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Assessing the wind-induced bias for an impact disdrometer using numerical simulation and wind tunnel experiments

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Wind is a recognised source of environmental bias in precipitation measurements, affecting both catching and non-catching instruments. The latter are a family of precipitation measuring instruments that do not require the collection of hydrometeors inside a reservoir (see e.g., Lanza et al., 2021). All instruments behave like bluff-body obstacles when exposed to wind and produce strong velocity gradients and turbulence near their sensing volume, with considerable impact on the measurement accuracy.

Among them, impact disdrometers present a roughly cylindrical shape, sometimes not fully radially symmetric, and operate by measuring the kinetic energy of incoming hydrometeors. In this work, the wind-induced measurement bias is assessed for the Vaisala WXT-520 gauge, for liquid precipitation, using Computational Fluid Dynamics (CFD) simulation and a Lagrangian Particle Tracking (LPT) model.

The OpenFOAM software was used to run CFD simulations, considering three different wind directions and seven different wind speeds (1, 2.5, 5, 7.5, 10, 15 and 20 m/s). CFD results showed significant updraft upstream of the instrument sensing area and a limited dependency on the wind direction. The numerical model was further validated using wind tunnel measurements performed in the DICCA laboratory on a real gauge.

The obtained airflow field was used as the basis for an uncoupled LPT model to compute trajectories of drops of various diameters (0.25, 0.5, 0.75 and from 1 to 8 mm) while approaching the instrument sensing area. Drops were injected in the simulation domain, starting from a regular grid, with a vertical velocity equal to their terminal velocity and a horizontal velocity equal to the undisturbed wind speed.

A Kinematic Catch Ratio (KCR) is defined as the ratio between the kinetic energy transferred to the sensor in windy conditions and the kinetic energy that would have been transferred in still air conditions. Results shows that at low wind speed (1 and 2.5 m/s) the reduction in fall velocity produced by the updraft reduces the total kinetic energy, resulting in KCR < 1, especially for the smaller drops. However, the increase in kinetic energy experienced by drops carried by strong wind is predominant with respect to the updraft, resulting in KCR values much larger than unity.

Analogously, the Kinematic Collection Efficiency (KCE) can be defined once a Drop Size Distribution (DSD) is chosen. KCE values showed a similar behaviour, with values close to unity at low wind speed, but significantly larger when increasing the wind speed.

Wind also affects the DSD sensed by the instrument, since drops with increased kinetic energy are detected as having a larger diameter. Therefore, the gauge tends to overestimate the number of drops at each drop size bin, showing a shift of the DSD towards the larger diameters, that increases with increasing the wind speed.

References:

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