Multi-Hydro modelling to assess flood resilience across scales, case study in the Paris region

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Main features of multi-hydro

- **Fully distributed** → **Capacity of taking into account small scale phenomenon, no need to use ad hoc parameterisation**

- **Physically based** → **Relying on physically parameters, no need of calibration**

- **Easily transportable** → **Availability of a dedicated module that easily convert widely available GIS data into inputs for the model, no need of wasting excessive time for generating inputs**

- **Relying on open source public software widely validated** → **Benefiting from a wide and active community of users for each module**

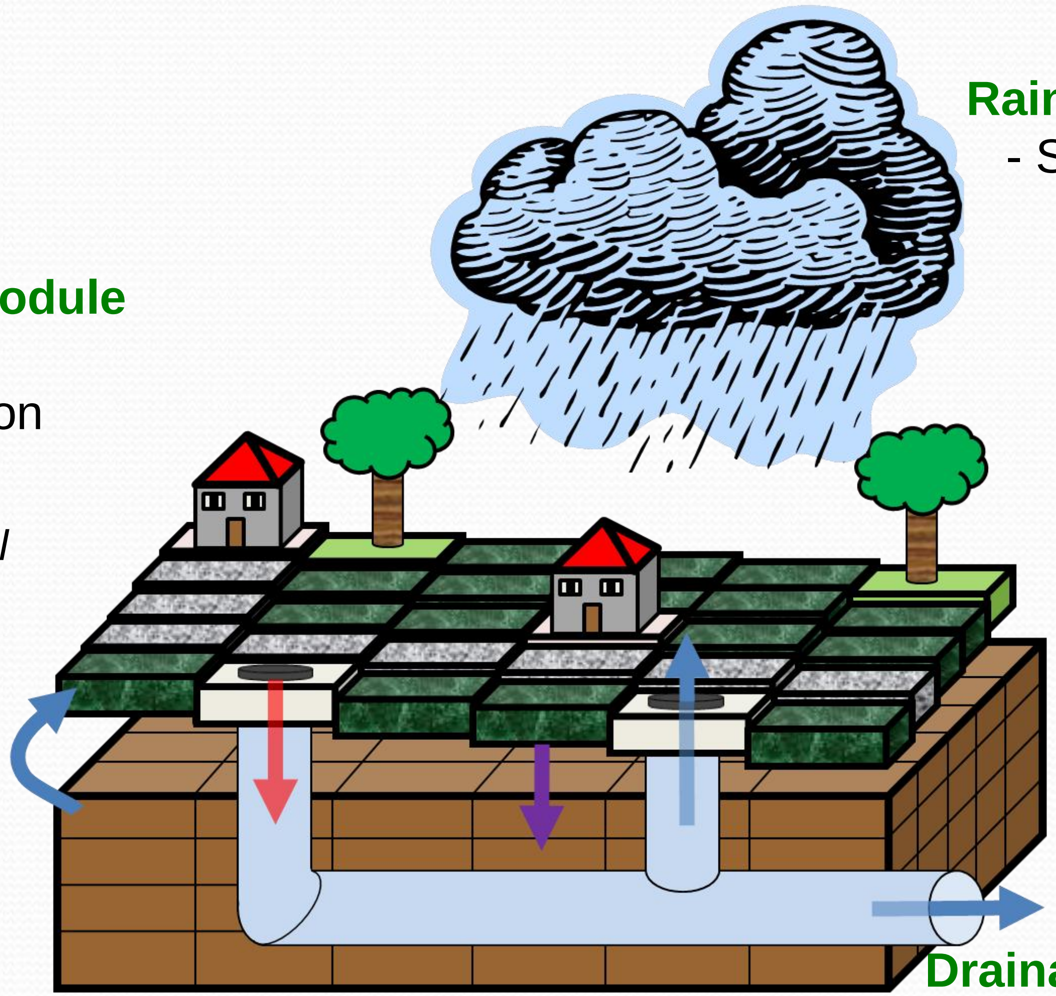
Overall structure

Urban area physical processes modeled in Multi-Hydro

Rainfall module
- Spatio-temporal rainfall

Surface module
- Runoffs
- Infiltration

Based on TREX model



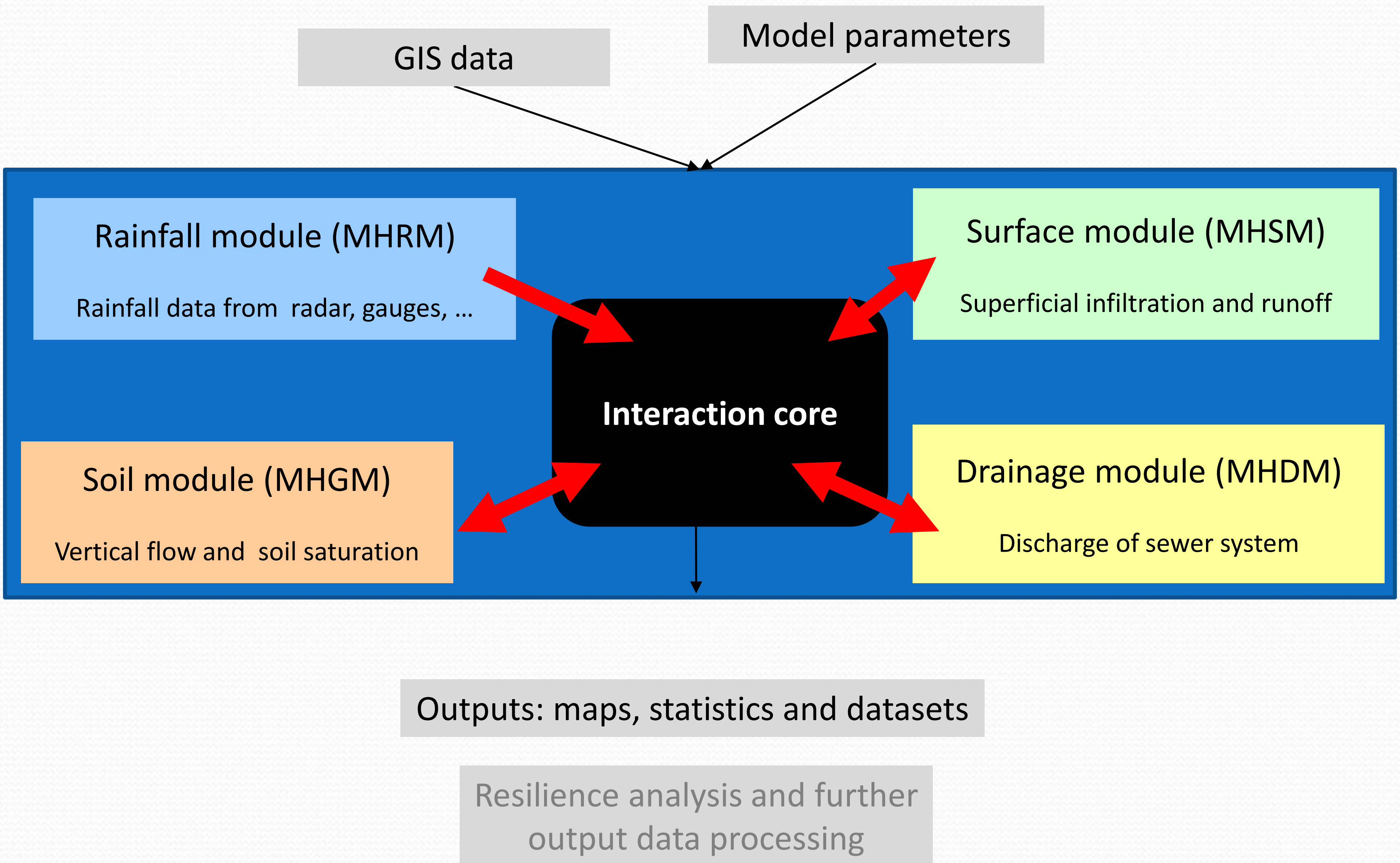
Soil module
- Vertical flow in the non-saturated area
- Saturation during a rainfall event

