FIELD TEST: Preliminary Report

PiTech Research
Pluvimate raingauge

Introduction

This report briefly summarises the performance of a Pluvimate raingauge during a two month period in which it was exposed adjacent to three other commercial professional standard gauges, namely a daily-read 'five-inch' standard checkgauge (the UK and Ireland reference gauge), a Lambrecht rain-e load cell-based instrument and a Didcot 0.2 mm tipping bucket unit (TBR). Results are presented in both absolute totals, and as percentages of the reference gauge.

The trial was conducted at the Stratfield Mortimer Observatory in south Berkshire, UK, which has been an official UK Met Office and Environment Agency rainfall site (no. 270162) since 1998. A photograph of the site identifying the gauges in question is shown as Figure 1.

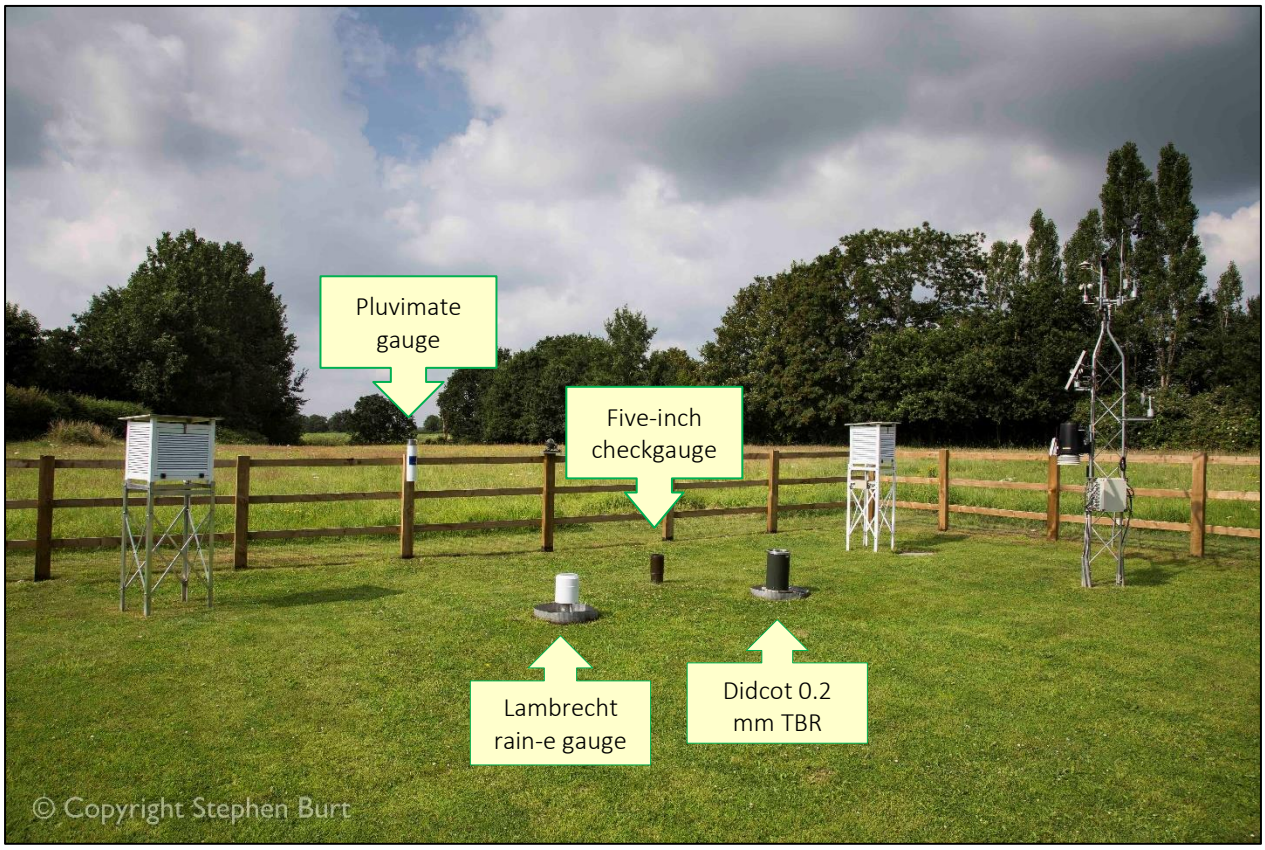

***Figure 1**. The Pluvimate raingauge installed within the enclosure at the Stratfield Mortimer Observatory in Berkshire, adjacent to three professional-standard raingauges as described in the text. This photograph was taken on 26 July 2021*

Data and methodology

The Pluvimate raingauge consists of a shallow funnel 127 mm in diameter and 90 mm deep mounted at one end of a sturdy plastic tube 400 mm in length. The funnel, which contains a seemingly dense mat of fibres acting as a filter, terminates in a nozzle designed to produce droplets which according to the manufacturer amount to exactly 0.01 mm of rainfall. Droplets fall freely from the nozzle down the length of the tube where they impact upon a Tinytag logger which has been modified to count the droplets, the action resulting from the kinetic energy of the falling droplet presumably registering via an accelerometer chip. The rainwater drains through holes in the base of the plastic tube. The logger is left in place in the tube and manually extracted from the tube for downloading at regular intervals. For this experiment the logger was set to log counts at 1 minute resolution. At this logging frequency the logged output consists mainly of zeroes, while the logger memory is sufficient for 23 days record. Accordingly, the logger was retrieved and the record downloaded at 2-3 week intervals.

The adjacent standard five-inch checkgauge is read daily at 0900 UTC using a calibrated measuring cylinder and the value thrown back to the previous day in accord with standard practice.

The nearby Lambrecht rain-e and Didcot gauges are also both logged at 1 minute intervals using a Campbell Scientific CR1000 logger, which forms part of the on-site automatic weather station measuring numerous other meteorological parameters such as temperature, wind speed and direction (at 3 m and 10 m AGL) and solar radiation. (Only rainfall data has been considered in this comparison.) Both gauges undergo regular calibration checks, and are checked daily for funnel obstructions/blockage.

