by Kurt Nemeth & Eduard Beck

HERE COMES THE RAIN

High-precision measurement of hydrometeors

A new version of the Parsivel laser-based disdrometer offers greater levels of accuracy in the precise identification of hydrometeors

A new system, the OTT Parsivel^2, is able to measure hydrometeors less than 2mm with an uncertainty of ±1 class, and hydrometeors over 2mm with an uncertainty of ±0.5 classes. As a result, Parsivel will improve the characterization and typing of precipitation, derived precipitation rate, visibility in precipitation, and radar reflectivity.

Standard rain gauges record the amount of precipitation, and many also provide an approximate value for intensity. An electronic disdrometer records the size and number of precipitation particles and, in addition to the amount and intensity, also determines the type of precipitation. Depending on the measurement method selected, the individual hydrometeor is recorded either mechanically when it hits a membrane or optically.

The extinction principle was first proposed in 2000 for the measurement of precipitation. This direct physical measurement principle registers precipitation particles on the basis of the shadowing effects that they generate when falling through a light band. From the degree and duration of the shadowing effects, the size and rate of fall of the particles can be derived. As a result, the precipitation event can be classified within a range of 32 precipitation classes, e.g. as drizzle or snow.

The extinction principle made it possible, for the first time, to classify hydrometeors and to determine their distribution and derive a number of further parameters. These included the kinetic precipitation energy, visibility during precipitation spectrum analyses, and the determination of weather codes.

Figure 1: New laser-based disdrometer OTT Parsivel^2

Laser-based disdrometer

Employing the extinction principle, OTT Hydromet developed a new kind of laser-based disdrometer in 2005. The OTT Parsivel was drift-free and automatically compensated for the influence of temperature and the aging characteristics of the laser diodes. It was comprised of two symmetrically arranged measuring heads. One of them housed the transmitting unit, which generated a horizontal laser beam; the other accommodated the receiving unit, which converted the beam into an electrical signal.

The absolute measurement accuracy of a laser-based disdrometer is proportional to the homogeneity and therefore to the quality of the laser energy concentration of the laser band. Although the OTT Parsivel showed device-specific, heterogeneous characteristics, these were individually calibrated using simulation with reference particles and statistical correlation methods, thereby enhancing the statistical measurement accuracy. However, the spectrum of the classes for size and velocity were corrected by the calibration data. This led to measurement uncertainties for the raw data classification (±2 to ±3 class widths in the whole measuring range from 0.2mm to 25mm). Assuming a natural statistical distribution of hydrometeors in the process of precipitation, the statistical correlation did indeed compensate the output data calculated, but not the actual spectrum of precipitation.

In comparison with optical disdrometers, which operate on video technology, the price-performance ratio of the OTT Parsivel was extremely favorable, and the system became widely popular in measurement networks. Seeking to continuously improve the technology, OTT Hydromet identified a need for a more homogeneous laser band and higher accuracy, including the raw data. This led to the development of OTT Parsivel^2.

Laser energy concentration

OTT Parsivel^2 provides homogeneous laser energy concentration over the complete laser bandwidth, offering an impressive measurement accuracy of the class widths, which until now has only been available in expensive disdrometers: 0.2 to 2mm, ±1.0 size class; 2 to 25mm, ±0.5 size class.

Naturally, the high accuracy of the raw data also has a direct effect on the calculation of precipitation intensity, present weather codes, visibility during precipitation, and radar reflectivity.

In addition to optimization of raw data accuracy, a number of further enhancements have been incorporated into the design of the Parsivel^2. These include:

integrated USB interface to facilitate laptop connection; integrated connector plug for power supply and data interfaces; electrical supply for measurement electronics and heating is separated galvanically to facilitate the utilization of solar power, while the heating system is supplied via the mains. Other enhancements include: reduced electricity consumption of 1.4W with a wide voltage supply range of nine to 36VDC; integrated temperature sensor, as in theory insects passing through the laser band could be interpreted as snow – this is now excluded through plausibility checks on the basis of measured temperature; and finally, control LEDs for displaying function, measurement, communication, and status.