Based on VS2DT model

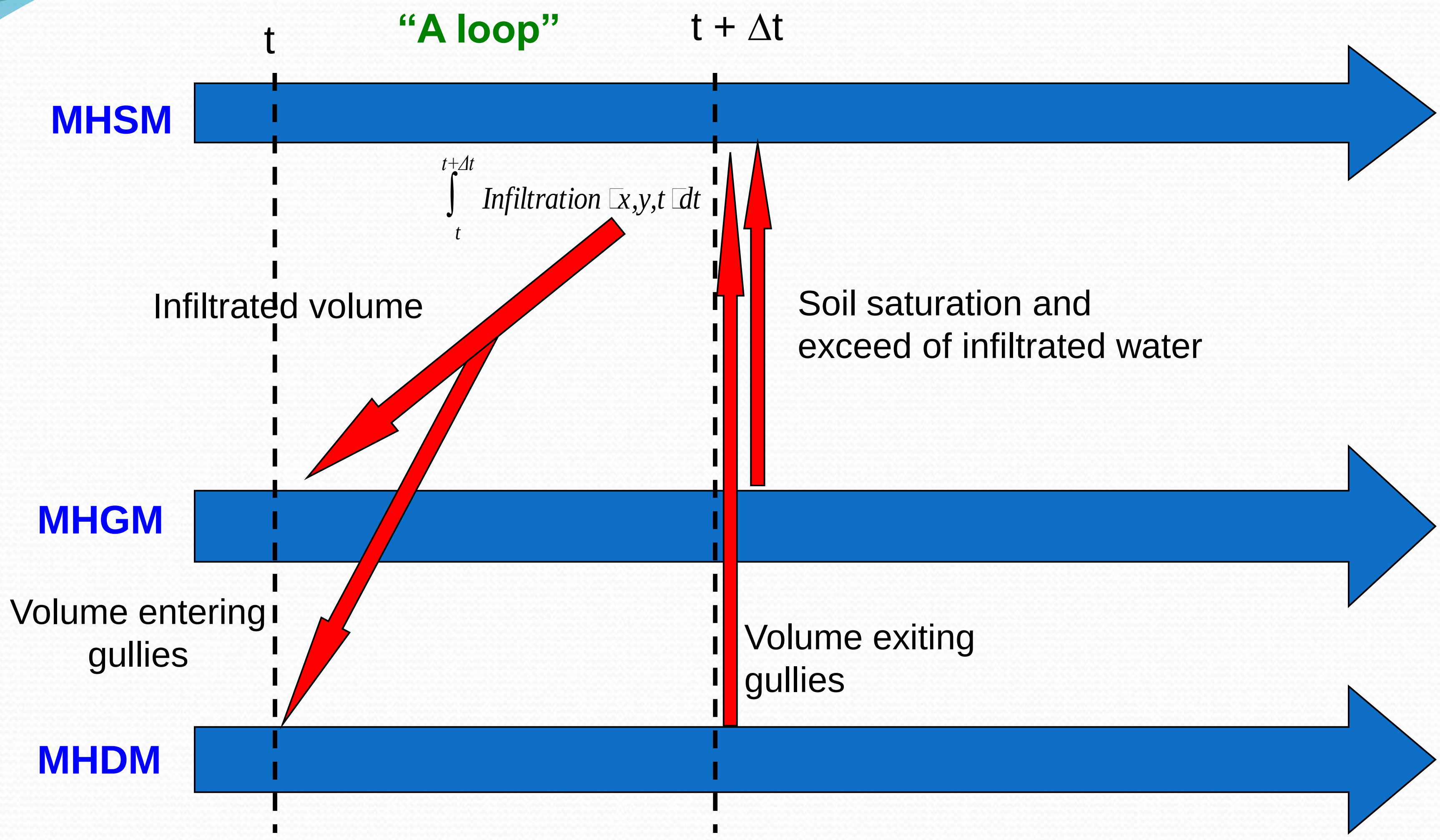
Drainage module
- Sewer flow (free surface and loaded)
- Overflow

Based on SWMM model

How it works


GIS data
Model parameters
Rainfall module (MHRM)
Rainfall data from radar, gauges, …
Surface module (MHSM)
Superficial infiltration and runoff
Interaction core
Soil module (MHGM)
Vertical flow and soil saturation
Drainage module (MHDM)
Discharge of sewer system
Outputs: maps, statistics and datasets
Resilience analysis and further output data processing

Interacting core



- Currently Δt=3min, >>δt the computation time of the models (~ s)

