The UK's highest low-level wind speed re-examined: the Fraserburgh gust of 13 February 1989

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Weather – January 2021, Vol. 76, No. 1

Stephen Burt

Department of Meteorology, University of Reading, UK

Accurate assessment of extreme wind gusts is important for many infrastructure requirements, particularly in building design standards and for insurance purposes. In a previous paper (Aylott *et al*., 2020), Northern Ireland's record wind gust – 108kn (56ms^{-1}) recorded at Kilkeel on 12 January 1974 – was critically re-examined, and found to be almost certainly incorrect due to instrumental error or a power surge. A recommendation was made that other long-standing United Kingdom record wind gusts should also be independently re-examined to assess their veracity. In this paper the arguments for and against the authenticity of the current record low-level wind gust for Scotland, and the UK national record, namely 123kn (63ms^{-1}) recorded at the Kinnaird Head Lighthouse at Fraserburgh on 13 February 1989, are reviewed. Two 'gusts' >100kn were probably record artefacts owing to brief power supply interruptions to the recording anemograph, and accordingly neither should remain included in the list of national wind speed records.

Introduction

High winds accompanying severe extratropical cyclones (windstorms) are a significant natural hazard for the UK (Shellard, 1976; Palutikof *et al*., 1997). These winds cause damage to buildings and forestry, disruption to transport and power supplies, and loss of life (Blackmore and Tsokri, 2004; Hewston and Dorling, 2011; Department for Transport, 2014). Impacts from windstorms are characterised usually in terms of their peak gusts rather than maximum mean wind speeds (Prahl *et al*., 2015). In the context of modern digital anemometer sensors, a 'gust' is defined as the temporary maximum of the 3-second moving average wind speed, a definition formalised and maintained by the World Meteorological Organization (WMO, 2014), following the work of Beljaars (1987). However, the duration of gusts recorded on older analogue equipment using paper charts is less easily determined (for a brief review of historical wind records and associated instrumental factors, see the boxed text in Aylott *et al*. (2020)).

The underpinning role held by wind gusts in relating windstorm intensity to windstorm impacts means that it is crucial – both scientifically and for users – that extreme wind gusts are reliably and accurately documented. Record wind gusts can influence building design standards, insurance pricing and the identification of locations where transport networks and forestry are most vulnerable to high winds. For example, users of wind data often require knowledge of the 50-year gust return period (Palutikof *et al*., 1999). As there may be a shorter period of observations with which to derive such statistical estimates, the impact on users of an erroneous extreme gust can be considerable (Cook, 2014), especially if it represents the highest gust on the available record. Of course, there are other sources of uncertainty with regard to wind record homogeneity, including those arising from changes of instrument and thus recording characteristics (including response time) during the period of record, changes in site and exposure which may or may not be fully documented, variations in manual record analyses, and the quality of analogue-to-digital data conversions. However, these other factors are less relevant to the focus of this article.

In the UK, lists of weather and climate extremes are documented and published online by the Met Office (Met Office, 2020a). With specific regard to extreme wind gust records, Met Office online notes clarify that published values for 'record' gust speeds are based exclusively on more recent observations (1969 onwards), exclude stations above 500m altitude, and that attempts have been made to verify these records by comparison with nearby stations. However, to our knowledge, these record gust values have not undergone independent scrutiny and verification, and have, in all likelihood, not been re-examined since shortly after the event in question. This matter is considered in more detail subsequently.

On 13 February 1989, a gust of 123kn (63ms^{-1}) was reported from the Kinnaird Head Lighthouse in Fraserburgh in north-east Scotland (57.70°N, 2.00°W) during an intense extratropical cyclone. This established a new record for the highest gust speed at any low-level station in the UK, a record that remains in place to date (Met Office, 2020a).[1] At the time, the Kinnaird Head Lighthouse was equipped with an electrical-recording cup anemometer system, located at 13m above ground level (29m above mean sea level (amsl), with an 'effective height' of 11m (Met Office *Monthly Weather Report*, February 1989).

The article is structured as follows. An overview of the synoptic situation leading to the extreme gust measurement at Fraserburgh is given, followed by a review of the wind data recorded during the storm at other sites in Scotland. The Fraserburgh anemogram for the period during which the record gusts were recorded is then presented and carefully examined, after which evidence for and against the veracity of the record is assessed. Finally, the implications of the findings are discussed.

Synoptic overview and storm damage

The 'Fraserburgh gust' was recorded at 2030 UTC on 13 February 1989, within the circulation of an intense extratropical cyclone passing just to the north of Scotland, moving towards southern Norway at about 35kn. Figure 1 shows the synoptic situation at 1800 UTC, taken from the Met Office *Daily Weather Summary*: Fraserburgh's location is marked by a red circle.

The occlusion associated with the cyclone cleared the east coast of Scotland soon after 1200 UTC. The southwesterly winds behind the occluded front were unremarkable, mean speeds mostly around 15kn over northern Scotland and 25kn over exposed parts of the Western Isles. A trough in the cold air behind the occlusion moved eastwards with the cyclone centre, and pressure rose very rapidly behind the trough as

[1]The highest gust reliably recorded within the UK remains one of 150kn (77ms^{-1}) recorded on the summit of Cairngorm (1245m amsl) at 0048 UTC on 20 March 1986 (Met Office, 2020a).

