Measurements of driving rain by a driving-rain gauge with a wiper

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CIB TG 21 meeting, Gävle, 5/6-6-1998

Abstract

Since December 1997 measurements of wind and driving rain are carried out at the Eindhoven University of Technology. Driving rain is measured by two types of driving-rain gauges which are located adjacent to each other on the west facade of the Main Building of the campus. (The dimensions of the Main Building are: (height) 45 m, (width) 167 m and (depth) 20 m.) The reference wind velocity is measured 127 m west to the facade at 45 m height on a mast. The reference horizontal rain intensity is measured at the same distance from the facade, on the roof of the Auditorium.

This paper deals firstly with the major design considerations of two driving-rain gauges: one is designed as a traditional driving-rain gauge, the other is equipped with a wiper which should improve the efficiency of driving rain collection, and thus reduce the measurement error. Secondly, the results of measurements of the two driving-rain gauges are presented: a driving-rain gauge with wiper collects two times more driving rain than a gauge without wiper.

1 Introduction

Many factors determine the deterioration of building envelopes. Heat and moisture transfer, dry and wet deposition of chemical substances, design deficiencies and imperfections during building affect the performance and durability of facades, and the costs of maintenance. Consequently these deterioration factors can affect the indoor climate, as the facade is the barrier between the indoor and outdoor environment.

In order to design good buildings with regards to deterioration, knowlegde of the exposure to the local outdoor climate is primordial. One of the climatological parameters is driving rain. The actual set of design rules and tools for building designers is small and rather inadequate. Only in the UK there is a standard for estimating driving-rain quantities [BSI 1992]. Also for reseach on moisture transport in e.g. brick walls, more knowledge of driving rain is useful, as driving rain is a major boundary condition.

For these both reasons, reseach on driving rain is taken up. This research implies both full-scale measurements and simulations by computational fluid dynamics (c.f.d.). In [van Mook et al. 1997] we presented some preliminary computer simulations using an approach which is useful for the understanding of the distribution of the impingments of raindrops on building envelopes, and for the estimation of driving-rain intensities.

In this paper we show the first results of full-scale measurements of driving rain. Since December 1997 we measure driving-rain intensities by two types of driving-rain gauges, installed adjacent to each other on the facade of the Main Building of the Eindhoven University of Technology (TUE). The main difference between the two driving-rain gauges is that one is equipped with a wiper and the other one is not.

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2 Measuring driving rain

Driving rain is here defined as rain which is carried by wind and driven onto the building envelope. It has been the subject of research for many years. Main surveys can be found in [Lacy 1965], [Frank 1973], [Prior 1985] and in [Flori 1988]. Details of the used equipment for the measurement of driving rain are not often given; Frank [1973], Flori [1990] and Osmond [1995] are the exceptions known to us. We did not find any reference on a comparison of different types of driving-rain gauges, and thus no reference dealing with the systematical error of a given driving-rain gauge type.

The most widely used driving-rain gauge consists of:

— a collector (a shallow tray) fixed to the wall of a building. The drops hit the tray, drip downwards and are collected by:

— a drainage channel, which leads the collected rain water to:

— a reservoir or a water flux gauge. A water flux gauge enables the measurement of the instantaneous driving-rain intensity.

It is obvious that the catch efficiency (and thus the measurement error) of a gauge depends on size, shape and finish of the gauge surfaces. One should prevent that drops remain on the collector or in the drainage channel and evaporate, that drops splash out of the gauge, and that the shape of the gauge causes extra wind disturbances.

It is very difficult, sometimes practically impossible, to find realistic tests for evaluation of every error factor. We concentrated on the limitation of remaining and evaporating drops. This idea was brought about by our observation at the facade of the Main Building of the TUE that much of the drops simply remain on the window glass, and do not drip downwards during many driving rains.

For the design of our driving-rain gauges we considered the following requirements:

1. estimated driving-rain intensity range: 0.05 ... $\geq$ 2.0 mm/h,
2. sampling rate: 1 per min,
3. practical realisable catchment area due to the window size of the Main Building: approx. 0.5 m^2,
4. estimated maximal collected driving-rain sum during 3 consecutive days: 5 mm,
5. hydrophobic coating to decrease the number of drops remaining on the collector,
6. preventing that the wind blows into the reservoir and preventing that the wind influences the desired flow of the drops into the reservoir (e.g. due to wind sucking).