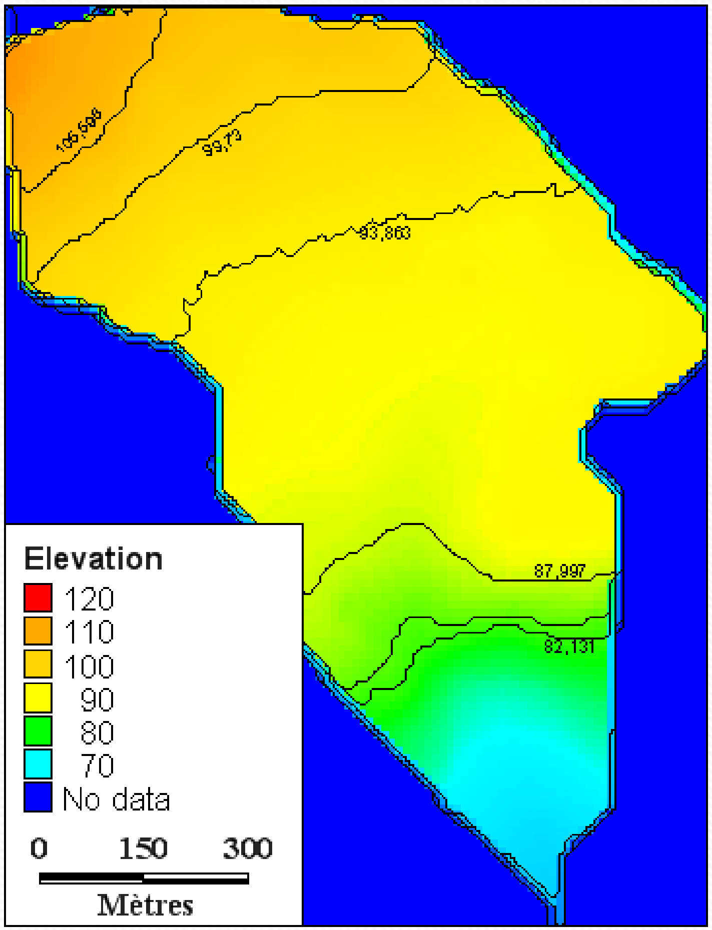
- At the beginning of the rainfall event a single loop of duration 15 min to fill the interception depth.

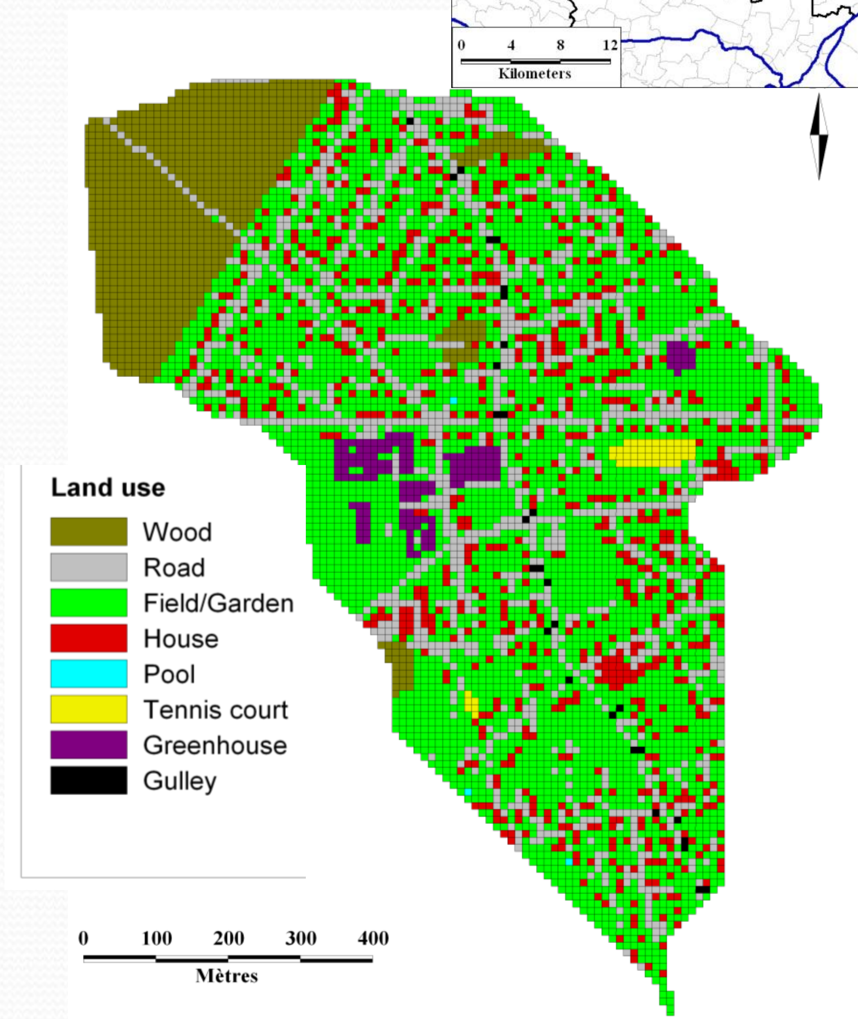
Results

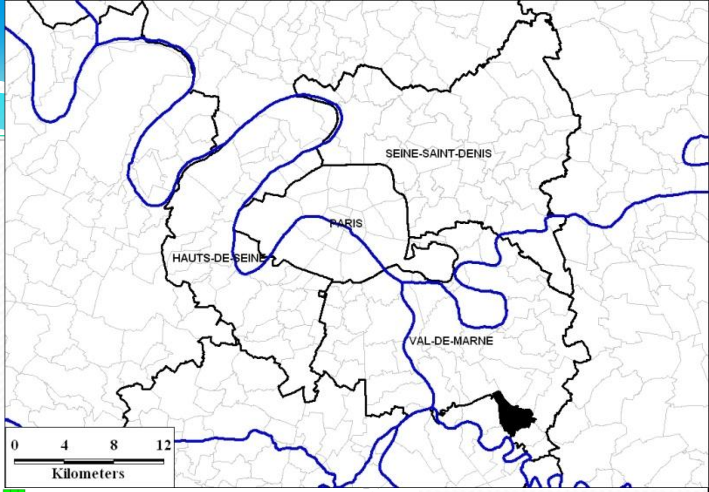
- With Multi-Hydro, we can obtain:
  - the height of surface water,
  - the location of this water,
  - the load and the overflows of the sewer system.
- Ability to characterize the large scale impact of small scale changes.
- Resilience measure can be tested and evaluated.
- Flood scenarios can be tested easily.

