantomime in the pier theatre, found that they could not leave because the pedestrian walkway had been damaged, and had to return to the auditorium for three or four hours until rescued.

At King's Lynn, a two-mile belt near the River Ouse was flooded to a depth of up to 4 feet, affecting 400 houses. Twenty-two children had to be evacuated from the children's ward of the hospital. Many parts of the town were affected by electricity failures.

At Wisbech, where the River Nene overflowed its banks, 700 people were evacuated, and 300 houses left empty—subsequently, there were reports of looting from the empty houses. A 70-year old woman was found drowned in her front lounge which was flooded to a depth of 3 feet.

Parts of Boston, Lincs., were flooded to 3 feet; at Wells-Next-the-Sea a 300 ton coaster from the Medway was washed up on the quayside.

(* Up to late 1969, Harwich, not Walton-on-the-Naze, was the reference port for the Essex and Kent coasts.)

At Herne Bay in Kent, boats and the wreckage of beach huts were washed up on to the street. Parts of Sheerness were flooded to 5 feet.

Several piers were badly damaged, the 150-year old pier at Margate being destroyed and the lifeboat station at the pier end left isolated. Much of the piers at Skegness, and at Hunstanton in Norfolk, was washed away, and the piers at Clacton, Walton and Herne Bay also suffered damage. The tide gauges on Margate and Walton piers were put out of action (this accounts for the blank in the table above).

The cause of the surge, which coincided with a Spring Tide, was a depression over the Dutch coast which established a strong north-north-easterly gale in the North Sea.

Meteorological situation

The development of the meteorological situation is shown in the accompanying Figures 1–4.

Figure 1 shows the situation at noon on 10 January. Depressions were centred off the south-east coast of Iceland and off the northern coast of Norway, and to the south of these a westerly airstream covered the British Isles. In this westerly airstream, a small wave depression had formed at 54°N, 15°W, and this moved east, deepening as it came. Meanwhile, the depression off south-east Iceland was moving south-east, to reach 59°N, 12°W by midnight; at this time the wave depression had reached Anglesey, so that an area of low pressure covered north-west Britain (Figure 2). The low-pressure area continued to move eastwards, and at 0600 GMT on 11 January, a deep depression was centred near the Wash (Figure 3). This moved south-east to the Dutch coast during the following 12 hours (Figure 4). As a result a strong north-east gradient (geostrophic winds around 030° 60 knots), affected the western half of the North Sea from about noon on the 11th to 0600 on the 12th.

Storm surge

Figure 5 shows the tidal 'residuals' (difference between actual and predicted* tides for Stornoway and various East Coast ports).

No appreciable positive surge occurred at the Scottish ports—only a small persistent residual of around 0·2 metre throughout 10 January, attributable to the low pressure. As the northerly winds became established on the west coast of Scotland, a marked 'negative' surge (levels below predictions) developed at Stornoway and progressed to Wick.

The north to north-east gradient became established in the northern part of the North Sea early on the 11th, and extended to the remainder of the North Sea coast during the day as the depression moved from the Wash to the Dutch coast. The peak of the resulting surge occurred somewhat after the time of the evening High Water on the 11th.

At North Shields, the surge peak occurred at 2000, with a level 0·75 m above prediction. High Water, 3 hours earlier, had been 0·69 m higher than predicted.

At Immingham the 1930 High Water was 0·96 m above the predicted value, and levels reached a value of 1·37 m above prediction at 0200. At estuarial ports, a fall in the surge is commonly observed at the time of High Water, but on this occasion it was almost absent at Immingham.

Immingham is the 'reference port' for the stretch of coast known as 'Division Two' in tidal warnings, the stretch from the North Yorkshire border to North Norfolk. With the north-east gradient, surge

* The terms 'predicted tide' and 'prediction' are used here and elsewhere in this paper to denote the tides expected from astronomical considerations only, i.e. those given in published tide-tables.

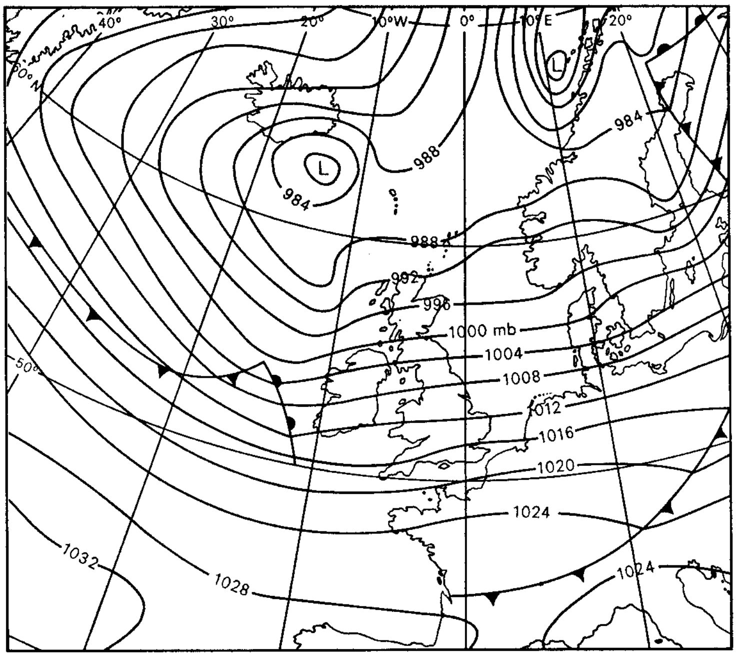

Figure 1. Synoptic situation at 12 GMT on 10 January 1978.

