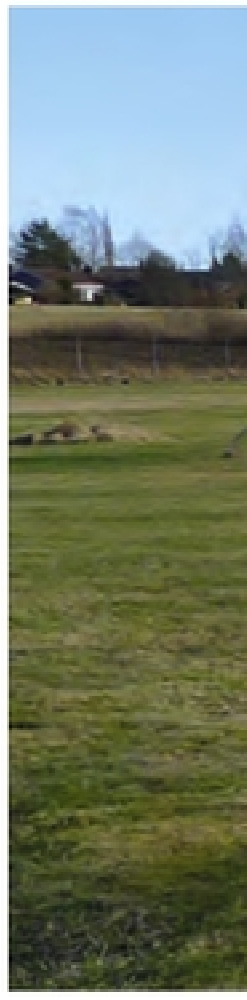
by Björn Mosdzien and Matthias Müller



SPECIAL MEASURES

The next step in the evolution of precipitation sensors

Lambrecht Meteo has taken over and extended Wilhelm Lambrecht's operations. It is launching new products, with special focus on the novel precipitation sensor, rain[e], and its unique measurement principle

The rain[e] sensor from Lambrecht Meteo is a new kind of precipitation sensor. Its development was born from the idea to combine a tipping bucket with a weighing cell – with the objective to weigh every single drop of rain that has been collected by the bucket and instantly provide the data. It has the benefit of taking the weight increase into consideration, thus avoiding evaporation or emptying effects.

The result is a precipitation sensor that combines the numerous advantages of weighing sensors with those of a tipping bucket. These benefits are to be found in the 'e' of rain[e]: ecological, exact, efficient, economical and easy.

The precipitation sensor rain[e] with its unique measurement principle will be showcased at Meteorological Technology World Expo 2015

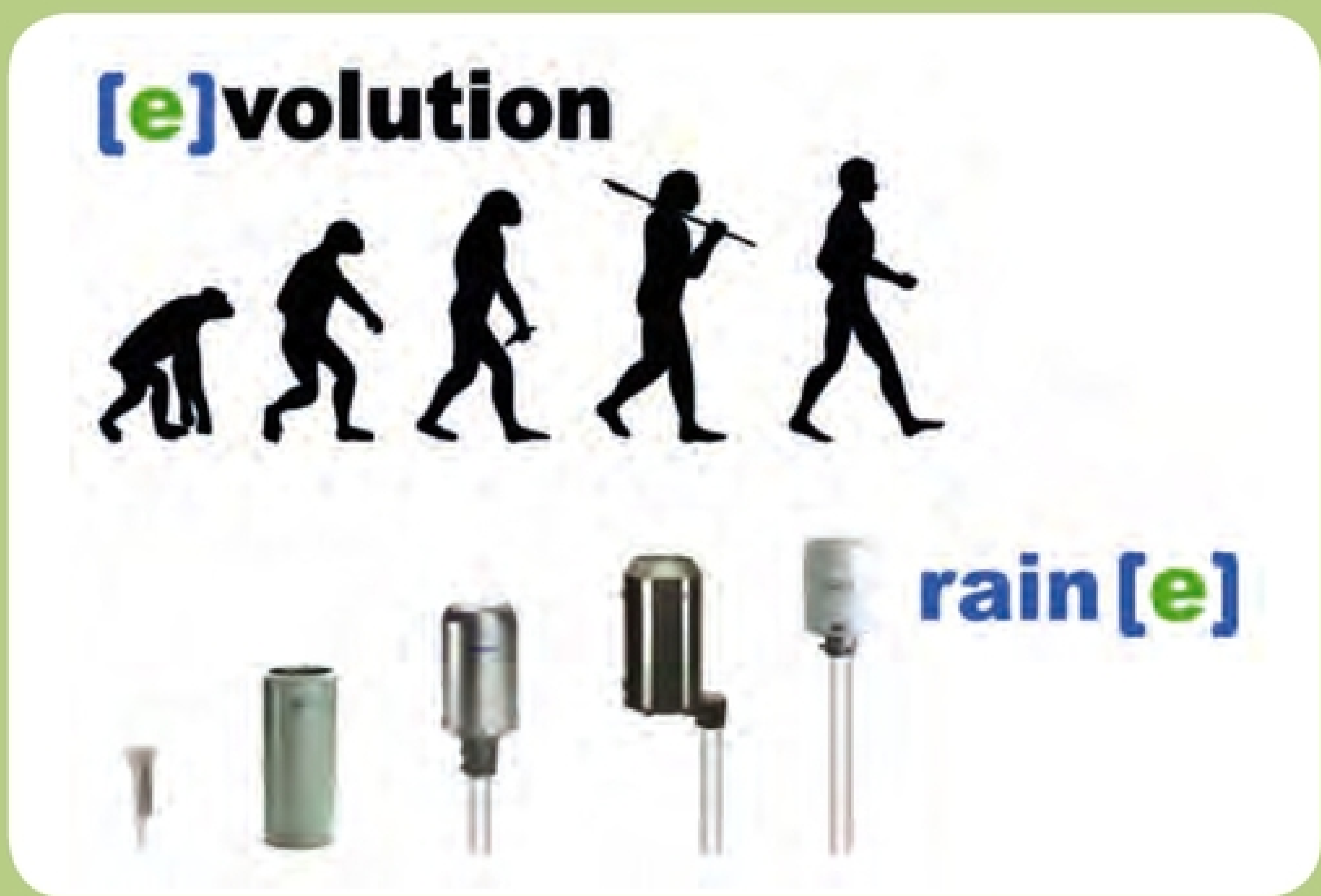
Ecological: The rain[e] is fully functional throughout the year under even the harshest winter conditions. As it works completely without any antifreeze, there is no extra cost or maintenance required.