Inputs data

Case study of Villecresnes (France)

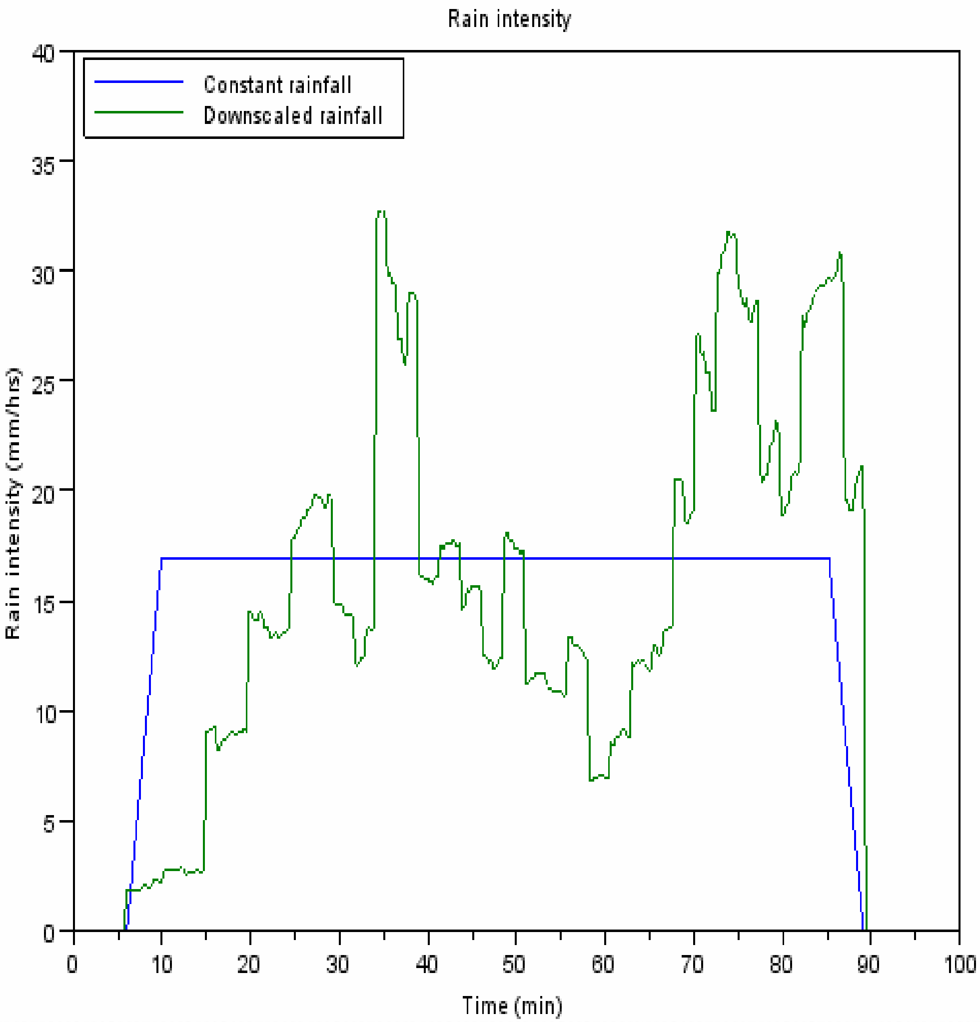


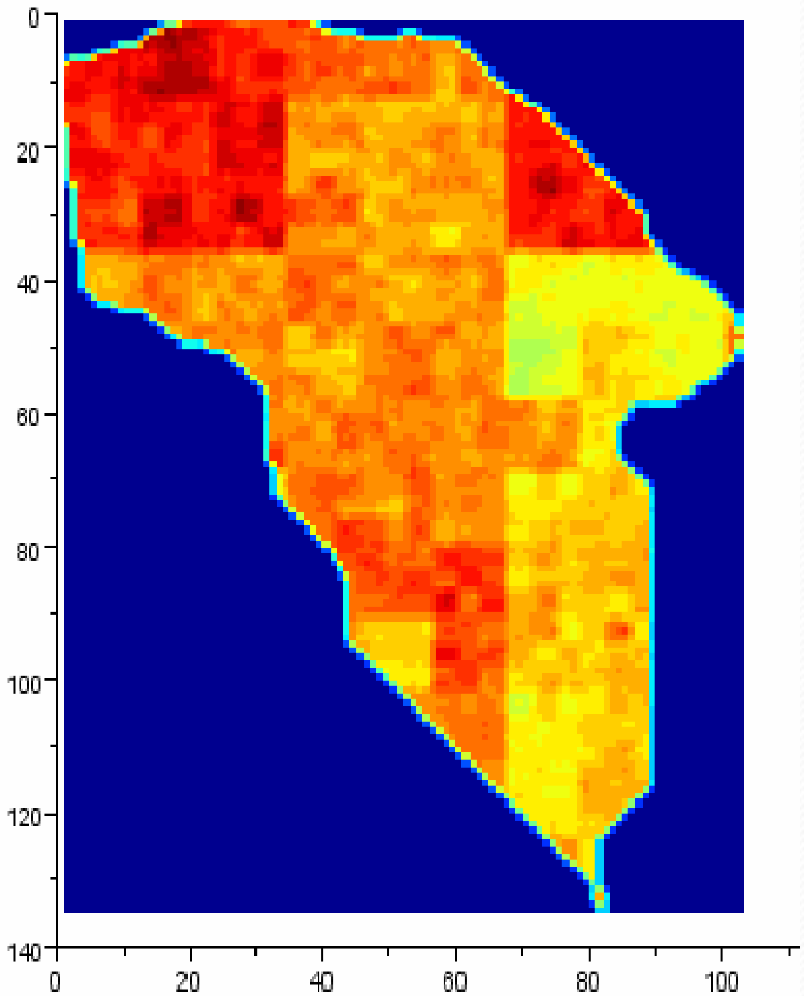




Maps by Richard J.

