ON THE AGGREGATION OF WIND/SNOW DATA WHEN USING A TRANSFER FUNCTION TO ACCOUNT FOR WIND-INDUCED ERRORS

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KEY POINTS

- *Solid precipitation measurements*
- *Wind-induced undercatch*
- *Transfer function*
- *Impact of temporal aggregation*

1 INTRODUCTION

The reliability of ground-based solid precipitation measurements is strongly influenced by the environment, especially in the presence of wind. It has been shown that the aerodynamic effect induced by the gauge body causes an acceleration of the airflow at the top of the gauge (*Goodison et. al*, 1998) with a relevant reduction of the gauge efficiency in collecting the falling snowflakes. This reduction of the catch efficiency affects the measurement of snow accumulation and snowfall rates (*Sevruk & Hamon*, 1984; *Goodison et. al*, 1998; *Nitu et al*, 2012).

Operationally, different types of windshields have been developed and employed to limit the wind effect, such as the Single Alter (SA) shield, or to provide reference solid precipitation measurements, as is the case of the Double Fence Intercomparison Reference (DFIR). By comparing the field measurements obtained from shielded and unshielded gauges and a reference value, the Collection Efficiency (CE) is empirically determined and some Transfer Function (TF), used to correct for the wind-induced undercatch (*Wolff*, 2015), is provided. More recently, dedicated CFD studies (see e.g. *Colli et al.*, 2015, 2016a,b) provided a sound theoretical basis to determine the Collection Efficiency of solid precipitation gauges as a function of the wind speed.

Since solid precipitation records, and the associated wind speed data, are commonly stored with a quite coarse resolution in time (30 or 60 minutes), we investigated the impact of the aggregation scale on the accuracy of data corrected by using the transfer functions. We used data from the WMO SPICE (Solid Precipitation Intercomparison Experiment) field campaign, observed at the Marshall field test site (Colorado, USA) during the winter seasons from 2013 to 2015. The snowfall rates were recorded by three Geonor weighing gauges with different configurations: unshielded (UN), SA shielded and a DFIR to serve as the reference. Both precipitation and wind speed data are quality controlled and provided with the time resolution of 1 minute.

2 METHODOLOGY

For the aim of this study, we selected a limited number of snow events from the Marshall field test site, and we considered only the snowfall measurements provided by the Geonor weighing gauge in the DFIR configuration, which is assumed here as the actual snowfall. This assumption may not be accurate since the DFIR measurements themselves have an associated uncertainty and systematic biases depending on the wind direction (*Thèriault et al.*, 2015). Such uncertainties therefore affect the derivation of the transfer function at the experimental site. For each event, the one-minute wind speed series has been considered as well, in order to apply the TF as described below.

In this study, the TF for the Single Alter gauge is obtained from the Heukeliseter data (Wolff et al., 2015) and is based on a sigmoidal shape, while the other two TFs (for the Single Alter and the unshielded gauge) are derived from the Marshall field test site (Colli et al., 2015) and based on a second order polynomial.

Using one-minute snowfall rates measured by the DFIR and the wind data, we applied the three inverse TFs to reconstruct the synthetic wind-affected snowfall series of the UN and SA gauges. These are assumed as the wind-affected measurements of each instrument that could be corrected by using the respective TFs, resulting in perfect agreement at the time scale of one minute.

Both the wind-affected snowfall rates and the wind speed time series have been aggregated at different time intervals (5, 15, 30 and 60 minutes), and the correction based on the appropriate TF has been applied at such timescales. We derived the corrected time series for the three gauges at different aggregation scales and compared them with the reference data at the same timescale.

Figure 1 shows the DFIR snowfall accumulation for a sample event together with the time series obtained by inverting the TFs for the SA and UN gauges (central panel). The upper panel reports the one-minute wind data, while the bottom panel shows the actual snowfall intensity measured by the DFIR at the time scale of one minute.

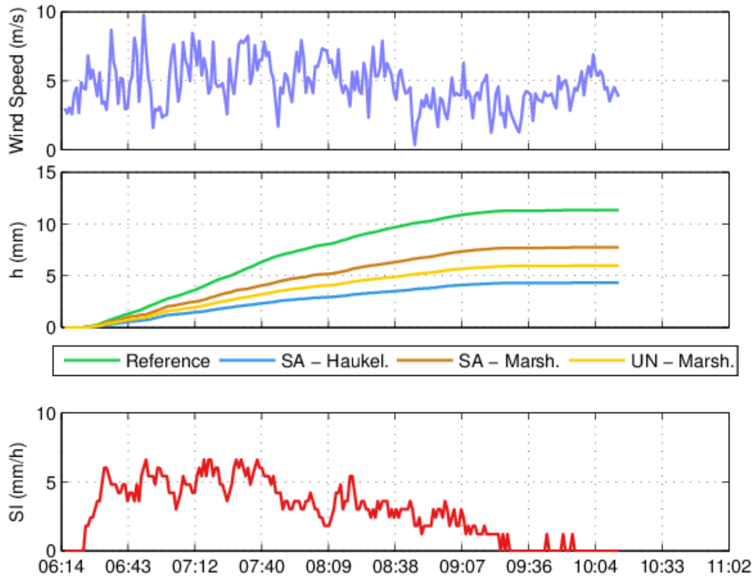

Figure 1. Measured and synthetic data from a sample snowfall event. The one minute wind speed (upper panel), the one minute snowfall intensity (lower panel) measured by the DFIR and the snow accumulation (central panel) measured by the reference (DFIR) and synthetic as obtained using the TFs from Heukeliseter (SA) and Marshall (SA and UN).