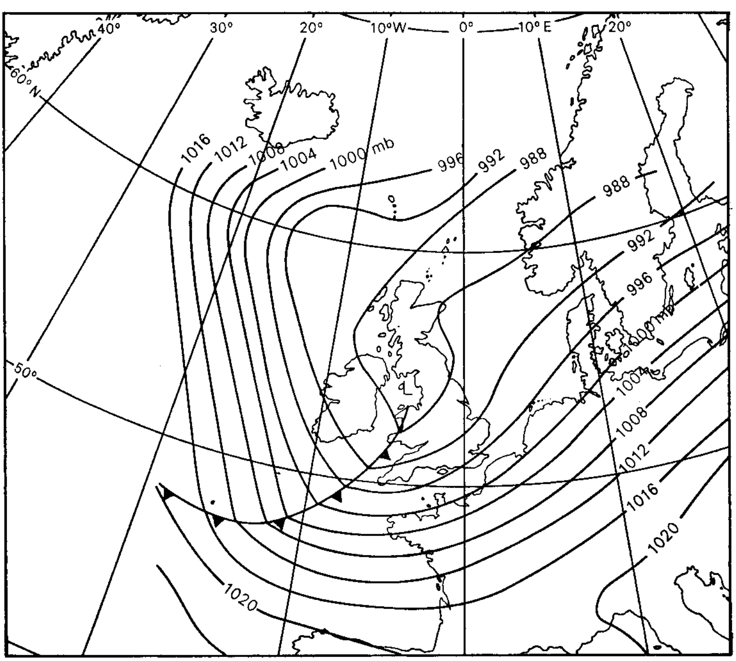

Figure 2. Synoptic situation at 00 GMT on 11 January 1978.

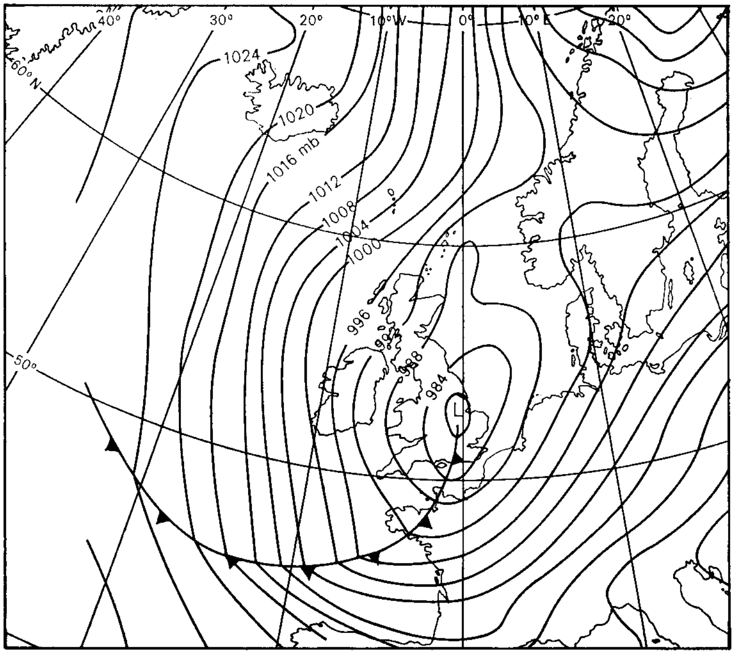

Figure 3. Synoptic situation at 06 GMT on 11 January 1978.

