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Impact of wind and temperature on snowfall measurements by Thies LPM and OTT Parsivel2 optical disdrometers compared with DFAR (Double Fence Automated Reference) measurements at WMO.SPICE Formigal-Sarrios site

Introduction

Optical disdrometers are present weather sensors with the ability of providing detailed precipitation information such as the **type or meteor** and **precipitation intensity**, together with information on the distribution of particle sizes and fall velocities (**PSVD**) of the hydrometeors.

Disdrometers have thus a large potential as non-capture precipitation recorders. However, they have issues that are not well known, such as the **effect of wind** on the quality of the records. Here we focus on their ability to **record snowfall amounts**, in comparison with a reference pluviometer located inside of the inner fence of a double fence Automated Reference (DFAR), according to WMO-Guidelines for the Solid Precipitation Intercomparison Experiment (SPICE).

Methodology

Six optical disdrometers (three Thies Clima LPM and three Ott PARSIVEL2) were installed at the Formigal-Sarrios WMO.SPICE site (42.775N, 0.416W, 1800 m asl) in the Spanish Pyrenees, in the following configuration (Fig. 1):

- One Parsivel2 (**P0**) and one LPM (**T0**) were installed inside the DFAR, i.e. protected from the effect of wind.
- Two Parsivel2 (**P1**, **P2**) and two LPM (**T1**, **T2**) were installed outside the DFAR without any wind protection. The devices were installed at a relative angle of 90° in the East-West and North-South directions, allowing to assess the impact of both wind speed and direction on the records.