3 RESULTS

To correct for the wind-induced undercatch, we applied the associated TF to wind-affected synthetic series at different aggregation time intervals. We then compared the results with the reference record (DFIR) to compute the deviations in terms of snow accumulation over each time interval. This value is assumed as an estimate of the average error made when using various aggregation intervals in correcting solid precipitation measurements.

Note from the results reported in Figure 2 that the total accumulation for the sample event here considered differs for almost all the aggregation scales and transfer functions employed. In particular, in Figure 2a (SA and TF from Heukeliseter) the corrected snow measurements overestimate the reference value for three aggregation scales considered.

The SA gauge data obtained using the TF from Marshall show a different behavior (Figure 2b). In this case, a good agreement with the reference is observed when considering the correction performed at the 5-minutes aggregation interval. An overestimation of the total snow accumulation occurs at the 15-minutes aggregation interval, while underestimation occurs for the 30 and 60-minutes aggregation intervals. Also from the results obtained for the UN gauge (Figure 2c) employing the TF from Marshall (Colli et al., 2015) we observe a general overestimation with respect to the reference for both the 5 and 15 minutes aggregation intervals. In this case, the total accumulation obtained using the 30 minutes aggregation interval seems to agree well with the reference, while the 60-minutes aggregation series still underestimates the reference.

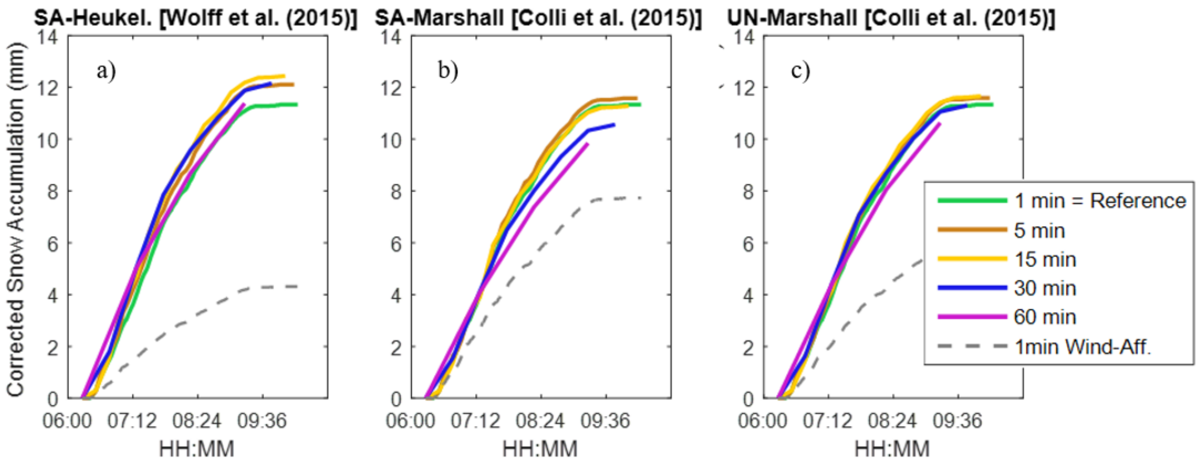

Figure 2. Wind affected (dashed line) and reference (green line) snow accumulations, compared with the corrected values at different aggregation intervals when using the Heukeliseter TF (Wolff et al., 2015) for the SA gauge (a), and the Marshall TF (Colli et al., 2015) for the SA (b) and UN (c) gauges.

Figure 2 shows that using different transfer functions lead to different behaviour of the corrected snowfall series. This is attributed to the non-linearity of the transfer function and the range of wind speed experienced during the event, and therefore varies on an event-by-event basis. It can be explained by considering the high variability of the wind speed at the highest time resolution (one minute) with respect to the average value within each time interval. Therefore, the corrected value calculated using the transfer function is strongly affected by the type of correction curve applied and the variability of the wind speed within the aggregation interval.

Considering the deviation from the reference, obtained using the TF at different aggregation scales, it can be noted from Figure 3 that this value increases for all the three transfer functions here considered when moving from the one-minute time resolution up to 60 minutes. The mean deviation of each time interval here considered is approximately zero for 5 and 15 minutes, while an average underestimation arises as the time interval increases.

It emerges that the shape of the TF used to correct the wind-affected snowfall data provides different results, in terms of average deviations, depending on the representativeness of the average wind at the aggregation scale considered.

