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PROPAGATION OF PRECIPITATION MEASUREMENT BIASES INTO THE HYDRAULIC MODELLING OF URBAN DRAINAGE SYSTEMS: A CASE STUDY OF THE PARCO D'ORLEANS SUB-URBAN CATCHMENT

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1 ABSTRACT

Aim of this study is to evaluate the impact of Precipitation Measurement Biases (PMBs) of tipping-bucket rain gauges onto the hydraulic modelling of urban drainage networks. As a case study, the monitored experimental suburban catchment of Parco d'Orleans located in the University Campus of Palermo, Italy and managed since 1987 by the Department of Engineering of the University of Palermo is considered. . Two tipping-bucket rain gauges provide a good spatial coverage of the catchment area and an acoustic level gauge is installed at the outlet of the drainage network for flow measurements. Contemporary high temporal resolution rainfall and runoff data series are available between 1993 to 1998 and are used for the calibration of the hydraulic model in terms of roughness of the urban surfaces. The total drainage area is 12.8 ha with 68% of impervious areas; the drainage network is composed of circular and egg-shaped concrete conduits. In the present work, the sensitivity of this rapid response system to the accuracy of the rainfall input is studied, with reference to drainage failures and urban flooding issues. In order to quantify the instrumental mechanical error of the two available Tipping Bucket Rain-gauges, these were calibrated at the rain gauge laboratory of the WMO Lead Centre on Precipitation Intensity "B. Castelli" following the procedure described in the recent EN 17277:2019 standard on precipitation measurements. For each gauge a calibration curve was provided in order to quantify the measurement bias and the associated calibration uncertainty.

For rainfall-runoff transformation in the urban drainage system, a conceptual model for urban catchment, which incorporates semi-distributed modelling concepts has been used. The urban basin is divided in external sub-catchments connected to the drainage network. Each external sub-catchment is modelled as two separate conceptual linear elements, a reservoir and a channel, one for the pervious part, the other for the impervious part of the investigated area. The drainage network is schematized as a cascade of non-linear cells and the flood routing is simplified in the form of kinematic wave and represented as a flux transfer between adjacent cells. The sensitivity of this rapid response system to the accuracy of the rainfall input has been studied with reference to drainage failures and urban flooding issues.

To examine the effects due to PMBs on the catchment response, a number of simulations were carried out using raw rainfall data and corrected data obtained after the application of the calibration curve for each rain gauge. Results, expressed in terms of comparisons between the hydrographs at catchment outlet, show a significant influence of the PMB on the peak flow and the total hydrograph volume.

2 INTRODUCTION

Precipitation is the primary source of freshwater, while it can have great socio-economical impacts associated with extreme weather events such as floods and droughts. Good quality hydro-meteorological data is an essential condition not only for climate analysis but also for warning systems, hydraulic structures design, risk assessment, etc. In fact, precipitation is one of the most intensively used variables in hydrological modelling and its measurement accuracy is of foremost importance (*Peterson et al.*, 1998). Accurate and timely knowledge of precipitation characteristics at urban and natural basins scales is essential for understanding how different catchment hydrological systems operate under changing climatic conditions and for improved applications that range from flash flood prediction to freshwater resource management. Difficulties in achieving accurate measurements arise from various instrumental and environmental sources of systematic biases, resulting in a significant underestimation or overestimation of precipitation in terms of rainfall depth or intensity. Instrumental errors are systematic and related to the sensor specifications (sensitivity, measuring principle), allowing correction techniques based on laboratory test (*Lanza & Stagi*, 2009; *Colli et al.*, 2013; *Colli et al.*, 2014). Although several attempts made to standardize measurements procedure, this has never been successfully achieved. Traditional rain gauges provide, still nowadays, the only direct measurement of precipitation. These allow a high measurement resolution in time but are local in nature, and the obtained information is often referred to as "point precipitation". In order to provide sufficient coverage of the catchment area of hydrological basins, multiple instruments are needed, while interpolation methods are used to fill in the area between the gauge locations.

3 MATERIALS AND METHODS

Aim of this study is to evaluate the impact of Precipitation Measurement Biases (PMBs) of tipping bucket rain gauges into the hydraulic modelling of urban drainage networks. As a case study, the monitored experimental suburban catchment of Parco d'Orleans located in the University Campus of Palermo, Italy and managed since 1987 by the Department of Engineering of the University of Palermo is considered (figure 1).

