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IMPACT OF RAINFALL DATA RESOLUTION IN TIME AND SPACE ON THE URBAN FLOODING EVALUATION

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Introduction

Local flooding is a recurrent problem for many European cities where drainage systems are often surcharged by the sole rainfall

A robust statistical frequency analysis of urban flooding could be a preliminary step to improve a proactive management of flooding

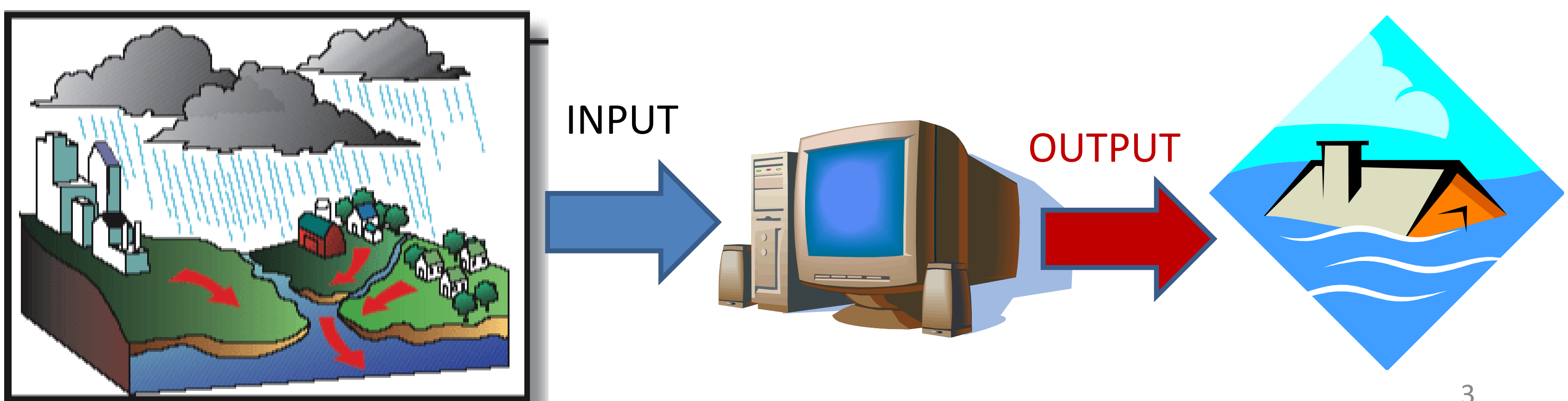
However, **in most cases historical series of flood data are unavailable for performing a statistical analysis of flooding events aimed to a reliable assessment of the urban flood risk**

Urban flood modelling

Usually flood frequency analysis in urban areas is indirectly carried out by adopting advanced hydraulic models to simulate long historical rainfall series.

Modelling results are affected by a grade of uncertainty

- Uncertainty in rainfall – runoff transformation
- **Imperfect knowledge of rainfall variability in time and space**



Objectives of the study

To analyse the effect of rainfall time and space resolution on flooding modelling:

- A mathematical model of urban flooding propagation was applied to a real case study
- The maximum efficiency conditions of the model and the uncertainty affecting urban flooding modelling results were evaluated by the means of a GLUE analysis
- The added value provided by the adoption of finer temporal and spatial resolutions of the rainfall was assessed

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Presentation outline

1. Description of the hydraulic model
2. Description of the case study and available database
3. Description of the proposed methodology
4. Results and discussions
5. Conclusions

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The adopted simulation models

Surface runoff

- Surface retention
- Infiltration phenomena

→ non-linear reservoir model

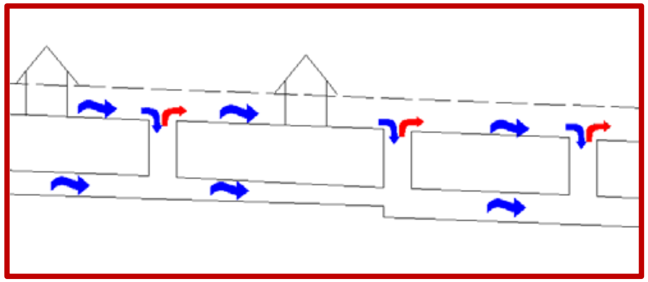
Pipe flow

- Backwater
- Surcharge

→ - 1D De Saint Venant equ.
- Preissman slot scheme

Propagation of surface floodings:

Flooding 1D – 1D mathematical model



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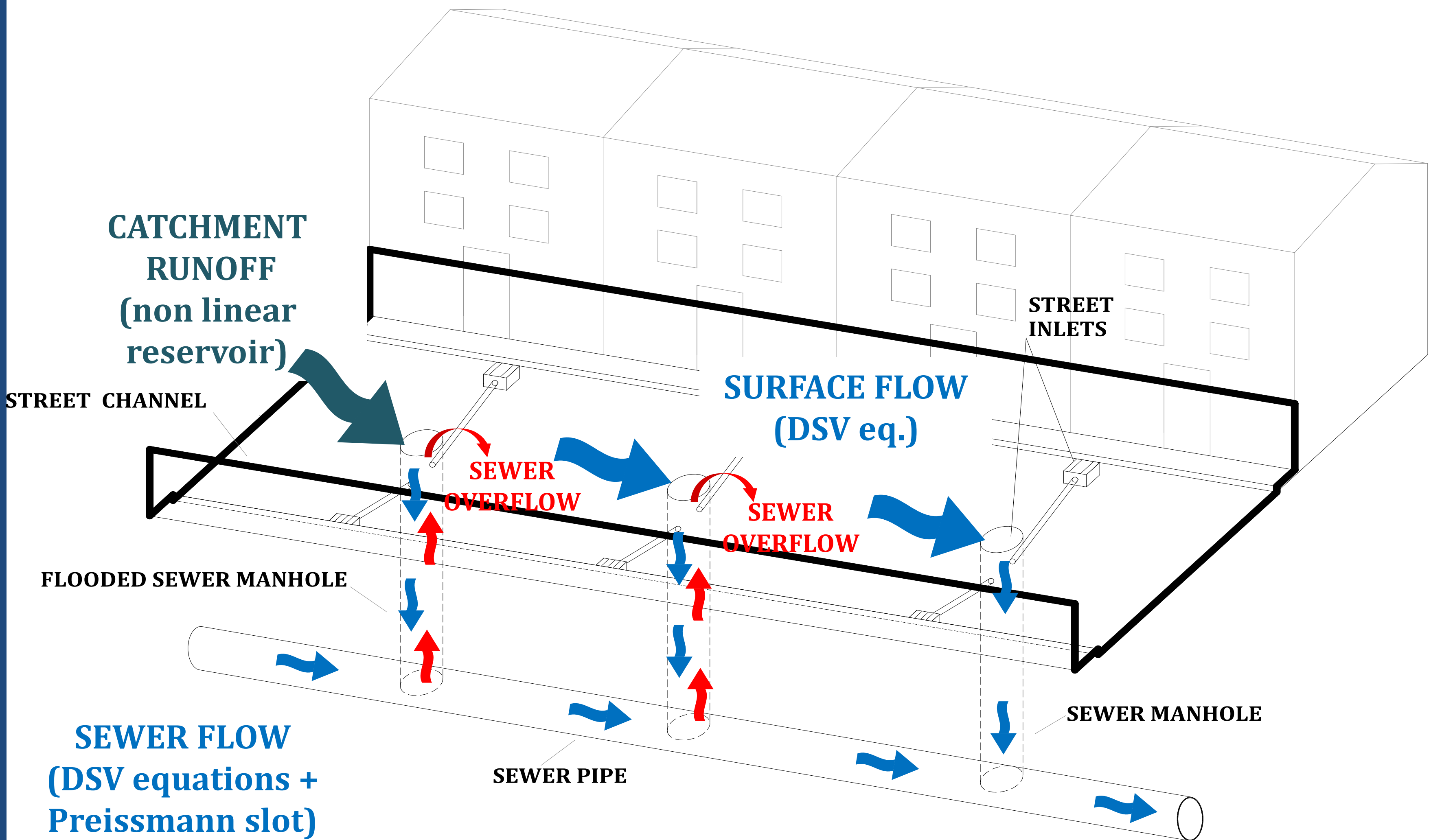
Flooding 1D – 1D mathematical model (SWMM)



