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Evaluation of wind-induced errors for the Hotplate precipitation gauge using computational fluid dynamic simulations.

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Wind is recognised as the major environmental source of error in precipitation measurements. For traditional catching type gauges, which are composed by a funnel to collect the precipitation and a container with a bluff body shape, the exposure effect produces the updraft and acceleration of the velocity field in front and above of the collector. These divert the trajectories of approaching hydrometeors producing a relevant under-catch, which increases with increasing the wind velocity. This problem has been recently addressed in the literature using Computational Fluid Dynamics (CFD) simulations and a Lagrangian Particle Tracking (LPT) model to provide correction curves for various instruments, which closely match the under-catch observed in field measurements.

The present work concentrates on the Hotplate precipitation gauge developed at the Research Applications Laboratory, National Center for Atmospheric Research in Boulder, Colorado. The Hotplate differs from the traditional catching type gauges because it operates by means of an indirect thermodynamic principle. Therefore, it is not equipped with any funnel to collect the precipitation and is composed by a small disk with a diameter of 13 cm with two thin aluminium heated plates on the upper and lower faces. On the plates three concentric rings are installed to prevent the hydrometeors from sliding off during strong wind conditions.

In order to quantify the wind-induced error, the Unsteady Reynolds Averaged Navier Stokes (URANS) equations were numerically solved, with a k-ω SST turbulence closure model, to calculate the airflow velocity field around the instrument. Numerical results were validated by comparison with wind tunnel flow velocity measurements from pressure probes and a Particle Image Velocimetry (PIV) technique.

Then, with the objective to calculate the Collection Efficiency (CE) the hydrometeor trajectories were modelled using a literature LPT model (Colli et al. 2015) that solves the particle motion equation under the effects of gravity and wind. The path of each particle was analysed, considering the complex geometry of the gauge body, to establish whether it is captured by the instrument or not.

For various particle size/wind velocity combinations, the ratio between the number of particles

captured by the instrument and the number of particles that would be captured if the instrument was transparent to the wind was calculated. Finally, the CE curve was derived assuming a suitable particle size distribution for solid precipitation.

The results show that the Hotplate gauge presents a very unique response to the wind if compared with more traditional instruments. The CE indeed decreases with increasing the wind speed up to 7.5 m/s, where the effect of geometry starts to overcome the aerodynamic effect, and slowly reverses the trend beyond that value. This effect is so prominent at high wind speed that slightly beyond 15 m/s the under-catch fully disappears and the instrument starts to exhibit a rapidly increasing over-catching bias.

References:

Colli, M., Lanza, L.G., Rasmussen, R., Thériault, J.M., Baker, B.C. & Kochendorfer, J. An improved trajectory model to evaluate the collection performance of snow gauges. Journal of Applied Meteorology and Climatology, 2015, 54, 1826–1836.