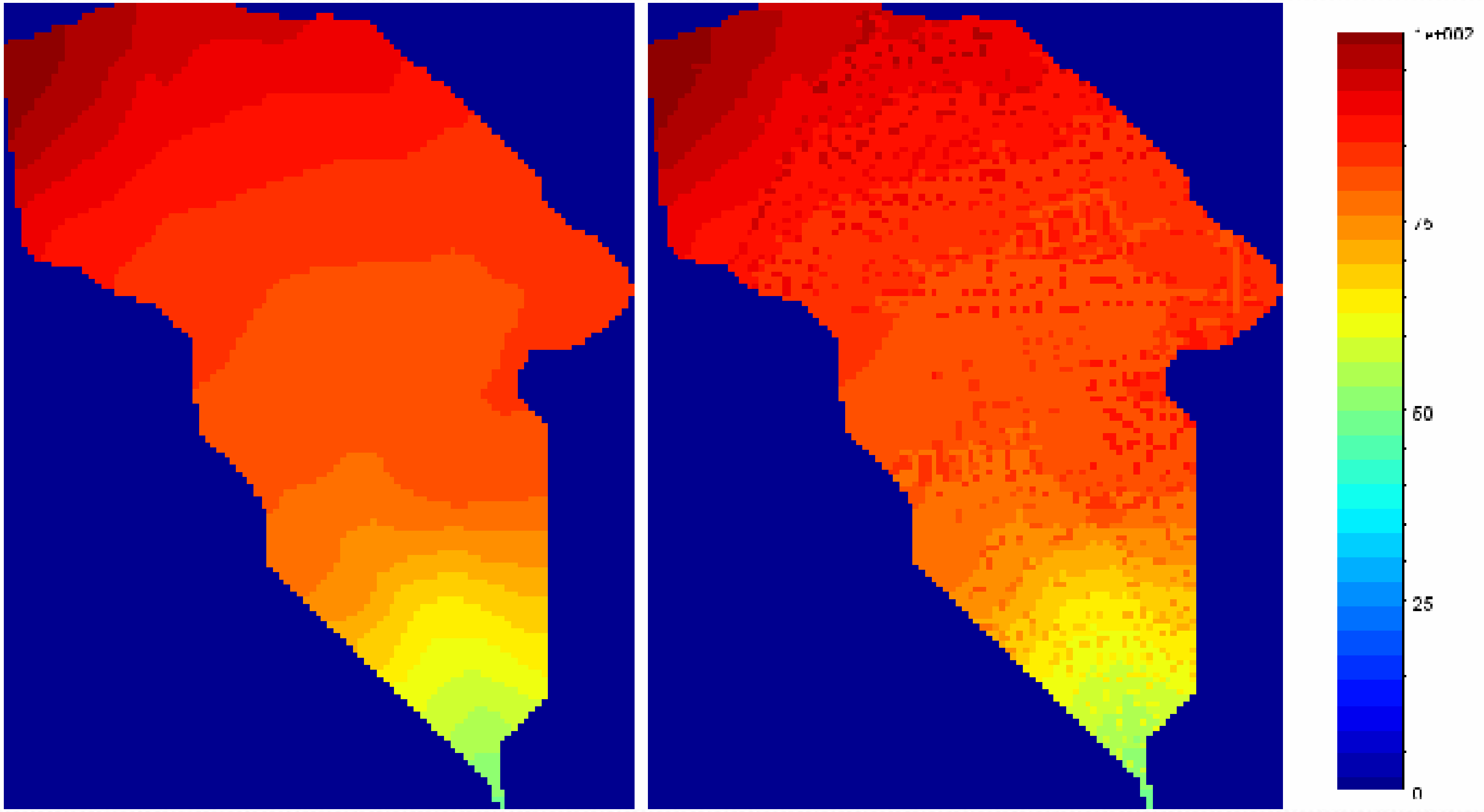
Two cases of rainfall





- **22mm of rainfall during 80 min in both cases (event of the 9th February 2009)**
- **Constant rainfall = constant in space and in time**
- **Downscaled rainfall = variable in space and in time**

Two cases of elevation

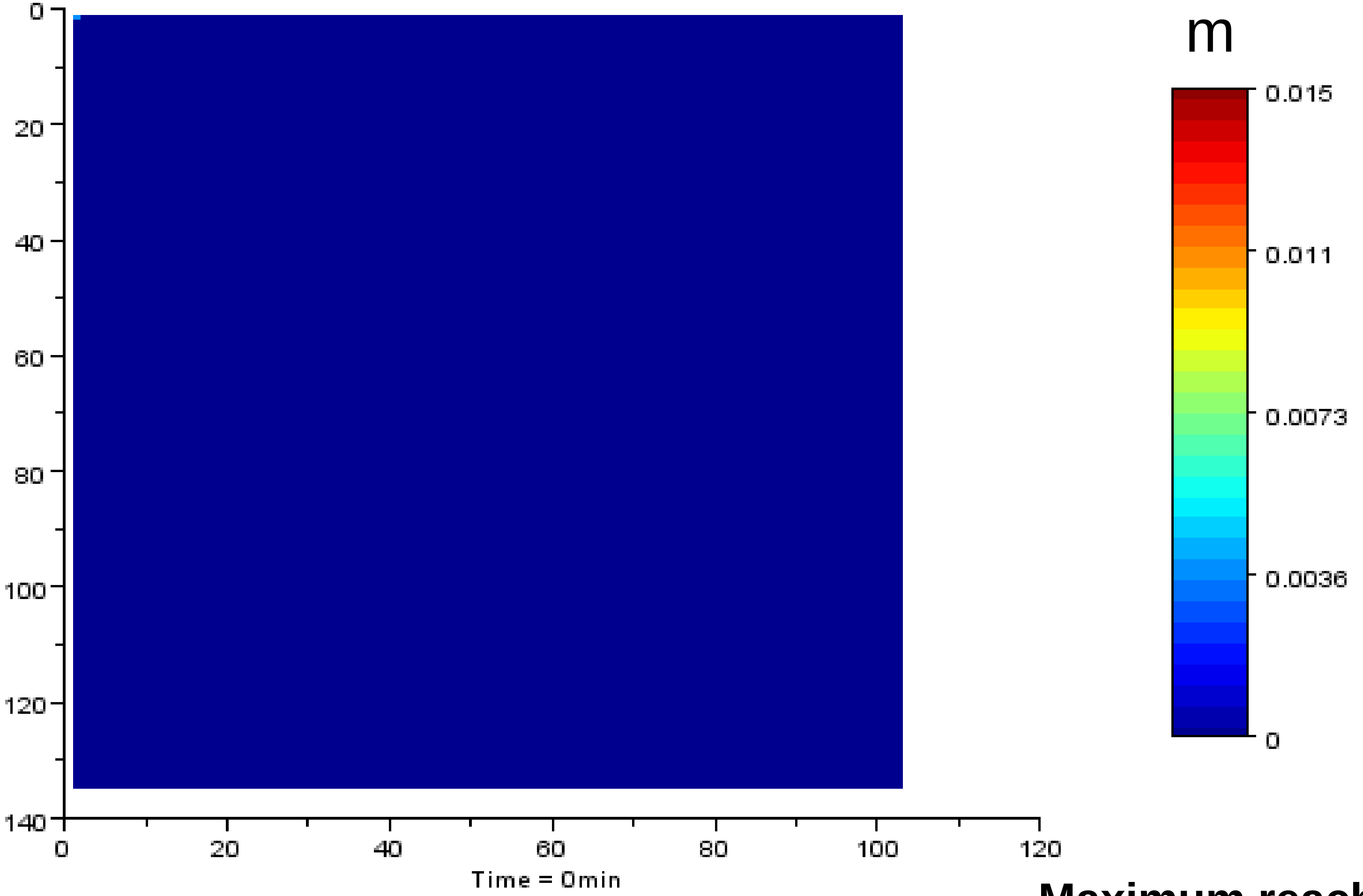


- **Decrease elevation of roads : - 15cm**
- **Increase elevation of houses : + 5m**