RMetS Royal Meteorological Society

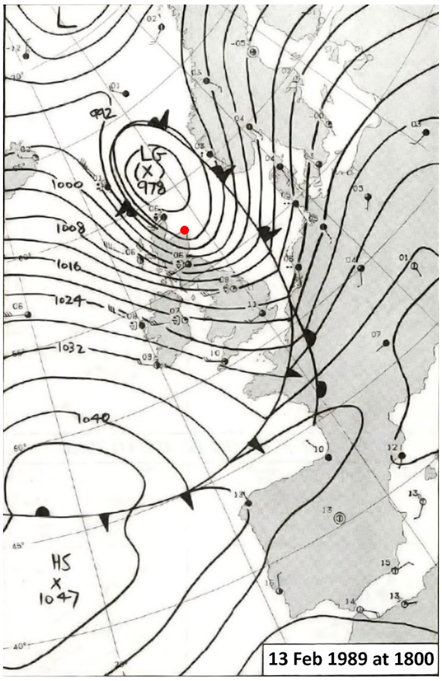

Figure 1. Synoptic situation at 1800 UTC 13 February 1989, from the Met Office Daily Weather Summary (archived online at https://digital.nmla.metoffice.gov.uk/). Fraserburgh is marked with a small red dot. (Source: © Crown Copyright.)

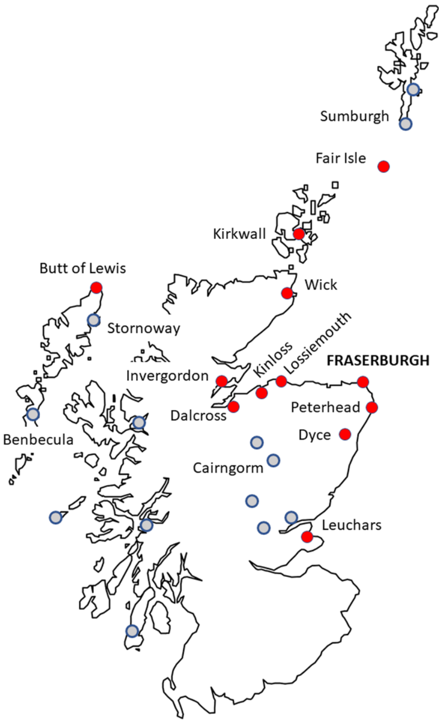

Figure 2. Location map for sites with hourly mean and maximum gust wind speed records for 13–14 February 1989; the sites with records listed in Table 1 and plotted in Figure 3 are named and shown with red circles. (Base map source: Creazilla.com, used under Creative Commons Attribution 4.0 International (CC-BY 4.0) licence.)

a strong ridge built behind the depression (3-hourly pressure rises of 19hPa occurred in the northwest of Scotland). A very strong pressure gradient became established on the south and southwest flanks of the cyclone centre, and at or just after the passage of the trough, the wind veered to westerly or northwesterly and increased very rapidly.

In a brief account of this storm, Lamb (1991) stated 'Widespread damage on land and at sea … large buildings, including hospitals, were unroofed'. High winds disrupted traffic and brought down trees as far south as Leicestershire and North Wales, with buses and high-sided lorries blown over. In Fraserburgh, the gable end of a house 1km west of the anemograph site was blown down and many buildings lost roof slates (*Fraserburgh Herald*, 17 February 1989). In Dunfermline, Fife, nine people were injured when the roof of a hospital ward was blown off (Met Office *Monthly Weather Report*, February 1989). The storm resulted in extensive damage and disruption to power supplies, and at one stage some 75 000 consumers in the sparsely populated area covered by the North of Scotland Hydro-Electric Board were without electricity (Marjory Roy, pers. comm). Damage to forests was also very considerable throughout northern and western Scotland. Near Sligachan on the Isle of Skye, off western Scotland, a number of large wooden poles carrying power lines were broken by the force of the wind, and it was estimated that a 3s gust of 130kn would be required to cause such damage. Forecast models provided timely warning of the expected strength of the winds, and there was no reported loss of life.

Surface wind observations

Hourly mean and maximum gust wind speeds are available for this event for 25 sites in northern and western Scotland, including Fraserburgh. The available records are shown in Figure 2: records from a subset of these sites (red circles) are given in Table 1 and plotted in Figure 3 (hourly mean wind speeds in upper plot and hourly maximum gust speeds in lower plot). All values are in knots (1kn = 0.51ms^{-1}). Station data were sourced from the Met Office Integrated Data Archive System (MIDAS) (Met Office, 2020b).

As the wind veered from southwest to west or northwest, mean and gust speeds increased very rapidly, within 60–90 minutes, particularly at sites directly exposed to winds with a considerable sea fetch. This was first evident in the Western Isles between 1400 and 1600 UTC: at the Butt of Lewis, the mean wind increased from 270° 22kn gusting 32kn for the hour ended 1500 to 330° 62kn gusting 92kn within 2 hours (Figure 3 and Table 1). The east and southeast progression of this sharp increase in wind speeds is evident from Figure 3, the most rapid increase in mean and gust speeds occurring between 1700 and 1800 UTC at Dalcross, between 1800 and 1900 UTC at Kirkwall, Wick, Kinloss, Lossiemouth, Dyce and Fraserburgh, and between 1900 and 2000 UTC at Peterhead Harbour. Further south, at Leuchars in Fife, the sudden increase in wind speed was absent; further north, at Fair Isle and in Shetland, the sharp rise in wind speed occurred somewhat later, between 2000 and 2200 UTC, as the movement of the centre of the depression further east advected the steeper gradients on its western flank.

Winds were strongest at locations most directly exposed to westerly or northwesterly winds with a long sea fetch. At Butt of Lewis and Fraserburgh, peak hourly mean wind speeds exceeded 60kn, while Kinloss and Lossiemouth (both sites with a substantial wind fetch across the Moray Firth) recorded peak hourly means of 46kn (Table 1). Over land, mean winds were somewhat lower, the highest hourly means ranging from 41kn at Dalcross (hour ending 1900 UTC) to 53kn at Wick Airport (hour ending 2000 UTC). Maximum gusts reached 100kn at Fair Isle (at 2130 UTC), 93kn at Benbecula and 92kn at Butt of Lewis[2]. The times of maximum gusts are plotted on Figure 4, and it is clear from this that the strongest gusts in north-east Scotland occurred between 1900 and 2100 UTC.

