

In Gusty Wind a Cup Anemometer Reads High, Because It Catches Up Faster with Faster Wind

— If the time an anemometer takes to catch up with the wind is a distance constant of **3 m** divided by wind speed, it catches up faster in faster wind — the separator is whether one asks about the mean wind or about whether response time changes with wind speed — [Paper 890]

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Abstract

It is easy to assume that an anemometer's mean reading represents the mean wind speed. This paper counts, in a model where the catch-up time changes with wind speed, that the mean reading in fluctuating wind departs from the mean wind. No new theorem or law is claimed. First, without fluctuation, the reading equals the wind: at a mean of **5 m/s** with no fluctuation, the mean reading is **5.000000** and the excess **0.000000** (Section 2). Second, and this is the core. In fluctuating wind, it reads high: fluctuation sizes **0.1**, **0.2** and **0.3** make the reading high by shares of **0.003909**, **0.015683** and **0.035459** (Section 2). Third, with a fixed catch-up time, there is no excess: with the catch-up time fixed at **0.6** seconds, the excess at fluctuation **0.3** is **−0.000001** (Section 3). Fourth, the excess grows faster than the fluctuation: tripling the fluctuation from **0.1** to **0.3** raises the excess from **0.003909** to **0.035459** (Section 2). Fifth, faster fluctuations give larger excess: at fluctuation **0.3**, a rate of **0.05** per second gives **0.001740** and **5** per second gives **0.044949**, a ratio of **25.829091** (Section 4). Sixth, the separator is whether one asks about the mean wind or about whether response time changes with wind speed: the excess comes not from fluctuation itself but from the bias of catching up faster with faster wind and slower with slower wind (Section 4). **Keywords:** anemometer, distance constant, overspeeding, response time, fluctuation.

Scope of this paper (scope note): No new theorem or law is claimed: that cup anemometers are characterised by a distance constant, and that their mean reading is high in fluctuating wind (overspeeding), are both known in meteorological instrumentation. No real instruments are claimed: the distance constant of 3 m and the fluctuation sizes and rates are model values matching no anemometer. Cup shape and direction are not included: cup shape, direction fluctuation, bearing friction and oblique wind are not included. Fluctuation is simplified: fluctuation is a single-rate sine wave; the broad frequency range of turbulence is not treated. Relation to earlier papers: Paper 884 showed that GI reflects how fast a food is absorbed only because it is cut at two hours. This paper stands beside it. There, the convention of when to cut moved the value. Here, the property that an instrument's response time changes with wind speed moves the measured mean. What is added is measuring the excess for each fluctuation size, checking that a control with fixed response time removes the excess, measuring the excess for each fluctuation rate, and placing the separator on mean wind versus response bias.

1. Notation and the Question

Setting: for wind speed $U(t)$, the anemometer reading V approaches the wind with catch-up time τ . For a cup anemometer, the catch-up time is the distance constant L divided by wind speed.

$$\frac{dV}{dt} = \frac{U - V}{\tau}, \quad \tau = \frac{L}{U}, \quad U(t) = U_0(1 + I \sin 2\pi ft)$$

With $L = 3$ m and $U_0 = 5$ m/s, the reading was followed in 0.002-second steps for 600 seconds and averaged after the first 60 seconds (300001 steps). The excess is the mean reading divided by the mean wind, minus 1. As a control, the catch-up time was also fixed at $L/U_0 = 0.6$ seconds.

Question: in fluctuating wind, does the mean reading represent the mean wind?

2. Fluctuation Size and Excess

Computation 2.1: with the fluctuation rate fixed at 0.5 per second, the excess was computed for varying fluctuation size.

fluctuation size I	mean wind (m/s)	mean reading (m/s)	excess
0	5.000000	5.000000	+0.000000
0.1	5.000000	5.019545	+0.003909
0.2	5.000000	5.078413	+0.015683
0.3	5.000000	5.177297	+0.035459

Observation 2.2

this is the core. In fluctuating wind, it reads high. At fluctuation 0.3 the mean reading is 5.177297 m/s against a mean wind of 5.000000 m/s, an excess of 0.035459: tripling the fluctuation from 0.1 to 0.3 raises the excess from 0.003909 to 0.035459, faster than the fluctuation grows.

