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Thermo-fluid dynamic simulation of the Hotplate precipitation gauge

Arianna Cauteruccio (1,2), Matteo Colli (2), Mattia Stagnaro (1,2), Andrea Freda (1), Luca Giovanni Lanza (1,2)
(1) University of Genova, Dep. of Civil, Chemical and Environmental Engineering, Via Montallegro 1, 16145 Genoa, Italy, (2) WMO/CIMO Lead Centre "B. Castelli" on Precipitation Intensity, Italy

The present study addresses the aerodynamic response of the recently developed "Hotplate" liquid/solid precipitation gauge when exposed to the wind. The Hotplate gauge employs two heated thin plates to provide a reliable method of precipitation measurement. The measuring principle is based on an algorithm to associate the latent heat needed to evaporate the snow, or the rain, falling on the instrument and the precipitation rate. However, the presence of the instrument body immersed in a wind field is expected to induce significant deformations of the airflow pattern near the gauge, with an impact on the associated catching efficiency. Indeed, the fall trajectories of the hydrometeors when approaching the gauge can be deviated away from the collecting plate resulting, in general, in some underestimation of the precipitation rate.
After an initial analysis of real-world "Hotplate" measurements from a field test site located in Marshall, CO (USA) and the comparison with more traditional measurements obtained from a co-located, shielded reference gauge, the role of wind-induced errors is highlighted. The main approach used in this work is based on the numerical simulation of the airflow field around the gauge, using Computational Fluid Dynamics (CFD) to identify areas where the wind-induced updraft, local acceleration and turbulence are significant. The performed CFD airflow simulations use the URANS SST $k - \omega$ modelling scheme, and are the first modelling step to quantify the associated undercatch. These will be possibly coupled in future developments with particle tracking models to derive suitable correction curves for operational purposes. Due to the specific measurement principle exploited by the "Hotplate" gauge, which measures the heat flux needed to evaporate the collected water amount under a constant plate surface temperature, thermo-fluid dynamic simulations are addressed as well. Dedicated tests have been performed in the wind tunnel facility available at DICCA, University of Genoa to validate simulation results.
Results indicate that the presence of wind is a relevant source of systematic bias when using the "Hotplate" gauge for the measurement of precipitation, and its effect must be corrected by adopting suitable correction curves as a function of the wind velocity. The magnitude of the correction can be derived from numerical thermo-fluid dynamic simulations and an assessment of the airflow patterns developing around the gauge at various wind velocity regimes is provided in this work. Wind tunnel tests allowed for a substantial validation of the numerical results, and possible improvements of the model are highlighted and proposed for future developments.