PROPAGATION OF PRECIPITATION MEASUREMENT BIASES INTO HYDROLOGICAL SIMULATION: A CASE STUDY

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KEY POINTS

- *Precipitation measurements are affected by instrumental and environmental factors*
- *Tipping bucket raingauges underestimation increases with precipitation intensity*
- *The impact on hydrological simulation was assessed using a spatially distributed model*

1 INTRODUCTION

Errors in precipitation measurements may be due to instrumental issues or environmental factors. For Tipping Bucket Raingauges (TBRs) the underestimation due to the mechanical bias was largely described in the literature and considered in the recently published measurement quality standards (e.g. EN 17277:2019), while wind is recognized as the main environmental factor affecting the measurement accuracy. Precipitation Measurements Biases (PMBs), both of instrumental and environmental origins, propagates into the modelling of hydrological processes at the catchment scale.

This work investigates the impact of systematic mechanical errors in precipitation measurements on the hydrological simulation. Here the case study of the Seveso river basin in Milan, Italy, is addressed – a highly urbanized catchment that suffered from severe floods in the last years.

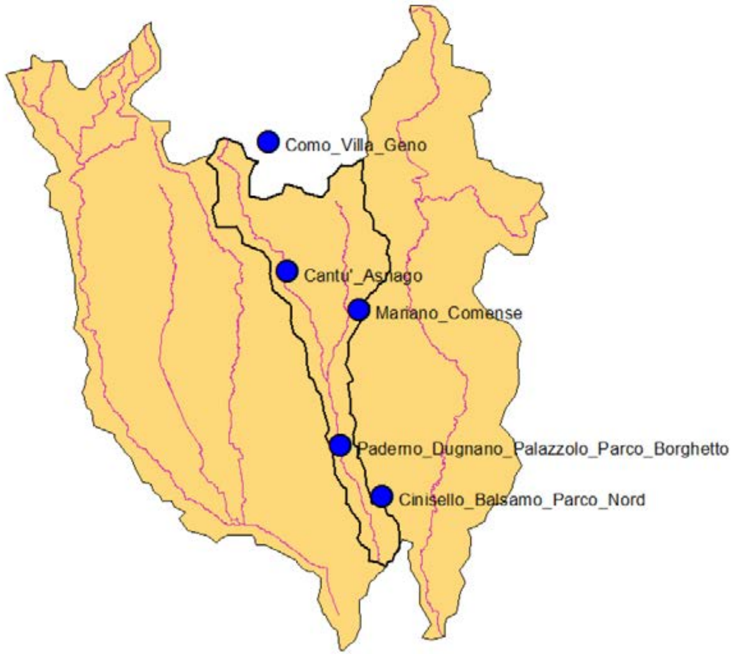

Figure 1. The Seveso river basin (marked with black line) and the location of raingauge stations managed by the Environmental protection Agency of the Lombardia region.

2 THE CASE STUDY OF THE SEVESO RIVER BASIN

The Seveso river basin has a total area of 207 km^2 (see Figure 1). This is a high flood hazard region where, during the 1970s, a series of risk mitigation works were carried out with the aim of reducing the frequent flooding of the urban areas. Urban development increased the percentage of impermeable areas within the Seveso river basin, and this exacerbated the frequency and intensity of floods. An accurate precipitation monitoring system, together with real time flood forecasting are recognized as paramount measures for risk mitigation in the area.

In this work, precipitation measurements from five raingauge stations were obtained from the Regional Environmental Protection Agency of the Lombardia region, which is in charge for the management of the meteorological and hydrological monitoring networks. Data at the time resolution of 1 minute are available for the Como, Cantù and Cinisello Balsamo stations, while the Paderno Dugnano station collects data at a resolution of 5 minutes, and the Mariano Comense station collects data at a resolution of 10 minutes. The available coverage is from January 1st, 2015 to December 31st, 2018. For the same period, flow rate measurements are available at the resolution of 5 minutes from the Paderno Dugnano flow gauge station.

