Assessing the wind-induced bias for the OTT Parsivel^2 optical gauge using CFD and particle tracking.

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Abstract

Amongst precipitation measurement instruments, the so called Non-Catching type Gauges (NCGs) (see Lanza et al., 2021 for a review) are quickly gaining market share, notwithstanding their higher cost and complexity. These instruments, also called in some case disdrometers, provide information about precipitation microphysical properties and being contactless with no funnel and no moving parts, require less maintenance than traditional gauges. They are often used as ground reference for validating radar and satellite measurements (see e.g., Barros et al. 2014). NCG measurements are however affected by wind, which impacts on the gauge body and produces strong velocity gradients that may divert incoming hydrometeors away from the gauge sensing area. This is a well-known bias of traditional catching gauges and is recently being investigated for more complex NCGs, that often present non radially symmetric shapes.

In this work, the wind-induced bias on the OTT Parsivel^2 measurements is evaluated by means of Computational Fluid Dynamics (CFD) simulation with Lagrangian Particle Tracking (LPT) using the OpenFOAM software. CFD results provide the velocity field – generated by wind – close to the gauge body. Simulations are run by solving the Unsteady Reynolds-Averaged Navier Stokes (URANS) equations, using a local time-stepping approach and a k-ω SST turbulence model. Various combinations of the wind speed and direction are simulated. Numerical results show a significant disturbance – close to the gauge sensing area – for a wind direction parallel to the gauge laser beam (Figure 1a). Minimal disturbance is instead observed when the wind direction is transversal to the laser beam. Strong turbulence generation – visualized using the Q criterion – also occurs in the wake of the instrument body (Figure 1b).

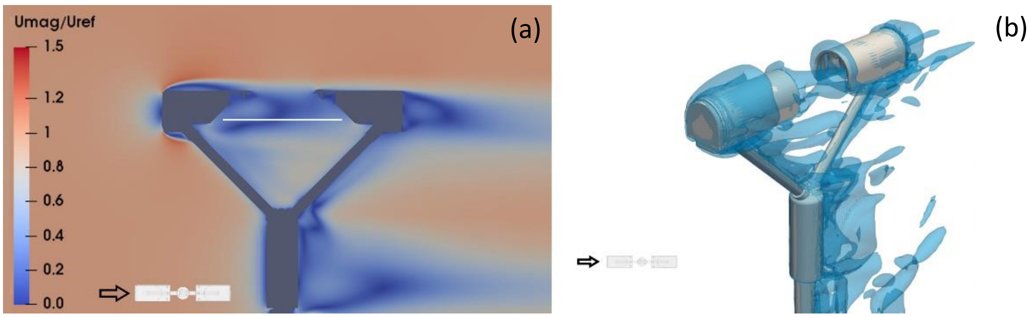

Fig 1: Magnitude velocity field around the Parsivel^2 for undisturbed wind speed U_{ref} = 5 m/s parallel to the laser beam (a). Turbulent structures close to the gauge body (b).

Hydrometeors trajectories are then computed using the simulated velocity field as input to the LPT model. Drops of diameters between 0.25 mm and 8 mm are released inside the computational domain along regular grids. Simulations are run until all trajectories reach the gauge, exit the domain, or fall significantly below the sensing area. From the simulated trajectories, the catch ratio (CR) of each monodisperse rainfall component is computed for the investigated combinations of wind speed and direction. The CR is the ratio between the number of trajectories that reaches the gauge sensing area and the number of drops that would have reached the same area in undisturbed conditions (as if the instrument was transparent to wind and precipitation).

CRs are presented as a function of the particle Reynolds number (see Figure 2a). For a wind direction parallel to the laser beam, some limited overcatch of small drops occurs at low wind speed (1 and 2.5 m/s), while severe underestimation occurs at high wind speed. When the wind direction is transversal to the laser beam, limited bias is present with some overcatch in the case of high wind speed. CRs are fitted with an appropriate function allowing to adjust measurements once the wind speed and direction is known at the gauge installation site.

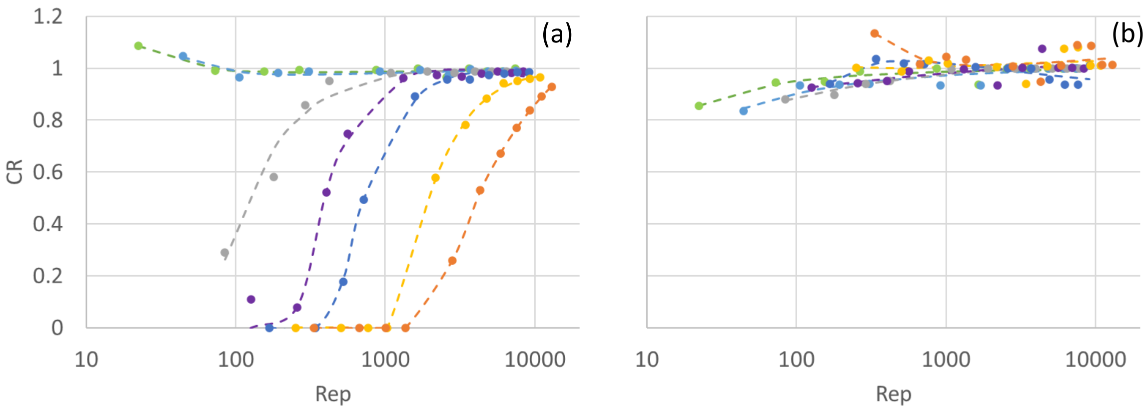

Fig 2: Catch ratios as a function of the particle Reynolds number for a wind direction parallel (a) and transversal (b) to the laser beam.

This disparity in the number of drops of different diameter sensed by the gauge also introduces a bias in the Drop Size Distribution (DSD) when measured in windy conditions. For some combinations of wind speed and direction, small drops are not sensed altogether, significantly affecting the shape of the DSD. The drop fall velocity is also affected, and especially the small size drops are slowed down by the wind-induced disturbance.

By choosing a DSD the bias on integral precipitation properties can also be evaluated. The Collection Efficiency (CE) is obtained by integrating the CRs over the whole diameters range. The CE is the ratio between the precipitation volume sensed by the gauge and the actual precipitation volume. Non negligeable overestimation of the rainfall volume is observed at a wind direction of 45° with respect to the laser beam, except for very low wind speed where the bias is limited. Another integral property often sought from NCGs measurements is radar reflectivity. Performance is evaluated by considering the Radar Retrieval Efficiency (RRE), defined as the ratio between the radar reflectivity computed from the DSD sensed by the gauge in windy conditions and the theoretical radar reflectivity. Very limited bias occurs for wind parallel to the laser beam in case of very high wind speed, while the bias is negligeable for other combinations of wind speed and direction. This is because radar reflectivity is mostly associated with medium size drops, which are weakly affected by wind.

In conclusion, wind introduces significant bias in the Parsivel^2 measurements of microphysical and integral properties of liquid precipitation. Adjustments are possible using the results of this work, based on ancillary measurements of wind speed and direction.

References

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