Overland water depth

Without modification of the elevation, downscalled rainfall

Overland water depth (m) during the rainfall event of 9th February 2009



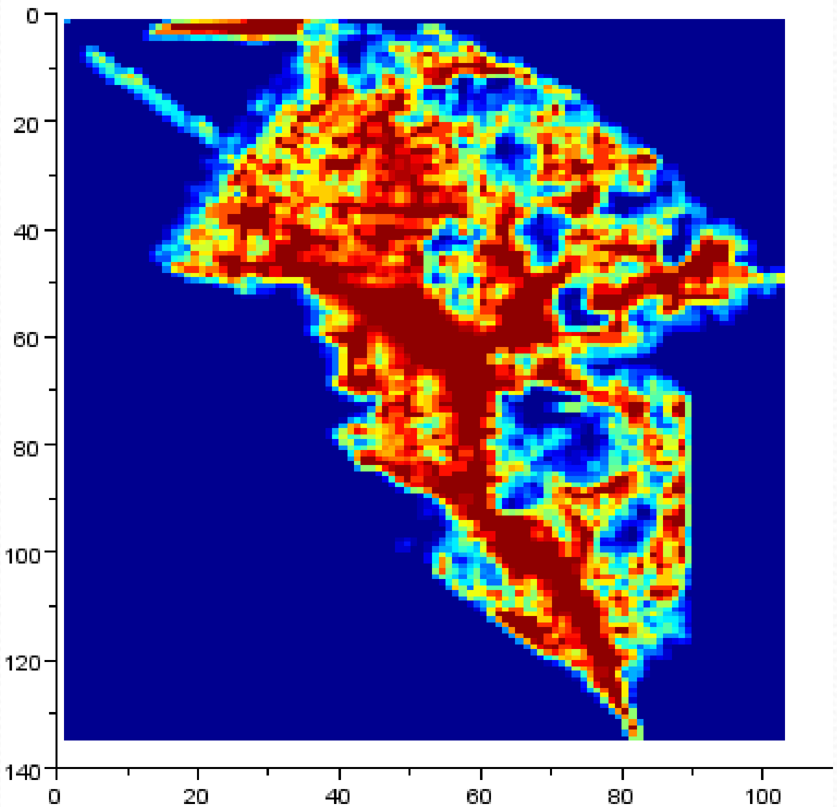
Maximum reached = 35 cm

Modification of the elevation according into the land use

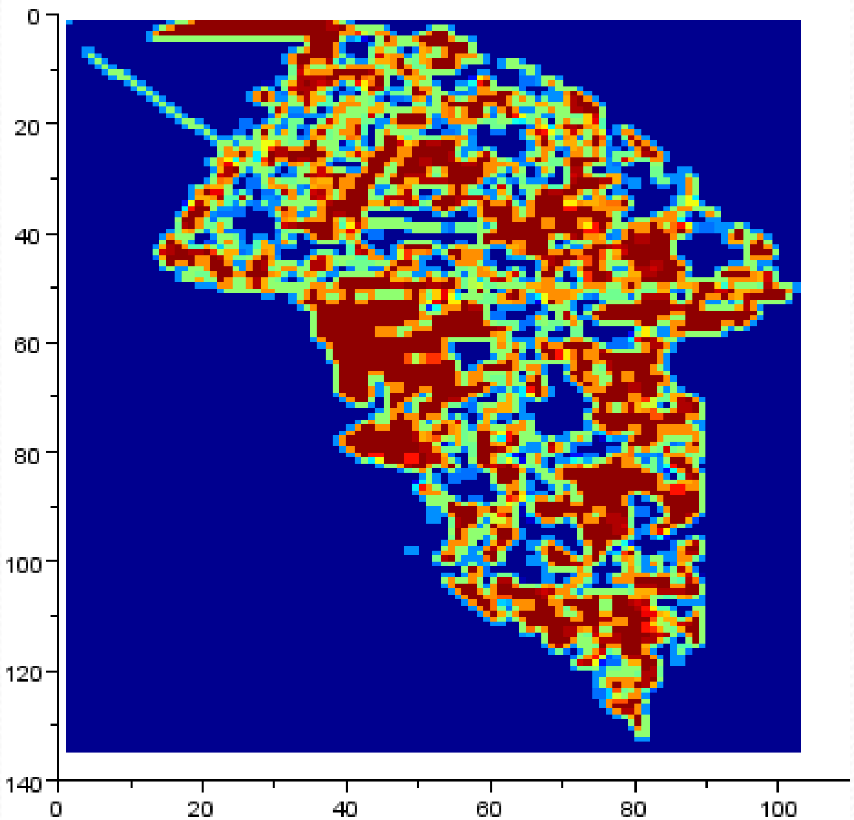
Location of the runoff water under constant rainfall

Comparison of raw and modified elevation in maps

Raw elevation



Modified elevation
(roads : -15cm ; houses : +5m)

