The gust that never was: a meteorological instrumentation mystery

Stephen Burt
Department of Meteorology, University of Reading, UK

During the early hours of Easter Monday, 28 March 2016, the passage of a very rapidly deepening depression southwest to north-east across central England resulted in a rare inland gale, with peak mean speeds close to 40 kn in exposed areas. At the University of Reading Atmospheric Observatory, the highest overnight gust1 at 10m above ground was 22.4ms⁻¹, 43kn, at 0609 utc from 250 degrees (west-southwest) (Figure 1).

A succession of squally showers followed in the polar maritime air behind the cold front, and during one of these, the anemometer at 10m above ground in the observatory registered a gust of 30.8ms⁻¹, or 60kn, at 1516 utc (Figure 1), associated with a heavy hail shower. This extreme gust was apparently confirmed by a similar gust recorded by another anemometer at 2m above ground (Figure 2). Although the meteorological situation was potentially favourable for very high gusts in association with showers that afternoon, this gust seemed very high in comparison with neighbouring sites – anemometers at Stratfield Mortimer (10km southwest of the university) and at Wokingham (6km south-east) logged peak gusts of 22kn (at 1509 utc) and 26kn (at 1528 utc), respectively, around the same shower. The observatory gust was notable as apparently the highest recorded at the site for almost 20 years.

As the day in question was a Bank Holiday, there were few people in and around the university grounds. However, a check across the campus on my return to work the following day revealed little evidence of considerable tree or structural damage that might have been expected with gusts of this strength. At this point, consideration of the circumstances (reliable and well-maintained instruments, with effective exposure on a good site, allied with plausible synoptics) would surely suggest the gust records were beyond reproach. However, an indefinable something did not feel quite right, and accordingly, all available records were examined more closely.

The Atmospheric Observatory samples and logs a wide range of meteorological parameters, including wind speed, at 1s intervals using a Campbell Scientific CR9000X logger (for more details, see https://research.reading.ac.uk/meteorology/atmospheric-observatory). For research and teaching purposes, anemometers are exposed on two adjacent masts at a range of heights from 0.56m to 10m above ground (Figure 3) – one mast has anemometers at 2m, 5m and 10m above ground (also a logged wind vane at 10m), and the other mast a few metres away has anemometers at 0.56m, 0.8m, 1.12m, 1.6m, 2.24m, 3.2m, 4.48m and 6.4m. All 11 locations use the same sensor, a Vector Instruments A100LM model optical pulse counter cup anemometer.

The initial check was against the logged 1s 2m wind speed, which at a glance appeared to corroborate the 10m record (Figure 2). On closer examination, however, something was definitely amiss – the highest 2m gust was even higher than that at 10m, namely, 31.6ms⁻¹ or 61kn. Winds at 2m would normally be expected to be somewhat lower, perhaps by 20%, than the 10m value owing to surface friction effects (e.g. the highest gust at 2m during the morning’s near-gale, 18.7ms⁻¹ or 36kn, was 16% lower than the peak 10m gust). The highest gust at 2m also occurred an unlikely 9s later than the 10m gust. There was also no significant change in wind direction, as might be expected in a sharp squall for example.

The record from the 5m anemometer, sited on the same mast between the 2m and the 10m sensors (Figure 3), was then examined. The highest afternoon gust from this instrument was just 10.9ms⁻¹, 21kn – recorded almost 2min after the highest 2m and 10m gusts. Which was right?

At this point, all the other anemometer records from the observatory were examined very closely. Figure 4 is a time series of the logged 1s speeds from 5 of the 11 anemometers within the observatory covering the period 1505–1525 utc, about 10min

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1Unless specified to the contrary, the maximum gust is defined here as the highest 3s running mean wind speed, per WMO CIMO protocols.
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The others for a period of about 2½ min centred on 1516 UTC. An expanded plot covering the remainder of the 24-hour civil day (not shown) showed that this was the only period of anomalous record. Nothing similar has been observed since.

So what caused this anomalous peak?

