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Improving the accuracy of tipping-bucket rain records using disaggregation techniques

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Abstract

We present a methodology able to infer the influence of rainfall measurement errors on the reliability of extreme rainfall statistics. We especially focus on systematic mechanical errors affecting the most popular rain intensity measurement instrument, namely the tipping-bucket rain-gauge (TBR). Such uncertainty strongly depends on the measured rainfall intensity (RI) with systematic underestimation of high RIs, leading to a biased estimation of extreme rain rates statistics. Furthermore, since intense rain-rates are usually recorded over short intervals in time, any possible correction strongly depends on the time resolution of the recorded data sets. We propose a simple procedure for the correction of low resolution data series after disaggregation at a suitable scale, so that the assessment of the influence of systematic errors on rainfall statistics become possible. The disaggregation procedure is applied to a 40-year long rain-depth dataset recorded at hourly resolution by using the IRP (Iterated Random Pulse) algorithm. A set of extreme statistics, commonly used in urban hydrology practice, have been extracted from simulated data and compared with the ones obtained after direct correction of a 12-year high resolution (1 min) RI series. In particular, the depth–duration–frequency curves derived from the original and corrected data sets have been compared in order to quantify the impact of non-corrected rain intensity measurements on design rainfall and the related statistical parameters. Preliminary results suggest that the IRP model, due to its skill in reproducing extreme rainfall intensities at fine resolution in time, is well suited in supporting rainfall intensity correction techniques.

Keywords: Rainfall; Measurement errors; Disaggregation; Depth duration frequency curves; Tipping bucket rain gauge

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1. Introduction

Urban hydrology applications commonly rely on the processing of historic rain rate data sets, recorded at a suitable measurement station located within or in the vicinity of the investigated basin. Correct estimation of the return period of a given rain event for design purposes is based on the prolonged and accurate measurement of rain data (Keifer and Chu, 1957) and low accuracy in data collection can lead to poorly effective storm water control within the considered basin.

At the same time, the measurement of rain intensity is affected by a number of errors, due to both catching and counting inaccuracies, related to the positioning and mechanics/electronics of the instrument employed (Marsalek, 1981; Fankhauser, 1997).

The measurement of rain intensity is traditionally performed by means of tipping-bucket rain gauges (TBRs), the most popular and widespread type of rain gauge actually employed worldwide (Fig. 1). These instruments are known to underestimate rainfall at higher intensities (>100 mm/h) because of the rainwater amount that is lost during the tipping movement of the buckets. The related biases are known as systematic mechanical errors and result in the overestimation of rainfall at lower intensities (<50 mm/h) and underestimation at the higher rain rates (Fankhauser, 1997; La Barbera et al., 2002).

Mechanical errors, although less important in terms of accumulated rainfall, have a strong influence on the measurement of moderate to high rain intensities, with increasing impact as far as the rain rate increases.

On the other hand, intense rain-rates are usually characterized by a short duration, so that any possible correction of the uncertainty connected with mechanical errors strongly depends on the available resolution in time of the considered time series (Lombardo and Stagi, 1998).

Though a simple and effective correction technique exists for the bias induced by systematic mechanical errors, namely dynamic calibration (Marsalek, 1981; Sevruk, 1982;

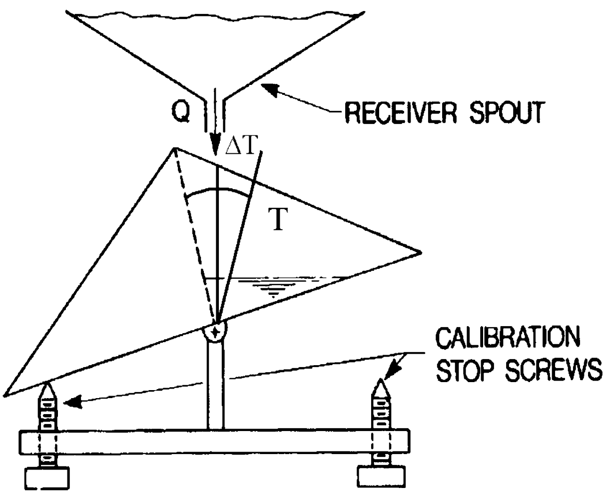

Fig. 1. The tipping-bucket mechanism (after Marsalek, 1981).