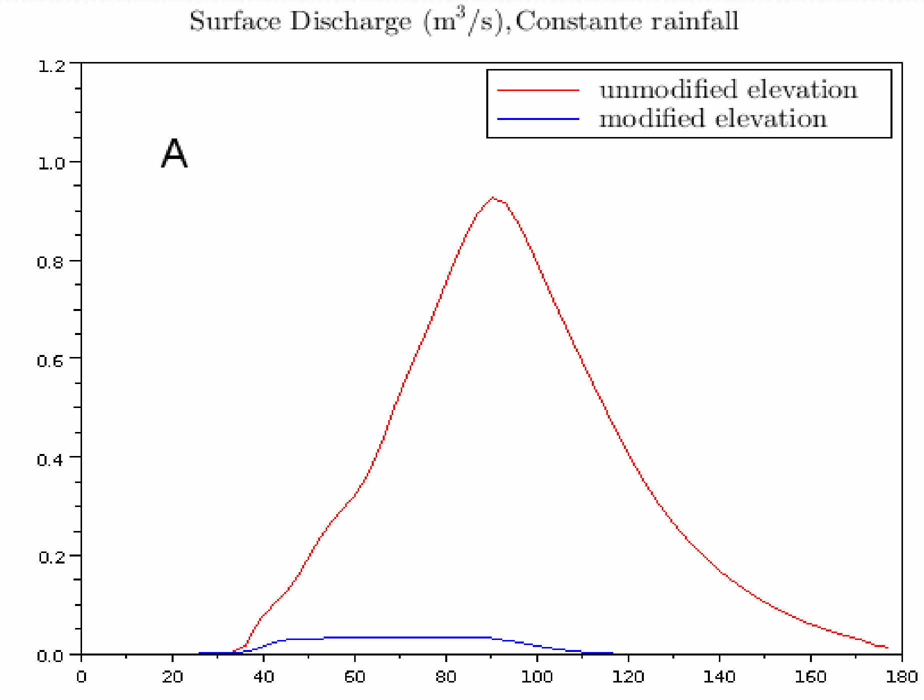


Overland water depth (m) at the end of the 9th Feb. 2009 rainfall event

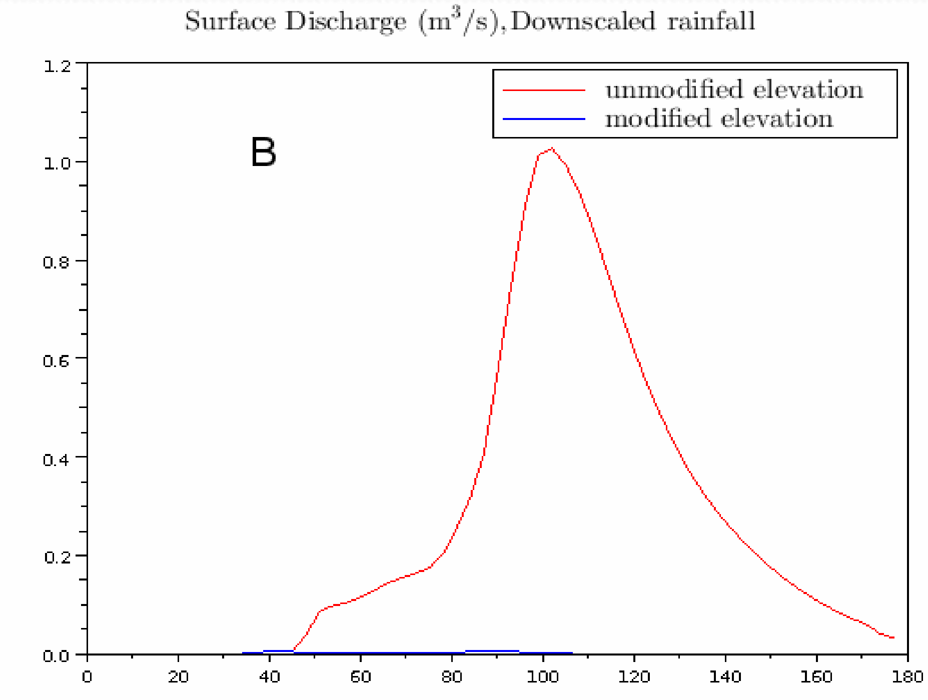
Modification of the elevation according into the land use

Surface water discharge (m^3/s)

Constant rainfall



Downscalled rainfall

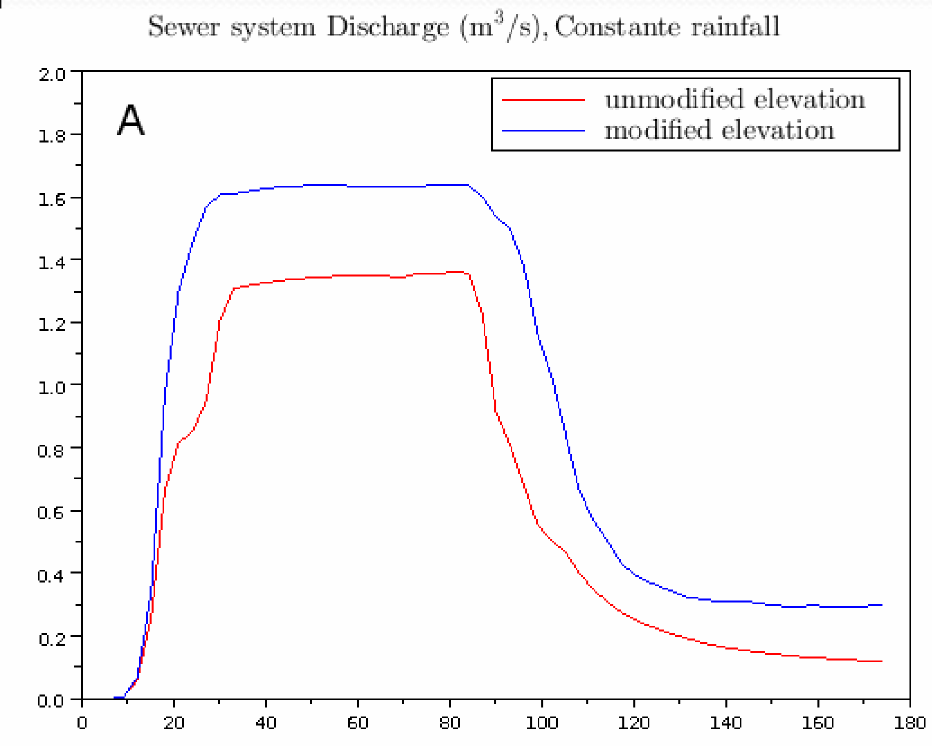


- Strong impact by the modification of the elevation, which confirms that the water leaves the catchment by another way.
- No important modification of the peak flow by the use of the downscaled rainfall but
- Impact of the design of the rainfall on the variability of the discharge

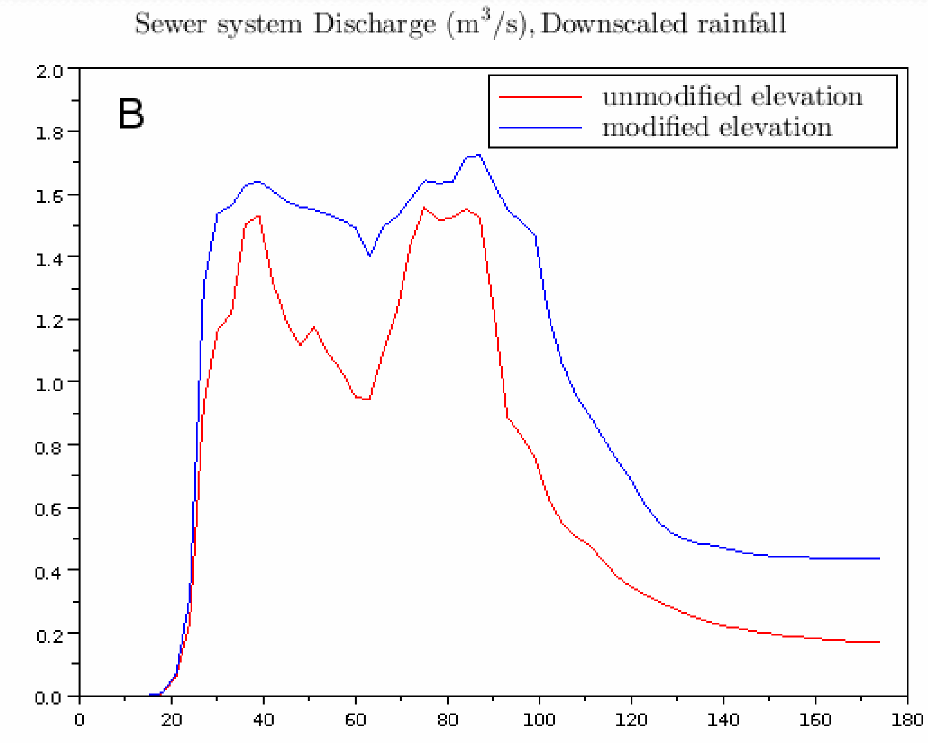
Modification of the elevation according into the land use

