FIELD TEST: LAMBRECHT RAIN[E] HIGH-PRECISION PRECIPITATION SENSOR

The rain[e] precipitation sensor from Lambrecht meteo GmbH of Göttingen, Germany (www.lambrecht.net) is a high-precision digital raingauge with a claimed resolution of 0.001 mm of rainfall and 3 seconds in time, the output from which is ideally suited to logging as part of an automatic weather station (AWS) or within a remotely telemetered precipitation network. The rain[e]'s high resolution, nominally 200 times better than a conventional 0.2 mm tipping bucket raingauge, offers numerous advantages when compared with conventional sensors, specifically the accurate determination of short-period rainfall amounts and intensities (from under 1 minute to 60 minutes), and the ability to output rainfall intensity continuously over periods down to a few seconds.

Figure 2. The experimental site at the Stratfield Mortimer Observatory in Berkshire, southern England, looking south-west. The Lambrecht rain[e] unit is on the left of the picture, with the 1000 cm² 0.1 mm TBR in the centre of the row of three raingauges and the 314 cm² 0.2 mm TBR on the right. The five-inch standard gauge is located between the TBRs and the enclosure fence. Photographed on 14 October 2015: © Stephen Burt.

This is particularly important for continuous real-time 'ground truth' calibration of radar and satellite remote sensing of precipitation, often poorly served by current raingauge networks. This instrument also appears capable of providing objective and repeatable measurements of rainfall duration, eliminating tedious and time-consuming manual analysis of paper chart records.

Instrument principles and design

The most common precipitation sensor in modern AWSs is the 'tipping-bucket', a mechanism first described by Christopher Wren around 1663. Precipitation from a collecting funnel is channelled into one of two 'buckets' balanced on a pivot: one bucket fills with water until its weight exceeds that of a counterbalance, at which point it 'tips' forward out of the path of the incoming flow of water, emptying as it does so and bringing the other bucket into place underneath the funnel. As the bucket tips, an integral magnet swipes over a reed switch, making and breaking a brief electrical contact: each pulse generated represents one increment of rainfall. The process repeats with the second bucket, after which the original bucket takes its place under the funnel once more and the cycle repeats as long as rainwater enters the funnel. The device is thus self-emptying and of infinite capacity: the total rainfall over any period is simply the number of tips during the period multiplied by the bucket capacity (in mm).

Although tip ***times*** can be determined accurately, the time taken to ***fill*** the bucket is unknown and may represent more than one period of rainfall, and so intensity estimates are poorly constrained, particularly in light precipitation. The Lambrecht unit mounts the tipping bucket mechanism on a load cell (Figure 1), thus generating continuous digital output of the mass of the sensor system — not a new idea, but requiring modern high-precision electronics to make it practical. The instrument seamlessly compensates for reductions in mass caused by the tipping of the buckets to generate continuous digital output of precipitation amount every 3 seconds. The collecting funnel is 200 cm² in area and the resolution of the load cell sufficient to provide better than 0.01 mm precipitation resolution from the small tipping buckets within the unit. Effectively, the resolution of the unit is limited only by surface tension.

Sidebar: How many drops?

Lambrecht claims their sensor "… allows single drop measurement at the high resolution of 0.001 mm". But is 'single drop measurement' really possible?

In practice, the surface tension of small droplets acts to resist droplet passage through the funnel and its dirt filter, especially when surfaces are dry: only once droplets reach a certain size will gravity outweigh surface tension and the droplets drip into the buckets and be weighed. What then is the minimum volume of water needed for the instrument to register, in number of raindrops?

The volume of liquid over any specified area is given by $\pi r^2 d$ where πr^2 is the area of a circular funnel of radius r, and d the depth. The area of the rain[e] collecting funnel is 200 cm² (2 x 10^5 mm²), so 0.001 mm depth of rainfall (the claimed resolution) amounts to 20 mm³ of water. Assuming spherical droplets, droplet size is given by the volume of a sphere (= 4/3 πr_d^3, where r_d is the droplet radius). A single 20 mm³ droplet thus has a radius of 1.68 mm - a very large raindrop or, more likely, the accumulation of numerous smaller droplets: just over 300 drizzle droplets of 0.25 mm radius, for example. In practice, even large single droplets tend not to drip into the sensor until the funnel is thoroughly wetted, and thus surface tension limits the working resolution to 0.01 mm or a little better. 'Single drop resolution' is doubtful, but even so a real twenty-fold improvement in resolution is very welcome.