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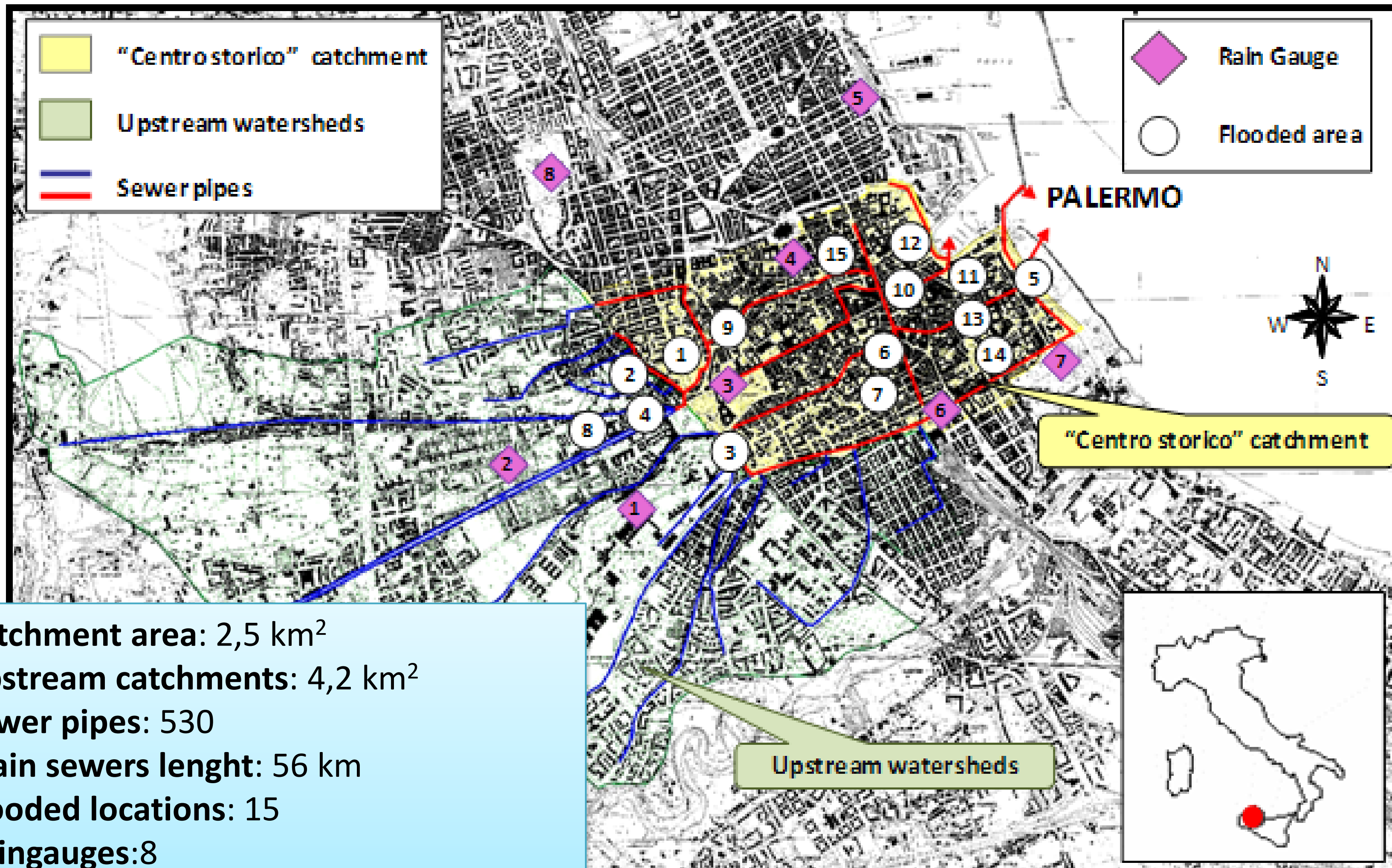
The case study: Palermo city centre (Italy)



Catchment area: 2,5 km^2
Upstream catchments: 4,2 km^2
Sewer pipes: 530
Main sewers lenght: 56 km
Flooded locations: 15
Raingauges:8
Monitored flooding events: 30 in the period 1994 - 2008

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Step 1 - Rainfall temporal resampling

12 historical rainfall time series recorded between 1993-1997 with high temporal resolution (1-3 min) by a network of 8 raingauges in the analyzed area was adopted

For each historical rainfall event, the duration was divided into n equal time intervals ranging from 5 to 15 min with step of 1 min and for each of these temporal windows the average intensity was evaluated.