Fraserburgh anemogram

The anemograph at the Kinnaird Head Lighthouse was a Munro Mk4 electrical cup anemometer and wind vane (Meteorological Office, 1981), producing a record using an inked pen on paper driven by an electrically driven chart roll. The instrument was equipped with an automatic range-change device designed to trigger the chart recorder pen to record at half-scale once the wind speed reached or exceeded 65–70kn (Meteorological Office, 1981). The instrument was checked by staff from Met Office Edinburgh a few days after the storm, and found to be in satisfactory working order (Roy, 1989).

The chart record for the Kinnaird Head Lighthouse for the period 1530 UTC 13 February to 0300 UTC 14 February 1989 is shown in Figure 5. This is a reproduction from a photocopy, as the original chart record appears to have been lost.

The rapid increase in wind speed commenced at the site at 1730 UTC, mean

[2]A gust of 106kn was recorded at the high-level site at Lowther Hill, Strathclyde (754m amsl) at 1806 UTC.

Table 1

Hourly mean wind direction ddd (veer from North, degrees), ff mean wind speed (kn) and highest gust (kn) for 13–14 February 1989 at a subset of the sites in northern Scotland shown in Figure 2. The highest mean and gust speeds at each site are shown in bold.

Date/time	**Butt of Lewis**			**Kirkwall**			**Wick**			**Dalcross**		
UTC (hour ending)	*ddd*	*ff*	*gust*	*ddd*	*ff*	*gust*	*ddd*	*ff*	*gust*	*ddd*	*ff*	*gust*
13/1300	230	28	41	180	24	37	180	16	27	230	21	35
1400	240	27	40	180	20	33	200	14	22	220	24	41
1500	270	22	32	190	14	25	200	17	32	220	23	38
1600	300	25	56	170	13	29	200	12	20	230	25	41
1700	330	**62**	**92**	230	15	23	200	10	16	270	18	38
1800	330	56	90	240	14	24	270	12	33	270	32	62
1900	330	54	82	270	19	66	300	35	71	310	**41**	**69**
2000	330	48	72	310	48	**75**	320	**53**	**79**	310	36	59
2100	330	39	62	310	**49**	72	320	49	72	310	35	62
2200	330	34	53	310	43	66	320	47	70	310	28	52
2300	320	30	56	300	36	58	310	44	62	310	27	48
14/0000	320	33	70	300	35	55	310	40	61	300	25	44
0100	320	35	58	300	30	46	310	29	49	300	20	31
0200	320	38	56	300	20	43	300	24	41	270	20	37
0300	310	34	52	300	19	31	290	24	44	270	17	36
0400	300	30	43	290	27	45	300	23	38	270	16	32
0500	300	29	42	290	23	35	290	23	49	280	16	30
0600	290	30	45	290	23	41	280	20	42	270	15	27

Date/time	**Kinloss**			**Lossiemouth**			**Fraserburgh**			**Peterhead**		
UTC (hour ending)	*ddd*	*ff*	*gust*	*ddd*	*ff*	*gust*	*ddd*	*ff*	*gust*	*ddd*	*ff*	*gust*
13/1300	240	27	42	240	23	40	180	16	37	180	24	38
1400	230	24	38	230	21	35	190	12	23	190	20	29
1500	230	21	33	230	21	48	220	14	31	210	20	32
1600	230	20	28	230	19	31	210	14	30	210	21	35
1700	250	20	27	250	19	32	220	17	29	210	22	32
1800	280	26	57	290	20	34	260	22	40	230	19	28
1900	310	**46**	72	310	42	65	280	36	65	270	19	37
2000	310	45	**73**	320	**46**	**78**	300	60	86	290	26	71
2100	310	35	57	310	38	65	310	**68**	**123**	300	**31**	**73**
2200	310	32	46	310	34	53	310	58	77	300	30	69
2300	310	34	56	310	30	47	310	60	79		*N/A*	
14/0000	310	30	48	310	27	41	310	55	74	310	26	59
0100	300	28	44	300	29	45	320	46	64	310	22	50
0200	310	22	39	300	25	44	310	42	56	310	15	37
0300	280	18	32	290	23	46	300	40	57	300	14	42
0400	300	19	37	300	25	41	300	40	60	280	13	32
0500	290	19	32	300	21	37	310	36	48	300	13	33
0600	290	20	33	290	22	38	300	36	51	290	11	33

speed increasing from approximately 15kn to 35kn in 30 minutes and remaining at about this level to 1900 UTC. Shortly before 1900 UTC, a gust to about 65kn caused the anemograph to switch into 'half-scale mode', and from this point until 2345 UTC, the wind scale was halved such that 30kn marked on the paper chart record corresponds to a 60kn wind speed. This half-scale record is shown enlarged in the inset to Figure 5.

The record shows the wind speed increasing still further, with the first gust in excess of 80kn recorded at 1935 UTC, followed by another of 86kn a few minutes later. The wind then diminished slightly before rising once more. At 2014 UTC[3] there was a gust of 86kn followed immediately by a (much thinner) pen trace marking a gust which, if it is

[3]There are no time marks on the portion of the chart record that has survived, and thus it is impossible to determine the accuracy of the chart timing. Accordingly, zero timing error has been assumed (but may not be reliable).

