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Application of optical Particle Tracking Velocimetry (PTV) to determine continuous discharge time series

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The measuring of flood events is associated with many challenges. Among them is the determination of flow velocities for the derivation of discharge. Most of the applied methods for velocity determination the disadvantage that they work in direct contact with water. This often makes measuring under critical flow conditions dangerous. Optical measurement methods have a great advantage because they can work remotely, i.e., without water contact.

For representative discharge measurements, flow velocity measurements over the entire width of the river cross-section are required. This is a major challenge in the application of PTV, because visible particles must be present across the entire cross-section, which is not always the case. The potential measurement gaps in the surface velocity distribution have a negative effect on the quality of the discharge determination. Because optical measurement methods are relatively new in hydrology, there is not yet a standardised procedure with which the discharge can be determined.

The "OptiQ" method presented here is an approach for determining discharge using PTV. This method is based on the continuity equation, which is dependent on two variables, the flow area and the mean flow velocity. The challenge here is to determine the depth-averaged flow velocity, because PTV is used to determine the surface velocity. To get the depth-averaged flow velocities, the PTV results are averaged over a transect and converted using a velocity coefficient. The arithmetic mean, the velocity area method (DIN EN ISO 748:2008-02) and the moving average are considered as averaging methods. A statistical approach was chosen for closing measurement gaps that occurred in the velocity distribution. In this approach, the measurement results with similar discharge conditions in the entire time series, i.e. PTV results for the same water levels, are statistically analysed, filtered and summarised in a lookup table. The gaps in the measurements due to missing particles are filled with the data from the lookup table.

For the data collection, three camera gauges were installed at regular gauging stations of the Saxon State Agency for Environmental and Agricultural Monitoring (BfUL). The camera gauges recorded short video sequences at regular time intervals, which were used to determine the velocity distributions using the FlowVelo tool (Eltner et al., 2020). This resulted in three time series covering a period of 10-15 months. For the validation of the optical discharge time series, the regular water level and discharge measurements of the BfUL are used.

The application of "OptiQ" shows a significant adjustment of the optically determined discharge data to the reference measurement at all three gauging stations. While acceptable results were determined with the arithmetic mean only at higher discharge, the results with the velocity area method and the moving average are similarly good at all discharges. At the gauging station in Elbersdorf, the average difference from the reference value could be reduced from 29% to 15% with "OptiQ". In the next step, it is planned to further develop the statistical model "OptiQ" by using Deep Learning.