Chair Hydrology for Resilient cities

High Resolution Urban Hydrology, PUB and Multi-Hydro

RainGain Project Meeting, Exeter, 6-7 Ocotober 2014

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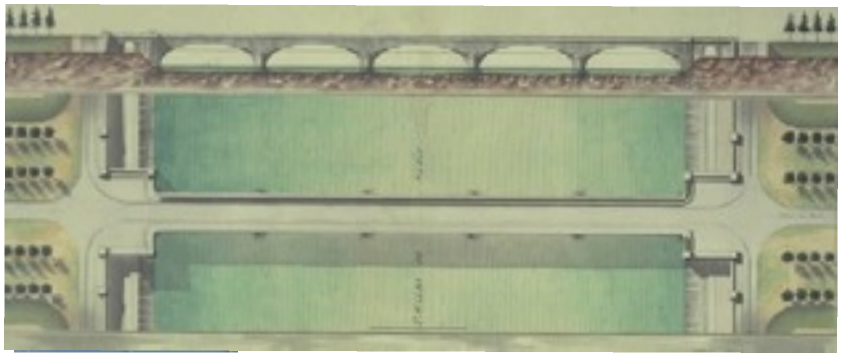
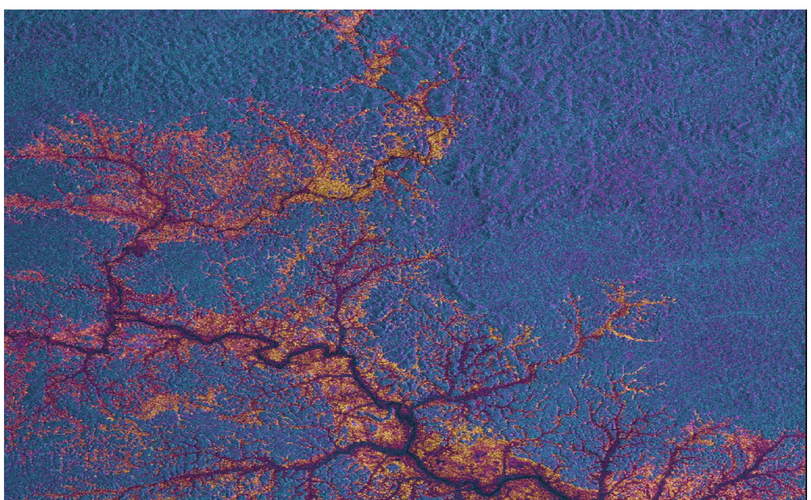
(HM&Co group)

Ecole des Ponts ParisTech





ERS view of the Amazon basin

- Formerly Ecole Nationale des Ponts et Chaussées ("National School of Bridges and Roads")
  - one of the world's oldest Civil Engineering School (1747)
  - Belgrand, Cauchy, Carnot, Coriolis, Darcy, Navier, Saint-Venant...
- last decades
  - beyond its more traditional fields and into an international institution,
  - adapting to the changing demands of the modern world
    - cofounder of ParisTech cluster and Paris-Est University
    - teaching complex systems, multifractals, etc. to young generations of engineers

High resolution urban hydrology challenges

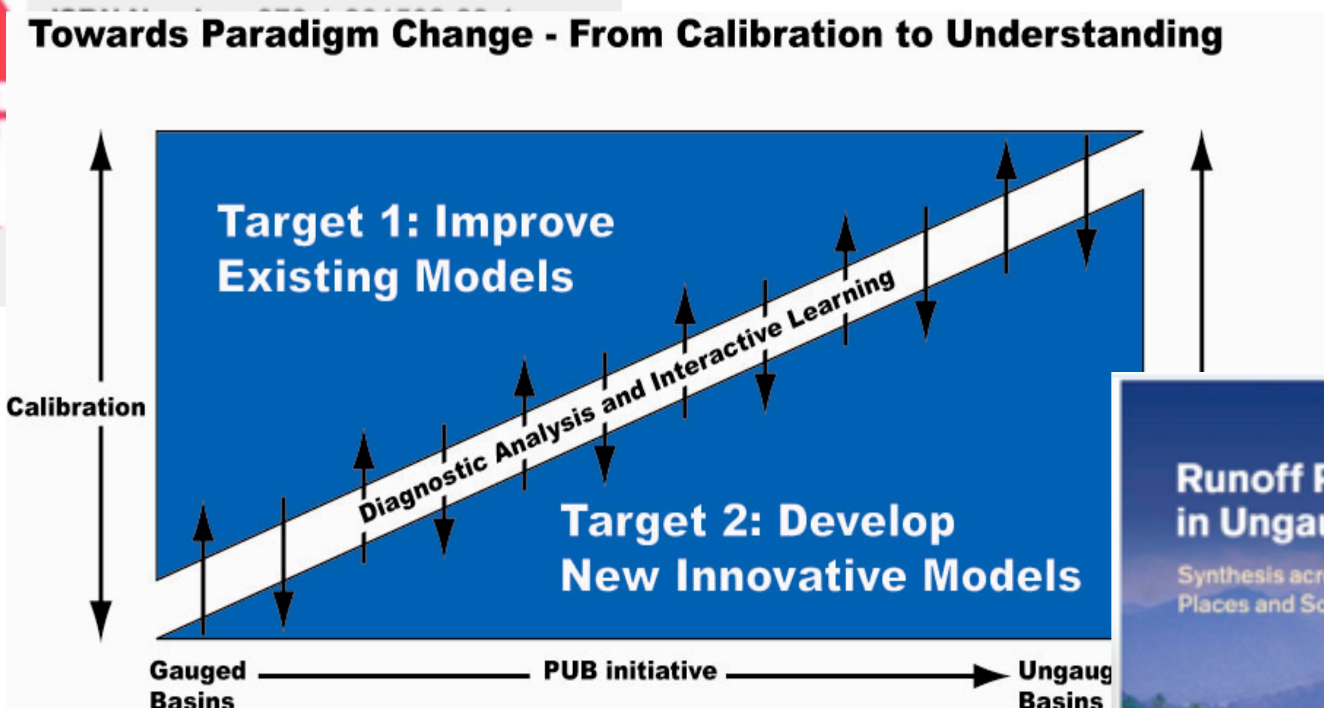
- For decades high resolution data were fundamentally missing for urban hydrology:
  - rainfall data: only km resolution
  - limited GIS and lidar data
  - computer limitations
  - … and limited foresight … as for PUB?
    - unbalance between research/innovation/operational ?

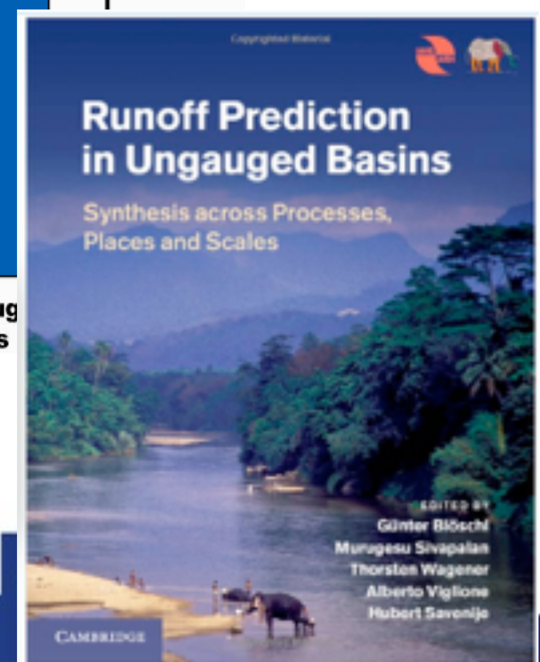
IAHS PUB decade 2003–2012

PREDICTIONS IN UNGAUGED BASINS: PUB KICK OFF

Author / Editor: D. Schertzer et al.
Publication Number: 309

Prediction in Ungaged Basins





Did IAHS PUB really hit its target?