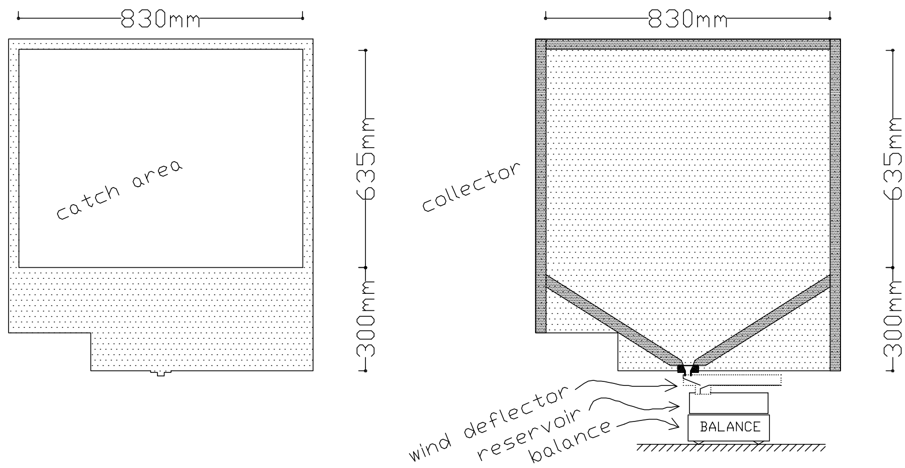

Figure 1: Driving-rain gauge, with driving-rain collector *I*, wind deflector, reservoir (2L) and balance. Left: foreplate with the rectangular catchment area (0.527 m^2). Right: backplate and the inside.

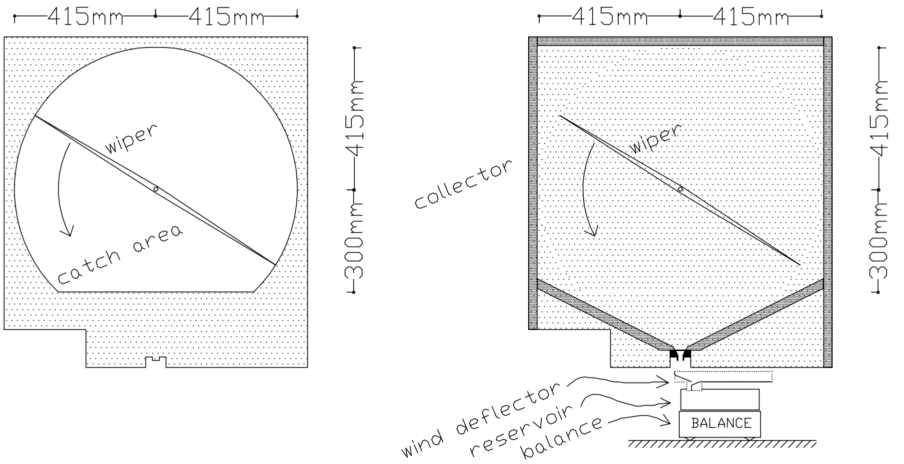

Figure 2: Driving-rain gauge, with driving-rain collector *II*, wind deflector, reservoir (3L) and balance. Left: foreplate with the round catchment area (0.492 m^2). Right: backplate and the inside.

The first and fourth requirement are estimations obtained from hourly meteorological data of De Bilt (KNMI). The driving-rain intensity range was calculated according to the principle of [Lacy 1965] and [BSI 1992]; see [van Mook 1996] for details.

The first three requirements imply that the minimal amount of water, measurable within a minute for a driving-rain intensity of 0.05 mm/h and through a catchment area of 0.5 m^2 will be 0.5 ml. We use a balance, which can easily and accurately measure such small quantities.

The fourth requirement implies that, if the catchment area is 0.5 m^2, the driving-rain gauge reservoir will collect at most 2.5 litres in three consecutive days.

Figures 1 and 2 show the two types of driving-rain gauges which we used for our measurements. Both types consist of a collector, a so-called wind deflector (to satisfy requirement 6), a reservoir and a balance (for the actual detection of the amount of water). Also for both types, all the inner sides have been coated with teflon (to comply with requirement 5). The main difference is that driving-rain gauge *II* is equipped with a wiper and driving-rain gauge *I* is not. The wiper is basically a standard windscreen wiper for cars, and is automatically switched on by a rain indicator. The speed is approx. 10 rotations per second; after every 5 seconds the wiper rests during 5 s to reduce wear and tear.