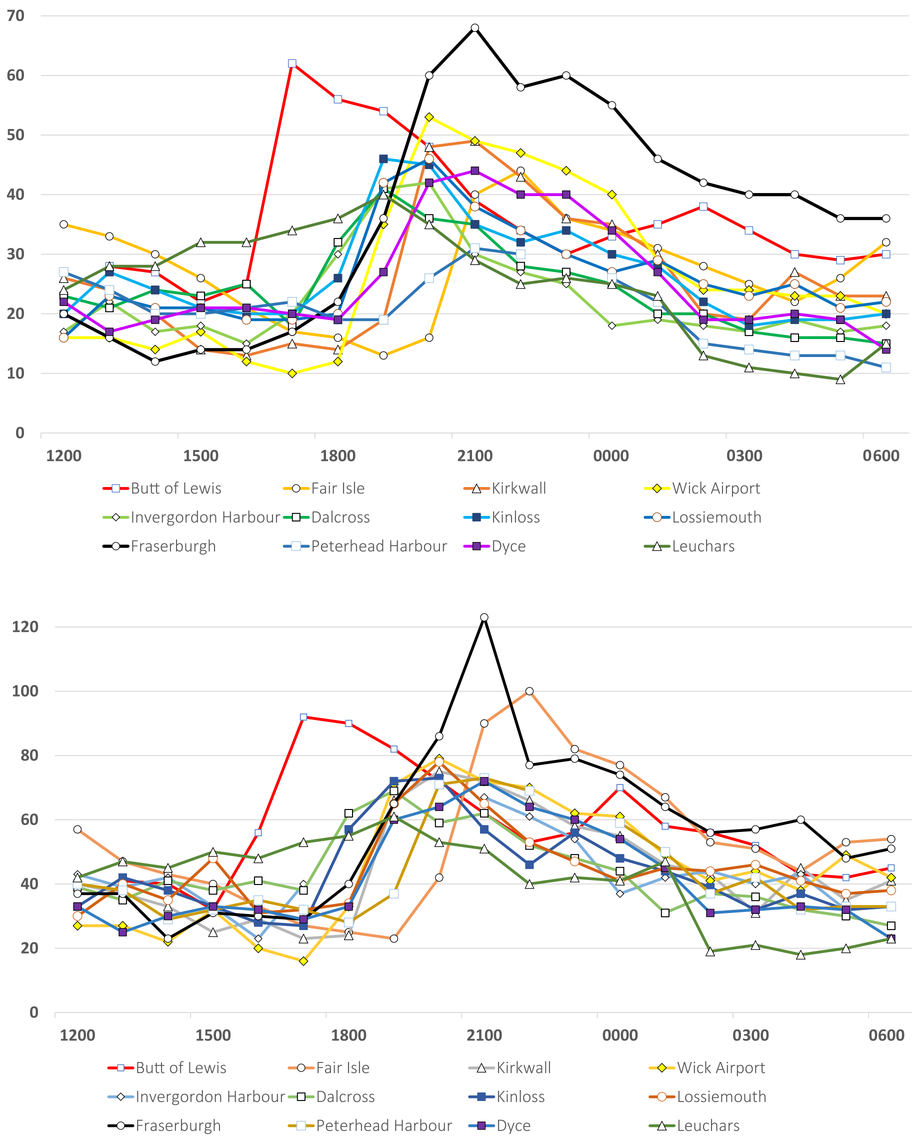

Figure 3. Hourly mean wind speeds (upper plot) and hourly maximum gust wind speeds (lower plot) for the 18 hour period 1200 UTC 13 February to 0600 UTC 14 February 1989, for the sites shown in Figure 2. Speeds are in knots (1kn = 0.51ms⁻¹), hours are 'hour ending'.

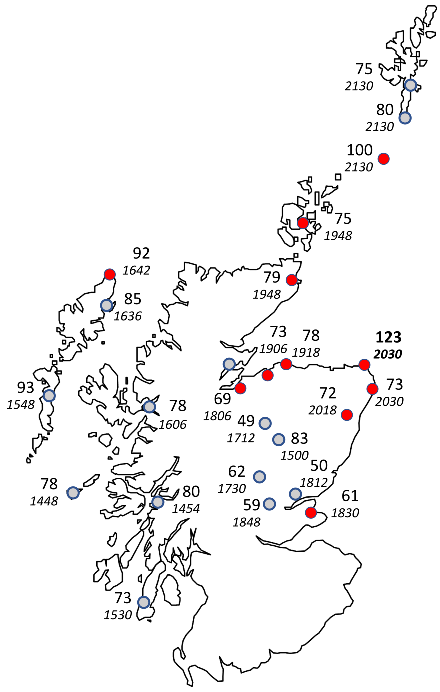

Figure 4. Speed (kn) and time (UTC) of highest gust on 13 February 1989. Times are given to a precision of 0.1h, that is, 6min. All were analysed from contemporary paper chart records.

genuine, peaks at 112kn (2 × 56kn half-scale, gust S1 on Figure 5 inset). A similar 'thin' pen trace at 2031 UTC marks the record gust of 123kn (spike S2, 2 × 61.5kn half-scale). This gust was accepted as a legitimate record, published in official publications such as the *Monthly Weather Report*, and duly archived in the MIDAS dataset (Met Office, 2019). At present, the Fraserburgh gust stands as the highest gust recorded at a low-level site within the UK. (The first gust, spike S1, was also accepted as genuine, but as it occurred within the same hourly analysis period as S2, only S2 as the highest hourly gust is held on the MIDAS record.) However, if we disregard both anomalous spikes, close examination of a greatly magnified portion of the chart record reveals that the highest gusts on the record were 86kn. Four such gusts can be identified, occurring at 1942, 2014, 2019 and 2033 UTC, of which the latter appears fractionally the highest.

Is the chart record reliable?