Gupta & S. (2014 in preparation)

High resolution urban hydrology challenges

- a PUB problem:
  - no longer calibration, but physical processes: discharges as a response to rainfall in a given medium
  - models should be easily *transportable*, *scalable* and *inter-operational*
    - large user community (inc. local water authorities): open access
    - limited workforce: use as much as possible what is available

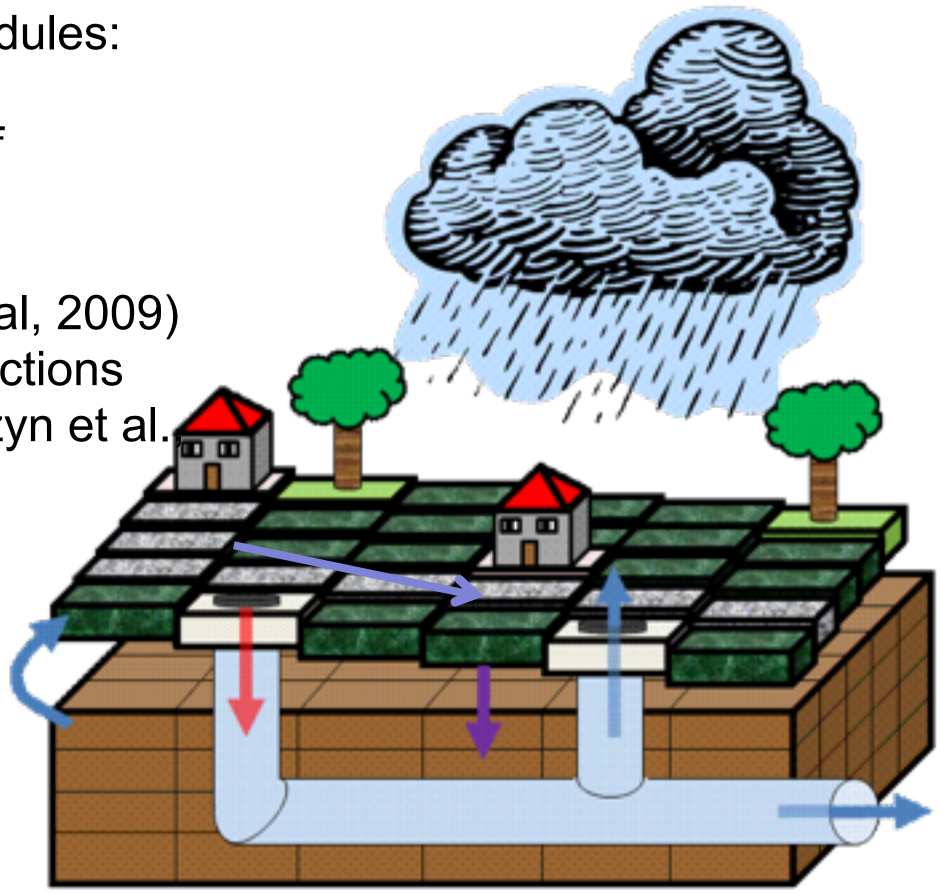
High resolution urban hydrology challenges

- uncertainties tracked along the whole data-modeling chain (Beven, Koutsoyannis and others..)
  - main sources: missing data, resolution/scale truncations
  - ensemble predictions,
    - next step: stochastic modelling ?

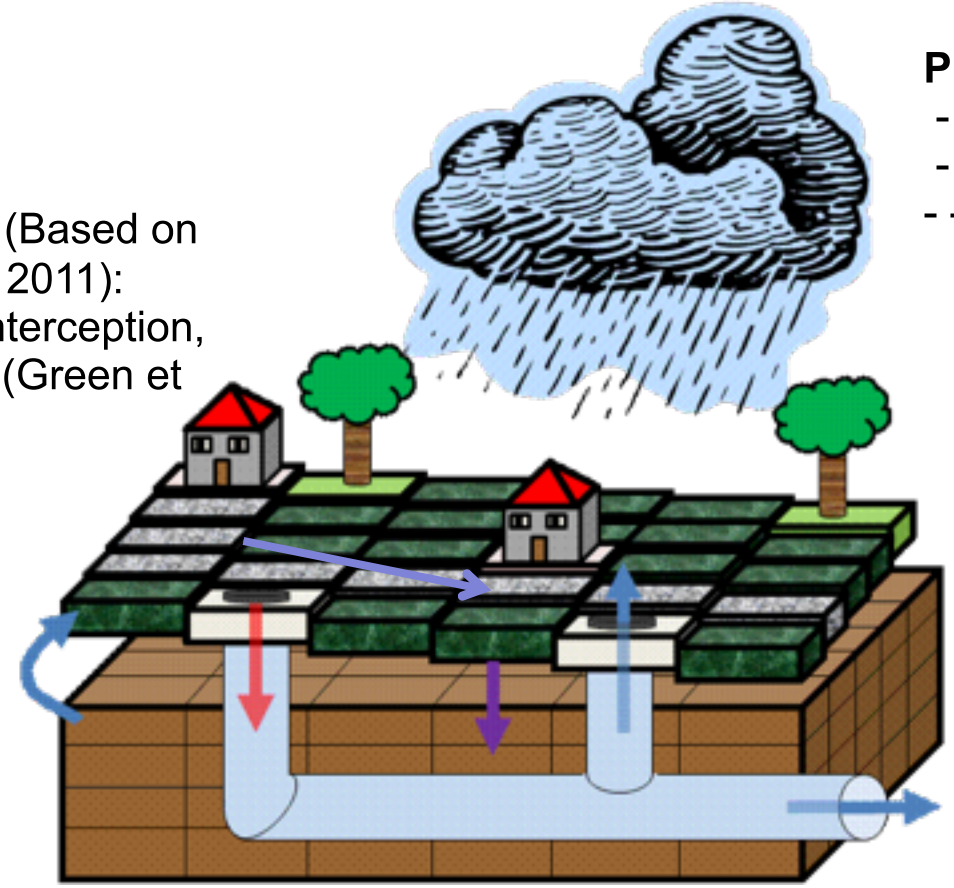
Multi-Hydro

Presently 4 modules:
- rainfall
- surface runoff
- soil infiltration
- sewers

(El Tabbach et al, 2009)
with their interactions
(Giangola-Murzyn et al., 2014)



Multi-Hydro



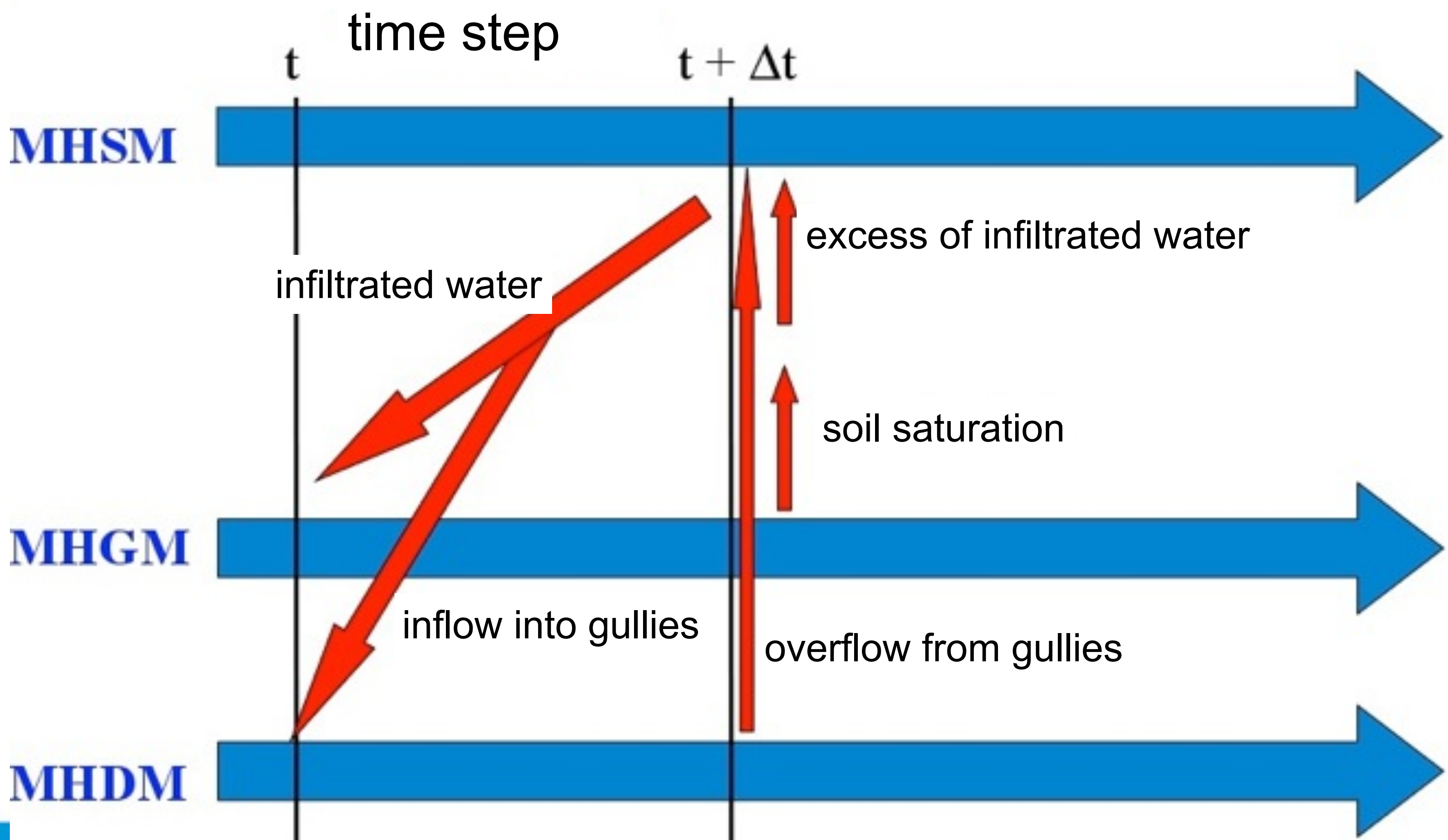
Precipitation Module
- radar data
- pluviometer data
- - multifractal desagregation