The shapes of the catchment area are different because driving-rain gauge *I* was designed well before gauge *II*, which has been designed as an improved version of gauge *I*. We do not expect that this difference will significantly affect the results.

The wiper serves to improve the catch ratio: drops on the collector are forced to coagulate and drip down. Furthermore the wiper keeps the surface of the driving-rain gauge clean. In our lab the driving-rain collectors were tested for their collection efficiency. By a plant sprayer drops were sprayed onto the collector and the collected amount of water and the sprayed amount of water were measured. Also the time of spraying was measured. Results of this test (figure 3) show mainly that wiping decreases significantly the dependence of the collection efficiency to the total sprayed amount *and* the spray intensity. The real effect of wiping can only be found by full-scale measurements; the drop spectrum of the used spray is different from raindrop spectra.

Details of the driving-rain gauges can be found in [van Mook 1998].

3 Site and measurement configuration

The driving-rain measurements are carried out on the west facade of the Main Building, on the campus of the Eindhoven University of Technology (TUE). The campus is situated near to the center of the town. Eindhoven has approximately 200.000 inhabitants.

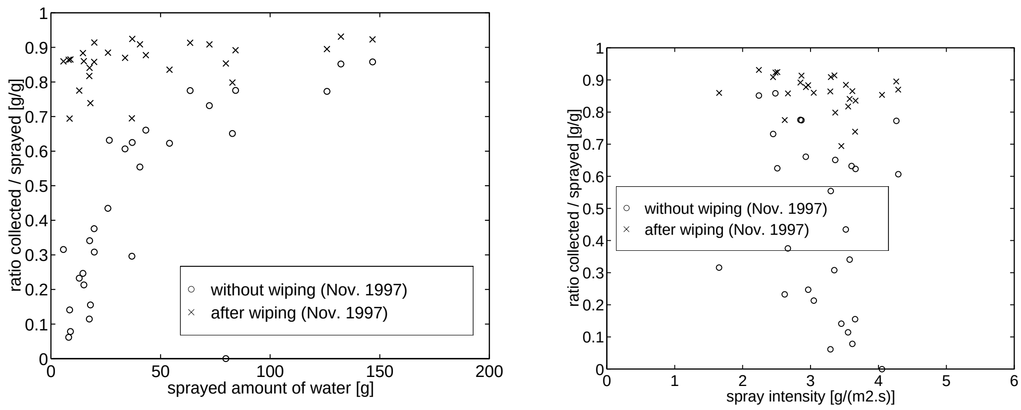

Figure 3: Spray test on driving-rain collector *II* of November 1997. The collector has not been exposed to the outdoor climate yet. A spray intensity of 1 g m^{-2} s^{-1} equals to 3.6 mm/h.

The dimensions of the Main Building are: (height) 45 m, (width) 167 m and (depth) 20 m. The Auditorium is 14 m heigh and is located at 72 m from the west facade of the Main Building. The reference wind velocity is measured at 45 m height on a mast on the Auditorium. The reference horizontal rain intensity is measured by two tipping-bucket rain gauges on the roof of the Auditorium at positions P2 and P3. See figures 4, 5 and 6, and table 1 for the instrumentation. Figure 7 shows a picture of the two driving-rain gauges.

A meteorologic station for air temperature, relative humidity and irradiation is situated on the roof of the Main Building, at position P0.

Table 1: Measurement positions and instrumentation. The reference quantities are marked with an asterisk; they are measured at the Auditorium. See also: figures 4, 5 and 6

position	quantity	instrument	(output) sample rate
P1	wind velocity (3d)*	Solent Research Ultrasonic Anemometer	1 / min
P2	horizontal rain intensity*	Young tipping bucket rain gauge 52202	2 / min
P3	horizontal rain intensity*	Young tipping bucket rain gauge 52202	2 / min
P3	duration of horizontal rain*	rain indicator	2 / min
P4	wind velocity (3d) at 75 cm from facade surface	Solent Windmaster 1086M Ultrasonic Anemometer	1 / s
P4	driving-rain intensity	driving-rain collector I without wiper + balance Mettler PB 3001	4 / min
P5	driving-rain intensity	driving-rain collector II with wiper + balance Mettler PB 3001	4 / min

The site is suited because the prevailing direction for wind and rain is between south and west. There are no large obstacles in south-west to west direction. The fetch in this direction is rough, and consists mainly of trees. The nearest high-rise building in this direction is 500 m away.