Both of the 'extreme' gusts indicated on the chart record appear out of character: they are well in excess of the 'background' gust level, the highest of which are no higher than 85–86kn in the preceding and following minutes. Both are also well in excess of the hourly mean wind speed (68kn): the gust factor (the gust speed divided by the hourly mean speed) is 1.81 for the nominal 123kn gust. Although this value appears broadly in line with other wind records during this event (Table 2), the previous wind history indicated by the chart record does not suggest that isolated very high gusts were a prominent feature of this particular event (indeed, the opposite is true). Further, at an exposed headland site such as Kinnaird Head the gust factor in wind directions with a long sea fetch (as on this occasion) would be expected to be considerably lower than at inland sites owing to reduced frictional turbulence over the sea: this assumption is reinforced by the narrowness of the wind direction trace. In the 21-year record from this site (1969–1990), of the 50 gusts to reach or exceed 70kn, the average gust factor was 1.38 in a near-normal distribution (the 10 highest gusts within individual storms are ranked in Table 3) with a standard deviation (σ) of 0.11. (On this distribution, the gust factor of 1.81 for the nominal 123kn gust on 13 February 1989 represents 4.0σ above the mean, with a probability of occurrence of <0.01%.) In the most comparable storm to that of 13 February 1989, namely 3 January 1984 when the site's second-highest gust was recorded (and winds from a similar direction gusted to 70kn or more for eight consecutive hours), the gust ratio for the highest gust was 1.26. If we assume the highest gust on 13 February 1989 was indeed 86kn, the gust ratio becomes 1.26 instead of 1.81 (Table 3).

The two anomalous gust spikes S1 and S2 in Figure 5, occurring suddenly, in isolation to and considerably higher than 'background' gusts, bear striking resemblance to the chart record for the disputed 108kn gust recorded at Kilkeel on 8 January 1974 (Aylott *et al.*, 2020). In addition, neither of the two extreme gusts were accompanied by a change in wind direction (as might be expected from a squally shower in a convective situation, for example), although the second gust can be seen to coincide with the 'resetting' to the centre of the chart of the wind direction pen arm. The Kilkeel gust was shown to be almost certainly incorrect owing to widespread disruptions to electri-

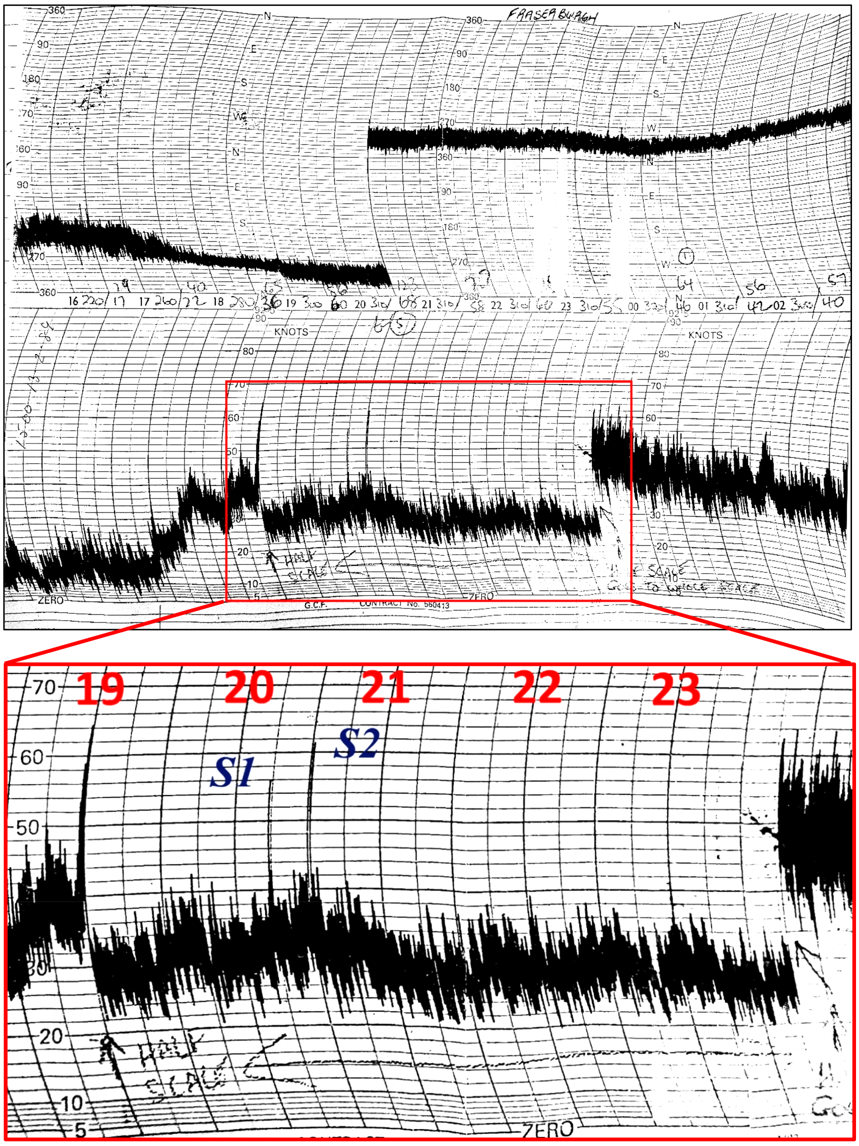

Figure 5. The anemograph record from Kinnaird Head Lighthouse, Fraserburgh for the period 1530 UTC 13 February to 0300 UTC 14 February 1989. The upper portion of the chart indicates the wind direction, the lower the wind speed (in knots). Between 1900 and 2345 UTC the wind speed scale is halved. The area of half-scale record within the red rectangle on the main plot is shown enlarged as an inset; on this the hours (1900 to 2300 UTC) are marked in red, and gusts S1 and S2 indicated (see text) in blue. The vertical scale is in knots at half-scale, that is, 40kn chart = 80kn record.

Table 2

Gust factors for sites in Scotland during the windstorm of 13 February 1989. The gust factor is calculated as maximum gust/mean wind speed, using the mean wind speed of the clock hour during which the highest gust was recorded. See Figure 2 for station locations.

