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Evaluating the catching performance of aerodynamic rain gauges through field comparisons and CFD modelling

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Accurate rainfall measurement is a fundamental requirement in a broad range of applications including flood risk and water resource management. The most widely used method of measuring rainfall is the rain gauge, which is often also considered to be the most accurate. In the context of hydrological modelling, measurements from rain gauges are interpolated to produce an areal representation, which forms an important input to drive hydrological models and calibrate rainfall radars. In each stage of this process another layer of uncertainty is introduced. The initial measurement errors are propagated through the chain, compounding the overall uncertainty. This study looks at the fundamental source of error, in the rainfall measurement itself; and specifically addresses the largest of these, the systematic 'wind-induced' error. Snowfall is outside the scope.

The shape of a precipitation gauge significantly affects its collection efficiency (CE), with respect to a reference measurement. This is due to the airflow around the gauge, which causes a deflection in the trajectories of the raindrops near the gauge orifice. Computational Fluid-Dynamic (CFD) simulations are used to evaluate the time-averaged airflows realized around the EML ARG100, EML SBS500 and EML Kalyx-RG rain gauges, when impacted by wind. These gauges have a similar aerodynamic profile – a shape comparable to that of a champagne flute – and they are used globally. The funnel diameter of each gauge, respectively, is 252mm, 254mm and 127mm. The SBS500 is used by the UK Met Office and the Scottish Environmental Protection Agency. Terms of comparison are provided by the results obtained for standard rain gauge shapes manufactured by Casella and OTT which, respectively, have a uniform and a tapered cylindrical shape. The simulations were executed for five different wind speeds; 2, 5, 7, 10 and 18 ms-1.

Results indicate that aerodynamic gauges have a different impact on the time-averaged airflow patterns observed in the vicinity of the collector, compared to the standard gauge shapes. Both the air velocity and the turbulent kinetic energy fields present structures that may improve the interception of particles by the aerodynamic gauge collector. To provide empirical validation, a field-based experimental campaign was undertaken at four UK research stations to compare the results of aerodynamic and conventional gauges, mounted in juxtaposition. The reference measurement is recorded using a rain gauge pit, as specified by the WMO. The results appear to demonstrate how the effect of the wind on rainfall measurements is influenced by the gauge shape and the mounting height. Significant undercatch is observed compared to the reference measurement. Aerodynamic gauges mounted on the ground catch more rainfall than juxtaposed straight-sided gauges, in most instances. This appears to provide some preliminary validation of the CFD model.

The indication that an aerodynamic profile improves the gauge catching capability could be confirmed by tracking the hydrometeor trajectories with a Lagrangian method, based on the available set of airflows; and investigating time-dependent aerodynamic features by means of dedicated CFD simulations. Furthermore, wind-tunnel tests could be carried out to provide more robust physical validation of the CFD model.