The period of the trial was from 1600 UTC on 24 July to 1300 UTC on 29 September. Gauge catches were compared at both daily and hourly sampling intervals, hourly totals being the sum of the 60 one-minute totals ending at the exact hour UTC. Spells of heavy rainfall were few, but one example is given to illustrate and compare short-period rainfall intensity measurements. The Campbell Scientific logger is adjusted via its operating system to remain within 2 s of UTC at all times; the Pluvimate logger was reset to UTC ± 1 s after every download, and thus differences in logged times were insignificant, amounting to < 60 s after 2-3 weeks logging interval.

Results – daily totals

Table 1 lists the daily totals, in mm, at each of the four gauges over the comparison period, together with their total rainfall recorded over this period. A dash (-) indicates nil. Gauge resolution is 0.1 mm for the five-inch checkgauge and the Didcot TBR, and 0.01 mm for the Lambrecht and Pluvimate units.

Examination of the daily totals shows that the agreement of the Pluvimate gauge with individual daily totals from the other gauges is often poor, and variable in sign. Taking only days with ≥ 0.5 mm by the checkgauge, 18 in all, only four days agreed within 5 per cent, whereas agreement within 2-3 per cent would be expected from commercial gauges. On the wettest day during the trial period, 28 September when 22.2 mm fell, mostly in a six hour period during the evening, the Pluvimate recorded only 0.20 mm. In contrast, on 9 August, when the other three gauges recorded between 14.7 mm and 15.0 mm, the Pluvimate recorded 18.45 mm. (This example is considered further below.) There were many dry days when the Pluvimate recorded small amounts. At least some of these appear to be spurious counts resulting perhaps from wind rock of the fence post on which the Pluvimate unit is mounted, or from disturbance as a result of nearby grass cutting activity within the enclosure. It was also apparent that the very act of changing the logger resulted in numerous spurious counts being recorded (the entries for 12 August, 30

August and 12 September are entirely due to this cause as these dates remained dry throughout) as the logger appears very sensitive to any movement or disturbance. While these are small and could easily be deleted from the record, if the logger happened to be changed during rainfall the true record would be more difficult to distinguish.