Surface Module (Based on TREX, Velleux et al - 2011):
2D shallow-water, , interception, infiltration potentielle (Green et Ampt)

Drainage Module (base on SWMM, Rossman - 2005)
- discharge (Saint Venant 1D)
- overflows

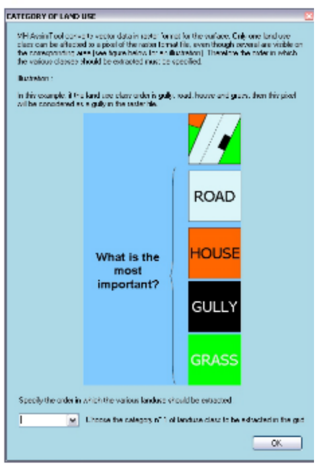
Ground Module (based on VS2DT, Hiesh - 2000)
- infiltration (Van Genuchten)
- interaction runoff/infiltration

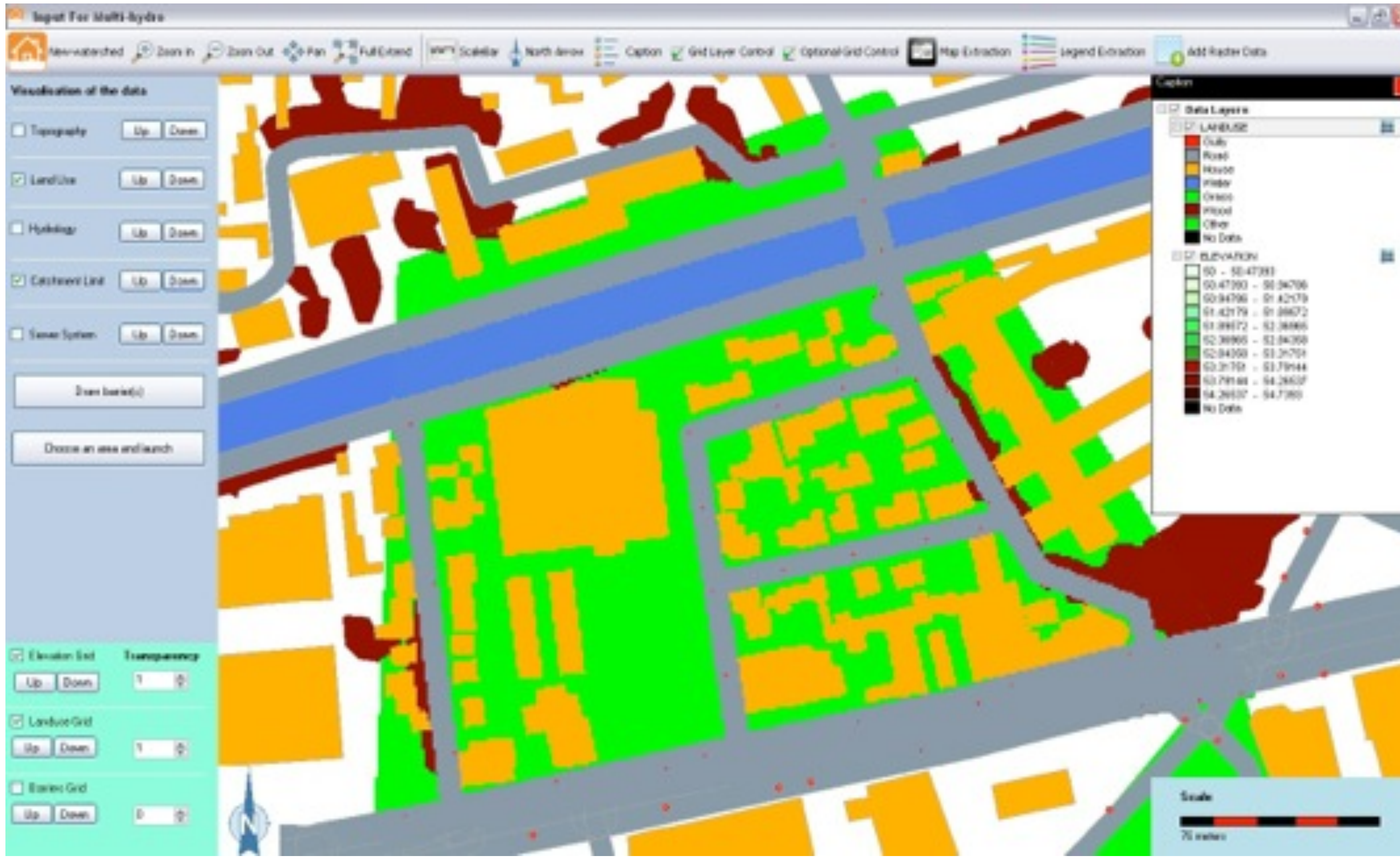
Module Coupling