The wind characteristics of the site have already been subject of study, see [Geurts 1997]. Details of the measurement configuration, data acquisition system and data processing can be found in [van Mook 1998].

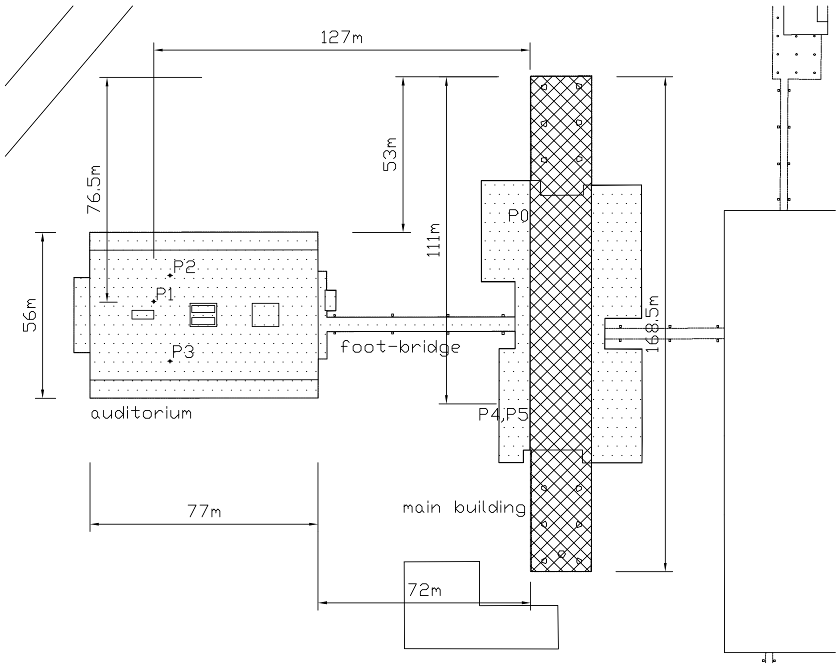

Figure 4: Measurement positions, plan.

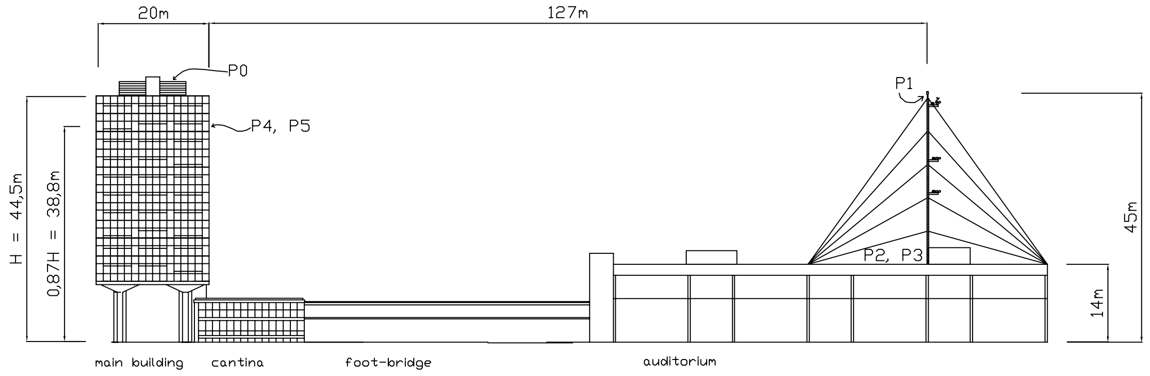

Figure 5: Measurement positions, view from north.

