Safer_RAIN: a Fast-Processing DEM-Based Algorithm for Pluvial Flood Hazard Assessment Across Large Urban Areas

Attilio Castellarin[1], Caterina Samela[2], Simone Persiano[1], Stefano Bagli[3], Valerio Luzzi[4], Paolo Mazzoli[5], Jaroslav Mysiak[6], Günter Humer[7], and Andreas Reithofer[7]

[1]University of Bologna
[2]University of Basilicata
[3]GECOsitema Srl
[4]Gecosistema Srl
[5]GECOSistema Srl
[6]CMCC Euro-Mediterranean Center on Climate Change, Ca' Foscari University of Venice
[7]Dipl.-Ing. Günter Humer GmbH

November 25, 2022

Abstract

Urban areas (i.e. cities, towns and suburbs) provide a home to over 70% of the EU-population, and this number is expected to exceed 80% by 2050 (Tapia et al., ECOL INDIC, 2017). The increase in frequency and intensity of extreme precipitation events caused by the changing climate (e.g. cloudbursts, rainstorms, heavy rainfall, hail, heavy snow) combined with the high population density and concentration of assets in urban areas makes them particularly vulnerable to pluvial flooding, hence, assessing their vulnerability under current and future climate scenarios is of paramount importance. Detailed hydrologic-hydraulic numerical modelling is resource intensive and therefore scarcely suitable for a consistent hazard assessment across large urban settlements. Given the steadily increasing availability of LiDAR (Light Detection And Ranging) high-resolution DEMs (Digital Elevation Models), several studies highlighted the potential for consistent pluvial flood hazard characterization of fast-processing DEM-based methods, such as the Hierarchical Filling and Spilling or Puddle-to-Puddle Dynamic Filling and Spilling (see e.g. Zhang et al., J HYDROL, 2014; Chu et al., WATER RESOUR RES, 2013). As part of the activities of the EIT Climate-KIC Demonstrator project SAFERPLACES (https://saferplaces.co/), we developed a fast-processing algorithm, named Safer_RAIN, that enables one to map pluvial flooding in large urban areas by implementing a filling and spilling procedure that accounts for spatially distributed rainfall input and infiltration processes (Green Ampt method). We present the first applications of the algorithm to model recent urban inundations occurred in Northern Italy. These preliminary applications, compared against ground evidence and detailed output from a two-dimensional hydrologic and hydraulic numerical model, highlight limitations and potential of Safer_RAIN for identifying pluvial-hazard hotspots across large urban environments.

H13J-1832 Safer_RAIN: a Fast-Processing DEM-Based Algorithm for Pluvial Flood Hazard Assessment Across Large Urban Areas

Attilio Castellarin[1] **(attilio.castellarin@unibo.it)**; Caterina Samela[1]; Simone Persiano[1]; Stefano Bagli[2]; Valerio Luzzi[2]; Paolo Mazzoli[2]; Jaroslav Mysiak[3]; Günter Humer[4]; Andreas Reithofer[4]

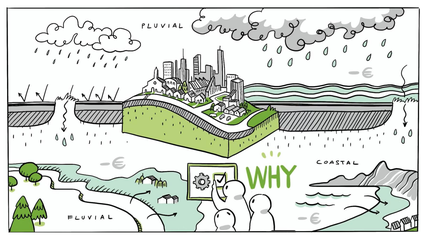
[1] University of Bologna
[2] GECOsitema Srl
[3] CMCC – Centro Euro-Mediterraneo sui Cambiamenti Climatici
[4] Dipl.-Ing. Günter Humer GmbH

Climate-KIC is supported by the EIT, a body of the European Union

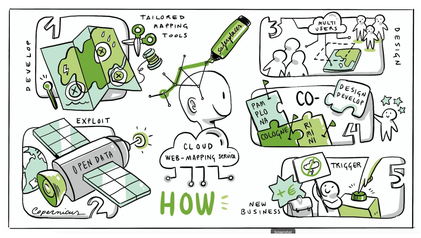
1. SaferPlaces https://saferplaces.co/

Climate-KIC Demonstrator Project

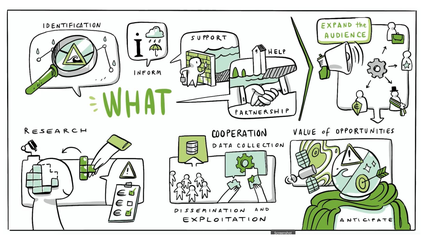
SaferPLACES - Improved assessment of pluvial, fluvial and coastal flood hazards and risks in European cities as a means for building safer and more resilient communities



WHY: CITIES ARE FLOODING!
Anthropogenic pressure (soil sealing, land subsidence) and increasing in occurrence of Extreme weather events (Pluvial, Fluvial and Coastal Hazards)
NEED FOR INNOVATION in urban flood-proofing tools and data.



HOW: IMPROVE ASSESSMENT
New simplified and Computationally efficient tools
exploiting open data and high-resolution DEM for Real-time analysis of multiple scenarios for supporting intelligence-led climate service, resilience and adaptation in our cities



WHAT:
CLOUD-WEB PLATFORM TAILORED FOR MAPPING FLOOD HAZARDS AND RISK IN URBAN AREAS

Follow us!
Twitter: **@SaferPlacesCKIC**
Hashtag: **#SAFERPLACES_CKIC**

2. Safer_RAIN Algorithm

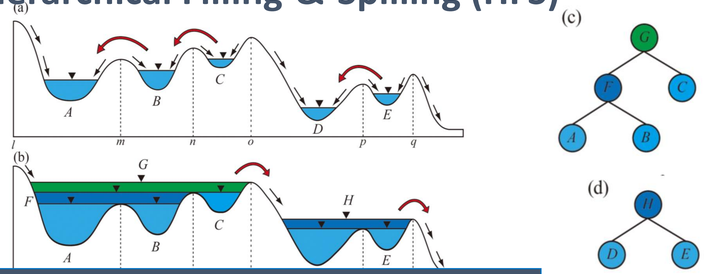
Poster's focus: Pluvial-flooding in urban areas

Why pluvial flooding?