Installation and logging

The gauge is mounted onto a 60 mm outer diameter pedestal or tube. The standard height for a raingauge rim in the UK is 30 cm above short grass, but because the input and output cables exit from the base of this unit it cannot be installed with its base at ground level – the minimum achievable rim height is about 37 cm (greater rim heights make for easier cable access, but will increase wind-related precipitation losses). For this trial, the gauge was installed with its rim at 37 cm. It is vital to ensure the gauge rim is level, for even slight errors will affect gauge catch and the balance of the tipping bucket mechanism. The unit requires a 12 v supply; a heated option is available for measurement of snow. Various output protocols are available, both digital and analogue, including SDI-12 and RS-485: for this trial, a simple pulse output of 0.01 mm resolution was used, an easy substitution for a standard 0.1 or 0.2 mm tipping bucket by making a trivial adjustment to the logger calibration.

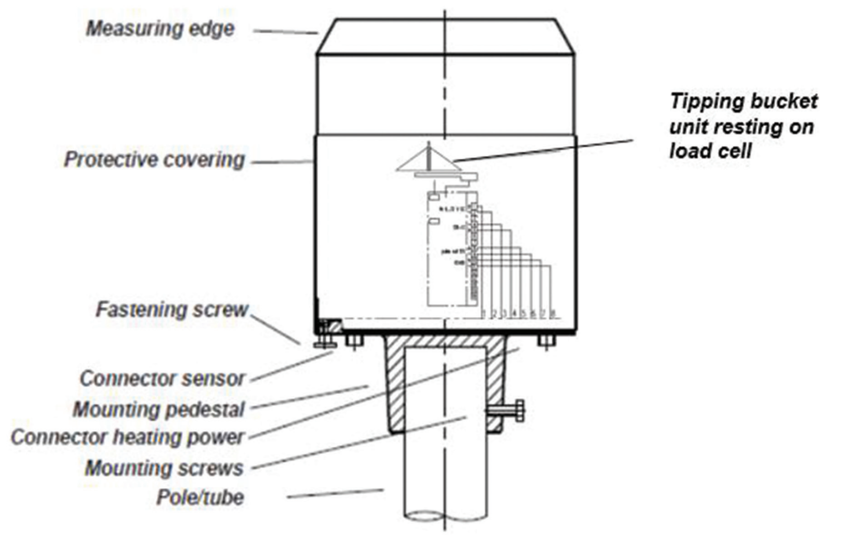

Figure 1. The main components of the Lambrecht rain[e] raingauge.
The funnel is 200 cm² in area, and the body of the gauge itself is 223 mm between the rim and the base plate.

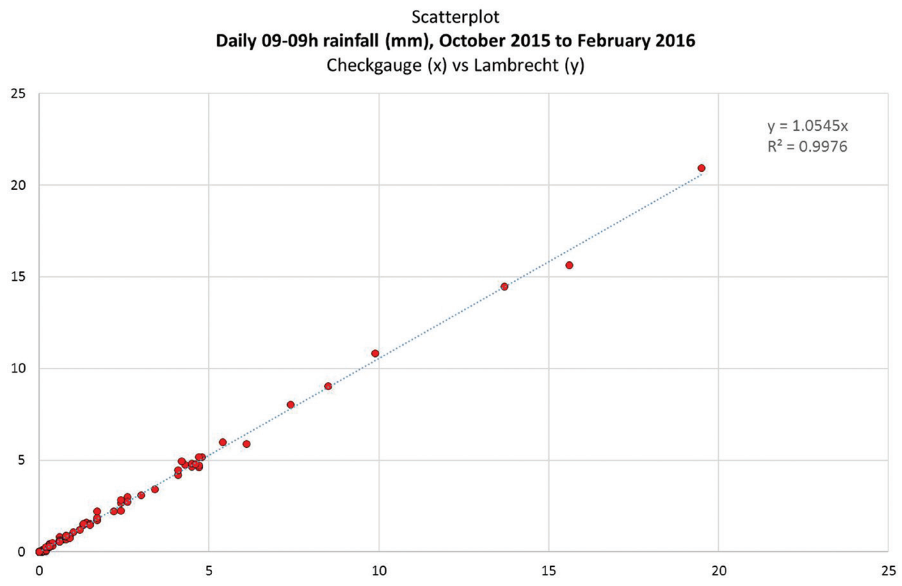

Figure 3. Scatterplot of daily totals (0900-0900 UTC) in millimetres from the five-inch checkgauge (abscissa) versus the Lambrecht rain[e] raingauge (ordinate): October 2015 to February 2016, all 108 days with 0.1 mm or more of precipitation.

Results

This field trial was conducted at Stratfield Mortimer Meteorological Observatory in Berkshire, an official UK Met Office and Environment Agency rainfall site. A new production unit was supplied by Lambrecht through their UK distributor Skyview Systems (www.skyview.co.uk). The reference gauge for daily rainfall totals was a UK-standard five-inch (127 mm) diameter storage gauge, read at or close to 0900 UTC: sub-daily totals were referenced against two professional-quality tipping bucket raingauges (TBRs), one with 0.1 mm resolution (1000 cm² area funnel) and a second 0.2 mm resolution instrument (314 cm² funnel), both polled at 1 second intervals and logged every minute. Rainfall intensities were calculated over 10 seconds, 1 minute and 5 minute intervals. All four gauges were located within 3 m (Figure 2); the rim of the five-inch gauge was at the standard 30 cm above ground, the others between 37 cm and 43 cm.