↓

For each historical rainfall event 11 hyetographs with a coarser temporal resolution were obtained

According to the mass balance principle, for each time step, the real event and the re-sampled one are characterised by the same rainfall volume.

STEP 2 - Rainfall spatial resampling

Rainfall data from some of the raingauges present in the watershed were neglected to analyse the influence of the spatial rainfall aggregation on the efficiency of rainfall-runoff model predictions

- The number of sampled raingauges was selected between 1 and 8 and all possible combinations of raingauges were evaluated.
- For each combination, urban sub-catchments were linked to the closer raingauge according to the minimum Euclidean distance criterion.

The total number of raingauge combinations was **255**

The analysed spatial and temporal resolution scenarios were in total **2805** (255x11).

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STEP 3 – Evaluation of rainfall performance indicators

- To quantify the goodness of rainfall estimates with respect to the reference rainfalls adopting the whole raingauge network (8 RG) with the finer temporal resolution
- The resampling performance and accuracy in the description of a rainfall event in time and space was analysed by **BALANCE** and **GORE** indices *(Andréiassian et al., 2001)*:

$$\text{BALANCE} = \frac{\sum_{i=1}^{n} P_i^E}{\sum_{i=1}^{n} P_i} \qquad \text{GORE} = 1 - \frac{\sum_{i=1}^{n}\left(\sqrt{P_i^E}-\sqrt{P_i}\right)^2}{\sum_{i=1}^{n}\left(\sqrt{P_i}-\overline{\sqrt{P_i}}\right)^2}$$

BALANCE quantifies the overestimation (when >1) or underestimation (when <1) of the rainfall volume in each analysed scenario.

GORE compares the sum of squared errors in the rainfall estimate in each scenario to the temporal variance of the reference precipitation (obtained with the maximum temporal resolution and the whole raingauge network).

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STEP 4 – Modelling efficiency evaluation

- Modelling results obtained with historical rainfall events were compared with those achieved using coarser estimate rainfall data

- The uncertainty inherent in flood modelling results was assessed within the GLUE framework using the Nash and Sutcliff criterion (N-S) adopted as likelihood measure

$$E = 1 - \left(\frac{\sigma_e}{\sigma_0}\right)^2$$

Methodology application to a case study

At first,

- **the mathematical model was calibrated for all 2805 considered scenarios** by defining 1000 random Monte Carlo sets of parameters (rainfall – runoff parameters and drainage system roughness) and then selecting the one providing the highest N-S criterion computed on flooding depths.

Then,

- **the rainfall performance indicators were evaluated and compared with model efficiency in the flood depths appraisal;**
- **the model uncertainty was correlated to the availability of rainfall data** considering the impact of different possible combinations of a fixed number of raingauges

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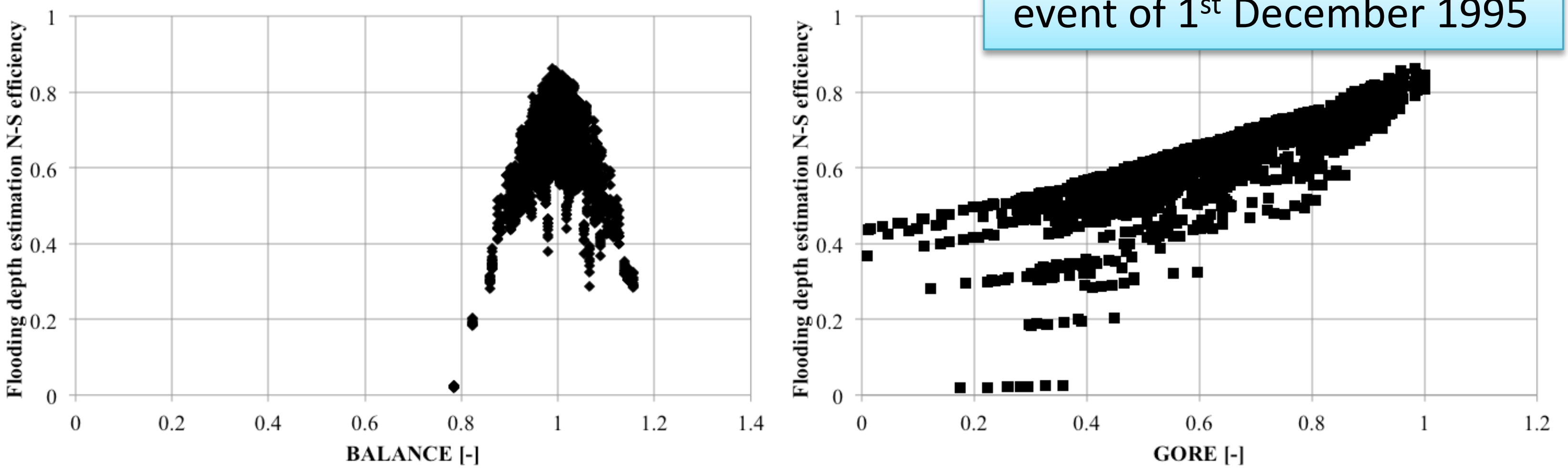
BALANCE and GORE indices *vs* model efficiency N-S