3. Fixing the Response Time

Computation 3.1: with the catch-up time fixed at 0.6 seconds, the excess at fluctuation 0.3 was computed.

Observation 3.2

with a fixed catch-up time, there is no excess. In the fixed control, the excess at fluctuation 0.3 was -0.000001 : with the same fluctuation but a catch-up time independent of wind speed, fast and slow wind are caught up with alike, and the mean does not shift. What produces the excess is not fluctuation itself but a response that catches up faster with faster wind.

4. Fluctuation Rate

Computation 4.1: with fluctuation size fixed at 0.3, the excess was computed for varying fluctuation rate.

fluctuation rate (per second)	excess
0.05	+0.001740
0.5	+0.035459
5	+0.044949

Observation 4.2

faster fluctuations give larger excess. Slow fluctuation at 0.05 per second gives 0.001740, and 5 per second gives 0.044949, a ratio of 25.829091: slow fluctuations can be followed in both fast and slow wind, so little bias appears. At 5 per second, with a period shorter than the 0.6-second catch-up time, the excess was largest.

Observation 4.3

the separator is whether one asks about the mean wind or about whether response time changes with wind speed. Asking only about the mean wind, the mean reading seems bound to represent it: asking whether response time changes with wind speed shows that catching up faster with fast wind and slower with slow wind shifts the mean of fluctuating wind upward.

Observation 4.4

placed beside Paper 884.884 showed that GI reflects speed only because it is cut at two hours. There, the convention of when to cut moved the value. Here, an instrument's response time, a property of how it measures, moves the measured mean.

5. Census and Closing

1. catch-up time L/U (Section 1): **faster in faster wind.**
2. no fluctuation, excess 0.000000 (Computation 2.1): **no shift.**
3. 0.003909 at fluctuation 0.1 (Computation 2.1): **small.**
4. **0.035459** at fluctuation 0.3 (Computation 2.1): **the core.**

5. mean reading **5.177297 m/s** (Observation 2.2): **wind 5.000000**.
6. fixed time gives **−0.000001** (Observation 3.2): **the excess vanishes**.
7. **0.001740** for slow fluctuation (Computation 4.1): **little bias**.
8. **0.044949** for fast fluctuation (Computation 4.1): **larger bias**.
9. ratio **25.829091** (Observation 4.2): **by fluctuation rate**.
10. mean wind, or response bias (Observation 4.3): **the separator; Paper 884**.

Closing: In gusty wind a cup anemometer reads high, because it catches up faster with faster wind. With the catch-up time as a distance constant of 3 m divided by wind speed, a mean wind of 5 m/s with fluctuation 0.3 gives a mean reading of 5.177297 m/s, an excess of 0.035459, because it catches up quickly with fast wind and slowly with slow wind, so the reading lingers on the fast side. Fixing the catch-up time at 0.6 seconds removes the excess to −0.000001, and raising the fluctuation rate from 0.05 to 5 per second multiplies the excess by 25.829091: the excess comes not from fluctuation itself but from bias in the response time. Placed among the earlier papers: beside Paper 884's "the convention of when to cut moves the value", we placed that an instrument's response time moves the measured mean. To be honest: fluctuation is a single-rate sine wave, and cup shape, direction and friction are not included.

References

1. World Meteorological Organization (2008). *Guide to Meteorological Instruments and Methods of Observation* (7th ed.). WMO.
 2. Yamagishi, Y. (2026). *GI Reflects Absorption Speed Only Because It Is Cut at Two Hours; Uncut, the Area Depends Only on the Carbohydrate* [Paper 884]. YOI: <https://www.yamagishiyuuki.com/yoi/884>
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