Site	Maximum gust (kn) A	Time of maximum gust UTC	Mean hourly wind speed (kn) B	Gust factor A/B
Fair Isle	100	2130	44	2.27
Kirkwall	75	1948	48	1.56
Wick Airport	79	1948	53	1.49
Dalcross	69	1806	41	1.68
Kinloss	73	1906	46	1.59
Lossiemouth	78	1918	42	1.86
Fraserburgh (123kn)	123 ?	2030	68	1.81
Fraserburgh (86kn)	86			1.26
Peterhead Harbour	73	2030	31	2.35
Dyce	72	2018	44	1.64
Leuchars	61	1830	40	1.53

cal power supplies caused by the storm, and in view of similar storm-related disruption to power supplies in this storm evidenced by existing accounts, it seems reasonable to call into question the veracity of the Fraserburgh record. To relegate the status of the Fraserburgh gust, a long-standing national record, from 'possibly incorrect' to 'probably incorrect' requires additional supporting evidence. Fortunately, such supporting evidence has recently come to light.

Doubts about the operation of the 'half-scale' mechanism

There is no doubt that the Fraserburgh chart record had switched to 'half-scale' between 1900 and 2345 UTC on 13 February 1989. The strength of the mean wind speed assessed on this basis (highest hourly mean 68kn) is fully supported by evidence from the closest sites. Both Kinloss and Lossiemouth, sites with less exposure and fetch across the Moray Firth than Fraserburgh's Kinnaird Head Lighthouse[4], recorded hourly means as high as 46kn. At Peterhead Harbour, the highest hourly mean wind (31kn) was considerably lower than at Fraserburgh owing to frictional retardation over land in the northwesterly storm-force winds. Contemporary media accounts describe extensive disruptions to power supplies during this storm, but the existence of an apparently continuous chart record for the storm at the Fraserburgh site would suggest that any power disruptions experienced there were of very short duration.

If the power supply was briefly interrupted, perhaps only for a few seconds, while the wind was gusting above 70kn, how might the instrument respond? It would not be unreasonable to expect it would restart in default 'normal scale' mode, switching very quickly to half-scale once the instrument registered winds at or approaching the 65–70kn switchover threshold. Evidence for this would be left on the chart as a very rapid rise of the inked pen (i.e. a thin trace) to about 60kn, followed by the operation of the half-scale mechanism and the continuation of the record in half-scale[5]. A reset or wider ampli-

[4]With winds from the northwest, the anemometer at Lossiemouth is about 2km inland from the windward coast, and at Kinloss about 4km.

[5]A suggestion regarding possible full-scale reset/half-scale confusion in such events was also made by Marjory Roy (personal communication, 31 January 2020). Additionally, it should be possible to test this hypothesis by connecting appropriate voltages across the input terminals of a Mk4 recording anemograph fitted with a half-scale mechanism, and then briefly interrupting the power supply. Unfortunately, few if any remain in operational use for such a test to be attempted.

Table 3

Ranked ten highest gusts recorded at Fraserburgh, period of record 21 years 1969–1990. Only the highest gust in individual storms is included; gusts of 70kn or greater were recorded in 50 hours in the 21 year record. The gust factor is the highest gust divided by the mean speed in the hour that the gust was recorded, and the hourly means refer to the 'hour ending'.

Date	*Max gust speed (kn)*	*Time of max gust* UTC	*Hours with gusts ≥ 70kn*	*Direction of max gust (°)*	*Hourly mean wind direction (°)*	*Hourly mean wind speed (kn)*	*Gust factor*
13 Feb 1989	123 ?	2030	5	310	310	68	1.81
13 Feb 1989	86	2016, 2031					1.26
3 Jan 1984	83	1224	9	280	280	66	1.26
22 Sept 1969	83	2318	1	310	310	60	1.38
28 Sept 1969	81	1848	1	300	300	58	1.40
14 Dec 1973	80	0718	2	310	310	58	1.38
23 Nov 1981	80	2142	5	270	270	53	1.51
18 Dec 1989	78	0506	3	260	260	60	1.30
20 Jan 1976	76	1636	4	270	270	53	1.43
19 Nov 1973	74	0500	3	280	280	53	1.40
18 Dec 1989	74	N/A	1	N/A	260	56	1.32
27 Feb 1990	74	2124	1	280	280	55	1.35
6 Dec 1973	73	0906	2	290	290	52	1.40
7 Feb 1969	72	1154	1	340	340	43	1.67
30 Oct 1986	71	1512	1	320	330	54	1.31

Note: A gust of 280°/75kn at 0712 UTC on 12 November 1973, hourly mean wind of 290°/34kn and resulting gust factor 2.21, has been excluded from this table as instrumental defects may have affected the record.