3 ASSESSMENT OF SYSTEMATIC MECHANICAL ERRORS OF TBRS

The five TBRs available for the Seveso river basin were tested in the field using a portable calibrator device (illustrated in Figure 2a) in order to quantify their systematic mechanical error (see e.g. *La Barbera et al.*, 2002; *Molini et al.*, 2005). The calibrator allows generating constant flows by selecting one out of four output nozzles and opening one out of three air intakes. Each air intake provides a constant pressure head to the output nozzle during the empting time and ensures that the outflow is constant. Furthermore, the calibrator is provided with five optical sensors able to detect the passage of the water level inside the calibrator cylinder and to measure the time needed to empty the volume between each couple of sensors. Each volume was previously calibrated in the laboratory and measuring their empting time allows evaluating the outflow rate. Three equivalent flow rates were generated, equivalent to 50, 100 and 200 mm/h (for a 1000 cm^2 gauge collecting area). Results are provided in terms of percentage relative errors, defined by the following equation:

$$e_{rel}\,(\%) = \frac{RI_{meas} - RI_{ref}}{RI_{ref}} * 100$$

where RI_{meas} is the rainfall intensity value measured by the instrument and RI_{ref} is the reference value generated by the calibration device. In Figure 2b field test results are shown for the three raingauges operating at a resolution of 1 minute.

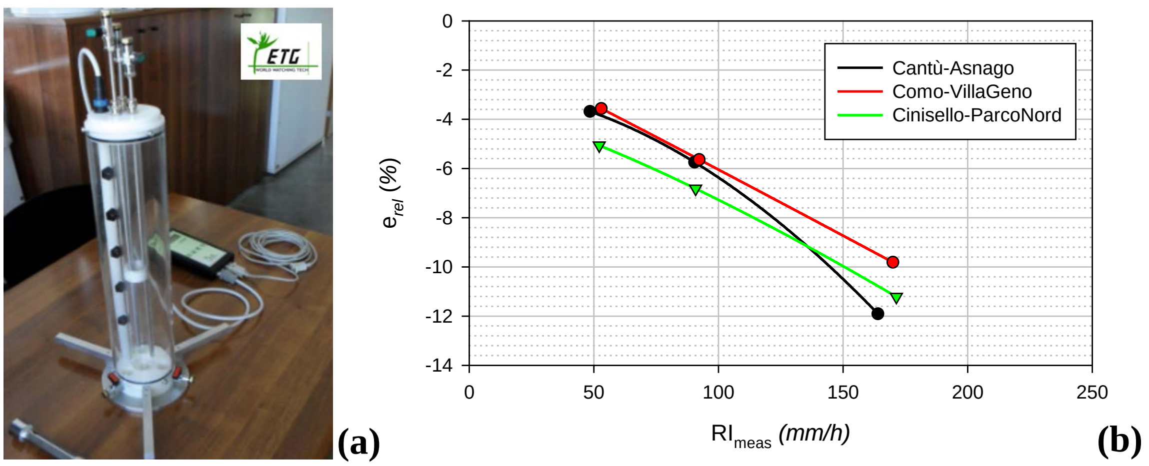

Figure 2. The portable calibrator (a) and field verification results for the three raingauges operating at a resolution of one minute (b).

4 THE HYDROLOGICAL MODEL

The physically-based spatially distributed FEST-WB model developed on top of MOSAICO library (*Rabuffetti et al*., 2008 2010; *Ceppi et al*., 2013; *Ravazzani*, 2013) was employed for simulating the rainfall-runoff transformation. FEST-WB computes the main processes of the hydrological cycle (according to the schematics of Figure 3): evapotranspiration, infiltration, surface runoff, flow routing, subsurface flow, snow melt and accumulation. The computational domain is discretized with a mesh of regular square cells (200 × 200 m in this study), in each of them water fluxes being calculated with a hourly time step.