The weather during the field test period (October 2015 to February 2016) was dominated by frequent and often persistent but rarely heavy rain and drizzle from Atlantic frontal systems. Although the frequency of precipitation was greater than normal during this period, rainfall for four of the five months was close to normal. All precipitation was of rain with the exception of two days when small quantities of sleet and snow fell. There were very few instances of purely convective rainfall.

Monthly and daily totals

The Lambrecht gauge recorded slightly higher daily totals than the standard gauge and the other two TBRs, by about 7 per cent overall. The scatterplot of daily totals from the standard five-inch gauge versus the Lambrecht unit (Figure 3) shows consistent agreement between the two gauges.

Sub-daily totals

The real benefit of the additional resolution becomes clearer when examining sub-daily records. Even in slight precipitation (less than 0.5 mm/h), the Lambrecht instrument distinguished onset and cessation of periods of slight drizzle and fogdrip down to 0.03 mm/h. In long periods of moderate pre-frontal and frontal precipitation, typically 0.5 to 4.0 mm/h, the greater resolution of the rain[e] gauge permitted precise measurements of occasional short, intense pulses of rainfall otherwise difficult to quantify.

Figure 4 shows 1 minute rainfall intensities from the Lambrecht unit (red, 0.01 mm resolution) and the 0.2 mm resolution TBR (grey) for the period 1400 to 2400 UTC 30 December 2015, a prolonged period of mostly moderate rainfall from a slow-moving cold front. The beginning and end of rain spells between 1500 and 2000 UTC are more clearly shown by the Lambrecht record, as is the onset of the short period of heavy rain marking the cold front itself at 2155 UTC. The 0.2 mm TBR recorded 12 mm/h over 4 minutes commencing 2153 UTC, while the Lambrecht resolved a single, sharper peak intensity of 16 mm/h in the minute ended 2155 UTC.

Few spells of heavy or intense rainfall (4.0 mm/h to more than 60 mm/h) were observed during the trial period. These were mostly in association with line squalls at cold fronts: the highest 10 s intensity logged was 122 mm/h at a cold front passage on 3 December. A longer trial period over the summer will assess performance in convective rainfall.

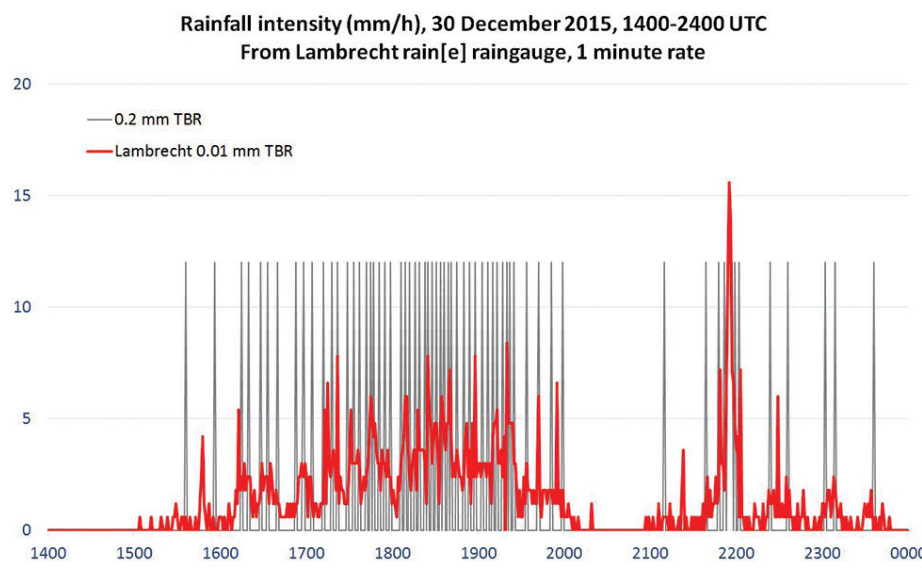

Figure 4. Time series of the 1 minute Lambrecht rain[e] raingauge intensity (red) versus the 0.2 mm TBR (grey) for a period of moderate to heavy pre-frontal and frontal rainfall, 1400-2359 UTC on 30 December 2015. Plotted every minute, units mm/h.

Summary and conclusions

The Lambrecht rain[e] raingauge combines a robust, easy to use, 'install and forget' instrument with exquisite sensitivity in both time and volume. Its high resolution permits the generation of a continuous automatic datastream of rainfall intensity at intervals of 1 minute or less, down to 0.6 mm/h or less (0.1 mm/h when sampled over 5 minutes). Its accuracy is within acceptable limits, and probably capable of improvement with on-site calibration.

Disclaimer

Opinions expressed in this article are those of the author and may not represent the views of the University of Reading.

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