MH-AssimTool : user interface

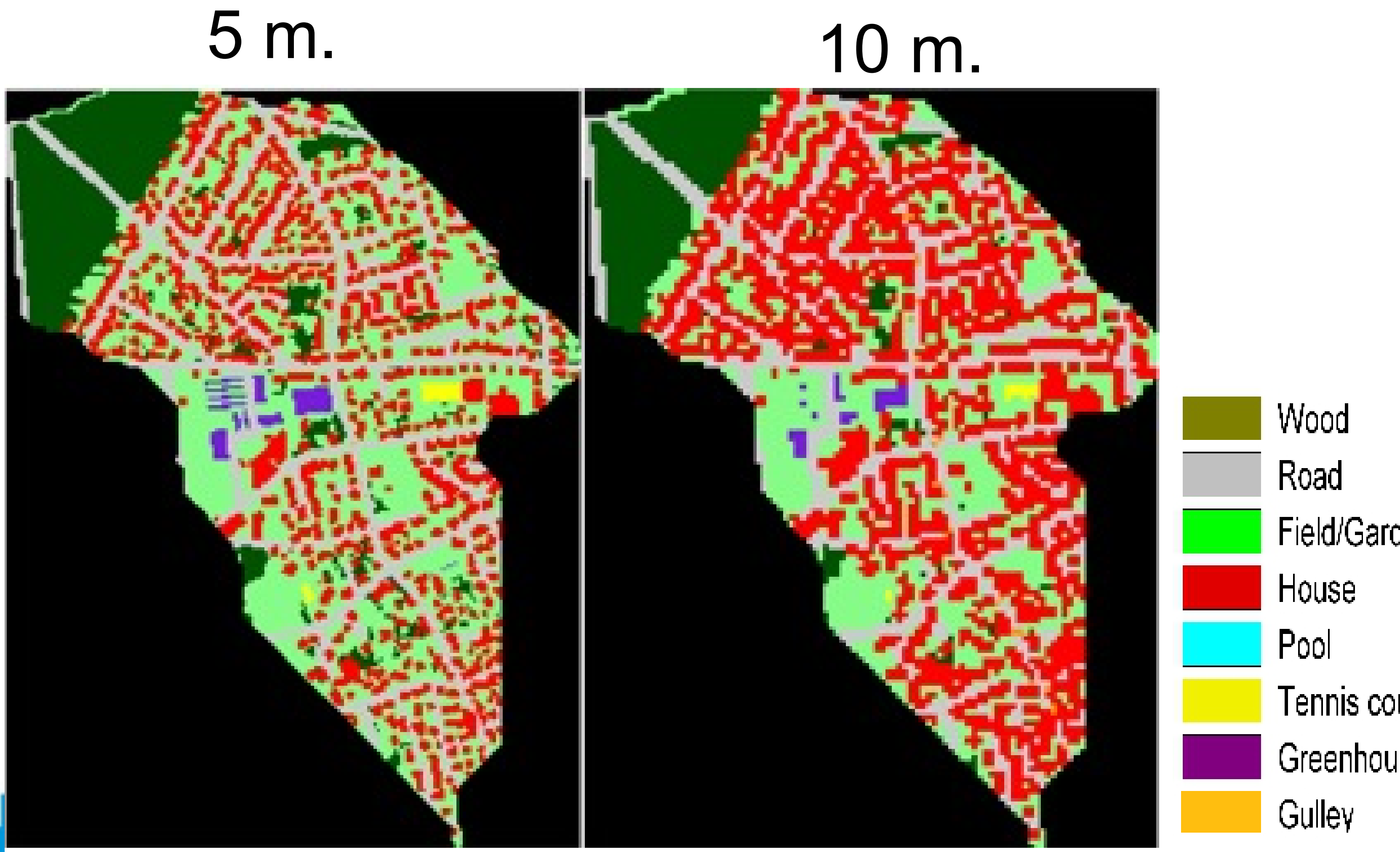
- Main MH-AT window



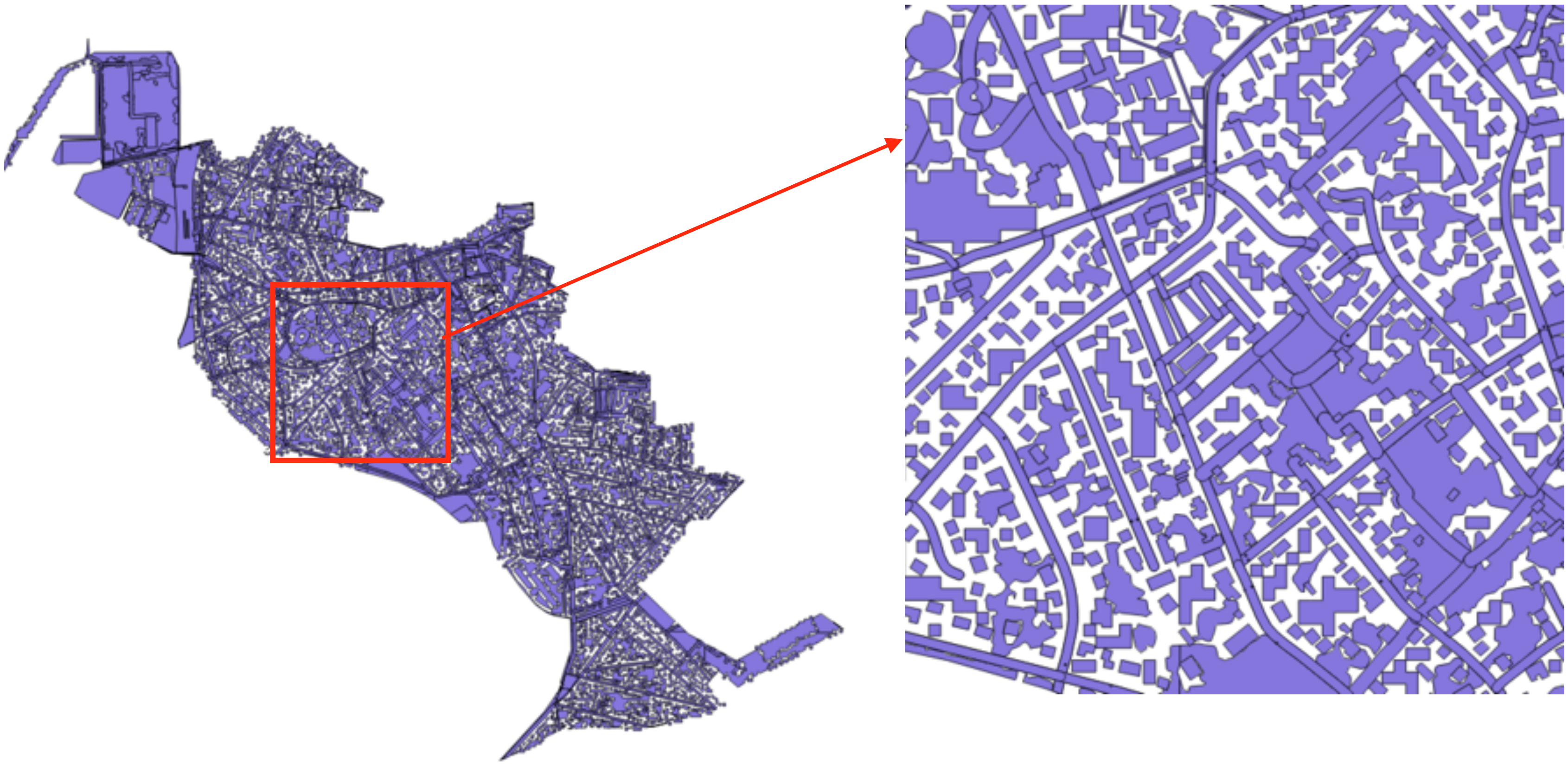


- based on GIS techniques: raster <—> vector data

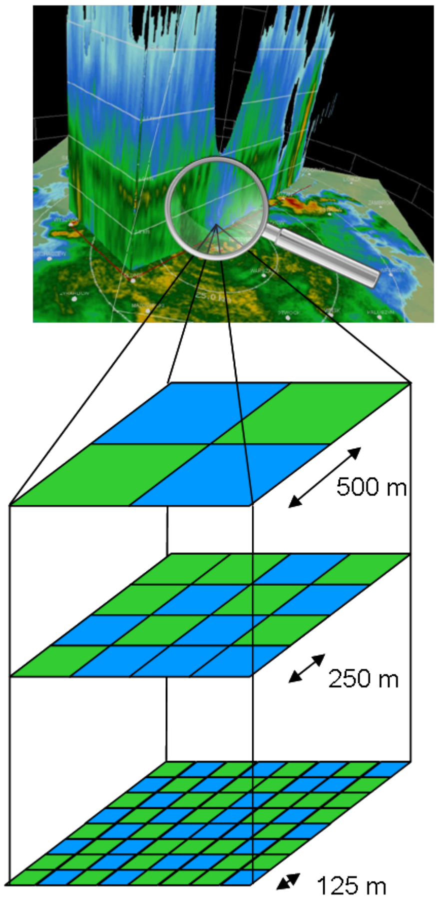
MH-AssimTool : resolution change



Missing data



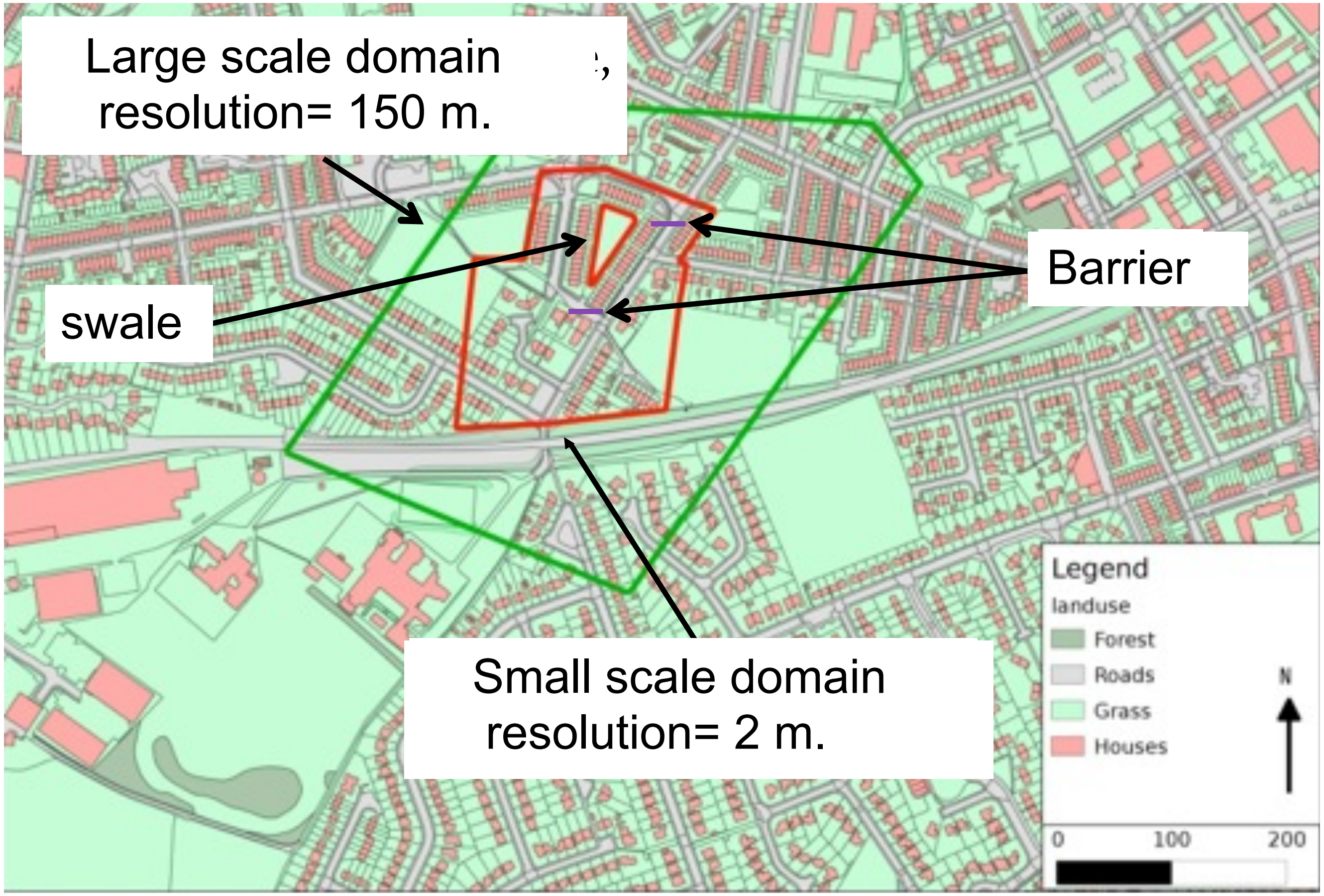
Missing or LR Data



Mulitfractal desagregation/ interpolation of missing/low resolution data

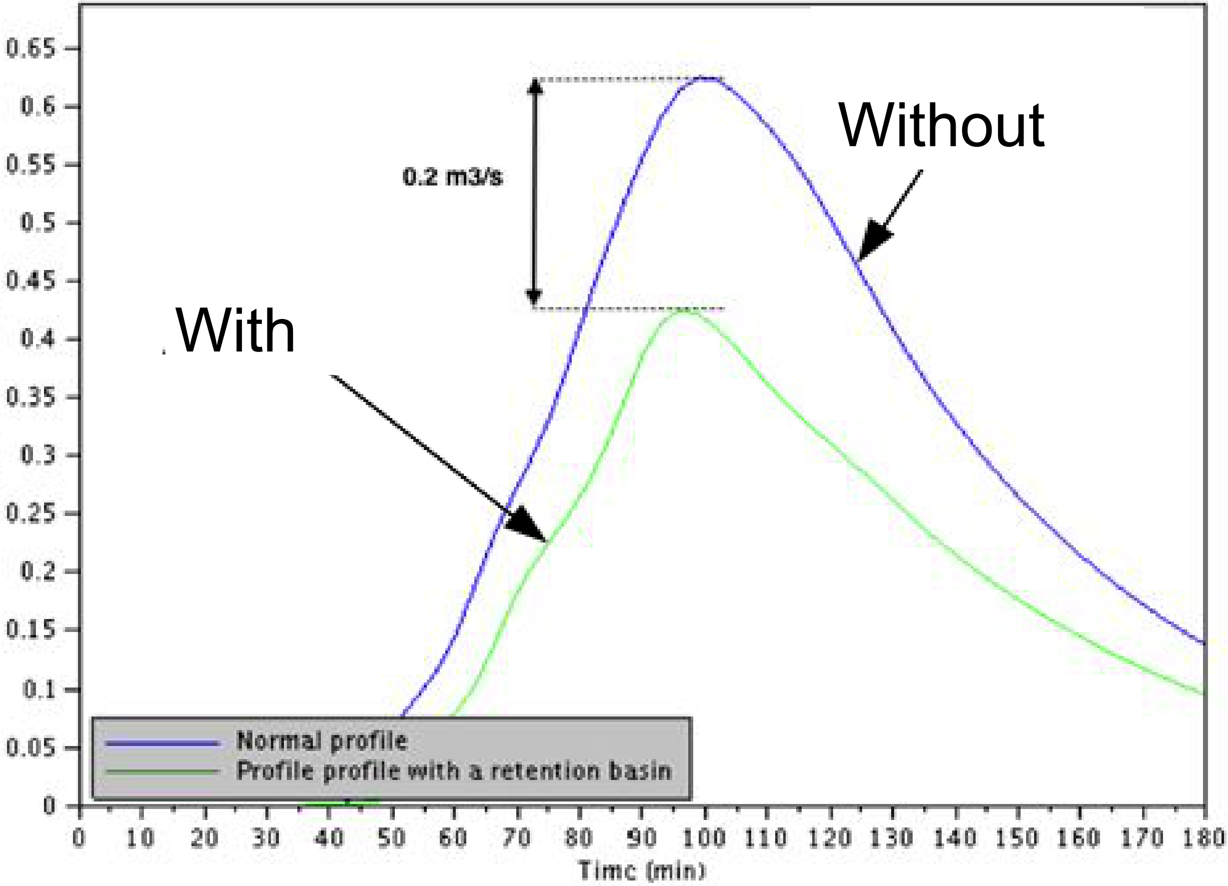