The sensor has automatically controlled heating, enabling low energy consumption. For example, it uses only 25% of the available heating power at -20°C. Therefore the total cost of heating for five months at temperatures constantly below freezing is only around €30 (US$33) – calculation based on the high electricity prices in Germany – as opposed to €50 to €100 (US$55 to US$111) for antifreeze in precipitation collection sensors. Additionally

EVOLUTION OF RAIN[E]

In meteorology and hydrology, a precipitation sensor is applied to monitor and document precipitation per time unit. Occasionally a differentiation is made between rain gauges for liquid precipitation and snow gauges for frozen precipitation. Precipitation sensors that are equipped with (adjustable) heating can monitor both liquid and frozen precipitation (after melting).

Rain gauges have existed for many centuries. In ancient Greece, precipitation was monitored as early as 500 BC. The first standardized precipitation sensors were introduced in Jeonju, the present-day South Korea, in the mid-15th century by King Sejong and his son. The device was basically a standardized container, deployed as an official instrument throughout the country. The first precipitation sensor with a mechanical self-emptying tipping bucket was developed around 1662 by Sir Christopher Wren. Most of the tipping buckets used today function with two shovels or containers, symmetrically assembled like a seesaw around an axis. These tipping buckets are designed so that either of the buckets is below a funnel. The precipitation is captured by the funnel and falls into the bucket. Once a defined volume is exceeded, the seesaw tips and the second bucket goes below the funnel. Through a magnet, this movement transmits a pulse to a switch, which in return provides the signal for the measurement. For the standardization of the signal, the collecting area of the funnel and the bucket volume are



rain[e] installed in north Norway

the antifreeze usually requires costly disposal as a hazardous waste.

Exact: The high-precision self-emptying collecting device has two chambers that fill alternately with the collected precipitation. At a certain volume the collector tips over and empties. Each drop entering the collecting device is monitored at the remarkable resolution of 0.001mm/m², enabled by a high-precision weighing cell with a measurement accuracy of ±0.01g.

Efficient: rain[e] combines the highest functionality with a very compact design. A total of six analogous, digital and serial interfaces enable data output of precipitation volume, intensity, event and status. Its highly efficient and intelligent heating consumes less than 0.84kWh on a normal winter day and minimizes evaporation. No negative measuring effect by the funnel could be detected in field tests when meteorological services and institutes directly compared the rain[e] with collecting weighing sensors. The rain[e] regularly tests its heating functionality, even in warm weather, to detect failure before heating is required.

Economic: rain[e]'s small dimensions and low weight enable an 80% lower logistic cost than the larger collecting weighing sensors. rain[e] is approximately 50% less expensive than other weighing precipitation sensors – and has comparable or even superior functionality.