Comparison of rainfall indices and N-S criterion computed on the flooding depths obtained in each of the 15 flooding locations of the watershed by the simulations carried out for each of the 2805 considered scenario

event of 1st December 1995



Model sensitivity to BALANCE is higher: rainfall depth has a major impact on flooding

There is a sort of linear dependency between GORE and N-S: the model, during calibration phase, is able to slightly compensate the wrong estimation of rainfall input

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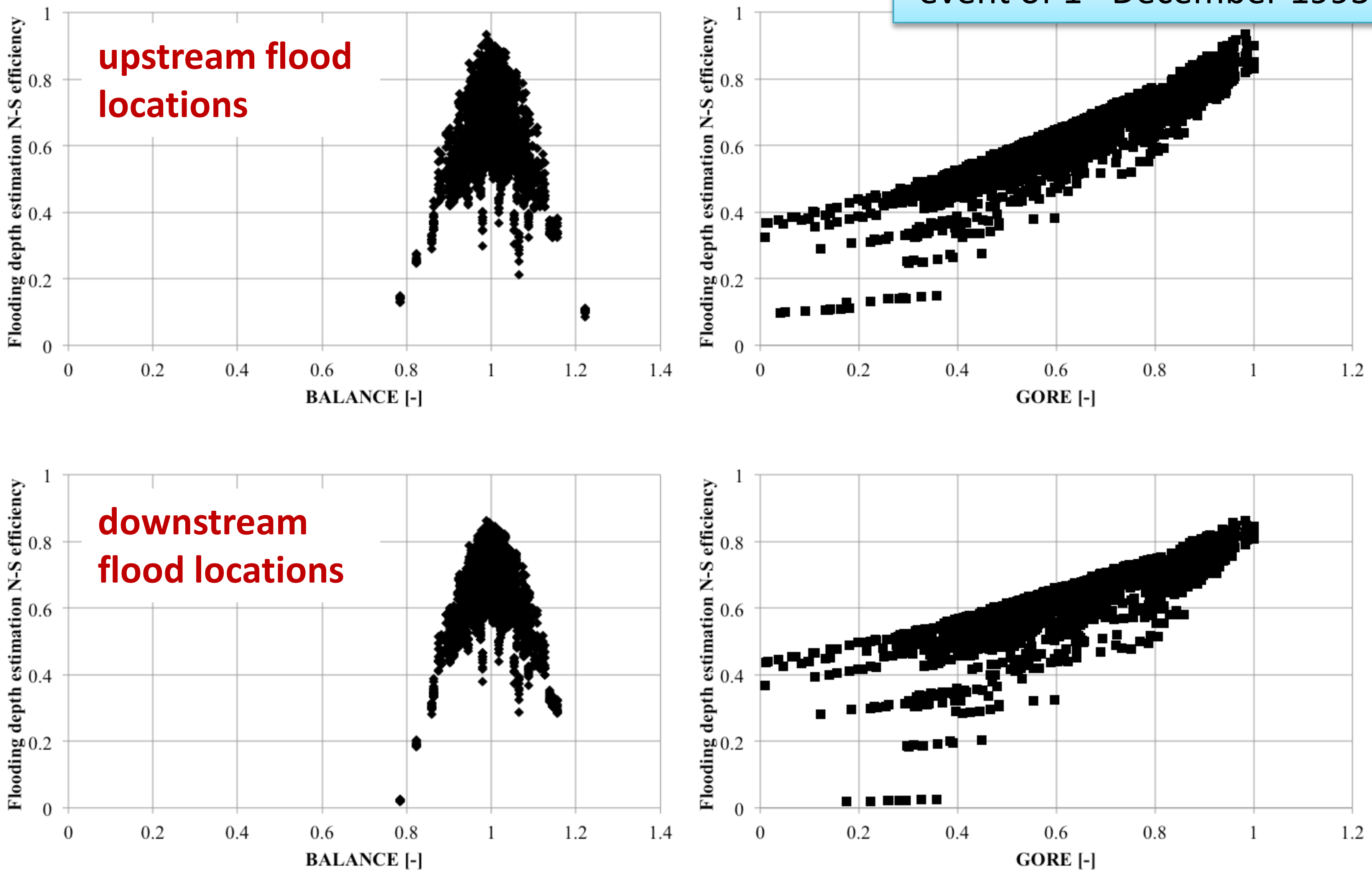
BALANCE and GORE indices *vs* model efficiency N-S separating the upstream and downstream flooding areas