– larger scales can be used to estimate the cascade parameters, if not known:
  - H: mean field scaling
  - C_1: intermittency of the mean
  - a : variabilty of the intermittency = multifractality

Multiscale simulations



SMARTeST Manchester case study (Giangola-Murzyn et al., , 2004

Case study of a swale



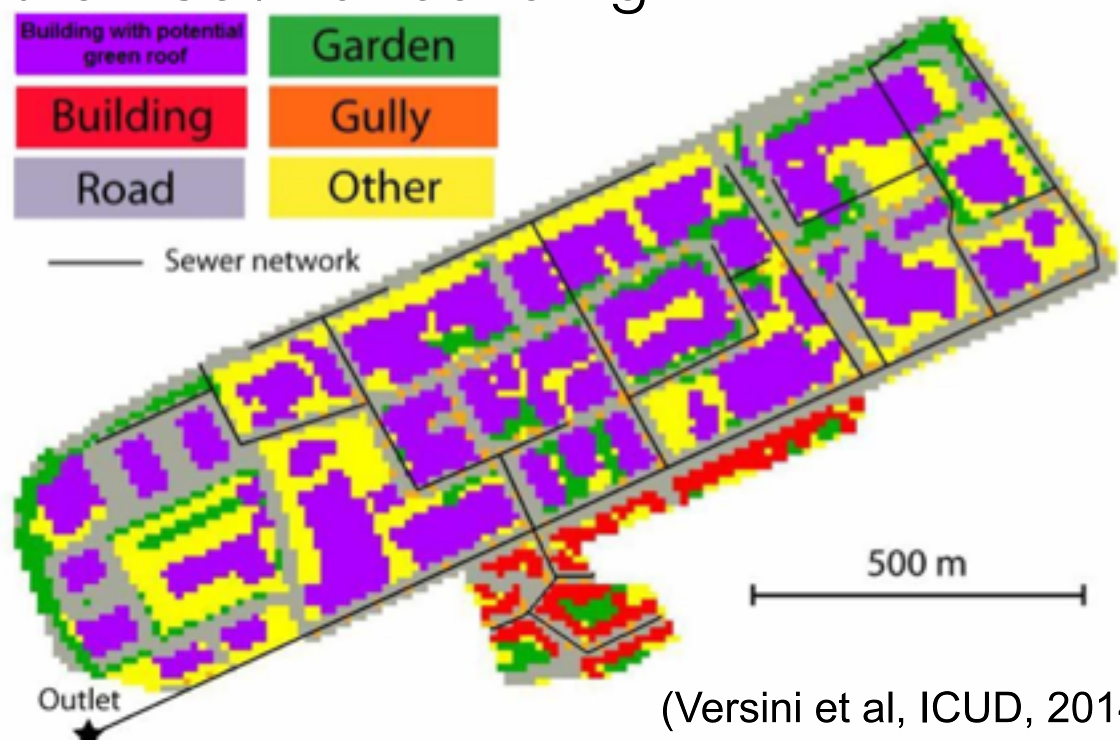
(Giangola-Murzyn et al., , 2004

MH and green roofs

Loup basin (Villepinte, France)

