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The role of free-stream turbulence on the collection performance of catching type precipitation gauges

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The numerical studies reported in the literature about the wind-induced bias of precipitation measurements assume that turbulence is only generated by the interaction of the airflow with the gauge body, and the associated CFD simulations are generally performed under the hypothesis of steady and uniform incoming airflow. However, wind is turbulent in nature due to the roughness of the site and the presence of obstacles so that, in operational conditions, precipitation gauges are immersed in a turbulent flow. In this work, further to the role of the local generation of turbulence due to the obstruction to the airflow caused by the bluff body nature of the precipitation gauge, the natural free-stream turbulence inherent to the wind, and its influence on precipitation measurements, are investigated. With the aim to obtain turbulence intensity values characterizing the wind near to the ground surface, 3-D sonic anemometer measurements at the gauge collector height were preliminarily analyzed. Data were kindly provided by Environmental Measurements Ltd. (EML) from the Nafferton (UK) experimental site and are composed of 38 minutes of high-frequency (20 Hz) wind measurements. The role of the free-stream turbulence on the collection performance of a chimney shaped gauge was investigated by performing Large Eddy Simulations (LES) both in uniform and turbulent free-stream conditions. The free-stream turbulence was generated by introducing geometrical obstacles upstream of the gauge and their distance from the gauge, along the longitudinal direction, was calibrated to obtain the desired level of turbulence intensity, as measured at the Nafferton site. The two free-stream turbulence conditions were compared in terms of catch ratios and collection efficiency. Catch ratios for dry snow particles were obtained by running a literature Lagrangian Particle Tracking model (Colli et al. 2015) applied to the LES airflow fields obtained for each free-stream turbulence condition. From the comparison, a stronger undercatch emerges for small size particles (less than 2mm) under turbulent free-stream conditions with respect to the uniform case, while the opposite occurs for larger particles (d > 2 mm). This is due to the higher attitude of the small size particles to follow the turbulent velocity fluctuations while larger particles are more inertial. The overall effect of the free stream turbulence on the collection performance of the gauge was quantified by computing the Collection Efficiency (CE) as the integral over the full range of particle diameters after assuming a suitable Particle Size Distribution (PSD) for the precipitation process. Results show that a higher CE is obtained under turbulent free-stream conditions, and demonstrated that the numerical derivation of correction curves for use in precipitation measurements as proposed

in the literature based on the simplifying assumption of uniform free-stream conditions is affected by a systematic overestimation of the wind-induced error.

References:

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