Easy: rain[e] is easy to handle. At 2.5kg it is lightweight among precipitation sensors. It is also easy to lift, transport and install. Adjustment and calibration of the weighing system is performed simply by using a precise calibration ball. For this purpose, the collecting device is manufactured in such a way that the ball automatically rolls to the center for reproducible measurements.

rain[e] operation

The chart in Figure 1 depicts how rain[e] functions. The precipitation is collected by the funnel with its standardized collecting

adjusted to each other so that one seesaw tip corresponds to a precipitation height of 0.1mm per 1m² (mm/m²) or 0.2mm/m². Sometimes (in countries using the metric system) the precipitation height is scaled in 0.01in but still per m².

A connected datalogger monitors, saves and accumulates the triggered pulses, which are depicted as total precipitation per time. The usual units for the intensity are millimeters of precipitation per minute (mm/min), per hour (mm/h) or per day (mm/d), while the precipitation amount in millimeters relates to 1m² (1mm/m² corresponds to 1 liter/m²). Thus the additional indication '/m²' is usually not applied. Generally, tipping buckets are prone to intensity dependent measurement errors. These can be minimized, but not fully eliminated, by mechanical methods. Consequently, intensity-based deviations of the measured precipitation can be compensated for electronically, either directly in the sensor or in a connected datalogger.

A further measurement technique is to weigh the precipitation that is collected in a large container. While these systems measure the precipitation quantity very accurately and at the high resolution of 0.01mm or 0.001mm, they often are bulky and expensive. They also require maintenance, specifically during as well as shortly before and after the winter months, by adding and replacing antifreeze liquids.

Other devices employ optical or even acoustic methods for precipitation measurement.

Optical methods are based on building a light band. Precipitation drops falling through this band are counted and their size is measured to calculate the precipitation. These optical precipitation sensors are known as disdrometers. Typically they are expensive, less suitable for volume measurements and prone to erroneous precipitation events caused, for example, by insects or seeds. However they are a good choice for monitoring precipitation intensity. Acoustic systems basically hear the impact of the precipitation and can thus differentiate between intensities. However, they are limited when it comes to monitoring fine drizzle, snow or generally fine precipitation.

Fairly recently, precipitation sensors based on radar technology have entered the market. As with acoustic systems, the radar based devices are mostly suitable for precipitation intensity rather than quantity and have the same limits in the measurement of fine snow.