Relative to fluvial and coastal flooding:
localized damages
yet
higher frequency

Non-negligible
Expected yearly losses

Safer_RAIN Algorithm: Hierarchical Filling-&-Spilling (HFS)

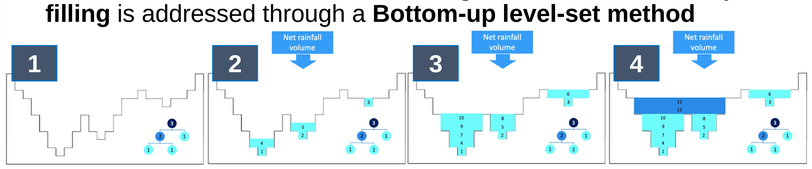


DEM PRE-PROCESSING (STATE OF THE ART)

1. Definition of **horizontal hydrological hierarchy**: identification of blue-spots (first-level depressions, **G** and **H**) through **DEM pit-filling**, and corresponding pour-point and contributing watersheds;
2. Definition of **vertical hierarchical structure within each blue-spot**, the higher-level depressions (**A**, **B**, **C**, **D**, **E**, and **F**), their hierarchical relationship and water-level / volume relationship through **Top-down level-set method**, *Wu et al.*, 2018)

FLOODING PHASE (NEW)

3. Identification of **flooded areas for a given rainfall volume, partial filling** is addressed through a **Bottom-up level-set method**



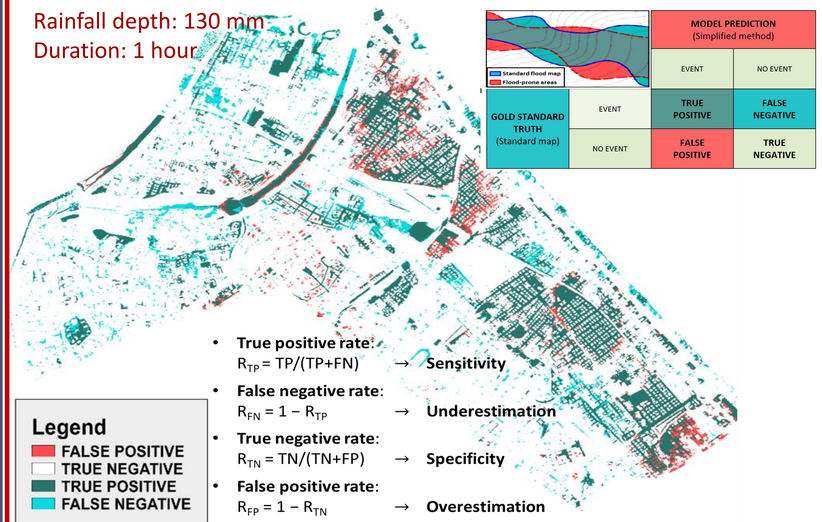
Wu and Lane, HESS, 2017
Wu et al., JAWRA, 2018

3. Safer_RAIN Applications (A & B)

A. Benchmarking on Rimini pluvial flooding

(Available DEM: 2m LiDAR, hypothesis: completely impervious surface) relative to water depth at 180 min simulated through a fully-2D hydrological-hydrodynamic model (https://ib-humer.at/en/)

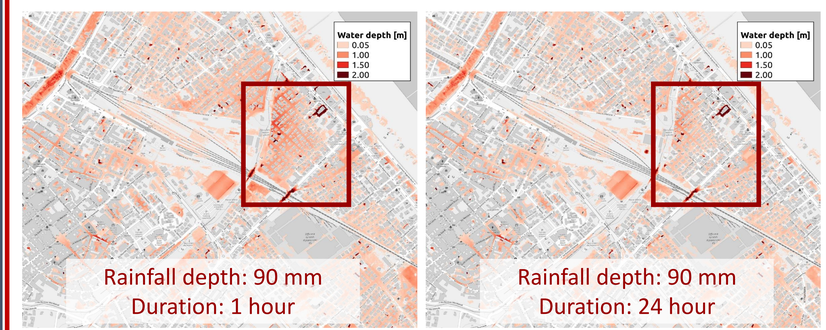
Rainfall depth: 130 mm
Duration: 1 hour



- True positive rate: $R_{TP} = TP/(TP+FN)$ → **Sensitivity**
- False negative rate: $R_{FN} = 1 - R_{TP}$ → **Underestimation**
- True negative rate: $R_{TN} = TN/(TN+FP)$ → **Specificity**
- False positive rate: $R_{FP} = 1 - R_{TN}$ → **Overestimation**

Rainfall [mm]	Sensitivity (TPR)	Underestimation (FNR)	Specificity (TNR)	Overestimation (FPR)
130	70%	30%	98%	2%

B. Green-Ampt pixel-based infiltration



Wrap-up

Limitation: flooding dynamics is not modelled
Advantage: fast-processing and computationally effective (quick tests on multiple hazard scenarios); pixel-based spatially variable net-precipitation; reliable detection of pluvial-hazard hotspots
Efficient tool for urban flood-proofing (e.g. optimal location of detention tanks/ponds)