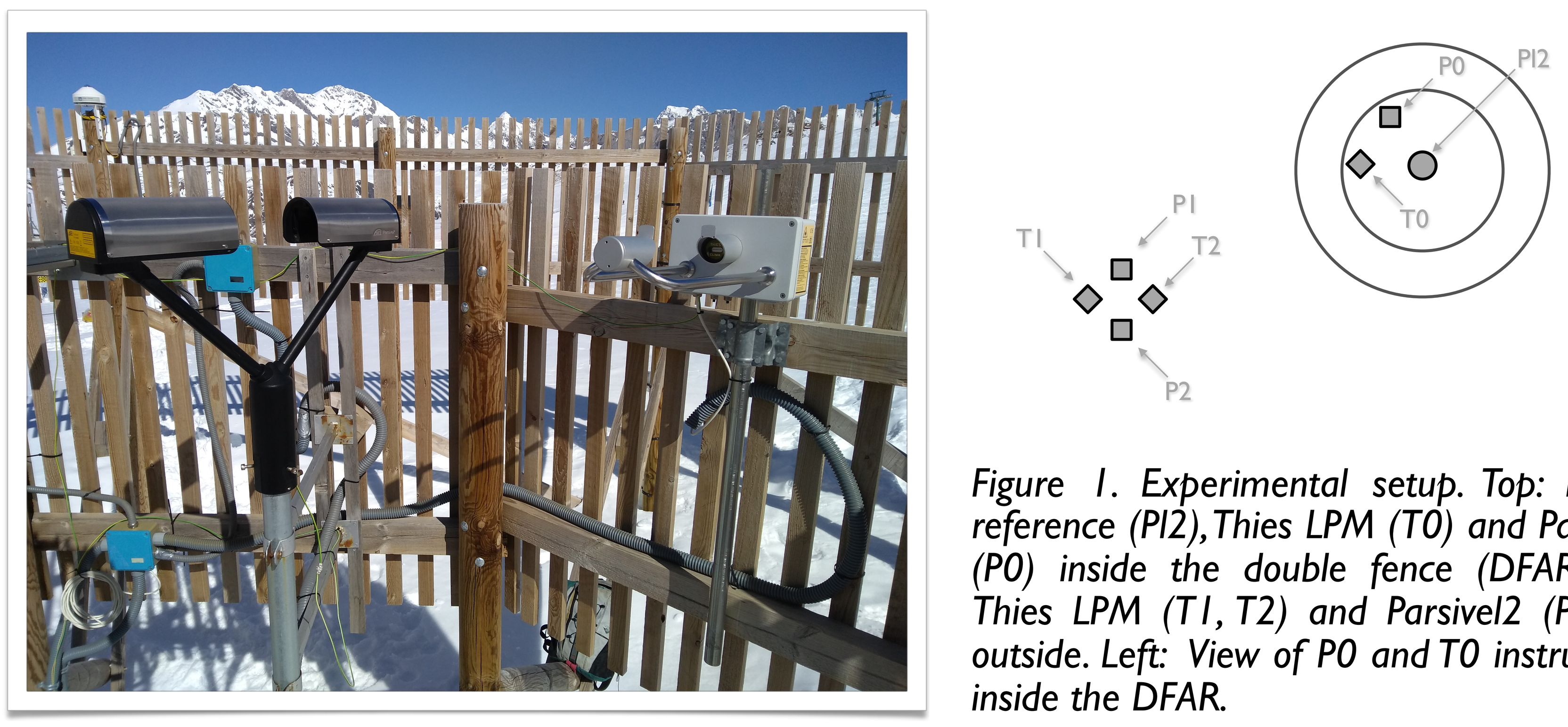

Figure 1. Experimental setup. Top: Pluvio2 reference (PI2), Thies LPM (T0) and Parsivel2 (P0) inside the double fence (DFAR); and Thies LPM (T1, T2) and Parsivel2 (P1, P2), outside. Left: View of P0 and T0 instruments inside the DFAR.

Five-minute snowfall amounts recorded by the LPM and the Parsivel2 devices between January 1st and May 15th 2018 were collected, and compared with the reference measurements of a Pluvio2 weighing gauge situated in the center of the DFAR (**PI2**). Wind speed and direction, and air temperature, were also recorded (Figure 2).

The identification of precipitation types (rain, snow and mixed) by each device was compared by means of the SYNOP codes generated automatically by them.

The effect of wind and temperature in the snow intensity records was evaluated by means of cumulative precipitation plots and also by direct comparison of the five-minutes records.

Gamma generalised linear model (Gamma-GLM) regression was used to establish the differences between the two disdrometer types and between inside and outside DFAR locations, considering the effect of wind and temperature.

Regression analysis results allowed for the development of transference functions for correcting the raw records provided by the devices.

Results: type of meteor

Only the five-minutes periods with some hydrometeor identified in all the devices were analysed (Table 1). Snow accounted for 80% of the hydrometeors recorded by the reference Pluvio2 device, and this value was matched very closely by the two disdrometers located inside the DFAR (P0 and T0), and in general by those located outside as well, with small differences. Only one of the Parsivels (P2) showed a tendency towards recording more rain.

	snow	rain	mixed	other	N
P0	77 %	17 %	1 %	6 %	3940
P1	73 %	20 %	1 %	7 %	3587
P2	64 %	28 %	1 %	7 %	3550
T0	75 %	21 %	2 %	1 %	5420
T1	75 %	20 %	4 %	1 %	5278
T2	74 %	22 %	3 %	1 %	5399

Table 1. Hydrometeor classification.

Results: total precipitation

Considering only the complete records, total precipitation during the experiment was 979 mm in the reference device, PI2, with snow accounting for 82% of that (Table 2). Inside the DFAR, the Thies disdrometer, T0, gave a very close result of 1035 mm, and underestimated the amount of snow (72%). The Parsivel device, P0, overestimated the total amount by 40%, but yielded a similar proportion of snow (85%). All the devices outside the DFAR overestimated total precipitation (between 29 and 220%), with Thies LPM giving the poorest results. This confirms the great importance of wind shielding when working with disdrometers, and suggests that relevant differences may exist between the two devices in how they are affected by wind.

	snow	rain	mixed	other	total
P0	1168	182	20	197	1568
P1	1078	177	26	324	1605
P2	1392	262	27	308	1990
T0	746	209	79	69	1104
T1	1638	318	191	225	2372
T2	1179	236	127	247	1788

Table 2. Precipitation totals per meteor type (mm).