TABLE 1. Daily rainfall totals 0900-0900 UTC from the four gauges, in mm

Date 2021	**Checkgauge**	**Lambrecht TBR3**	**Didcot TBR2**	**Pluvimate**
24 Jul	0.1	0.16	0.2	0.01
25 Jul	0.1	0.15	0.2	-
26 Jul	0.1	0.14	-	-
27 Jul	-	-	-	-
28 Jul	5.5	5.67	5.4	4.39
29 Jul	1.4	1.59	1.6	1.36
30 Jul	2.9	3.10	3.0	3.04
31 Jul	2.4	2.53	2.4	2.33
1 Aug	1.8	1.97	2.0	2.18
2 Aug	0.3	0.38	0.2	0.01
3 Aug	-	-	-	-
4 Aug	-	-	-	0.01
5 Aug	2.1	2.68	2.0	2.37
6 Aug	5.8	5.82	6.0	6.40
7 Aug	3.8	3.85	3.8	4.09
8 Aug	2.0	2.10	2.0	2.18
9 Aug	14.8	14.70	15.0	18.45
10 Aug	-	-	-	-
11 Aug	0.3	0.32	0.2	-
12 Aug	-	-	-	0.10
13 Aug	-	-	-	-
14 Aug	0.1	0.14	-	-
15 Aug	-	0.01	-	0.01
16 Aug	-	0.05	-	-
17 Aug	-	-	-	0.01
18 Aug	-	-	-	1.48
19 Aug	3.0	3.06	3.2	0.45
20 Aug	0.5	0.48	0.4	0.02
21 Aug	0.1	0.07	-	0.34
22 Aug	-	-	-	0.03
23 Aug	-	-	-	0.01
24 Aug	-	-	-	0.03
25 Aug	-	0.02	-	0.01
26 Aug	-	-	-	0.02
27 Aug	-	-	-	0.04
28 Aug	-	-	-	0.03
29 Aug	-	-	-	0.03
30 Aug	-	0.05	-	0.81
31 Aug	-	-	-	0.03

TABLE 1 continued. Daily rainfall totals 0900-0900 UTC from the four gauges, in mm

Date 2021	**Checkgauge**	**Lambrecht TBR3**	**Didcot TBR2**	**Pluvimate**
1 Sep	-	-	-	-
2 Sep	-	-	-	-
3 Sep	-	-	-	-
4 Sep	-	-	-	-
5 Sep	-	-	-	-
6 Sep	-	-	-	-
7 Sep	-	-	-	-
8 Sep	0.7	0.76	0.6	0.38
9 Sep	2.5	2.78	2.8	2.97
10 Sep	0.2	0.04	-	0.01
11 Sep	-	-	-	0.22
12 Sep	-	-	-	0.31
13 Sep	5.2	5.02	5.2	7.31
14 Sep	0.8	0.59	0.6	0.84
15 Sep	-	0.01	-	-
16 Sep	-	-	-	-
17 Sep	-	-	-	0.02
18 Sep	0.1	0.25	0.2	-
19 Sep	-	0.01	-	-
20 Sep	-	-	-	-
21 Sep	-	-	-	0.03
22 Sep	-	-	-	0.04
23 Sep	-	-	-	0.07
24 Sep	-	-	-	0.02
25 Sep	-	-	-	0.03
26 Sep	5.0	5.27	5.0	0.01
27 Sep	0.2	0.24	0.2	0.18
28 Sep	22.2	22.00	22.2	0.20
TOTAL	84.0	86.00	84.4	62.91
% reference		102.4	100.5	74.9
Excluding 28 September				
TOTAL	61.8	64.01	62.2	62.71
% reference		103.6	100.6	101.5

