Società Idrologica Italiana
Italian Hydrological Society

UNIVERSITÀ DEGLI STUDI DI UDINE

Le Giornate dell'Idrologia
della Società Idrologica Italiana 2024
Udine, 24-26 Giugno 2024

MODELLING OF PLUVIAL FLOODING: THE IMPACT OF ACCURACY AND SPATIO-TEMPORAL RESOLUTION OF THE RAINFALL INPUT

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Abstract

In the present work the input rainfall data availability issue, with a specific focus on their accuracy and the spatio-temporal resolution, is addressed by comparing pluvial flooding scenarios obtained with 2-D flood model forced by rain gauges and opportunistic sensors for an urban case study. This approach allows us to mimic different rainfall monitoring levels of an urban basin from the ungauged ones to a high level of accuracy of the rainfall data.

Introduction

In this paper flood hazard maps were derived assuming different spatial and temporal scales of the forcing phenomena. The selected area is located within the urban catchment in the Sampierdarena district of Genoa whose extension is about 1.8 km^2. Regarding water management, the area is mainly served by a combined sewer system partially overlapped with the natural stream network (now culverted) and solely a marginal area is drained by a stormwater drainage system. In the present paper the rainfall event that occurred on September 24th,2022 has been investigated, such an event was characterized by a low return period (T between 1.5 and 3 years). The areas flooded during this high-intensity and short-duration rainfall events are distributed across the district, mainly in the downstream subcatchment areas characterized by a degrading steepness.

Materials and methods

In the present work the investigated area is limited to the downstream part of the catchment. It is equipped with a traditional tipping-bucket rain gauge station (Arpal-FI) managed by the environmental protection agency of the Liguria region (ARPAL) and one Smart Rainfall System (SRS-SA). Two further SRSs and two ARPAL raingauges are available close to the investigated area. The position of instruments is shown in Figure 1a also indicating the naming codes. Measurements from the ARPAL rain gauges are available at 5 minutes resolution while SRSs provide measurements at 1 minute resolution. Depth Duration Frequency (DDF) curves were derived using the DICCA-UNIGE raingauge, a highly accurate rainfall data set, about thirty years of corrected rainfall intensity measurements (from January 1st, 1988, to December 31st, 2021) at one minute resolution. Pluvial flooding scenarios were modelled using the HEC-RAS 2D software (*USACE* 2021), solving the shallow water equations (SWE-EM stricter momentum) at fixed time steps of 0.5s and a mesh size equal to 5m. Spatial information is provided by a high resolution (1m) DTM, where buildings were added using a GIS software. The Manning coefficient was set equal to 0.018 $s/m^{1/3}$ (see *Palla et al., 2018*) and 0.030 $s/m^{1/3}$ for roads and green areas, respectively. The boundary of the domain was set permeable. Roads are set as impervious surfaces while the roof of buildings discharge directly in the underground drainage network. This is modelled using a dedicated infiltration layer. (see *Chinchella et al.* 2024 for further details). The following scenarios were investigated: a) symmetric Chicago hyetographs at T = 10 years using raw and corrected DDF curves, for d = 2 hours; b) rainfall event occurred on September 24th, 2022 as measured by Arpal TBRs and the SRSs; c) rainfall event occurred on September 24th, 2022 as measured by the rain gauge Arpal-FI, located within the investigated urban area, assuming different temporal resolutions equal to 5 – 15 – 30 and 60 minutes.

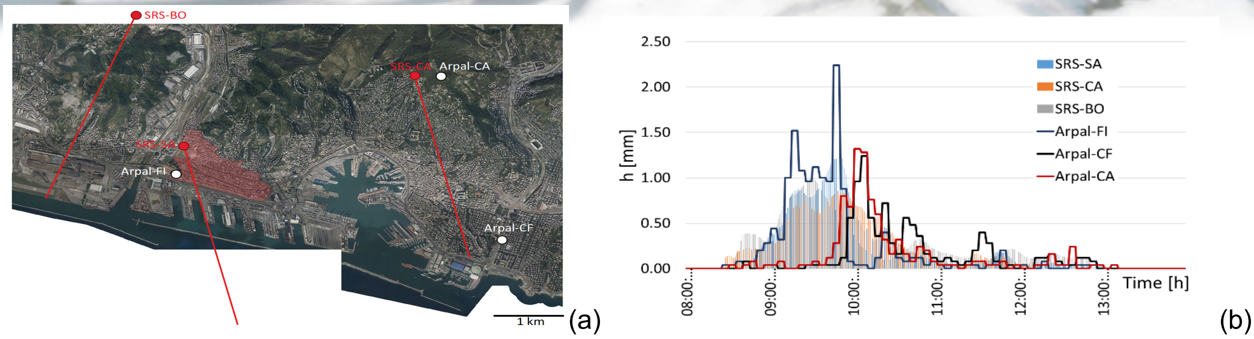

Figure 1. (a) overview of the investigated urban area (red portion) with indicated the position of the three rain gauges (white circles) and the three SRSs (red circles) with the associated atmospheric links (red lines), (b) temporal evolution of the investigated rainfall event (September 24th, 2022) as measured by the various sensors.

Results

Simulation results can be summarized in terms of maps of the flooding water depth and velocity. Significant differences were observed and quantified between flooding scenarios obtained by simulating the distribution of excess rainwater when various rainfall data are considered. Although the overall flooding conditions are captured in all the examined cases, due to the simplification adopted in the flow modelling approach, it is evident from the results that significant differences in the expected flood volumes and maximum water depth and velocity are obtained using various sources, accuracy, and temporal resolution of the rainfall information. Larger differences were obtained in the case of the simulated event, revealing that the role of opportunistic sensors located within or in the proximity of the study area largely outperforms the contribution of nearby rain gauge data when these are located even only 5 km far from the study area. The ratios of the conditional flooded volume and the maximum water depth between each sensor and the reference value are summarized in Table 1.

Scenario	Instrument	Rainfall Ratio	Peak ratio	Volume ratio when h>5cm	Max Depth ratio
a)	$DICCA_{raw}/DICCA_{corr}$	0.94	0.89	0.96	0.99
b)	Arpal-CA/Arpal-FI	0.62	0.59	0.54	0.91
	Arpal-CF/Arpal-FI	0.64	0.55	0.50	0.91
	SRS-SA/Arpal-FI	1.07	0.56	0.90	1.02
	SRS-CA/Arpal-FI	1.02	0.38	0.84	1.01
	SRS-BO/Arpal-FI	1.08	0.45	0.79	1.03
c)	$Arpal\text{-}FI_{15}/Arpal\text{-}FI_5$	n.a.	0.53	1.00	1.00
	$Arpal\text{-}FI_{30}/Arpal\text{-}FI_5$	n.a.	0.47	0.99	1.00
	$Arpal\text{-}FI_{60}/Arpal\text{-}FI_5$	n.a.	0.43	0.98	1.00

Table 1. Rainfall event and flooding parameters as a comparison with the reference instrument for each scenario.

References

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