Results: regression analysis

A Gamma-GLM model was fit to the snow records, taking the following form:

$$E[y\,|\,x_1, x_2, x_3] \;=\; exp(\alpha + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3) \;=\; \hat{y}$$

where x_1, x_2 and x_3 stand for the disdrometer snowfall intensity, wind speed and temperature, respectively; β_n are regression coefficients and α is an intercept. The results showed a remarkable effect of wind speed, and also strong differences between devices (Table 3). The corrected snow amounts matched well the reference (Figure 3). However, this correction includes random device effects, so it is not generalisable to other devices of the same types. More research is required to better understand the differences observed in the recording of snowfall by the disdrometers analysed.

	α	β_1	β_2	β_3
P0	-0.246	0.303	-0.036	0.066
P1	-0.026	0.226	-0.021	0.066
P2	0.197	0.144	-0.051	0.066
T0	-0.269	0.445	-0.009	0.066
T1	0.129	0.160	-0.033	0.066
T2	-0.065	0.268	-0.028	0.066

Table 3. Regression coefficients.

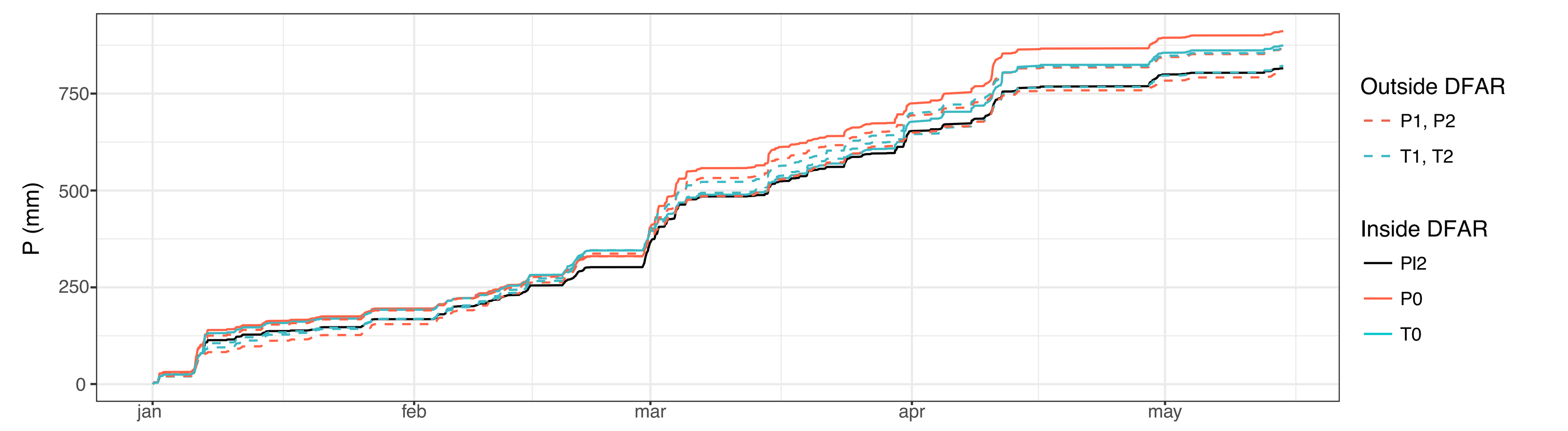

Figure 3. Corrected snow accumulation from the results of the regression model. This model includes random device effects, so it can not be applied to other device