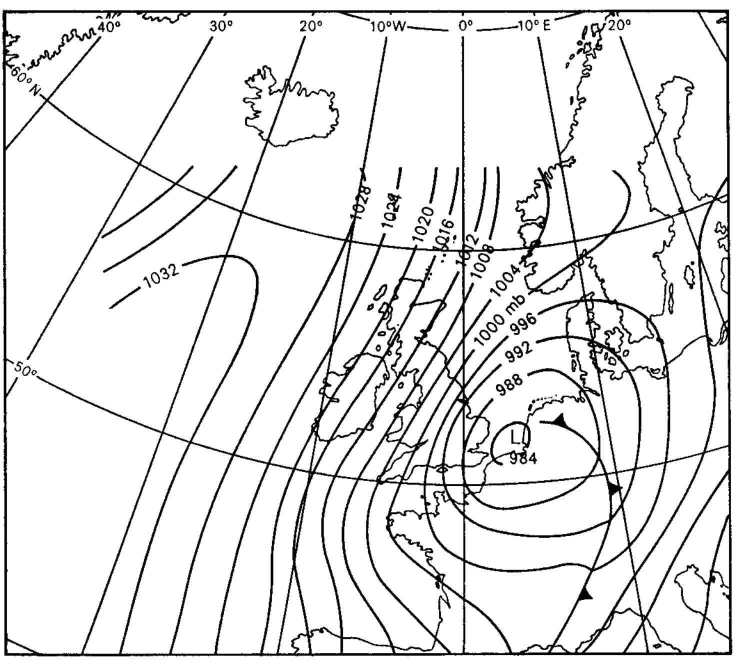

Figure 4. Synoptic situation at 18 GMT on 11 January 1978.

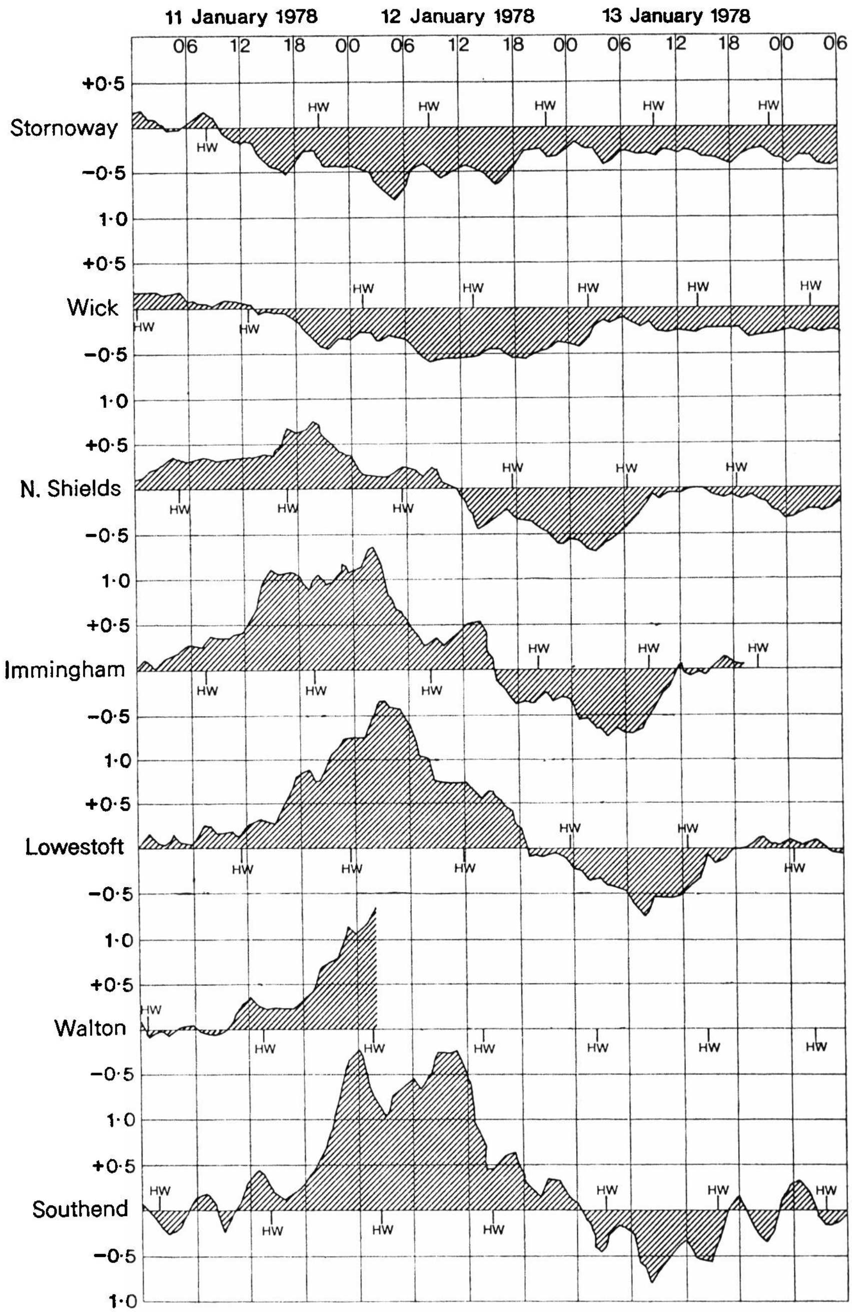

Figure 5. Surge residuals (observed minus predicted tidal levels in metres).

levels in the southern part of the Division were considerably higher than in the northern part: at King's Lynn the High Water was 1·49 m above its predicted value, and at Wells 1·8 m above prediction.