Without direct and on-site eyewitness observations, it is difficult to be sure exactly what happened in and around the observatory during those few minutes. Accounts from university staff living nearby spoke of a heavy but short-lived hail shower, with drifts of hail accumulating for a time. No lightning was observed in the Reading area, although there were isolated lightning strikes elsewhere in southern England that afternoon – none closer to Reading than about 50 km – providing evidence of convective electrification in some of the airmass showers. The tipping-bucket rainfall record showed that 4.0 mm of precipitation fell in the 9 min commencing 1515 UTC.

The peak precipitation intensity (based on time between successive 0.2 mm tips) was 48 mm h⁻¹ at 1516 UTC, coinciding exactly with the reported peak 2 m and 10 m gusts: this intensity may be underestimated if hail in the funnel took some time to melt. This coincidence of the commencement of heavy precipitation is shown even more clearly in Figure 5, which is Figure 4 with tip times over-plotted as vertical columns (right-hand axis). Could water ingress into the sensors, or the cabling, be responsible for the spurious gusts? Figure 5 clearly shows that both 2 m and 10 m sensors were affected simultaneously, perhaps suggesting some kind of cabling or connection problem rather than a fault of the individual sensors – as it is extremely unlikely that both sensors would fail in exactly the same manner at exactly the same time, particularly as these are rugged, long-life sensors without any previously known discrepancies of this kind. However, that would not explain the 5 m record, the sensor for which is identical, located on the same mast and sharing the same cable run and connections to the logger. It did, in any case, seem unlikely that a possible water ingress issue would affect the anemometers in the way that it did (Figure 5), and for less than 3 min in all. In any case, water ingress seemed an unlikely failure mode for these anemometers, whose mode of operation is optical, a low power pulsed output transducer or ‘optical chopper’, pulses from which are logged and converted to wind speed using the sensor’s specified calibration.

The mystery deepened. The 2 m and 10 m anemometers were replaced by new units a couple of days later, and the units in use on 28 March were dismantled and inspected closely. No fault in the sensor, or water ingress, was found. The same was true of the cable runs and connections – all dry.

After that, we were left baffled. Water ingress was all but ruled out by subsequent examination. The hailstorm might be responsible somehow, but what mechanism could affect two of the three anemometers on that mast, and not the third, and in doing so generate a very plausible record lasting for almost 3 min? We considered all the more obvious possibilities. In desperation, we even considered a close-passage tornado, affecting one mast but not the other, but that would not explain why the 5 m record agreed with the anemometers on the second mast – and neither was there any supporting infrastructure damage to trees and buildings elsewhere on campus.

After considering – and ruling out – many other possibilities, the observatory’s atmospheric electricity records were examined as nearby convective clouds can produce considerable variations in atmospheric electricity (see the summary by Bennett, 2017, on work in detecting lightning for a useful summary of the field). The observatory has numerous atmospheric electricity instruments, including a Chubb electric field mill and a point discharge current or corona current sensor. The field mill measures the Potential Gradient (PG), which has the same magnitude as the atmospheric electric field. The point discharge current (PDC) is the current flowing through an upwards-pointing metal tip to earth, in some ways reminiscent of a lightning conductor. The geometry of the sharp metal tip concentrates the electric field, which means that it is sometimes sufficiently large for electric breakdown (corona) to occur (see Box 1). As a result, PDC can be very variable over a wide range, and the PDC system in use is designed specifically for this (Marlton et al., 2013) as it has a bipolar logarithmic electrometer, allowing it to detect corona currents from 10⁻¹² A to 10⁻⁸ A (i.e.
sor measured negative corona currents of (the cause of the hailstorm). The PDC sen-
sa strongly electrified passing convective cell 
due to the intense electric field caused by 
electric field mill, saturated at −1000Vm
−1 (the sign of electric field), measured by the
Figure 3, and logged simultaneously at 1Hz.
20m northwest of the 10m mast shown in
are mounted at 3m above ground, some
polarity. Both the field mill and PDC sensor
are very often also associated with large and
systems very often also apply to other pulse-counting sensors,
itself. By implication, similar findings probably
ior above or alongside sensors of this type
ble to do so and fitting a pointed conduc-
tor above instrumented masts wherever feasi-
ence of good electrical engineering of sig-
tional systems for meteorological instruments,
avoiding cheaper plastic components wher-
ever possible: it also suggests that measures
avoiding cheaper plastic components wher-
ial systems for meteorological instruments,
late, attributable to the charging–discharging mechanism of
exposed pointed objects nearby.