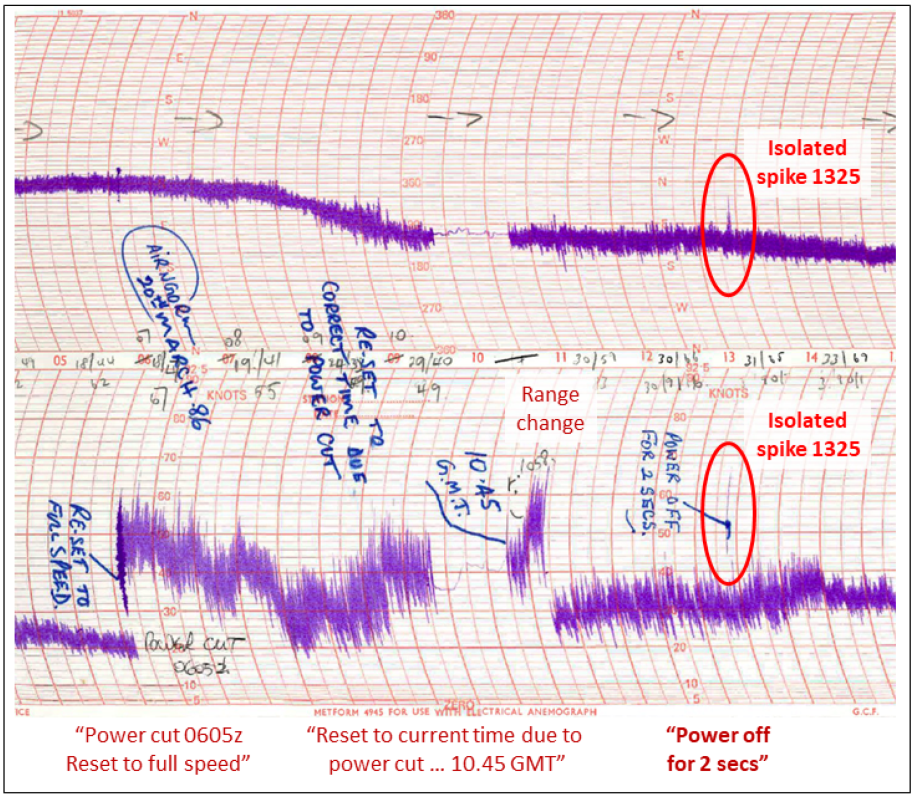

Figure 6. A section of the Cairngorm Chairlift anemogram for 20 March 1986, showing a clear 'isolated spike' gust feature in strong winds; see text for explanatory detail. Note that the wind direction as recorded is in error by about +135°, although accuracy in this regard is not material to the discussion. Chart annotations are on the original.

tude swing of the wind direction pen might also be expected at restart, and there is clear evidence of both on the Fraserburgh record at 2031 UTC. Accordingly, it is suggested that the spikes S1 and S2 on the record in Figure 5 resulted from two such transient interruptions in the instrument's power supply, at 2014 and 2031 UTC, at a time when the wind was at or close to its peak and gusting in excess of 80kn.

Fortunately, unambiguous evidence of such behaviour during transient power cycling from the record of similar instruments fitted with 'half-scale' mechanisms has recently come to light. Figure 6 shows a section of record from the anemograph on the Cairngorm Chairlift, located at 10m above ground and 1075m amsl, for a period of 7 hours from shortly before 0600 UTC on 20 March 1986, the date on which the UK record 150kn gust was recorded at the Cairngorm Summit site (at 1245m amsl and about 1km to the south of the Chairlift anemometer instrument). The chart type is identical to the Fraserburgh record in Figure 5, with wind direction at the top of the Figure and wind speed below. The annotations on the chart are original.

The chart extract commences shortly before 0600 UTC running in 'existing' half-scale mode. At this point, the mean wind speed was around 40kn. A short power cut at 0605 UTC then caused the instrument to restart: note that it restarts in 'full-scale' mode with an excursion of the wind direction trace. Although there are three gusts in excess of 60kn over the following hour, the instrument did not reset itself back into 'half-scale' mode.

Shortly after 0945 UTC, the power failed again, this time for an hour, and the instrument record recommenced at 1045 UTC. The wind was increasing at this point, and the range-change cut in at 1110 UTC, as is evident on the wind speed chart. At 1325 UTC, while in 'half-scale' mode, another power cut lasting 2s is marked on the chart. A thin and broken pen trace extends briefly up to 67kn on the scale – significantly, exactly the speed at which the half-scale range-change cut in at 1110 UTC – before the 'half-scale' mechanism cut in once more. The instrumental record continued in half-scale to show one or perhaps two close gusts of 90kn at 1410 UTC, and a 10 minute mean speed reaching 74kn around 1418 UTC.

The short 'full-scale' spike on this chart record occurring during the short power cut at 1325 UTC, while 'resetting scale' in 60–70kn winds, is remarkably similar to spikes S1 and S2 on the Fraserburgh record for 13 February 1989. A short additional excursion of the wind direction pen arm is also evident on the Cairngorm Chairlift record at the time of the brief power interruption (Figure 6, upper plot), corroborating evidence from the Fraserburgh chart. The conclusion is therefore that a similar brief interruption to the power supply at Fraserburgh resulted in a short period of 'full-scale' record, which was switched back to 'half-scale' as soon as the threshold wind speed had been registered by the instrument. Accordingly, it is proposed that the two gusts of '112kn' and '123kn' marked on the Fraserburgh anemograph trace are, in reality, gusts of 56kn and 61.5kn recorded briefly in 'full-scale' mode before the instrument quickly reset itself back into 'half-scale' mode.

Compilation and assessment of evidence

As with the Kilkeel gust previously referred to (Aylott *et al*., 2020), further doubt regarding the veracity of the 123kn Fraserburgh gust comes from its enormous return period, assessed as being in excess of 1 million years (much higher than other sites' return periods during this storm). This return period was deduced by applying the method of independent storms with a robust peak-over-threshold extreme value analysis (Saunders and Lea, 2017) to all the Fraserburgh hourly gust data recorded between 1969 and 1990, when records at the site ceased. Table 3 shows the 10 highest gusts recorded at Fraserburgh over this period; setting aside the dubious 123kn gust for the reasons above, it is notable that the (reliably documented) 86kn gusts during the February 1989 storm still head this list.

Table 4 lists the evidence for and against the veracity of the 123kn gust at Fraserburgh. The occurrence of very high hourly mean winds at Fraserburgh on this occasion is beyond dispute, supported by closest neighbouring wind records and augmented at Fraserburgh by the increased fetch across the Moray Firth when compared with Kinloss and Lossiemouth. (Table 3 amply demonstrates the predominance at Fraserburgh of very strong winds from 260 to 310°). Also in favour are the observed 'gust factor' ratios of gust speed to mean speed observed at Fraserburgh, which broadly accord with other stations in north-east Scotland during this storm, although the highly climatologically atypical gust factor for this site (Table 3) argues more persuasively in the opposite sense.