At Lowestoft, High Water was 1·21 m higher than predicted: the greatest difference between observed and predicted levels was 1·63 metres at 0300.

At Walton, where the pier was damaged, the tide gauge went out of action at just about the time of High Water—levels were then about 1·3 m above prediction.

At Southend, the usual drop in residuals at the time of High Water, due to surge–tide interaction, was well marked; the surge rose to a peak of 1·78 m at midnight, fell away to 1·04 m at 0200 (High Water) and rose again to a second peak of 1·76 m at 1000.

As Figure 5 shows, this positive surge was followed by a negative surge. By midday on 12 January, the depression had moved from the Dutch coast into North Germany, and a ridge of high pressure lay across Ireland and Scotland. As this swung south-east across England, winds in the northern part of the North Sea backed round to west. With the relaxation of the north-easterly gradient, the negative surge which had been affecting the Scottish coast advanced down the east coast of England (probably emphasized by an oscillation of the surface following the large positive surge). Tidal levels at North Shields reached 0·7 m below prediction at 0230 on the 13th, at Immingham at 0530, and at Lowestoft at 0800, and at Southend the levels fell to 0·8 m below prediction at 0800.

Forecasting the surge

Issuing flood warnings is the task of the Storm Tide Warning Service, a small unit housed in the main Meteorological Office at Bracknell and staffed by the Hydrographic Department of the Navy. Heights of High Water at the five 'reference ports' are calculated using empirical equations in which the parameters are tidal levels at more northerly ports (where H.W. occurs earlier) and winds in various parts of the North Sea. A first calculation is made 12 hours before High Water, and if the result is close to or above Danger Level, a preliminary 'Alert' is issued. A second calculation is made 4 to 6 hours before High Water and if it still indicates that Danger Level will be passed, a Danger Warning is sent stating by how much the predicted tide will be exceeded. In borderline cases, where the calculated height is close to Danger Level and it cannot be stated with certainty whether the Danger Level will be passed or not, the second warning is worded 'Alert Confirmed'. Root-mean-square errors of the empirical equations used are of the order of 0·2 or 0·3 m (which implies occasional errors of three times as much).

(During the recent (1978–79) winter, trials are being made of a mathematical model technique for forecasting surge heights.)

On this occasion, the calculated heights were very satisfactory except at North Shields, where the final calculation underestimated the height by about 0·4 m. Here, an 'Alert Confirmed' warning was issued; elsewhere 'Danger' warnings were sent. The forecasts are tabulated on the facing page.

At 2300, a further calculation was made of the level expected at Southend, based on the observed level of High Water at Lowestoft. This gave an improved result of 4·12 m, which was passed to the Greater London Council for use in the London Flood Warning System. On the strength of this, the preliminary warnings that they had passed to the local boroughs could be cancelled.

In view of the considerable difference in surge size between Immingham, the reference port of Division Two, and King's Lynn and Wells in the south of that division on this occasion, the practice has since been adopted of quoting High Water heights for King's Lynn and Wells as well as for Immingham in Division Two Danger Warnings.

Port	Predicted H.W.	Observed ht of H.W.	'ALERT' sent	Calculated ht at Alert	Final Warning	Final calc. height
North Shields	11th 1652 2·81 m	3·50 m	0635	3·56 m	1315 ALERT CONFIRMED	3·12 m
Immingham	11th 1928 3·71 m	4·67 m	0625	4·86 m	1318 DANGER 0·84 m above predicted	4·55 m
Lowestoft	11th 2308 1·16 m	2·37 m	1150	2·58 m	1810 DANGER 1·18 m above predicted	2·34 m
Walton	12th 0127 2·25 m	—	1320	3·26 m	2048 DANGER 1·2 m above predicted	3·46 m
Southend	12th 0219 3·14 m	4·18 m	1320	4·46 m	2048 DANGER 1·2 m above predicted	4·33 m

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The International Conference on Meteorology and Oceanography in The Hague

By R. M. Morris
(London Weather Centre)

An international conference on meteorology and oceanography applied to the engineering, installation and operation of offshore structures was held in The Hague on 31 October and 1 November 1978. The conference was organized by the Society for Underwater Technology, the Royal Meteorological Society and the division for underwater technology of the Royal Institution of Engineers in the Netherlands in conjunction with the Netherlands Council for Oceanology. The conference was attended by about 200 people from a wide range of disciplines, including environmental modellers and offshore operators as well as meteorologists and oceanographers; the program was divided into four sessions each concerned with a different aspect of environmental data.