Two tipping-bucket rain gauges provide a good spatial coverage of the catchment area and an acoustic level gauge is installed at the outlet of the drainage network for flow measurements. In addition, over the years, the Department of Engineering has improved its precipitation monitoring with an optical disdrometer (OTT Parsivel2), and a weighing rain-gauge (OTT Pluvio), all located in the Campus; a single polarization X-band weather radar providing rainfall information related to both PPI (Plan Position Indicator) and RHI (Range Height Indicator) scan modes; a rain-gauge network constituted by 18 tipping bucket rain-gauges spread over the area of Palermo.

Contemporary high temporal resolution rainfall and runoff data series are available between 1993 to 1998, and are used for the calibration of the hydraulic model in terms of roughness of the urban surfaces. The total drainage area is 12.8 ha with 68% of impervious areas; the drainage network is composed of circular and egg-shaped concrete conduits. In the present work, the sensitivity of this rapid response system to the accuracy of the rainfall input is studied, with reference to drainage failures and urban flooding issues. In order to quantify the instrumental mechanical error of the two available Tipping Bucket Rain-gauges, these were calibrated at the rain gauge laboratory of the WMO Lead Centre on Precipitation Intensity "B. Castelli" following the procedure described in the recent EN 17277:2019 standard on precipitation measurements.

Figure 1. The Parco d'Orleans case study.

For rainfall-runoff transformation in the urban drainage system, a conceptual model for urban catchment, which incorporates semi-distributed modelling concepts has been used (*Aronica & Cannarozzo*, 2000). The urban basin is divided in external sub-catchments connected to the drainage network. Each external subcatchment is modelled as two separate conceptual linear elements, a reservoir and a channel, one for the pervious part, the other for the impervious part of the investigated area. The drainage network is schematized as a cascade of non-linear cells and the flood routing is simplified in the form of kinematic wave and represented as a flux transfer between adjacent cells. The sensitivity of this rapid response system to the accuracy of the rainfall input has been studied with reference to drainage failures and urban flooding issues.

4 RESULTS

For each gauge, a calibration curve was obtained in order to quantify the measurement bias and the associated calibration uncertainty. The calibration results are presented with reference to two different rain gauges and two methods for determining the intensity of precipitation. The first refers to the method of counting the overturns that occur for each test minute (tip counting), the second method instead provides for the measurement of the time elapsed between two successive overturns and attributes a precipitation intensity value to each overturning (intertip), the rainfall data are then aggregated to the one-minute time scale. For both algorithms, two graphs are proposed, one that illustrates the performance of the instrument without applying any correction and one that shows the performance with the application of the respective calibration curve. In figure 2, for example, relative errors related to one rain gauge without correction and with correction are reported, where the correction is applied by using the intertip algorithm. As can be seen, without correction of the systematic mechanical error, the instrument underestimation ranges between 15% and 30% in the measurement range considered. The underestimation of the rain gauge is significant throughout the intensity range, also due to the inconsistency between the adjustment of the tilting volume of the weighing platform and the nominal resolution of the instrument (0.1 mm). The correction of the systematic mechanical error brings the deviations back to more contained values between ± 3% (Class A), being able to attribute Class A for almost the entire range of intensity 0-300 mm/h.

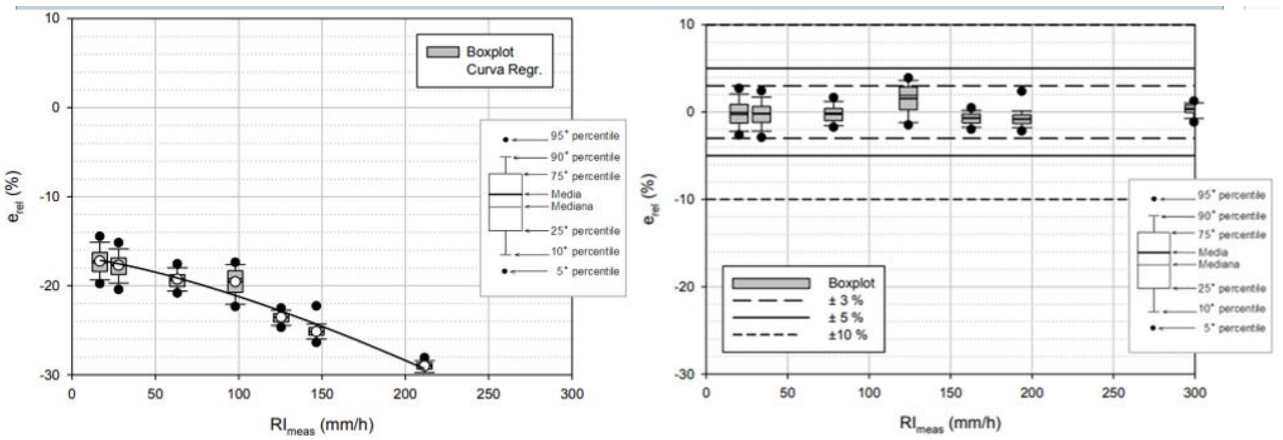

Figura 2. Relative errors (in %) related to ISCO 674 Rain Gauge without correction (left) and with correction (right) obtained using the intertip algorithm.