The argument against the 'Fraserburgh gust' is more finely nuanced than was the case with the Kilkeel event, but the case for rejecting the value is sound and compelling. Both alleged gusts are strikingly similar to the record produced by another instrument of the same type following an instrumental restart into 'full-scale' mode as a result of a short interruption to the power supply, and bear strong resemblance to the spurious gust spikes evident on the (since discounted) January 1974 Kilkeel record. At a local level, although some minor building damage was reported from in and around Fraserburgh, it was broadly consistent with wind gusts of 80–90 knots rather than in excess of 120kn. Accordingly, the conclusion presented is that Scotland's, and the UK's, low-level gust record is incorrect.

Finally, repeating and extending previous comments, attention is drawn to the fact that, at the time of writing, all the current UK national (Scotland, Northern Ireland, Wales and England) records for low-level gust speed were set between 1969 and 1989 during the initial 21 years of digitised UK windspeed data (Met Office, 2020a). In contrast, no national record has occurred during the subsequent 30-year period between 1990 and 2019, despite greater coverage by operational recording anemometers following automation of the Met Office station network (Green, 2010) and the occurrence of frequent winter windstorms including the recent stormy winters of 2013/2014 (Kendon and McCarthy, 2015) and 2019/2020. Unless the intensity of windstorms resulting from intense extra-tropical cyclones affecting the British Isles has decreased since the 1970s and 1980s, the lack of entries appears odd to say the least, and raises questions about the

Table 4

Summary of the evidence for and against the authenticity of the 123kn gust at Fraserburgh on 13 February 1989.

For:
• A very tight pressure gradient resulted in widespread high wind speeds, and these were especially strong in western and northern Scotland, where mean wind speeds exceeded 60kn in places • The Fraserburgh anemograph was very exposed to westerly and northwesterly winds, so higher mean wind speeds than at less exposed inland sites were not unexpected • Unambiguous evidence of very high gusts in northern Scotland at similar times, although none were within 20% of the 123kn gust at Fraserburgh • Gust factor similar to that of highest gusts at nearby stations • 'Gusts' clearly recorded on anemogram • Anemograph inspected for errors shortly after this event and found to be satisfactory • Wind damage reported across Scotland, including within Fraserburgh
Against:
• Two sudden isolated gusts 'out of character' with chart record of high winds during this event • Climatologically extreme gust factor (1.81), against the average for 70kn gusts at this site (n = 50) of 1.38 and standard deviation 0.11, and that for a similar storm in January 1984 of 1.26. • Return period >1000 000 yr and 40kn higher than second highest gust at Fraserburgh (excluding only the first 112kn gust also recorded on the anemogram during this event) • Lack of documentation regarding default instrumental behaviour/recording when automatic range change device resets to 'half-scale' in event of power failure during strong winds • Documented interruptions to power supplies – short-term power failure/instrument could produce brief full-range record, subsequently interpreted as half-scale and mistakenly doubled • Original anemogram lost – only a poor photocopy available for verification • No reports of storm damage in north-east Scotland compatible with levels expected from wind gusts well in excess of 100kn

veracity of other long-standing UK national record gust speeds.

Conclusion and recommendation

The anemograph record from the Kinnaird Head Lighthouse in Fraserburgh during the severe storm on 13 February 1989 was probably affected by two brief interruptions in the electricity supply at the height of the gale. On each occasion it seems likely that the instrument restarted briefly in 'full-scale' mode before switching to 'half-scale', and that the two isolated 'full-scale' gusts have been misinterpreted as 'half-scale' records and doubled as a result. Several gusts to 86kn were reliably recorded during this event, qualifying in their own right as the strongest gusts recorded during the 22 year anemometer record at this site, but the veracity of the two 100+ kn gusts shown on the anemogram (including the 123kn gust, accepted until now as the highest low-level wind gust on record within the UK) must now be regarded as extremely doubtful. Indeed, the evidence presented suggests there could be many other examples of spurious gust events with a similar cause in the historical data record.

If the Fraserburgh record is deemed invalid as a result, the Scottish and UK national low-level wind speed record reverts to the gust of 118kn recorded at Kirkwall on 7 February 1969 (Met Office, 2020a), although it is possible that a closer examination of that record may show similar grounds for concern.

The doubt now cast upon two long-standing country record wind gusts (Northern Ireland and Scotland) strengthen the case for an expert panel to be established to examine, adjudicate upon and publish the official record values for all UK national and regional weather and climate extremes, including but not restricted to wind speed. Such a committee, which could reside under the mantle of the RMetS's Meteorological Observing Systems Special Interest Group, would have terms of reference similar to that of the WMO Global Archive of Weather and Climate Extremes (Purevjav *et al*., 2015) and of the National Climate Extremes Committee in the USA (Cerveny *et al*., 2007). Impartial assessment of UK extreme weather records is particularly relevant for record gusts because these records are long-standing and there remain unresolved questions concerning the homogeneity of wind speed records made by older anemometer instruments (Smith, 1981; Miller *et al*., 2013; Cook, 2014). The creation of an impartial weather and climate extremes panel in the UK would ensure the validity and reliability of extremes by collecting and assessing all the available evidence before such extremes are published in 'official' listings, and act to ensure permanent and secure archiving of all documentation related to the event.

Acknowledgements

I am most grateful to the staff of National Records Scotland, to the Met Office Library and Archive in Exeter, and to Marjory Roy (ex-Superintendent of Met Office Edinburgh), for their help in sourcing data and chart records used in this study. This article builds upon a research project undertaken by Lucy Aylott during her MSc dissertation at the University of Reading, supervised by the author and Mark Saunders (UCL), which examined the nature and veracity of several UK record extreme gusts, a project originally conceived by Mark Saunders.

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Correspondence to: Stephen Burt

s.d.burt@reading.ac.uk

doi: 10.1002/wea.3864