The first session dealt with data requirements and the specific demands of the offshore industry and there were five presentations roughly equally divided between operational and design requirements. The operational aspects included the use of wind, sea state (including wave spectra) and pressure, temperature and ocean current data for activities involving helicopters, supply boats, cranes, tankers, derrick barges, diving and towages. The raw data have to be processed on board using mini-computers which calculate the characteristics and limitations of the equipment under the given weather conditions. The value of and need for accurate forecasts of wind and sea-state parameters was clearly brought out. In particular Captain Mervyn Jones of Noble Denton Associates underlined how important it is during special operations to have a weather forecaster close at hand to give up-to-the-minute advice. The value of weather forecasts to salvage operations was shown dramatically in a film presented by the BV Bureau Wigsmuller who successfully salvaged a tanker in the English Channel over a three-month winter period.

The data requirements for design purposes were presented in some detail by an engineer, Dr J. H. Vugts of Shell International. The engineer is concerned with maximum loads on the foundations, extreme loads on the superstructures and fatigue in relation to the distribution of load. The three major factors influencing design are wind, ocean currents and waves but Dr Vugts pointed out that long-term statistical distributions of these parameters would not necessarily provide sufficient information. The dynamical nature of the environment is very important and so the second-order interrelationships between these parameters may be more significant. A practical example of designing an offshore structure was presented by Dr B. J. J. Van der Pot of Delta Marine Consultants, Rijswijk who described the design of the Dunlin A platform. The problem of resonance associated with a particular wave period and height was especially interesting and in order to determine optimum location of loadings, directional wave data were needed.

In summing up the first session, the Chairman emphasized both the interest in obtaining accurate weather forecasts for offshore operations and the design requirement for sequential analyses of directional wave spectra. The second session was concerned with the gathering of data. The session began with three presentations on different data buoys. EMI described the design and deployment of the U.K. national data buoy DB1 which is located 280 km from Land's End on the south-west edge of the continental shelf in a water depth of 170 m. Under contract to the UKOOA Oceanographic Committee for collection of (initially) one year's data, the buoy had recorded and transmitted data satisfactorily since early summer but it was recognized that it had not yet experienced severe weather conditions. Marex then gave a description of their own data buoy which has been deployed in many world-wide locations. There was some reference to the Marex buoy deployed near Foula west of Shetland where both the original buoy and replacement had suffered damage in these very hostile waters with a considerable loss of data over a period of some two years. Although that performance was clearly unsatisfactory, there was unfortunately no evidence yet to suggest that DB1, for example, would perform any better in such severe weather. A major advantage with DB1, however, is the facility to transmit real-time data every hour to a land station which permits a constant monitoring of the system and the build-up of a secondary data bank. Information on a new lightweight buoy, called DABS 3M, was given by the British Aerospace Dynamics Group from Hatfield, and it was a pity that this presentation was so dull. This buoy appeared to have most of the qualities of DB1, also a capacity for recording and limited processing on board and an ability to transmit to a shore base using HF or VHF radio. The buoy is not expected to be ready for trials until summer 1979 at the earliest but a major attraction will undoubtedly be its cheapness compared to DB1. A presentation by Dr R. E. W. Pettifer described the Meteorological Office involvement with data acquisition offshore including the installation of automatic weather stations on data buoys as well as on remote islands and platforms. These systems include micro-processors and transmit real-time data to a shore base.

Following the presentations on buoys, emphasis switched to the sensors themselves. The basic requirements of the meteorological sensors including robustness and an ability to withstand severe exposure were stressed by Dr D. N. Axford of the Meteorological Office. Display boards, recorders and communications were discussed and also the need for routine maintenance and regular calibrations to ensure quality and reliability. Whilst the requirement for real-time observations was re-emphasized it was also pointed out that offshore observers should be properly trained to observe in accordance with internationally agreed standard procedures.

Oceanographic sensors were described by Mr E. G. Pitt of the Institute of Oceanographic Sciences. After a brief description of the basic wave theory, wave rider buoys were described in great technical detail, mostly without illustration. Several promising projects were outlined including those involving ocean currents. The use of radar to observe waves was described by M. A. Fontanel of the Institut Français du Petrole. The technique is still developmental and uses the Doppler shift principle in the micro-wave region. The radar operates from shore using HF and has 200 km range with a seven degree angular spread. Experiments so far indicate a good correlation between the wind and wave directions. It is planned to experiment next spring off the Atlantic coast of France. The session was completed by a description of the role and purpose of the Meteosat satellite given by Mr P. Berlin of the European Space Operations Centre in Darmstadt. Among the uses of Meteosat is the facility to relay observations from platforms to a land-based receiving station. In view of the length of message transmitted by Meteosat, it appears that the system is ideal for relaying a large network of observations.

Summarizing the second session, the Chairman, Mr G. Larminie of BP Environmental Control Centre said it appeared that the meteorologists and oceanographers knew what they wanted in data collections but he wondered whether the offshore industry knew what it wanted. There was an increasing emphasis on the need for real-time data, particularly as the industry moved from the exploration to the production phase. My own reaction to a long and arduous session was that there was a vast amount of information crammed into a relatively small amount of time. Inevitably there was some overlapping and common ground largely because competitive systems were being described. This may have been the only way the organizers could be fair to the designers but it was rather hard going for the conference as a whole.