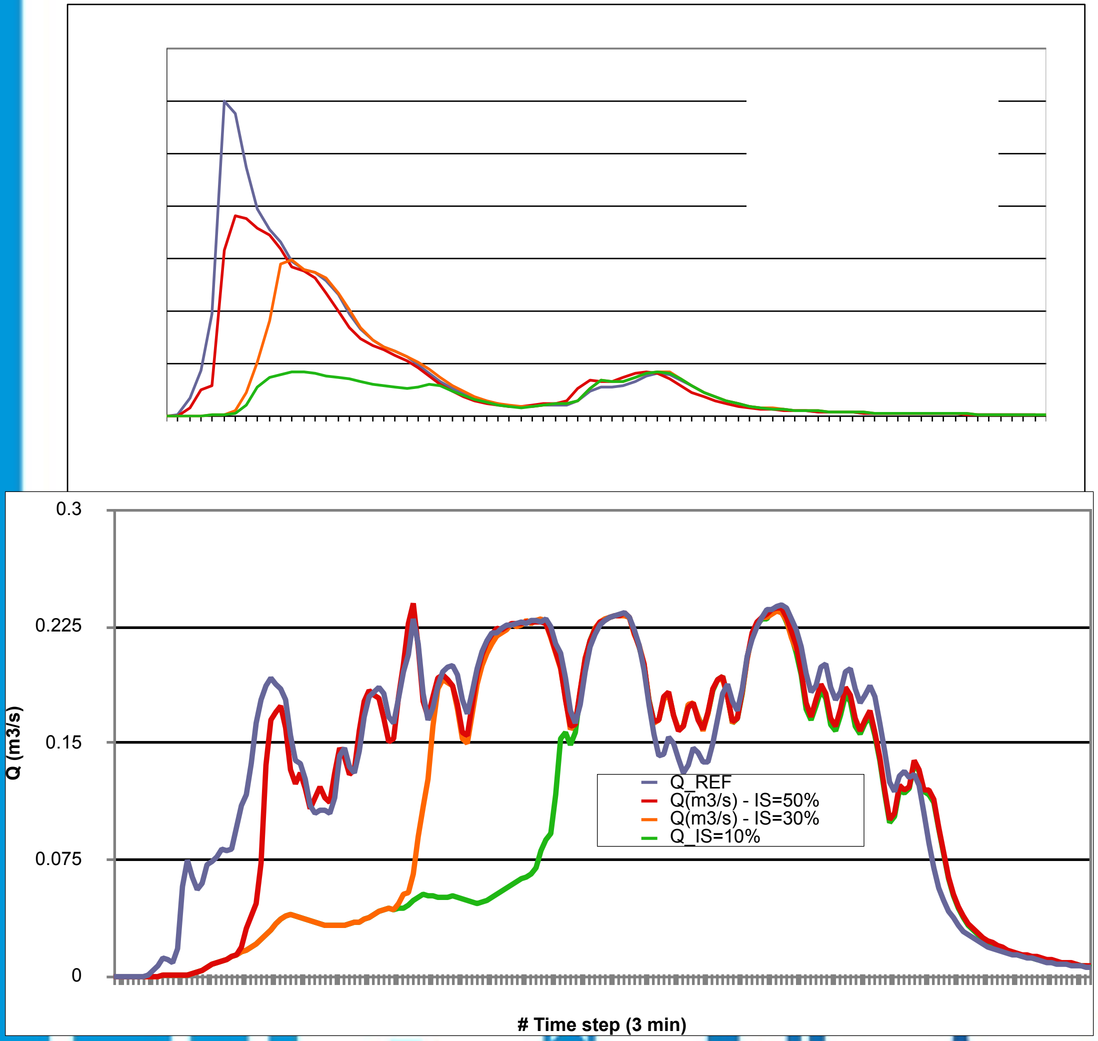
- Area : 65 ha
- highly impervious (close to 90%)
- covered by more than 38% of building

Industrial building roof area represents more than 34% of the basin area



(Versini et al, ICUD, 2014)

MH and green roofs



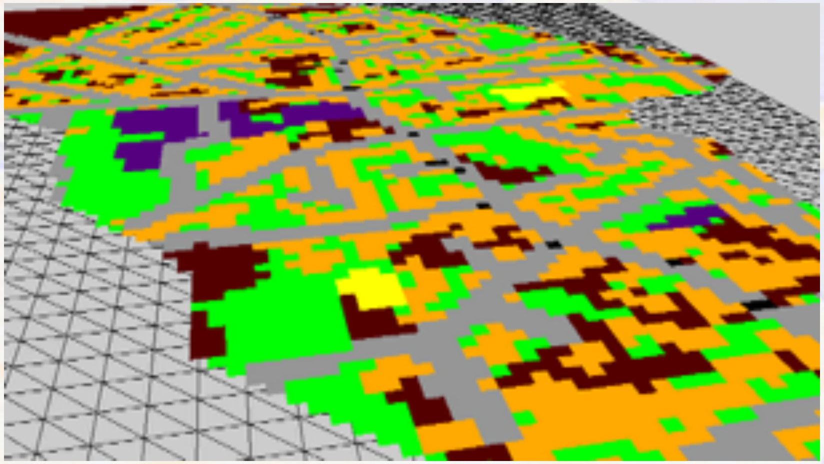
Green roof is very efficient for current rainfall events in terms of peak discharge and runoff volume reduction

Green roof has low impact on long rainfall events in terms of peak discharge

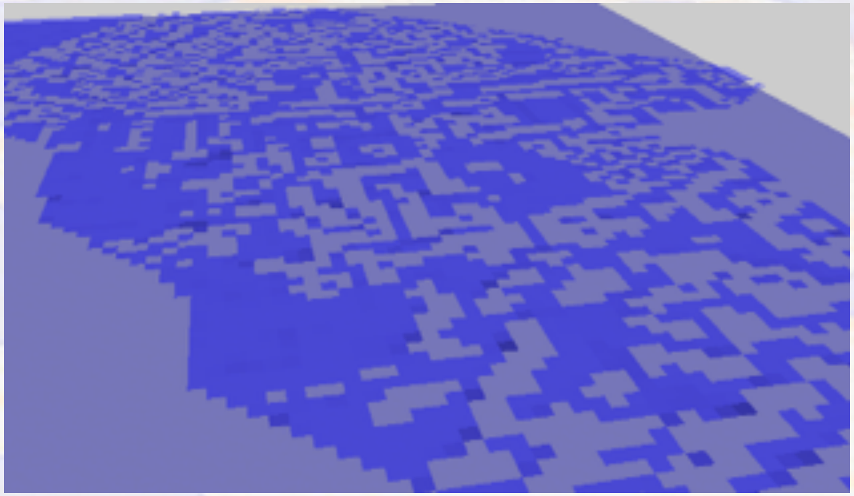
(Versini et al, ICUD, 2014)