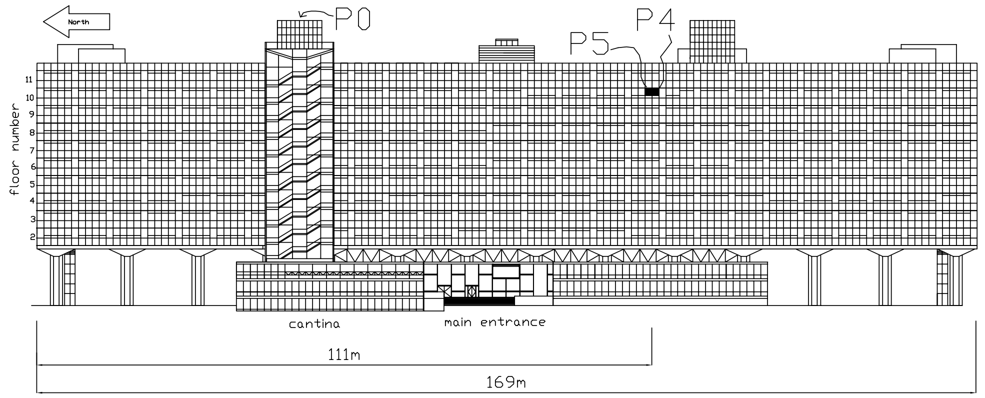

Figure 6: Measurement positions at the west facade of the Main Building of the TUE.

Figure 7: Driving-rain gauges in the west facade of the Main Building at position P5 (left, d.r. gauge *II* with wiper) and P4 (right, d.r. gauge *I* without wiper).

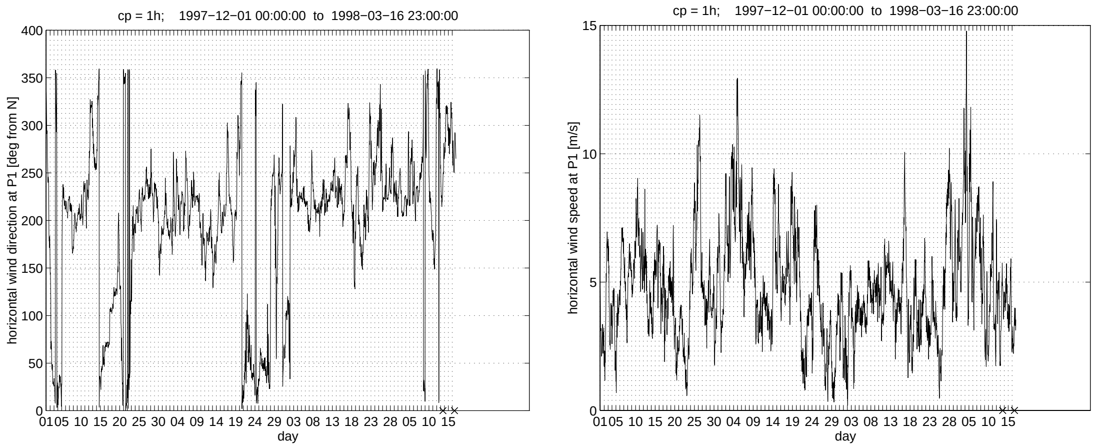

Figure 8: Horizontal wind direction [left] and horizontal wind speed [right] at position P1 (Auditorium) as function of time. Average period $cp = 1$ hour.

4 Measurement results

The results presented here are of the period of 1-12-1997 to 16-3-1998. Much rain and strong winds occurred from 25-12-1997 till 9-1-1998 and from 27-2-1998 till 9-3-1998. These periods were ideal to test the measurement set-up and to compare the two different driving-rain gauges: driving-rain gauge *I* without wiper and driving-rain gauge *II* with wiper.

Figure 8 shows the reference horizontal wind direction and speed (hourly averaged). (Note that a wind direction of 0° is due north; 270° is west.)

Figure 9 shows the reference horizontal rain sum S_h at position P3 obtained from 10-min summations. According to KNMI [1997] the rain sum in Eindhoven for December 1997 was 53 mm. At our site we measured approx. 62 mm at P2 and 57 mm at P3.

The results of driving-rain gauge *I* (at position P4) and driving-rain gauge *II* (P5) are depicted in figure 10. It clearly shows that driving-rain gauge *I* without wiper catches two times less rain than the driving-rain gauge *II* with wiper! The factor 2 is also seen in figure 11.