event of 1st December 1995

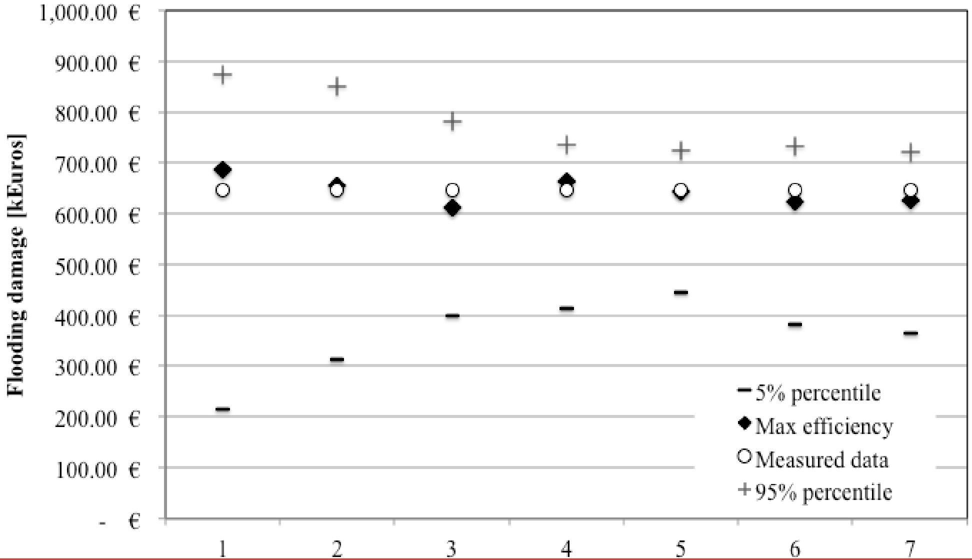


Uncertainty affecting flood damage estimates

To estimate total monetary flood damage depth-damage curves for **buildings** and **vehicles** obtained by available data in the area were used