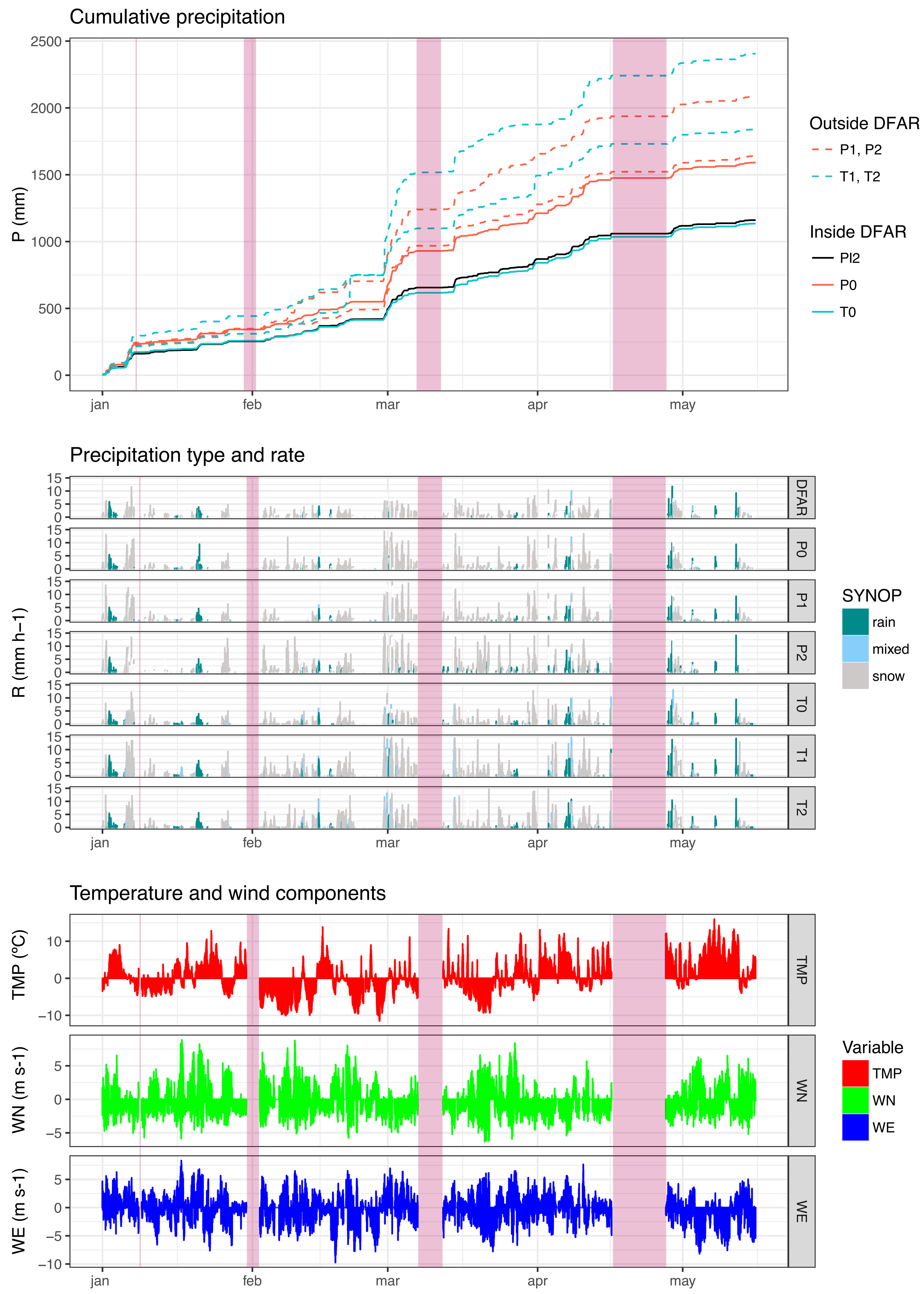

Figure 2. Time series of the variables recorded during the experiment. Only the five-minutes periods with records on the seven devices measuring precipitation are shown. Magenta strips indicate the periods not analysed due to malfunctioning of at least one of the devices.