Figure 12 shows the large scatter of the driving-rain sums S_{dr} (d.r. gauge *II*) as function of the horizontal wind speed and direction. The data has not been selected. Remark the general large scatter, and the large number of data points scattered over the wind velocity range with zero driving rain and nonzero horizontal rain.

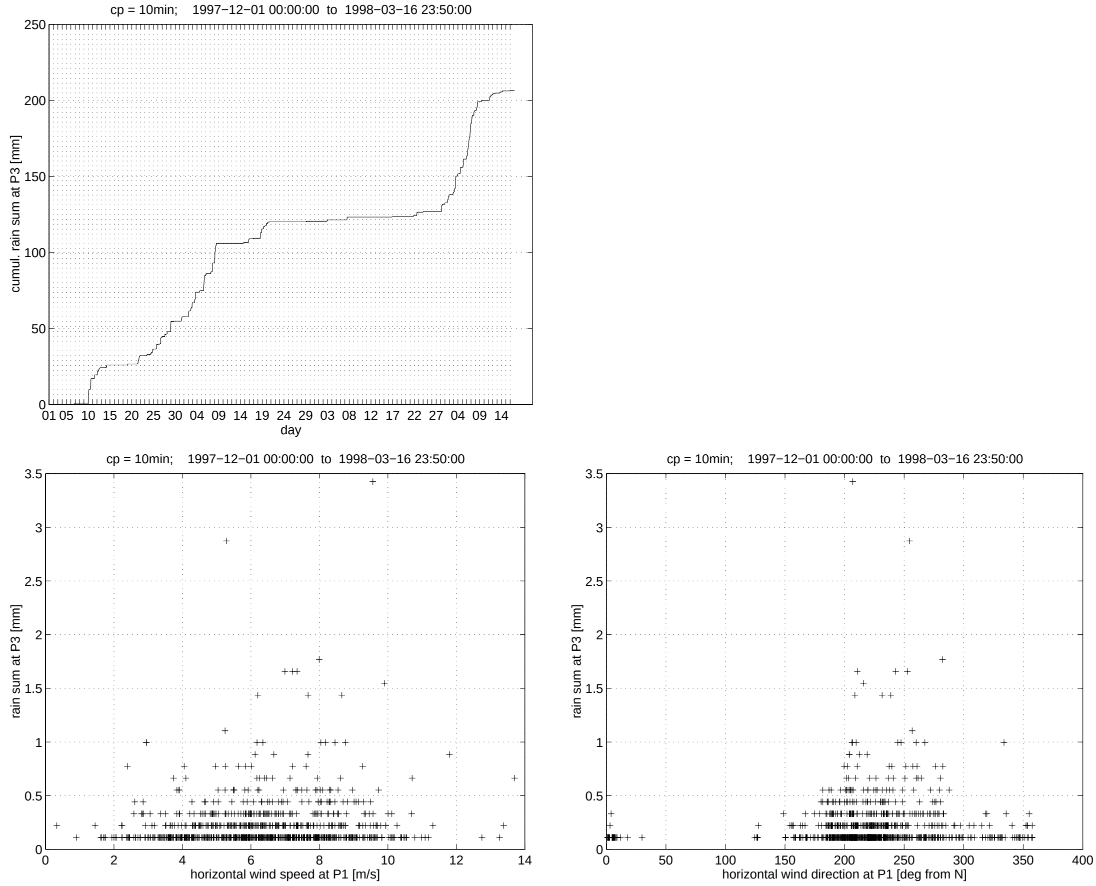

Figure 9: Horizontal rain sum S_h at position P3 (Auditorium), as function of time [top], horizontal wind speed [botom left] and horizontal wind direction [bottom right] at P1 (Auditorium). Summation period $cp = 10$ min.