The third session, on data management, was chaired by Dr B. J. Mason, Director-General of the Meteorological Office. Mr E. J. English of Meteorological and Plotting Services began by emphasizing the importance of quality control of the observational data and he compared visual observations with automatic observations such as those recorded by data buoys. Several systems of checking were described including internal consistency, time series, ranges and, most important, the operational quality control exercised by the human analyst using his charts in real time. Finally the need to specify the format and content of data files was stressed because the data would in many instances be made available to users other than those who collected and originally processed the data. An example of the use of offshore data collected by a close network was presented by Mr C. Van der Burgt of the Dutch Public Works Deparment. Strictly this exercise is concerned with predicting the onset of flooding in the Netherlands and data gathered from the automatic stations offshore in the southern North Sea are vitally important to the operation of storm surge barriers. The conference was then given an insight into the work of WMO in organizing the first GARP global experiment (FGGE) scheduled for 1979. Unfortunately this presentation was not particularly well done and the visual aids were poor. The question was raised of how quickly improvements could be expected in long-range forecasting after FGGE. The view was that it would take several years.

The importance of establishing an adequate data base was the main theme in a presentation by Mr D. J. Painting of the Meteorological Office. It was argued that there were insufficient data for fixed offshore locations in areas of special interest; these are necessary for example to determine the probability of exceeding certain thresholds or to calculate extreme values. Fortunately there exists another source of data namely the ships of the world's voluntary observing fleets (VOF) whose synoptic observations have been used for weather analysis during the past 100 years. These data have been checked and then stored by the Meteorological Office in a marine data bank, which now contains some 3 million observations from the continental shelf around the U.K. as well as 40 million observations from other parts of the world. Confidence in the reliability of the VOF data was greatly strengthened by a comparison of the measured wind data from OWS 'K' (1962–75) with the VOF data for the same area and period. The profiles of frequency distribution of wind speeds were almost identical. Despite some doubts being expressed concerning the quality of the VOF wind data in more northern waters, Mr Painting resolutely stated his belief that the VOF data are good and represent a very sound data base from which the offshore designers and operators could extract much profitable information. This session concluded with a presentation on extreme wave heights in Norwegian waters by Professor O. G. Houmb from the Division of Port and Ocean Engineering at the University of Trondheim. The longest series of data available were visual observations and hindcast studies based on them; these covered some 30 years, whereas there are less than 10 years of instrumental data. It was therefore concluded that the most reliable estimates of extreme heights are those based upon hindcast data.

The third session was probably the most stimulating and interesting, mainly because of the variety of presentations on different aspects of data management. Certainly Mr Painting's presentation generated much interest and many enquiries long after the conference closed.

The fourth and final session was essentially concerned with the application of data for use in offshore operations. A presentation by Mr H. D. Barnard of Phillips Petroleum purported to show how knowledge of the local site wind and sea state climatology could help an offshore drilling supervisor to interpret his daily weather forecasts. The presentation was handicapped by the fact that the visual aids were virtually invisible to the audience but the gist of the theme seemed to be that if the forecast values approached the extreme values determined by climatology, drilling activity should cease. This was followed by a presentation from Mr D. F. Bertonneau of Ocean-Routes who deviated from his synopsis to deliver a sales talk on the virtues of Ocean-Routes services to offshore operations. There was a useful description of how spectral wave data could be applied to determining the relative response characteristic of barges, ships and semi-submersibles by calculating heave, pitch and roll. This presentation brought comment from the floor to the effect that none of the response characteristics would be adequately determined without calculation of tidal surge. Commander A. Wood of Sea and Storm Service Specialists Ltd, then spoke about uses of satellite data for offshore forecasting, but his talk was considerably shorter than scheduled and bore no relation to the impressive synopsis in print; the presentation consisted almost entirely of a series of satellite cloud pictures and was devoid of explanation as to how meteorologists incorporate satellite data into their routine synoptic analyses. From this presentation the conference could be excused for thinking that weather forecasters had not made any significant advances using this powerful extension to their resources.

The session was completed by two fairly light-hearted presentations. Professor H. O. Mertins of the Seewetteramt of the Deutscher Wetterdienst in Hamburg described the routeing of a delicate cargo across the Baltic and finally Mr D. M. Houghton of the Meteorological Office spoke about the prospects for long-range prediction up to six months ahead. There was a good illustration of the variability of climate over decades, emphasizing the need for long-period samples of data. The importance of the tropical oceans as storehouses of energy was brought out with a striking illustration of the variability of cloud cover from year to year within the tropics. After the presentation of some figures of success rate for seasonal forecasts the talk concluded with a forecast for Europe during the coming November.