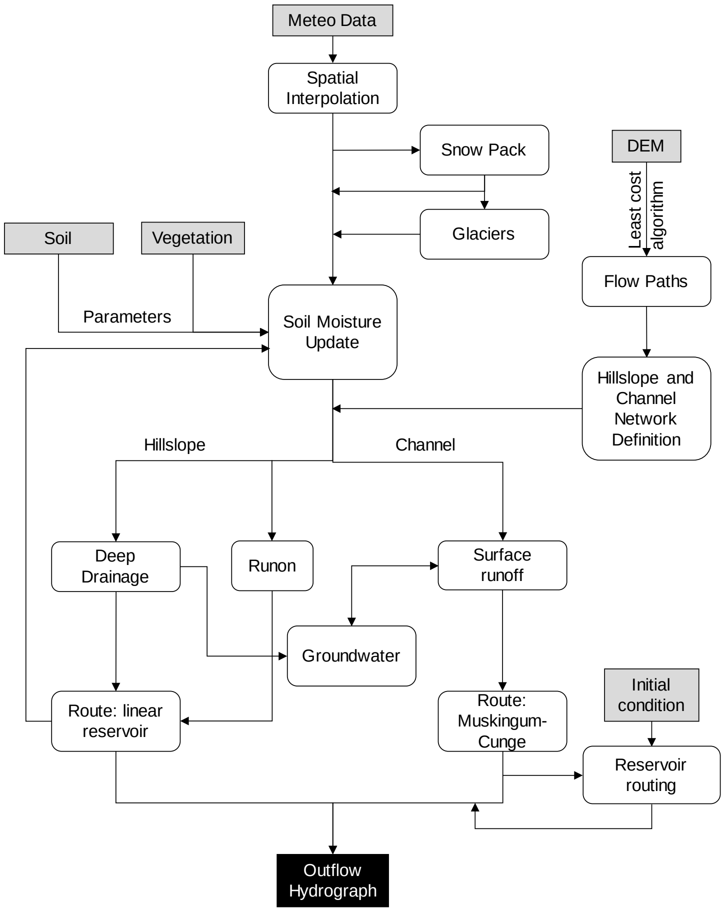

Figure 3. Flow chart of the FEST-WB hydrological model.

5 SIMULATION RESULTS

Simulation results for a significant convective event occurred on June 2017 are presented in Figure 4. The event is characterized by two main consecutive precipitation spells that generated a two peaks flood hydrograph. The return period of the precipitation intensity for 30 minute duration is about 50 years. As the error in precipitation measurements is more relevant at the highest intensity values, the larger impact is noticeable on the peak values of the hydrograph. The difference between the original and adjusted cumulated precipitation is about 5%, which causes a difference of peak discharge of about 4%. The correction does not affect though the timing of the flood peak, as expected.

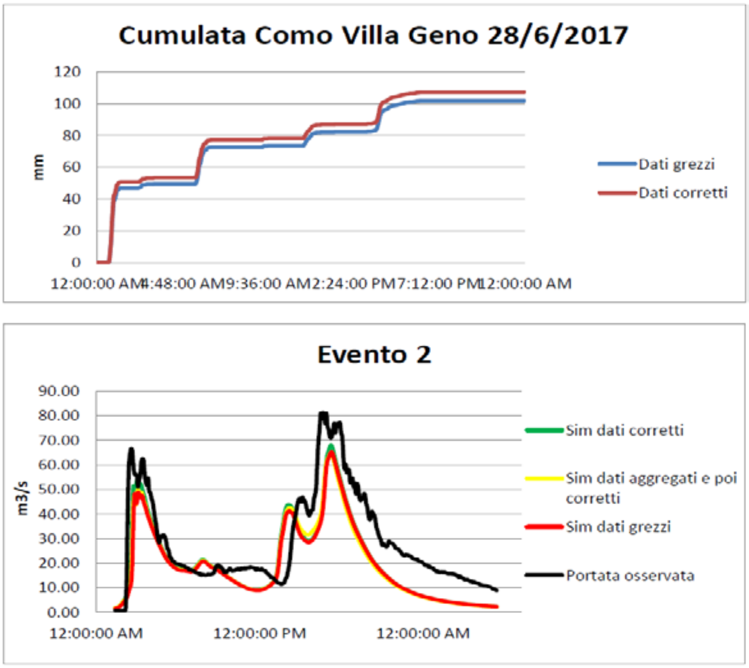

Figure 4. Cumulated precipitation (upper panel) and hydrograph (lower panel) simulated with original and adjusted precipitation.

6 CONCLUSIONS

The systematic mechanical errors of tipping bucket raingauges investigated in this work show an increasing underestimation with increasing the rainfall intensity, reaching more than 10% for the highest tested intensity of 200 mm/h. Considering the events occurred in the period 2015-2018, the maximum impact of this error was detected during the June 2017 event characterized by two spells of heavy precipitation. The error on cumulated precipitation was an underestimation of about 5%, which resulted in a shift of the peak discharge of about 4%. Further ongoing analysis will consider the impact of wind on the precipitation measurement and its propagation into the hydrological modelling.

ACKNOWLEDGEMENTS

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