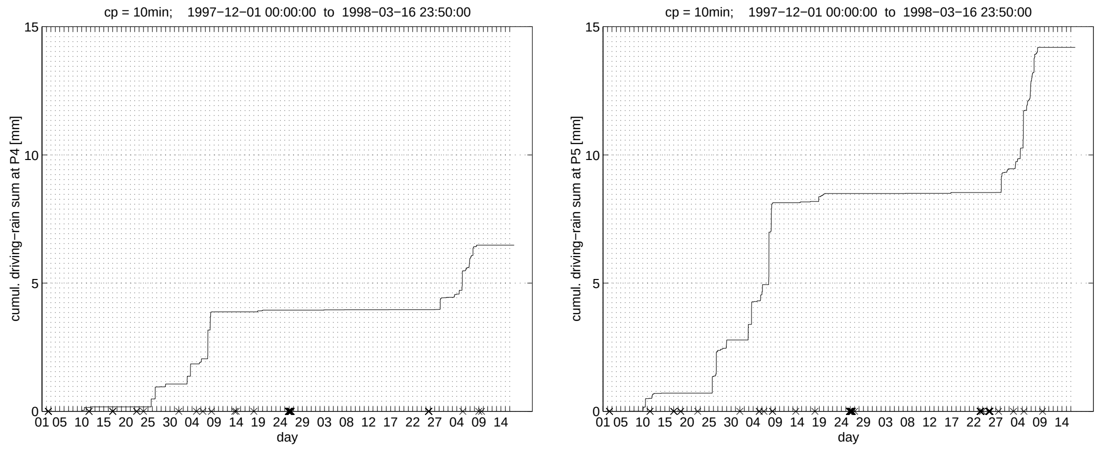

Figure 10: Cumulative driving-rain sum at position P4 (facade of Main Building, d.-r. gauge *I* without wiper) [left], and at position P5 (facade of Main Building, d.-r. gauge *II* with wiper) [right] as function of time.

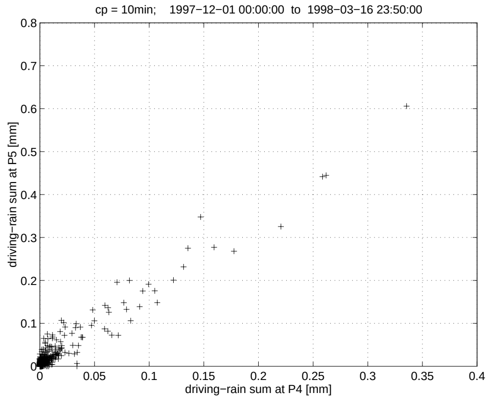

Figure 11: Comparison of the driving-rain gauge results: driving-rain sum at position P4 (d.r. gauge *I*) resp. P5 (d.r. gauge *II*). Summation period $cp = 10$ min.

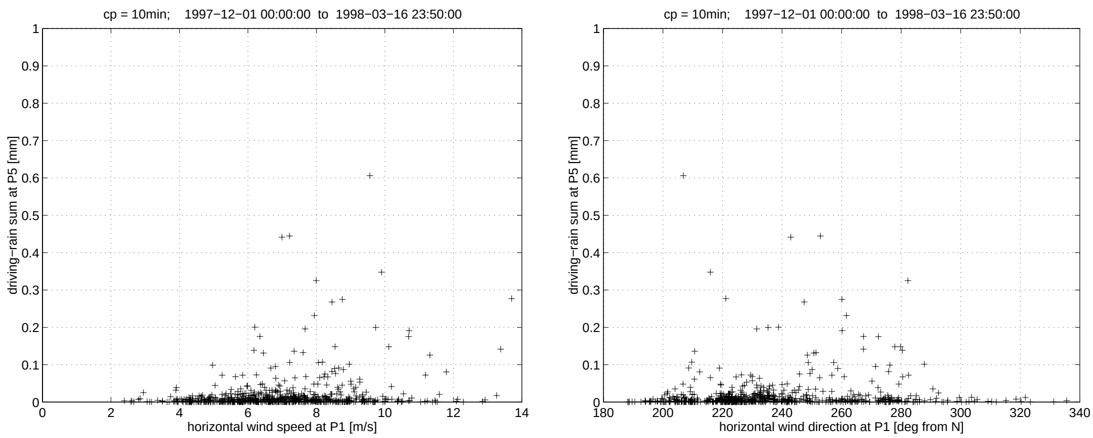

Figure 12: Driving-rain sum S_{dr} at position P5 (facade of Main Building, d.-r. gauge *II* with wiper) as function of reference horizontal wind speed [left] and reference horizontal wind direction [right]. Summation period $cp = 10$ min.