It is also clear from Table 1 that for whatever reason the Pluvimate gauge did not record accurately after about 16 or 17 September, and the record of the heavy fall on 28 September was almost entirely lost. This would be disastrous where a reliable continuous daily record was required. Frequent small daily amounts were logged by the Pluvimate unit during the dry conditions 20-25 September. Whilst it is possible that these resulted from fog or dewfall, it is more likely that they are the result of windrock or logger malfunction. (Note however that the logger was functioning correctly for at least a few days after being downloaded and restarted on 12 September).

Considering the period totals shown above, over the period 24 July to 28 September, the Pluvimate under-recorded by 25 per cent. The discrepancy is almost entirely due to the missing record for 28 September, and excluding this date the period comparison is more reasonable – within 2 per cent. However, this appears to be little more than statistical luck, as few individual daily totals are in good agreement as discussed above, and many dry days show small, probably spurious amounts in the Pluvimate record.

Results – hourly totals

Figure 2 and Figure 3 show scatterplots of the Lambrecht hourly total (x axis) versus the Pluvimate hourly total (y axis) - the first for all events, the second with the axes constrained to 1.0 mm to show behaviour at small rainfall amounts. The Lambrecht gauge has been used for these comparisons as its 0.01 mm resolution matches the nominal resolution of the Pluvimate, and it is also available at sub-daily resolution. It can be considered to be a reasonable proxy for the five-inch checkgauge total, which is of course only available daily, as Table 1 shows the two gauges total differed by only 2.4% during the comparison period.