4 Discussion

From actual field measurements of snowfall rates and wind speed, we obtained synthetic wind-affected time series for various snow gauge configurations at the time resolution of one minute. We obtained these synthetic data series by employing three different collection efficiency curves presented in the literature. We then aggregated the synthetic data series at different time intervals and corrected the snowfall data of each gauge by using the associated transfer function.

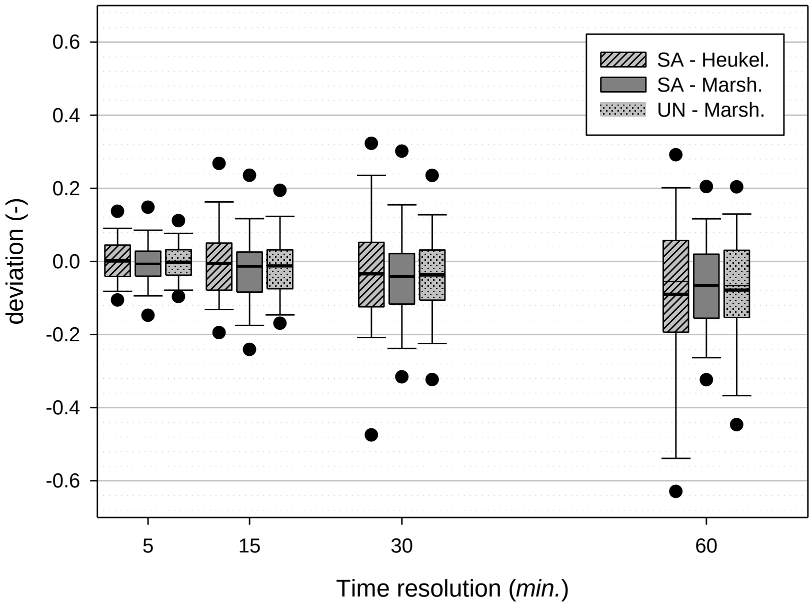

Figure 3. Non-parametric distribution of the deviations from the reference of three corrected synthetic time series, in terms of snowfall accumulation within each sampling interval.

It can be noted that, with increasing the aggregation scale, the bias of the corrected time series increases, and the result is strongly influenced by the shape of the transfer function used to correct the wind-affected snowfall data, and by the variability of wind within each specific aggregation interval.

Finally, we calculated an estimate of the deviation from the reference as expected when using various aggregation intervals. The deviations increase when moving from 5 to 60 minutes for all three TFs here considered, and an average underestimation of about 5 to 10% arises when the aggregation interval exceeds 15 minutes.

References

Colli, M., Rasmussen, R., Thériault, J.M., Lanza, L.G., Baker, C.B. & Kochendorfer, J. An improved trajectory model to evaluate the collection performance of snow gauges. Journal of Applied Meteorology and Climatology, 2015, 54(8), 1826-1836.

Colli, M., Lanza, L.G., Rasmussen, R.M. & Thèriault, J.M. The collection efficiency of shielded and unshielded precipitation gauges. Part I: CFD airflow modelling. Journal of Hydrometeorology, 2016, 17(1), 231–243.

Colli, M., Lanza, L.G., Rasmussen, R.M. & Thèriault, J.M. The collection efficiency of shielded and unshielded precipitation gauges. Part II: modelling particle trajectories. Journal of Hydrometeorology, 2016, 17(1), 245–255.

Goodison, B., Louie, P. & Yang, D. WMO solid precipitation measurement intercomparison: final report. WMO Tech. Document 872, World Meteorological Organization, Geneva, Switzerland, 1998.

Nitu, R., Rasmussen, R., Baker, B., Lanzinger, E., Joe, P., Yang, D., Smith, C., Roulet, Y., Goodison, B., Liang, H., Sabatini, F., Kochendorfer, J., Wolff, M., Hendrikx, J., Vuerich, E., Lanza, L., Aulamo, O., & Vuglinsky, V. WMO intercomparison of instruments and methods for the measurement of solid precipitation and snow on the ground: organization of the experiment. In WMO Technical Conference on meteorological and environmental instruments and methods of observations, pages 16–18, Brussels, Belgium, 2012. World Meteorological Organization.

Sevruk, B. & Hamon, W (1984). International comparison of national precipitation gauges with a reference pit gauge. WMO-IOM 17, Tech. Document 38, World Meteorological Organization, Geneva, Switzerland.

Thèriault, J.M., Rasmussen, R.M., Petro, E., Trépanier; J.Y., Colli, M. & Lanza, L.G. Impact of wind direction, wind speed and particle characteristics on the collection efficiency of the Double Fence Intercomparison Reference. Journal of Applied Meteorology and Climatology, 2015, 54(9), 1918–1930.

Wolff, M. A., Isaksen, K., Petersen-Øverleir, A., Ødemark, K., Reitan, T., & Brækkan, R.: Derivation of a new continuous adjustment function for correcting wind-induced loss of solid precipitation: results of a Norwegian field study, Hydrology and Earth System Sciences, 2015, 19, 951-967.