To examine the effects due to PMBs on the catchment response, a number of simulations were carried out using raw rainfall data and corrected data obtained after the application of the calibration curve for each rain gauge. Results, expressed in terms of the comparison between the hydrographs at catchment outlet, show a significant influence of the PMB on the peak flow and the total hydrograph volume. As an example, in figure 3 the comparison of the hydrographs at catchment outlet is shown, for one sample event. The comparison in figure 3 between the two hydrographs, shows that for an increase of about 20% in terms of total rain volume corresponds a greater increase in terms of flood volume and flood peak, of about 80%; this results confirms the propagation of precipitation measurement biases into the hydraulic modelling of urban drainage network.

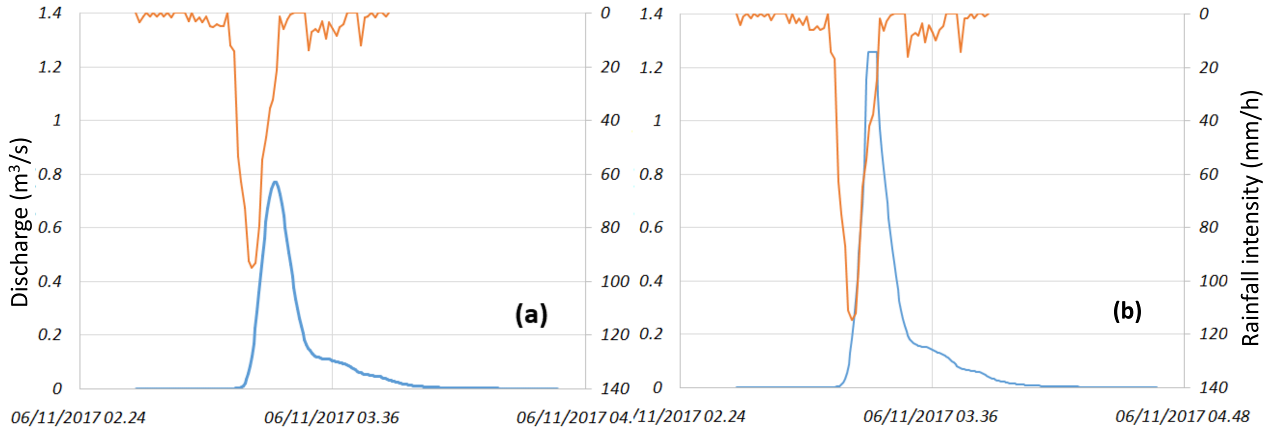

Figura 3. Hydrographs at catchment outlet for one sample event and for rain without correction (a) and with correction obtained using the intertip algorithm (b).

REFERENCES

Aronica, G.T., Cannarozzo, M. Studying The Hydrological Response Of Urban Catchments Using A Semi-Distributed Linear Non-Linear Model, Journal of Hydrology, 2000, 238(1-2), 35-43.

Colli, M., Lanza, L.G., La Barbera P. Performance of a weighing rain gauge under laboratory simulated time-varying reference rainfall rates. Atmospheric Research, 2013, 131, 3–12.

Colli, M., Lanza, L.G., La Barbera, P. & Chan, P.W. Measurement accuracy of weighing and tipping-bucket rainfall intensity gauges under dynamic laboratory testing. Atmospheric Research, 2014, 144, 186-194.

Lanza, L.G., & Stagi, L. High resolution performances of catching type raingauges from the laboratory phase of the WMO Field Intercomparison of Rain Intensity Gauges, Atmospheric Research, 2009, 94, 555–563.

Peterson, T.C., Easterling, D.R., Karl- T.R., Groisman, P., Nicholls, N., Plummer, N., Torok, S., Auer, I., Boehm, R., Gullett, D., Vincent, L., Heino, R., Toemenvirta, H., Mestre, O., Szentimrey, T., Salinger, J., Førland, E., Hanssen-Bauer, I., Alexandersson, H., Jones, P., Parker, D. Homogeneity adjustments of in situ atmospheric climate data: a review. International Journal of Climatology, 1998, 18, 1493-1517.