To sum up, there is no doubt that the conference as a whole was highly successful in that most people connected with the offshore industry learnt a great deal during the two days. There was a clear invitation for the Meteorological Office to demonstrate to the industry how efficiently it is geared up to support the daily operational activities offshore and increasing interest is being shown in verification of forecast accuracy. The great interest in the marine data bank could precipitate a major increase in the number and complexity of climatological enquiries from the designers and planners. One was also left in no doubt that if the Meteorological Office does not meet the needs of the offshore industry, commercial services will be quick to make the attempt.

Letter to the Editor

Tornadoes and the cold front of 3 January 1978

I was interested by Mr L. G. Chorley's synoptic analysis of the weather in eastern England on 3 January 1978 with its particular reference to the tornado at Newmarket (Chorley 1978). In his last paragraph the author states that 'the only tornadoes reported on 3 January 1978 were those at Hull and Newmarket'. In fact, at least ten damaging tornadoes have been reported to the Tornado and Storm Research Organisation (TORRO) for the same morning in eastern England. From the times of occurrence of these tornadoes and the nature of the eye-witness and press accounts, there is no doubt that these tornadoes were associated with the same line-squall/cold-front system which Chorley described. Full details have been given elsewhere (Meaden 1978). The places affected include the following: Wold Newton, NGR TA 0473, at 0640 GMT; Holme-on-Spalding Moor, SE 8238; Hull, TA 1030 at 0710; Aldbrough, TA 2438; Withernsea, TA 3428, at 0715; Scunthorpe, SE 8911; South Reston, TG 4084; Tattershall, TG 0755, at 0755; Ringsfield, TM 4088 (near Beccles); and Newmarket, TL 6363, at 0920 GMT. The overall path length is known to exceed 50 kilometres. The severest of the tornadoes was the Newmarket one; its strength on the TORRO intensity scale (Meaden 1976) was force 5–6 (Buller 1978, Meaden 1978). The other tornadoes were rated at TORRO force 1–3.

The frequency of occurrence of damaging tornadoes in Britain is much greater than is generally recognized. For the 16-year period 1963–78, over 335 have been listed by the Tornado and Storm Research Organisation; 1974 and 1975 were the peak years with 52 each. Many of the tornadoes were associated with cold fronts, several of the occasions being multiple events, as on 3 January 1978, with tornadoes breaking out at intervals all along the front or nearby squall line.

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References

Buller, P. S. J. 1978 Damage caused by the Newmarket tornado, 3 January 1978. *J Meteorol, Trowbridge*, **3**, 229–231.

Chorley, L. G. 1978 The Newmarket tornado of 3 January 1978. *Meteorol Mag*, **107**, 308–313.

Meaden, G. T. 1976 Tornadoes in Britain: their intensities and distribution in space and time. *J Meteorol, Trowbridge*, **1**, 242–251.

Meaden, G. T. 1978 Tornadoes in Eastern England on 3 January 1978. *J Meteorol, Trowbridge*, **3**, 225–229.

[Mr Chorley informs us that the tornadoes at Hull and Newmarket were the only ones known to him at the time of writing and the only two widely reported in the national press, although he realized that others might well have occurred in the conditions prevailing at the time. We are grateful to Dr Meaden for drawing our attention to the reports collected by his Tornado and Storm Research Organisation; his conclusions agree well with those of Lamb (1957)*: Editor.]

* Lamb, H. H. 1957 Tornadoes in England, May 21st 1950. *Geophys Mem* No. 99 (Vol. XII).

Reviews

Remote sensing of the atmosphere: inversion methods and applications (*Developments in Atmospheric Science 9*), edited by Alain L. Fymat and Vladimir E. Zuev. 245 mm × 165 mm, pp. xvi + 327, *illus*., Elsevier Scientific Publishing Company, Amsterdam and New York, 1978. Price US $54.75, Dfl 123.00, £36.70.

This ninth volume in the series 'Developments in Atmospheric Science' is devoted to publishing a selection of papers presented at conference sessions entitled 'Remote sensing of the atmosphere: inversion methods and applications'. These sessions organized by the editors Fymat and Zuev took place in Seattle in late August 1977 as part of the Second Special Assembly of IAMAP (International Association of Meteorology and Atmospheric Physics).

There are three sections each containing eight or nine specialist papers covering temperature sounding, composition sounding and particulate sounding. Each paper is distinct and only loosely related to the other papers in the same section; there is no discussion of the papers. As such the selection of papers represents some details of particular problems of interest to the authors, and airs a sample of current topics in remote sensing. This volume is not, and has no pretensions to be, a definitive review of atmospheric sensing. This book is one that appeals primarily to specialist research workers in the retrieval field, and as such is certainly worthy of inspection.