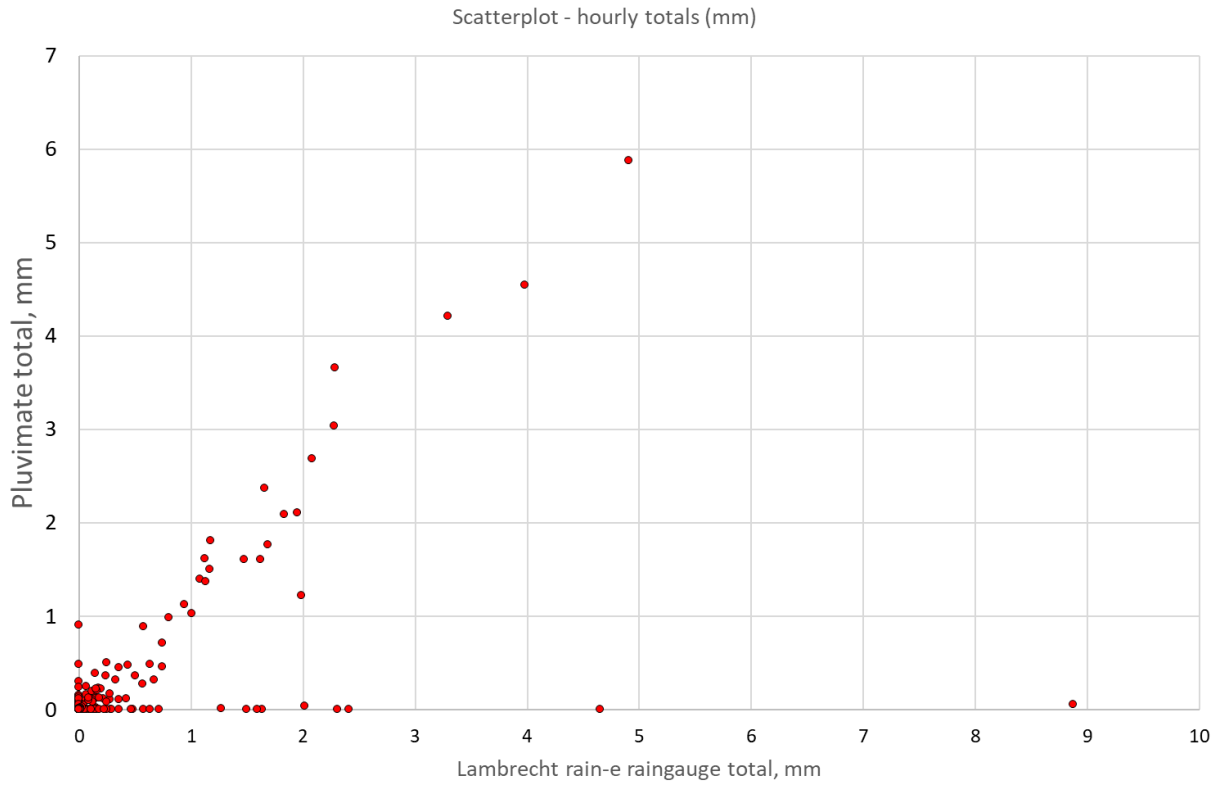

***Figure 2**. Scatterplot of hourly rainfall amounts (mm) as logged by the reference gauge (Lambrecht rain-e, x axis) and the Pluvimate unit (y axis) over the comparison period, 24 July to 29 September 2021*

Figure 2 shows that there is an approximately linear relationship between the Pluvimate output and actual rainfall, although the considerable scatter suggests the relationship is too variable to derive a reliable calibration. By eye, the Pluvimate gauge would appear to over-record by approximately 6/5 or 20%, at least above 1 mm in hourly samples. The almost complete omission of the heavy fall on 28 September is reflected in the line of near-zero Pluvimate values along the y axis.

For small amounts (Figure 3), the picture is very unclear. The purpose of this plot was to try to identify the effects of the dense fibre filter wedged within the funnel itself in conditions of light precipitation, which at least visually appeared to represent a considerable obstruction to the passage of rainwater through the base of the funnel. In support of this there are numerous zero records on the Pluvimate when rainfall was recorded in the Lambrecht gauge, but there are also a number of records when the converse is true. However, it is likely that at least some of the latter are spurious counts for various reasons as suggested earlier. A closer examination could examine logger change times, wind records etc in an attempt to narrow this down more precisely.