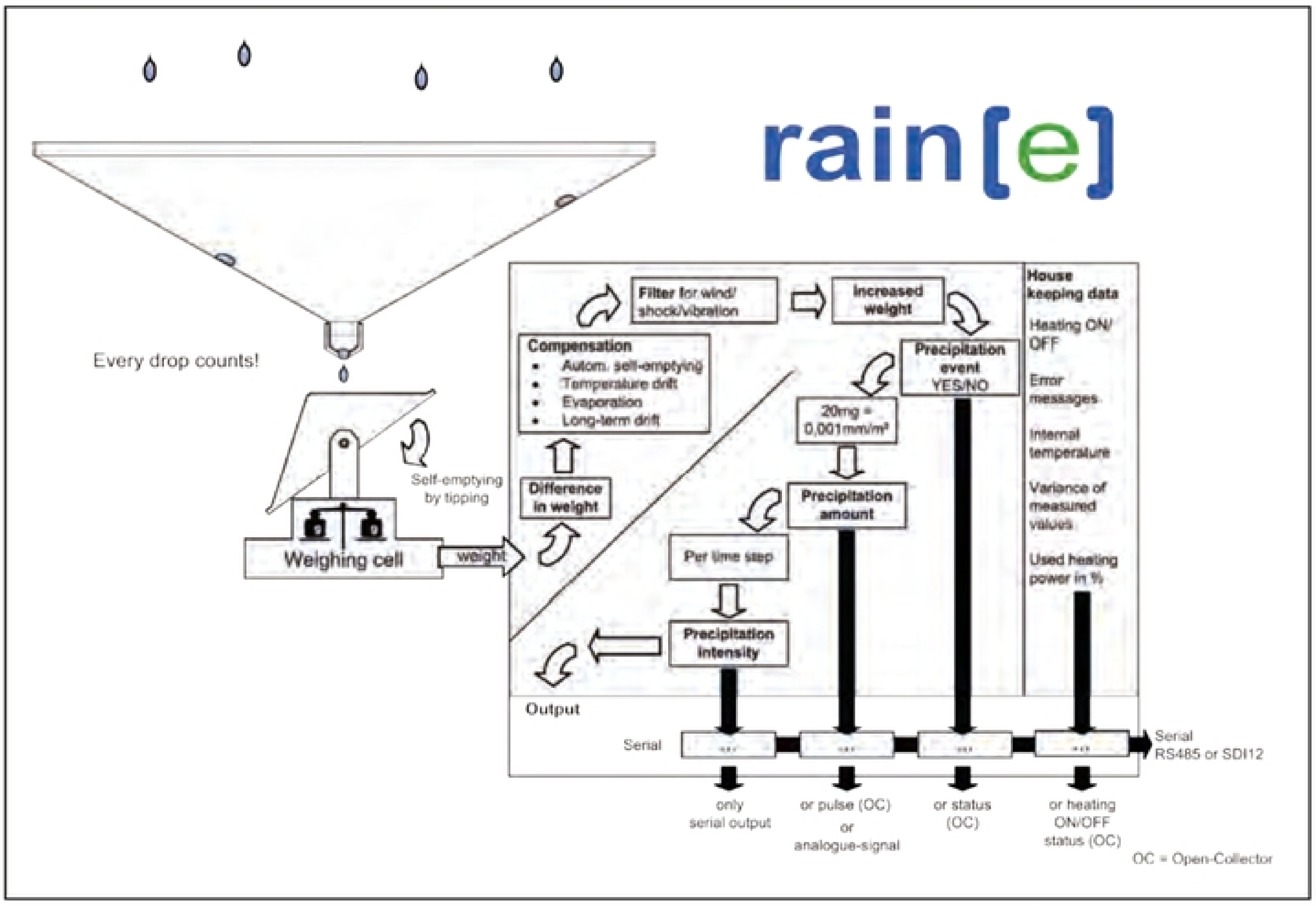


Figure 1: Function chart for rain[e] – note the internal heater for melting snow

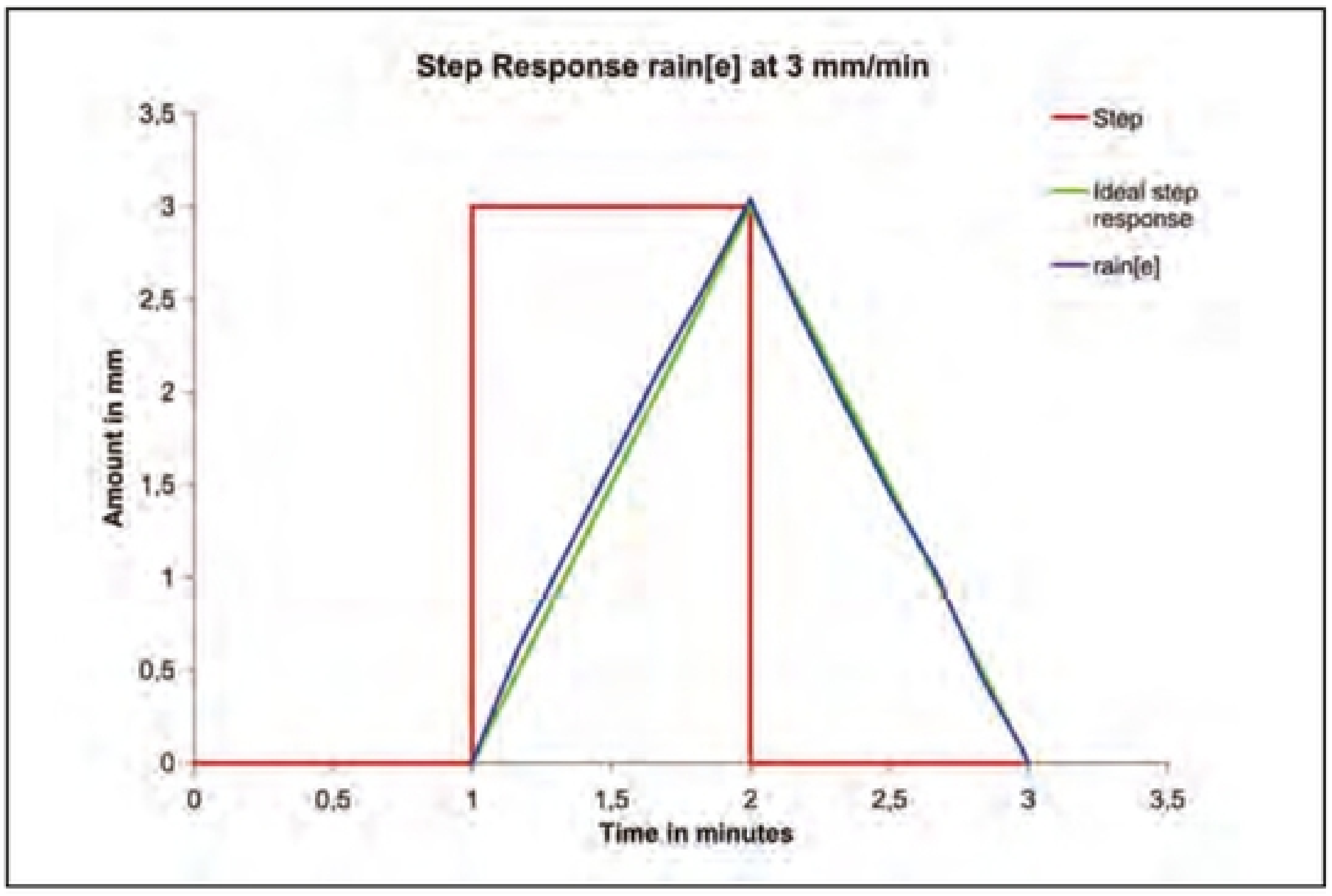


Figure 2: rain[e] step response after a one-minute precipitation of 3mm/min (see red line)

area of 200cm². Solid precipitation, such as snow, is melted by the intelligent heating.

The collected precipitation travels from the funnel through the drop shaper and ends in the self-emptying collecting bucket, where the drop is immediately weighed.

However it is not the absolute weight that is measured, but the weight increase over the former measurement. Based on the high sampling rate, the long-term drift of the weighing cell, temperature drift and evaporation are almost automatically compensated for. Once one of the measurement chambers is filled, the collecting device tips over and empties, and measurement continues in the second chamber. During the tipping process, the rain[e] sensor compensates for possible deviations through an in-built algorithm.

Subsequent filter stages compensate for wind, shock and vibration. The funnel, combined with the filter stages, gives a close to zero sensitivity to wind. Due to their bigger surface, collection weighing precipitation sensors are much more susceptible to wind, which affects measurement results.

After the filtration, the monitored weight increase is analyzed and – in the simplest case – depicted as a precipitation event. With the correlation of 0.02g = 0.001mm, the precipitation amount is calculated. The measured precipitation amount is provided as accumulated sum since the last data recall or total amount since start of the system with a resolution of 0.001mm.

The depicted step signal was monitored using rain[e]'s serial interface. Figure 2 shows the step signal following a one-minute precipitation of 3mm/min (red). The measured precipitation (blue) is in accordance with the ideal step signal of a sliding one-minute intensity (green), and demonstrates rain[e]'s fast reaction. The step response of most other collecting weighing sensors shows a time delay of several minutes. The step signal has been confirmed by several meteorological services.