Sewer system water discharge (m^3/s)

Constant rainfall



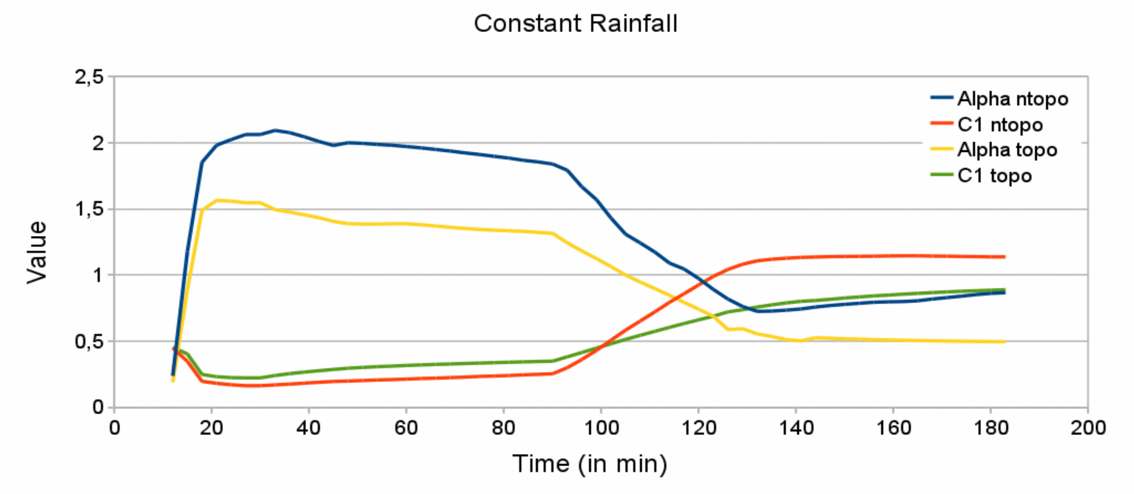
Downscalled rainfall



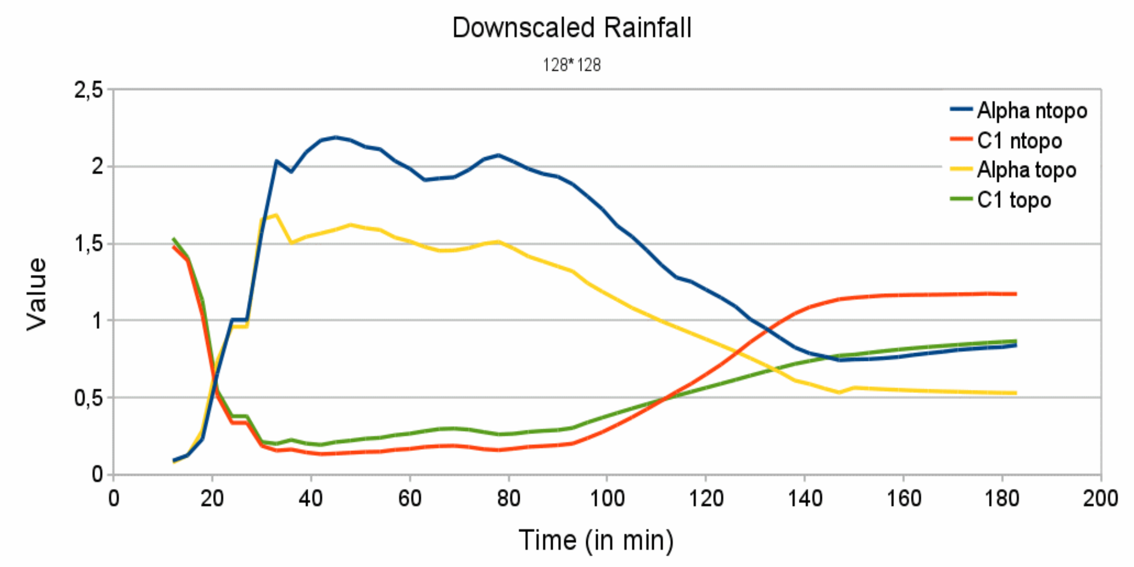
- Increase of the discharge by the use of a modified elevation due to the drainage of the water by the roads directly to the sewer system through the gullies.
- Impact of the design of the rainfall on the variability of the discharge

Modification of the elevation according into the land use

Multifractal analysis of the location of the surface water depth



Two parameters are:
- C_1 is the mean inhomogeneity of the overland water depth (C_1=0 for water being everywhere (i.e. all pixels), C_1=max for only sparse puddles);
- α indicates the variability in the overland water depths (among the pixels) .



- Decrease of the multifractality of the overland water depth with the modified elevation

- Temporal evolution of the parameters more precise with the downscalled rainfall.

Summary

- Multi-Hydro model
  - To model the interactions of urban water cycle processes and designed for being easily transposable to any peri-urban catchment.
  - Is based on several open source software packages, representing each process of the water, are widely validated on hydrologic data and interact together in order to compute the hydrological response of a given watershed.
  - Requires high-resolution spatially distributed data (mainly GIS data).
  - Provides detailed information about surface runoff, subsurface flow, and sewer discharge.

- Influence of two parameters on the case study of Villecresnes (Paris area):
  - the rainfall input (uniform in space and time or distributed)
    - no significant modification of the peaks flow of the water low of the runoff and in the sewer discharge
    - increased loads at different locations with downscalled rainfall that shows the need to take into account small scale phenomenons in urban hydrology.
  - the modification or not of the elevation regarding the land use.
    - implies a change in the location of the surface outlet of the catchment
    - important change in the discharge in the sewer system due to the drainage of the water by the roads

Conclusions

- Multi-Hydro is able to reproduce the effects of small changes in the land use of the considered catchment
  - It can be used to analyse the impact of the implementation of a measure of resilience.
  - Example : barrier = group of pixel with modified elevation

- The Multi-Hydro model is currently tested on other case studies, in the Paris area and in countries of the SMARTeST project partners.
  - Done in association with a social analysis of the decision process during a flood.
  - Can be use as a support to have a better understanding of the hydrologic behaviour of the catchment
  - The outputs of the Multi-Hydro model can be used as input data for the cost-benefit models developed by the other partners of the project, providing therefore an economical dimension of the flood modelling.

Thanks and your questions are welcome !!