The outcome also emphasises the impor-
tance of good electrical engineering of sig-
al systems for meteorological instruments,
avoiding cheaper plastic components wher-
ever possible: it also suggests that measures
to mitigate corona interference on exposed
optical pulse sensors should be considered.
Such measures could include siting sensors
as far as possible from the point or points
of greatest deformation of the electric field
around instrumented masts wherever feasi-
to do so and fitting a pointed conduc-
tor above or alongside sensors of this type

to prevent or reduce corona on the sensor

tor itself. By implication, similar findings probably
also apply to other pulse-counting sensors,
including, for example, tipping-bucket rain
gauges – particularly given that their records
are perhaps of most interest in convective sys-
tems. Such measures could include siting sensors
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tor above or alongside sensors of this type

2 I am grateful to the (anonymous) referee who
suggested this as a possibility.
Box 1. What is a coronal discharge?
The online glossary of the American Meteorological Society defines a coronal discharge as the following:

‘A luminous, and often audible, electric discharge that is intermediate in nature between a spark discharge (with, usually, its single discharge channel) and a point discharge (with its diffuse, quiescent, and nonluminous character).’

It occurs from objects, especially pointed ones, when the electric field strength near their surfaces attains a value near 1 × 10^7 V m⁻¹.

Aircraft flying through active electrical storms often develop corona discharge streamers from antennas and propellers, and even from the entire fuselage and wing structure. So-called precipitation static results. It is seen also during [electrically] stormy weather, emanating from the yards and masts of ships at sea.’

The manifestation of a coronal discharge in the atmosphere has been known since antiquity as St Elmo’s fire, the luminous plasma created by coronal discharge in a strong electric field from sharp or pointed objects such as masts, spires and chimneys. It often appears as a bright blue or violet glow, appearing like fire in some circumstances, hence the descriptive name, and can be accompanied by a distinct hissing or buzzing sound. St Elmo’s fire is one of four ‘electrometeors’ defined by the World Meteorological Organization – the other three being lightning, thunder, and the polar aurora (see https://cloudatlas.wmo.int/docs/wmo_407_en-v1.pdf, page 127).

There is a cautionary note to this tale. Atmospheric electrical interference to meteorological instrumentation does not need electric fields that are sufficiently large to cause lightning. As a university meteorology department, we expose and maintain a wide range of instruments for teaching and research purposes, as well as for continuation of our long climatological record. On this occasion, we were able to examine critically, and at high temporal resolution, the 2m and 10m wind records in comparison with other instruments. In doing so, we can assert beyond all reasonable doubt that the extreme gusts recorded on this occasion were incorrect. However, if we were in the more normal situation of possessing just a single anemometer record, whether at 2m or 10m, then this recorded extreme gust in excess of 30ms⁻¹ or 60kn, a 1-in-20-year event, would have been accepted without question – certainly very high in comparison with local sites but not inconceivable given the synoptic situation. How often has something similar occurred previously, resulting in spurious extremes, unsupported by local infrastructure damage appropriate to the recorded wind speeds? (See also Aylott et al, 2020, for other possible events of this nature). Such events can have a very considerable impact on assessed return periods and thus affect structures built to withstand wind speeds expected only once in 50, 100, or 1000 years.

I hope that this episode will give pause for thought for all users of instrumental data. Extremes always merit further investigation or additional corroboration, even where (as in this case) data provenance and site and instrumental metadata appear impeccable at first sight. Students and researchers – beware!

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Correspondence to: Stephen Burt
s.d.burt@reading.ac.uk
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