Measuring heads of OTT Parsivel²

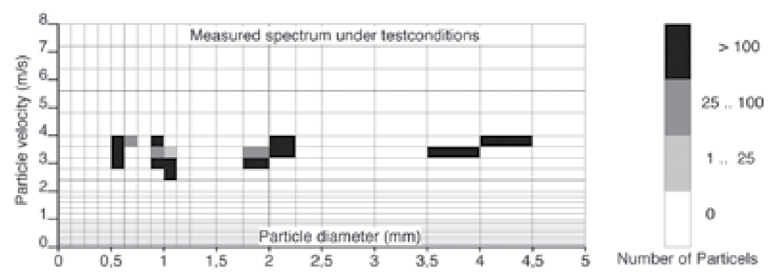
Raw data check

At the end of the production process for each new OTT Parsivel², the raw data is accurately and reproducibly checked. For this, the primary data, particle size and velocity are simulated with a transparent rotating disc incorporating black circles of various diameters. Following this evaluation, the maximum measurement uncertainty of ±1 size class is obtained and documented in the factory acceptance test certificate (FAT).

Individual calibration by statistical correlation is no longer necessary, as a result of the homogeneous laser module of the Parsivel². This is an advantage to users in the field because electronic components do not have to be sent in for repairs in the event of a defect. Instead they can be exchanged and repaired on-site by OTT Hydromet or authorized local partners. Factory checks and elaborate recalibration procedures are also unnecessary, as a result of the new features employed by OTT Parsivel². Static influences, such as the level of contamination of the optics and the aging characteristics/long-term stability of the laser diodes, are automatically calibrated by integrated software in the event of "no precipitation".

Accordingly, measurement results are not influenced by these parameters, and high levels of accuracy are maintained in the long term. Dynamic disturbance variables such as the temperature characteristic of the laser diodes are compensated by the differential extinction measurement method. Consequently, the device is virtually maintenance free and therefore ideal for unmanned use, even at remote measuring stations.

Testbericht	Test report		
Stromaufnahme bei 24 V	Current consumption at 24 V	[40 .. 65]	61 mA
Stromaufnahme mit Heizung	Current consumption with heating	[3400 .. 3600]	3515 mA
RS 485 Schnittstelle	RS 485 Interface		ok
SDI-12 Schnittstelle	SDI-12 Interface		ok
Impulsausgang	Pulse Output		ok
Messabweichung (Teststand)	Deviation (Test rig)	[0 .. 25]	20 % Abw.
Werkseinstellung	Factory setting		ok
Funktionstest	Performance check		ok



Detail of factory acceptance test (FAT) for a specific Parsivel²

Precipitation intensity

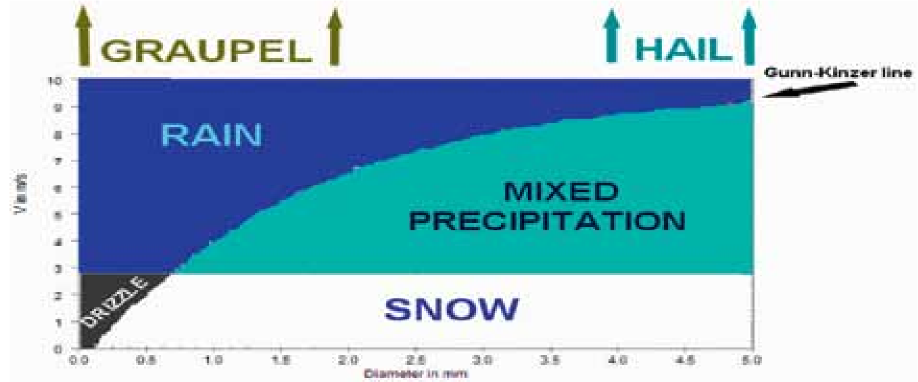
To determine the intensity of precipitation, the internal evaluation logic takes account of each individual hydrometeor in the raw data field. In addition, the absolute particle size, a drop shape model, and factors such as edge measurement correction are included in the calculation. This renders the calculation of intensity particularly precise. Just a few particles detected within the measurement interval lead to an intensity output without delay, corresponding to a discrimination threshold of 0.001mm/h.

For liquid precipitation the measurement accuracy is at least ±5% across the whole intensity range up to 1,200mm/h. This corresponds to the requirements of the World Meteorological Organization (WMO) in accordance with the WMO Guideline No. 8.

In this way, the system represents a maintenance-free alternative to tipping bucket or weighing rain gauges for liquid precipitation. The original OTT Parsivel had already been successfully tested in a WMO comparative test for precipitation intensity in Vigna di Valle, 2004 to 2008, and was found to be suitable for use in accordance with the WMO guidelines.