rain[e] calculates precipitation intensity, rated over time, based on the volume increase. The intensity is available as precipitation intensity during the latest measured minute in millimeters per minute and millimeters per hour, as intensity since the last measurement, or as precipitation intensity during a time, *t*, with average, minimum and maximum values.

For intensity measurements, it is best to use the rain[e] calculated values rather than manually calculating intensity based on counted pulses. rain[e]'s pulse output is merely intended for amount measurement, as depending on the precipitation intensity, pulse output can be delayed.

The serial interfaces RS485 and SDI-12 provide the best measurement results as well as the widest functionalities. As well as transmitting measurement data, the serial interfaces provide housekeeping data as well as error messages. Examples include information on heating (on/off) and heating energy consumption as a percentage of the maximum possible energy consumption. This value shows how much of the available heating power is really in use. To analyze measurement quality, variance in the measurement data is available.

Precipitation amount data can also be generated as an analogous value. This is a short term for the available analogue signals: 0 up to 20mA, 4 up to 20mA, 0 up to 2.5V and 0 up to 5V or as pulse via the Open-Collector. The latter can also provide status information such as precipitation event or heating on/off.

Lambrecht Meteo will present rain[e] at Meteorological Technology World Expo 2015, held from October 13-15 in Brussels, Belgium. Come and visit Booth 1220 to see how rain[e] measurements are done, and how efficiently and easily the self-emptying bucket operates. ∎

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