In a review intended for readers of the *Meteorological Magazine*, I will mention some of the more general papers on applications which have a significant meteorological content. In the temperature sounding section probably two out of the eight papers are of general interest. Halem, Ghil and Atlas describe a four-dimensional assimilation method for including satellite data in a combined analysis and forecast scheme, and demonstrate some improvement in a 48–72 hour forecast as a result. They also include a useful discussion of comparison criteria. McMillin discusses retrieval errors in cloudy situations for the National Environmental Satellite Service temperature retrieval scheme and indicates that 'lack' of effect, on analysis schemes, of satellite data is due to rejection of data in the meteorologically interesting but cloudy areas.

The composition sounding section mainly airs the problems of using 'limb sounding' data, particularly with reference to NIMBUS 6 LRIR (limb radiance inversion radiometer), and the retrieval of ozone and water vapour profiles.

In the particulate sounding section, the major contribution is two papers by Fymat on detailed aspects of Mie scattering and the experimental accuracy required to retrieve the size distribution and the complex refractive index of atmospheric aerosols. Of more direct meteorological interest is McCleese's paper on 'Remote sensing of cloud properties from NIMBUS 5'. He describes with examples the retrieval, from the NIMBUS 5 Selective Chopper Radiometer, of cloud top heights for opaque clouds, and cloud parameters of height, thickness and particle size for cirrus clouds.

An author index, which includes a citation index, and a useful subject index complete the volume.

D. R. Pick

The Australian climatic environment, by E. Linacre and J. Hobbs, 245 mm × 190 mm, pp. x + 354, *illus.*, John Wiley & Sons, Milton, Queensland, Australia, 1977. Price A$15.50.

The title of this book is a little misleading. It is really a well-designed, well-produced, and—on the whole—well written introductory text-book of meteorology and climatology with its illustrative examples drawn from the southern hemisphere in general and Australia in particular. The intended readership consists of 'school teachers, tertiary students who are taking geography or meteorology courses, and . . . the intelligent layman'. The main text is divided into five parts, each with about five chapters, entitled 'Energy Flows in the Atmosphere', 'The Cycle of Water Movement', 'Winds and Weather', 'Climates', and 'Applied Climatology'. There are two more parts: 'Additional Information' and 'Tests'..

The treatment is deliberately non-mathematical and a praiseworthy and largely successful attempt is made to convey the fundamental physical ideas underlying complicated processes. When such processes are not yet fully understood—for example in the separation of electrical charge in a cumulonimbus cloud—the reader is not misled into believing that they are, but plausible explanations get a fair mention.

Now and again, however, particularly in the section dealing with dynamical meteorology ('Meteorological Concepts')—why is the word concept so dreadfully over-used today, by the way?—simplification degenerates into error. For example: 'Wind following a curved path around either a high or a low is called a gradient wind, differing from the geostrophic wind because of the centrifugal effect' (p. 121); 'Winds are driven by pressure differences between various parts of an approximately horizontal layer of the atmosphere. In practice, the two driving forces combine to create the observed wind. The component due to the temperature difference is called the thermal wind and is a hypothetical wind, not measurable.' (p. 123). No mention is made at all of geopotential in the discussion of 'thickness' which is defined purely in terms of geometric height. The English is occasionally slovenly: on page 229 reference is made to 'the dividend of height to mass', meaning the ratio of height to mass, or the quotient of height by mass. These are, however, minor blemishes.

The diagrams are well chosen, clear and informative, and are largely derived from other, duly acknowledged, sources. (The registration of the overlays in Fig. 8.8. has, however, gone sadly awry.)

Part VI—'Additional Information'—contains useful physical constants, tables of data, meteorological symbols, a list of further reading and the bibliography. Part VII—'Tests'—contains essay questions, numerical examples, and a set of self-assessment tests comprising 20 questions for each chapter; these latter showed up several lacunae in the reviewer's knowledge.

At A$15.50 the book is better value than many.

R. P. W. Lewis

Notes and news

Snow Survey of Great Britain

These reports contain monthly descriptions and tables of snowfall in Great Britain, especially in the highland areas during the snow season from October to May, and are normally published in December each year. The Report for 1977/78 is now available from Meteorological Office Met O 3(b), London Road, Bracknell, Berks. RG12 2SZ at a price of £2 (post free), or a three-year advance subscription is offered at £5. Copies of the 1976/77 Report are still available at a price of £2 and limited numbers of the Reports for 1971/72 to 1975/76 are also available at a price of £1 per copy.

Award

The University of Manchester Institute of Science and Technology is to confer its highest honour, Honorary Fellowship, on Dr B. J. Mason, C.B., F.R.S., the Director-General of the Meteorological Office, at a ceremony to be held on 25 July 1979.

Correction

Meteorological Magazine, Volume 108, February 1979; article by A. Gilchrist. The patterns of isobars in Figures 3 and 4 should be transposed.

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NOTICES

It is requested that all books for review and communications for the Editor be addressed to the Director-General, Meteorological Office, London Road, Bracknell, Berkshire RG12 2SZ, and marked 'For Meteorological Magazine'.

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