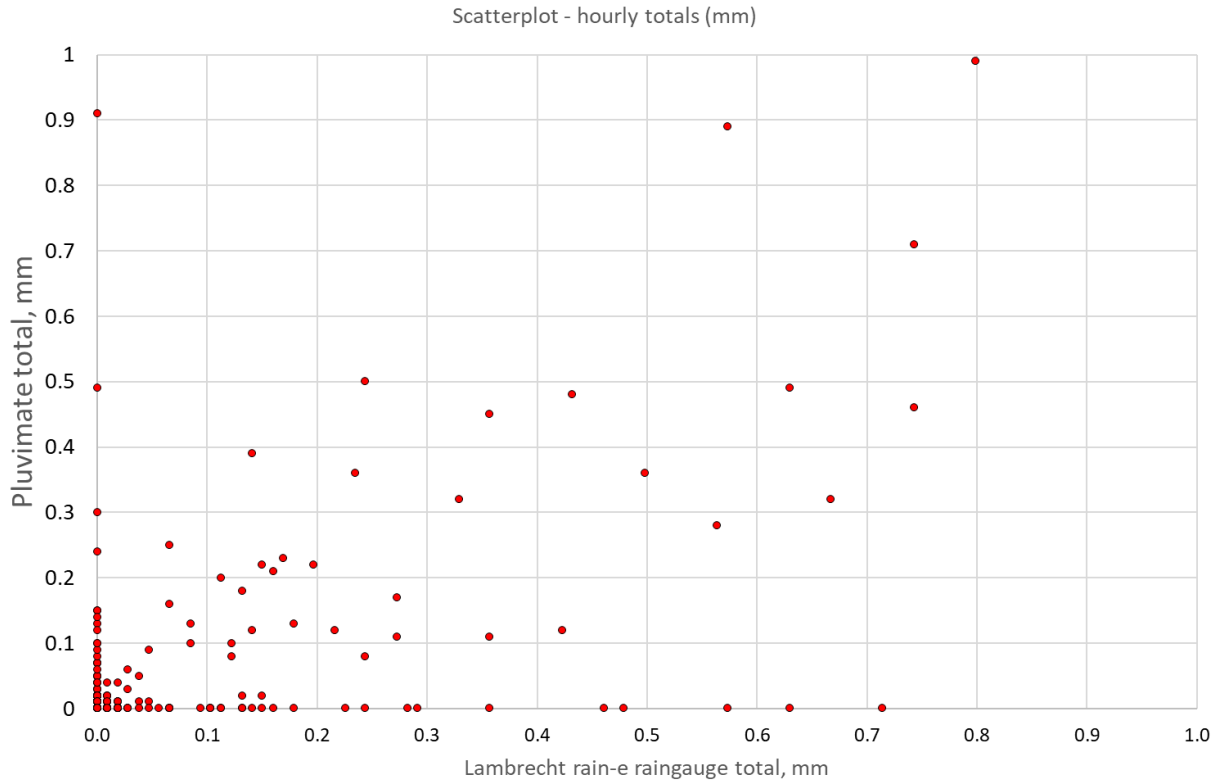

Figure 3*. The same dataset as in Figure 2, but with an expanded scale showing only hourly totals ≤ 1.0 mm for clarity on small amounts*

The relationship between any two properly exposed and calibrated raingauges should be linear, at least at rainfall rates below 50 mm/h or thereabouts. Figure 4 shows the equivalent hourly scatterplot for the Didcot TBR against the Lambrecht, for comparison with Figure 2. Here the distribution of points is less granular owing to the difference in resolution between the two gauges, namely 0.01 mm Lambrecht and 0.2 mm Didcot TBR, but the linear relationship is self-evidently much stronger than with the Pluvimate scatterplot in Figure 2; a confident least squares regression line can be fitted as shown (y = 1.0121x).