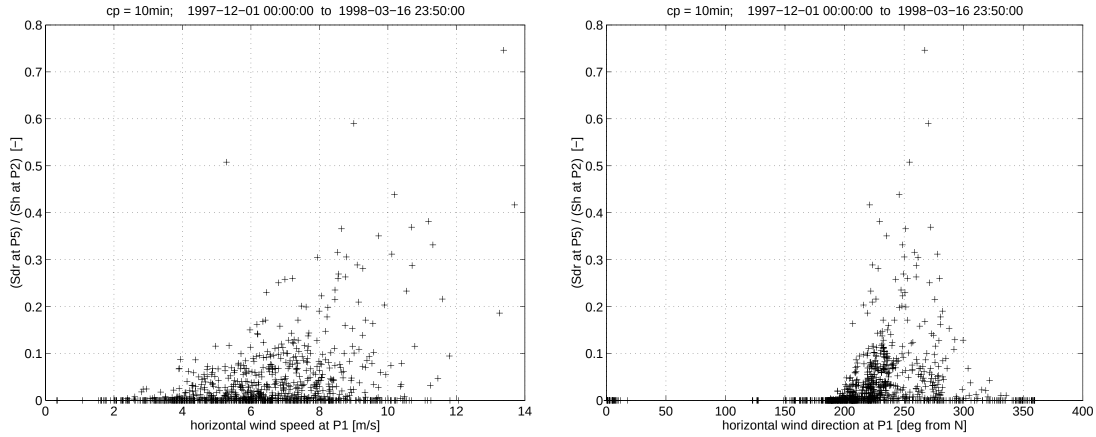

Figure 13: Ratio of driving-rain sum S_{dr} at position P5 (facade of Main Building, d.r. gauge *II* over reference horizontal rain sum S_h at position P2 (Auditorium), as function of horizontal wind speed [left] and reference horizontal wind direction [right] at P1 (Auditorium). Summation period $cp = 10$ min.

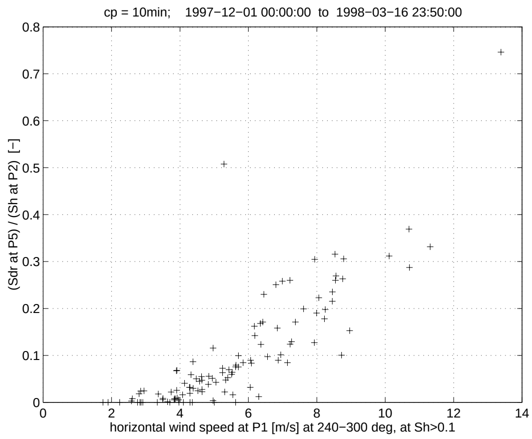

Figure 14: Ratio of driving-rain sum S_{dr} at position P5 (facade of Main Building, d.r. gauge *II*) over horizontal rain sum S_h at position P2 (Auditorium), as function of reference horizontal wind speed, selected for reference wind directions of 240°–300°, and for horizontal rain sums $S_h > 0.1$ mm. Summation period $cp = 10$ min.

In figure 13 the ratio of S_{dr}/S_h of the measurements with driving-rain gauge *II* is plotted. Figure 14 is obtained by selecting the data for a specified reference wind direction (between 240° and 300°) and reference horizontal rain sum ($S_h > 0.1$ mm).

Lacy [1965] assumes a linear relationship between S_{dr}/S_h and the reference wind speed through the origin of the plot. Figure 14 shows that this is a very rough assumption, and that perhaps a parabolic relationship could be a better fit to the measured data.

5 Conclusions

The major conclusion of the measurements sofar, is that a driving-rain gauge with wiper catches substantially more rain than a driving-rain gauge without wiper. We found a factor 2. The lab tests (spraying water on the driving-rain collector) showed that wiping decreases significantly the dependence of the collection efficiency to the total sprayed amount and the spray intensity.

Consequently, the measurements also show that only making the surface of the driving-rain collector more hydrophobic (e.g. teflon coating) is not adequate enough.

The linear relationship between S_{dr}/S_h and the reference wind speed, assumed by Lacy [1965], is a very rough fit, seen the measurements, which also show a large scatter.

Acknowledgements

The project is done in collaboration with prof. dr. ir. K. Kopinga of the faculty of Technical Physics of the Eindhoven University of Technology (TUE), and is partly funded by the common TUE commission on 'Technology for Sustainable Development'.

Thanks are particularly given to the numerous persons who helped for the realisation of the measurement configuration.

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