$$D = 867.85 \cdot h^{0.8409}$$

$$D = 1035.70 \cdot h^{0.5110}$$

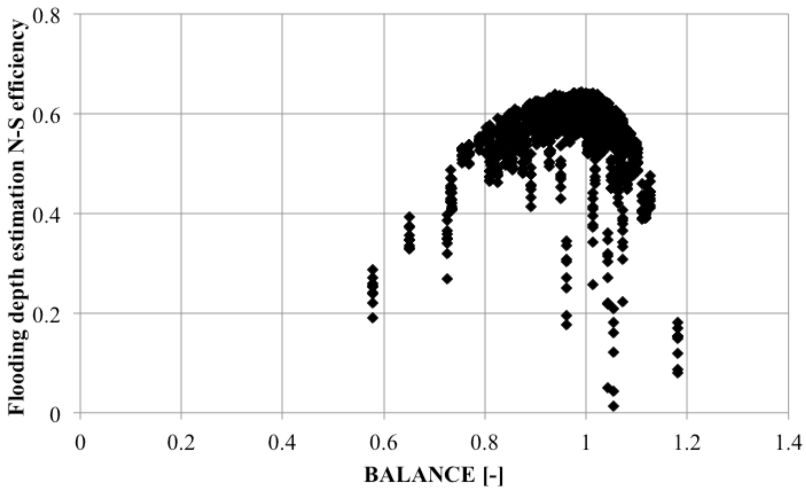


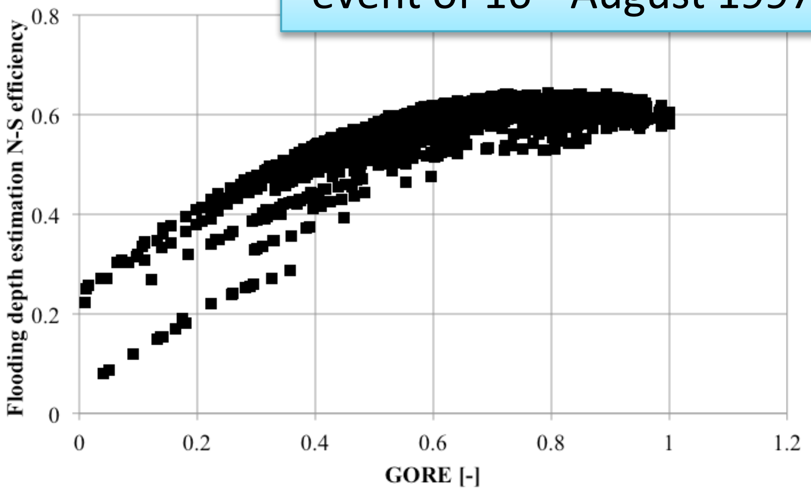
Uncertainty bands (5th and 95th percentiles) around the measured and calibrated flood damage in the entire catchment during the event of the 1st December 1995.

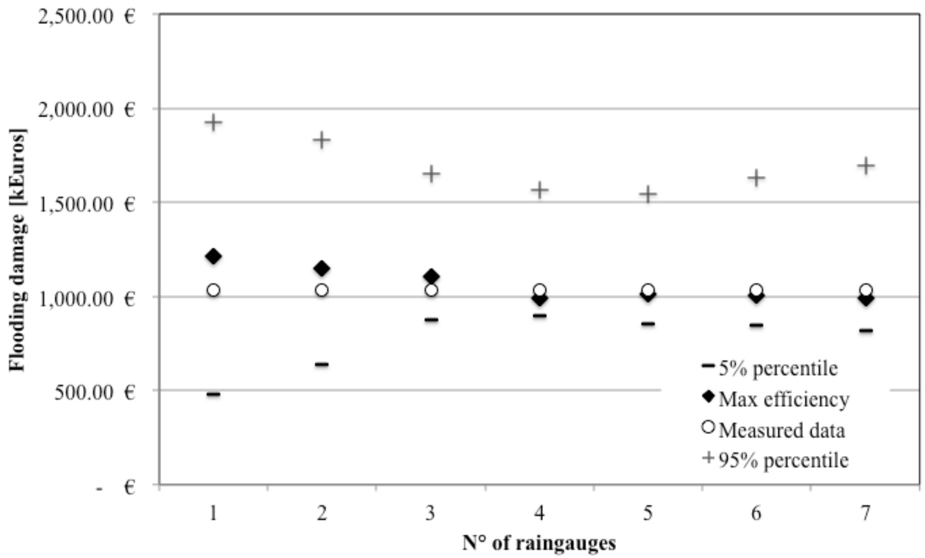
- The model is generally able for providing a good estimate of the measured damage.
- The best efficiency estimation is in the range of ±10% around the measured value.
- The calibration efficiency is progressively better if more rainfall data are available but the added value of using more than 4 raingauges is not relevant.

A shorter rainfall event

event of 16th August 1997







Conclusions

- The correct assessment of rainfall volume has a larger impact on flooding then the assessment of rainfall temporal pattern

- The use of a large number of raingauges may increase modelling efficiency but may also add uncertainty to flooding and damage estimation

- The analysis showed that rainfall information has higher impact on the upstream flooding areas

- Mathematical model has the ability of partially compensating the imperfect rainfall knowledge and the impact of imperfect rainfall knowledge is less evident in the downstream locations

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Thank you for attention!

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