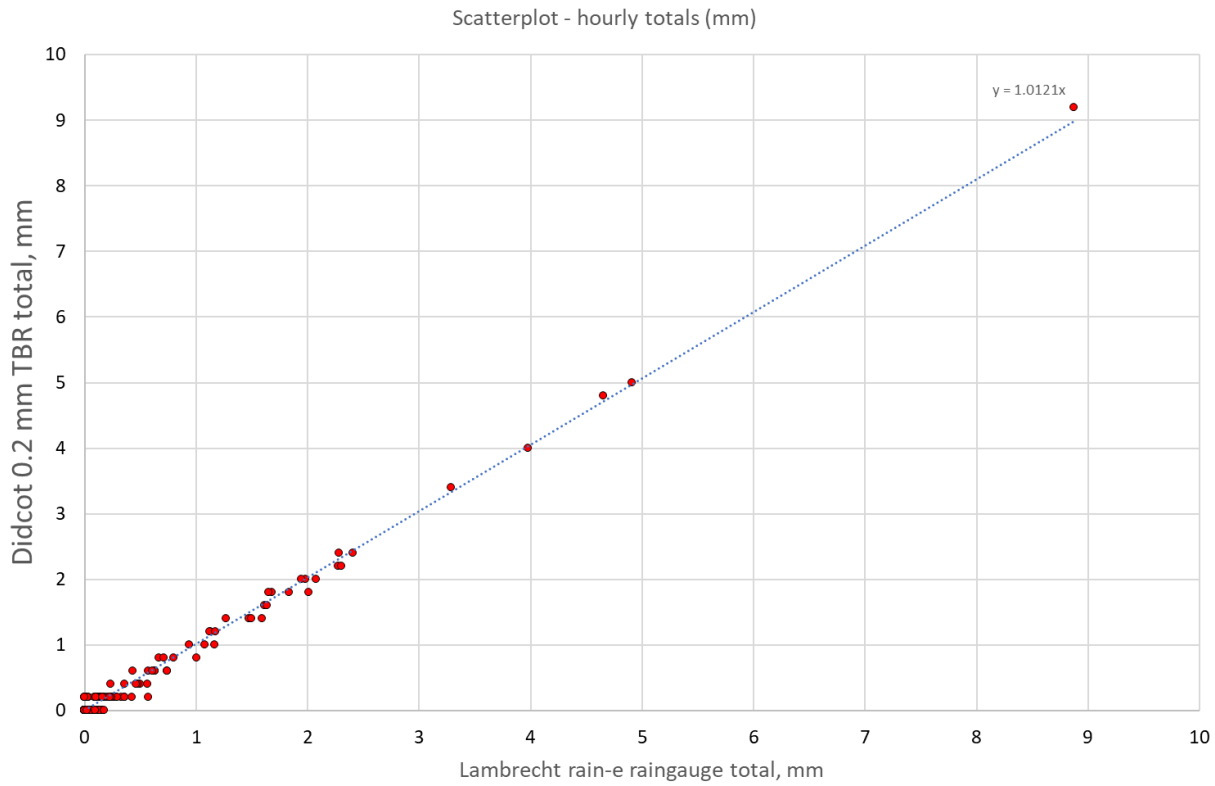

***Figure 4**. Scatterplot of hourly rainfall amounts (mm) as logged by the reference gauge (Lambrecht rain-e, x axis) and the Didcot 0.2 mm TBR (y axis) over the comparison period, 24 July to 29 September 2021; compare with Figure 2*

Comparisons of short-period intensity measurements

Other than the heavy rainfall event on 28 September, which the Pluvimate gauge failed to record, there was only one instance of heavy rainfall during the trial, namely during the afternoon of 9 August. Figure 5 shows the 1 minute intensities, in mm/h, from the Pluvimate gauge (green line) and the Lambrecht gauge (red line). The Didcot record is not shown as the 0.2 mm resolution is too coarse to permit reliable 1 minute intensity sampling. During the 2 hour period 1401-1600 UTC shown in Figure 5, the Pluvimate gauge recorded 10.09 mm (55% of the day's total of 18.45 mm) and the Lambrecht gauge 8.19 mm (56% of the day's total of 14.70 mm). The records are in good temporal agreement, but the Pluvimate record is (a) rather high (the daily total amounting to almost 25% in excess of the checkgauge fall of 14.8 mm, whereas the Lambrecht was within 0.1 mm of the checkgauge), and this is reflected in the intensity distribution; and (b) there is evidence that the nozzle continued to drip for some time between about 1455 and 1520 UTC after the cessation of the first period of heavy rainfall.

However, the lack of other short-period heavy rainfall events limits this observation to a sample of one event.