MH 3DV

Data preprocessing



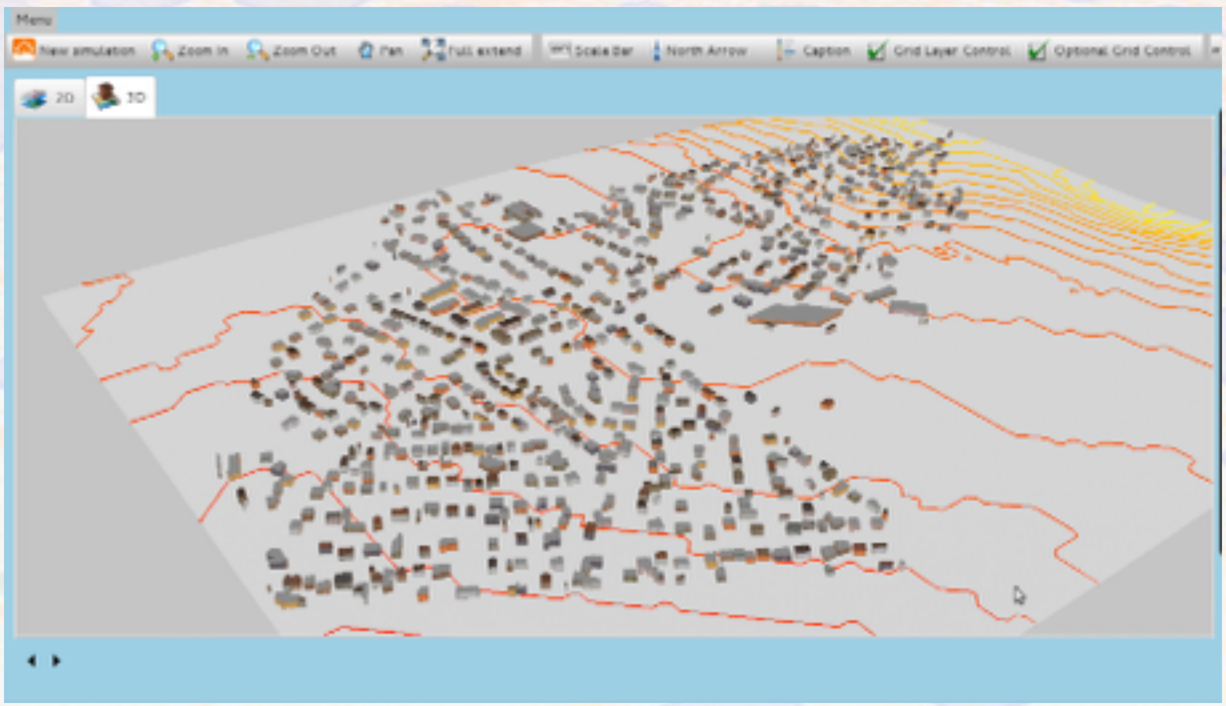
Land use



Water depth

MH 3DV

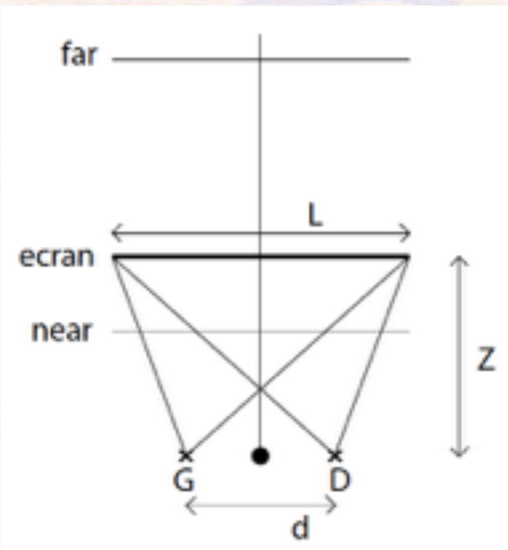
Animation with water depth

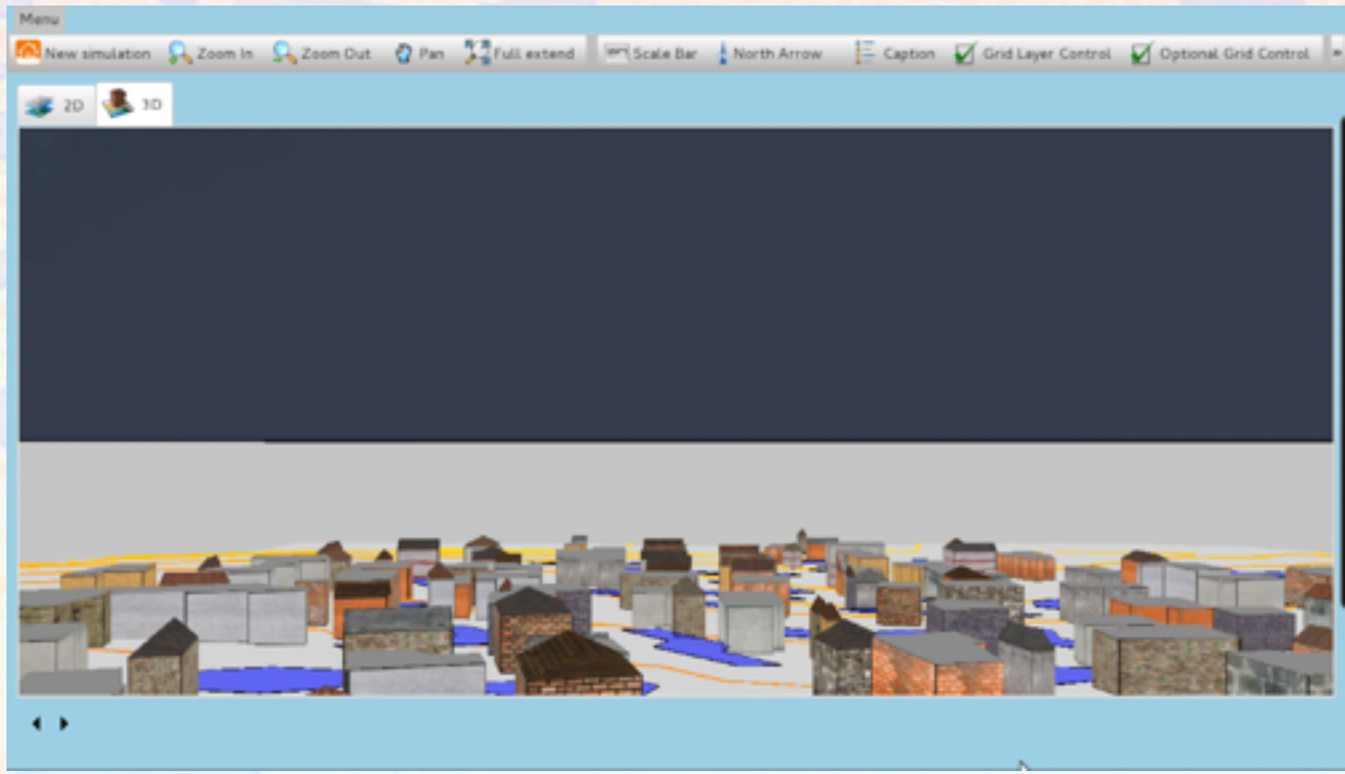


- Isolines (marching squares) 3 cm resolution
- 24 frames/sec
- water depths update every 2 frames

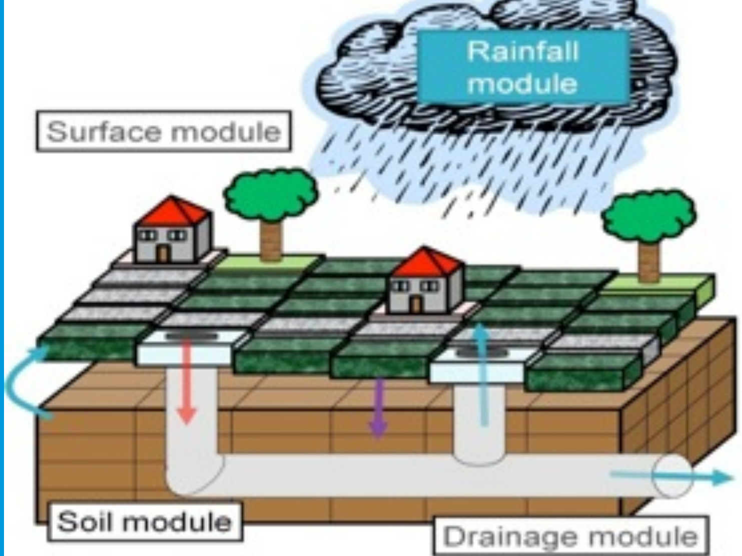
MH 3DV

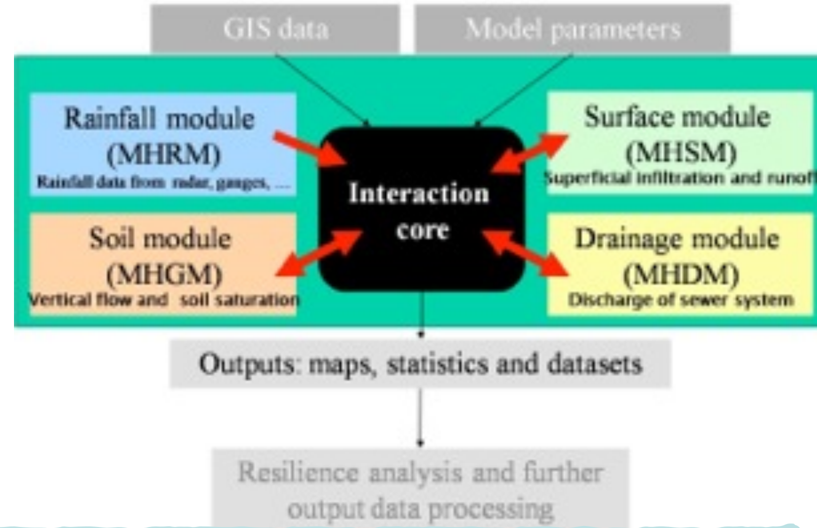
Stereoscopic immersion





MH: towards a successful story?