Present weather sensor (PWS)

As a PWS, the system classifies the current weather and the types of precipitation (rain, sleet, snow, hail, and graupel) in accordance with a weather code laid down by the WMO. Unmanned weather stations require an automatic and reliable method of identification. A high level of accuracy of the raw data is particularly important for weather phenomena during the lowest intensities, with only a few particles and mixed spectra. In field comparisons, this is where most discrepancies occur between



Classification of precipitation by drop size and velocity. The Gunn-Kinzer line indicates the terminal fall velocity for raindrops of various sizes

observed and automatically specified weather codes. Therefore, plausibility checks are required.

With the aid of the extinction method, the Parsivel² accurately measures the size and velocity of individual hydrometeors. Both parameters are incorporated into the DSD (drop size distribution) classification.

Plausibility checks of PW records are quickly conducted by analyzing raw data and spectra. Each transmitted spectrum can be displayed graphically and is easy for an observer to interpret, so that it can be used for any corrections to the automatic weather code. Naturally, checks are also possible via software routines at the control center, so that high observer quality can be maintained while manpower can be reduced at the measuring stations.

Optimizing weather radar through ground-based disdrometer data

To ensure a timely warning of impending flooding, it is necessary to measure the amount and spatial distribution of precipitation quickly and accurately. This goal is achieved with a combination of weather radar measurements (spatial information with reduced accuracy) and ground-based disdrometer measurements.

Normally, a precipitation radar measures the radar reflectivity (Z) on the basis of ground shadowing only from a height of 1,000 to 2,000m above the ground, therefore providing information to localize precipitation areas. In order to accurately determine the precipitation input, a quantitative recording of the precipitation intensity (R) on the ground is required. This requires both extrapolation of the radar data to the ground and derivation of the reflectivity factor Z to the precipitation rate R.

Usually, the spatial distribution of the precipitation rate from the radar measurement is adjusted with data from rain gauges on the ground with the shortest time delay possible. A potential problem is the so-called "bright band", i.e. the snow/rain melting layer, which is usually about 200-500m below the zero degree boundary. The bright band can lead to overestimates of the precipitation rate, as melting snow is highly reflective. However, the height of the bright band is not always accurately recorded by weather radars.

Conventional rain collectors can also fail in this respect: although they supply values to adjust the precipitation intensity R, they do not take account of either the type of precipitation or the height of the bright band. As a present weather sensor with a modern optical disdrometer, OTT Parsivel² supplies the type and distribution of precipitation at the reference height with the ground temperature. Based on this information it is possible to adjust weather radar data without delay. Precipitation forecasts that are derived from such data become considerably more precise and thereby improve the quality of flood forecasts.

"The bright band can lead to overestimates of the precipitation rate, as melting snow is highly reflective"

Despite the many advantages of the modern optical disdrometer, human weather observers are still indispensable for many locations. However, modern measuring devices offer a variety of functions that exceed human recording capacity and are able to deliver very accurate data in a timely manner. They are extremely robust and reliable; they never go on vacation or suffer from the frailties of human health; and they can withstand extreme weather conditions. ∎

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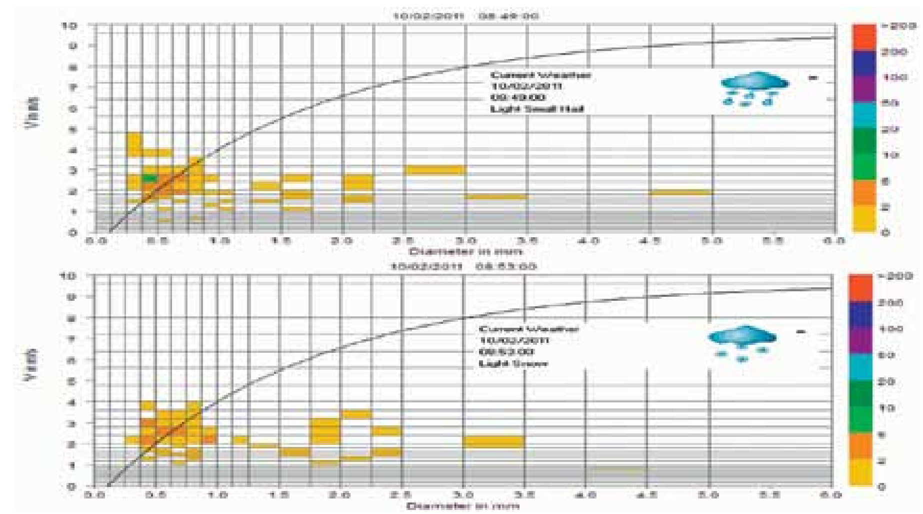

Displays of raw data spectra, showing Gunn-Kinzer line and automatic PW code (above "Light small hail"; below "Light snow"). The color code indicates the frequency of measured hydrometeors