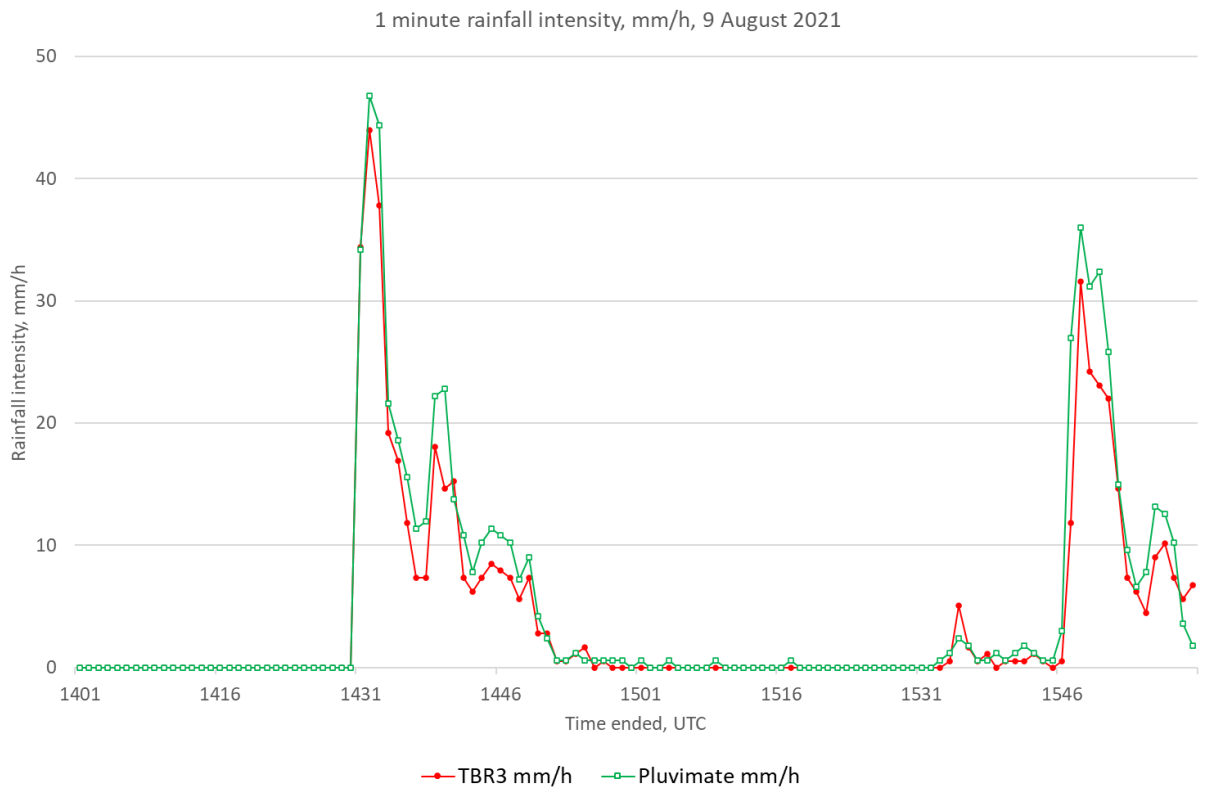

***Figure 5**. One-minute rainfall intensities (mm/h) as observed by the Pluvimate gauge (green) and the Lambrecht gauge (red), for the period 1401-1600 UTC on 9 August 2021*

Additional observations

The short period of this comparison and the time of year did not include any solid precipitation (hail or snow), but it is likely the Pluvimate's relatively shallow funnel would result in outsplash in heavy rain, bounce-out of hail, and limited retention of wind-borne snowfall. It is relevant to note that the three comparison gauges all include much deeper funnels for this reason.

The funnel is retained on the plastic tube by a single slot-head screw with a thread cut into the plastic tube itself. It was found to be very easy for the screw to fall out while being undone and drop into grass cover below the gauge. On one occasion it took several minutes searching on hands and knees to recover it. If these gauges were to be used within a network, a different fixing method, fitted with a retaining thread, would be advisable to prevent loss. It is also extremely easy to place the funnel nozzle-down accidentally on a nearby flat surface whilst retrieving and then replacing the logger; doing so could easily damage the surface characteristics of the nozzle itself and thus possibly the droplet calibration factor.

Summary and conclusions

Unfortunately, the performance of the Pluvimate gauge has been too erratic to consider it suitable for routine meteorological measurements. The gauge in its current form simply cannot be recommended where a reliable, accurate and consistent record of daily or sub-daily rainfall is required; a basic 0.2 mm tipping bucket gauge would, at similar cost, provide demonstrably more reliable, more consistent and

more accurate measurements, while a load-cell gauge such as the Lambrecht rain-e, although considerably more expensive, would allow much greater accuracy, reliability and reduced maintenance.

In conclusion: unless a compelling reason can be found to continue the comparison, it is proposed to terminate the trial at this point. PiTech Research are warmly thanked for the loan of the gauge.

Dr Stephen Burt

1 October 2021