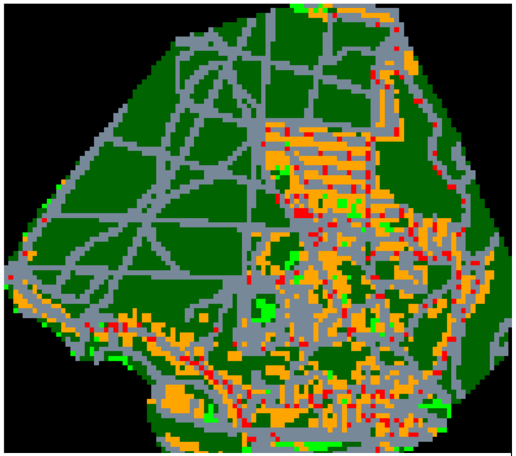




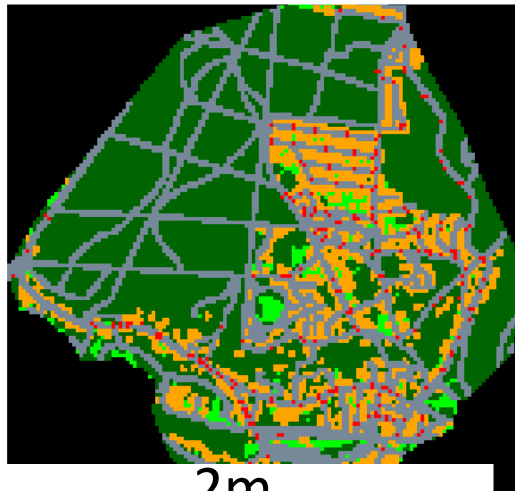
- Fully distributed
- Modular structure
- physically based ➔ no calibration
- SIG based ➔ transportable
- Multiscale generation of missing or HR data ➔ scalable
- OpenSource ➔ User community

Impervious "coefficient"?

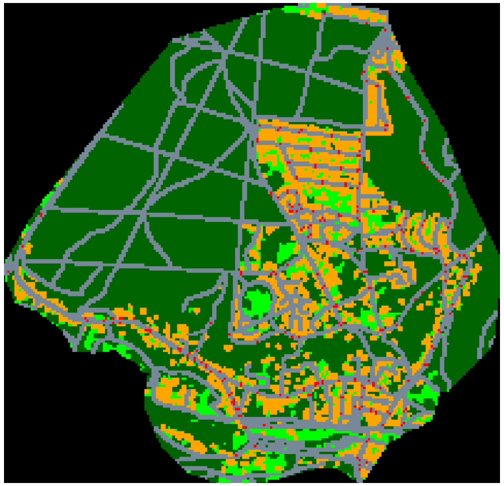
20m



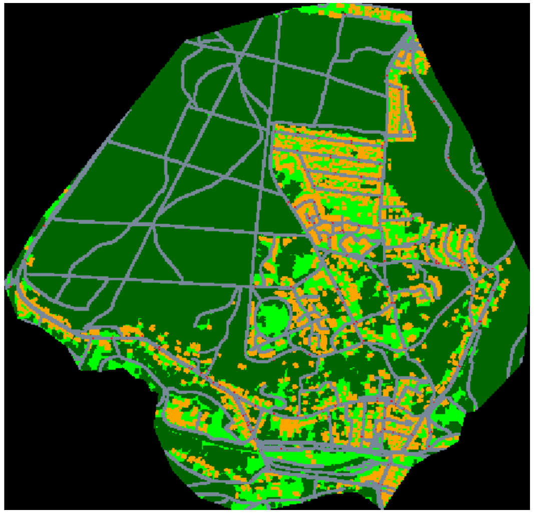
15 m



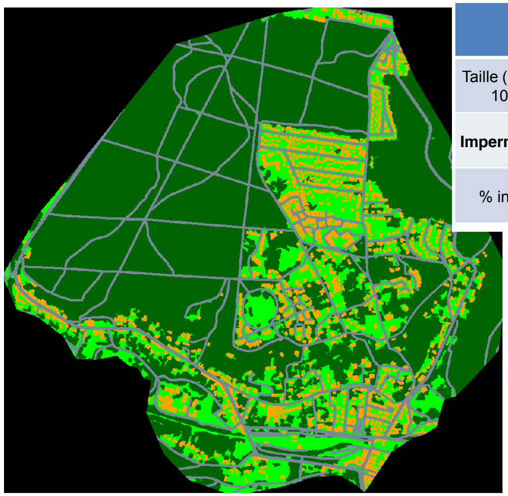
10m



5m



2m



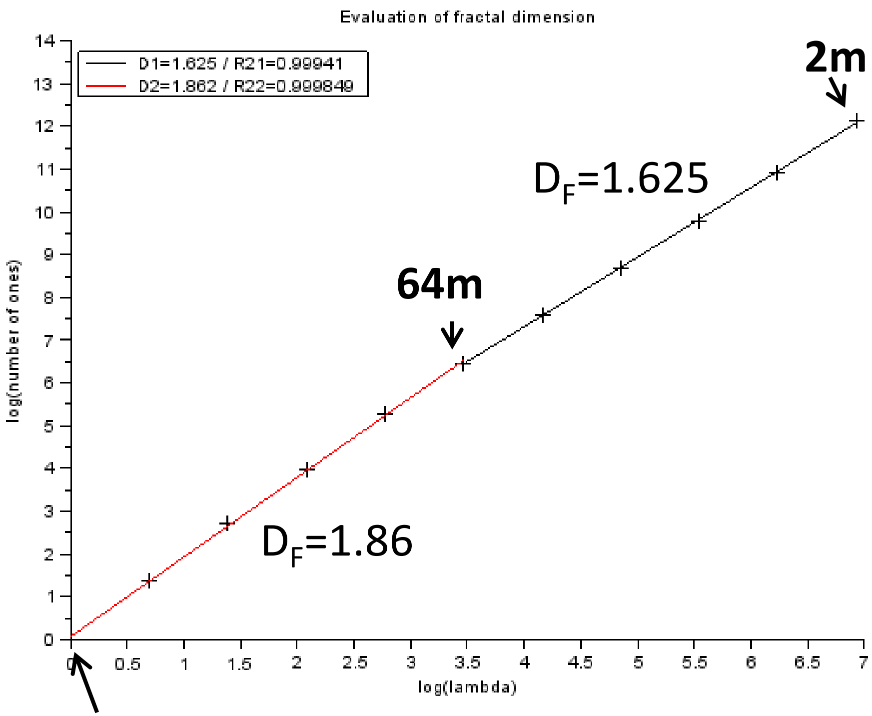
	20m	15m	10m	5m	2m
Taille (pixels de 100m²)	11 128	19 734	44 512	178 464	1 118 034
Imperméabilité	**55.4%**	**49.6%**	**42.3%**	**32.4%**	**24.7%**
% inconnu	31.3%	31.6%	32.2%	32.8%	33.3%

(Abbes, 2014)

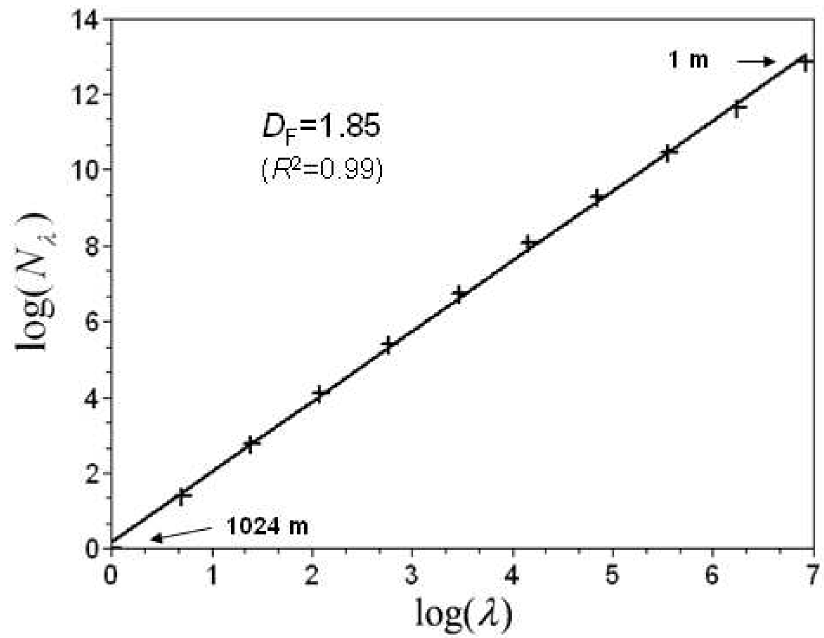
Impervious “coefficient”?

Impervious area, Jouy (roads+houses) at a 2m resolution

Comparison with Kodak catchment (Gires, 2012)

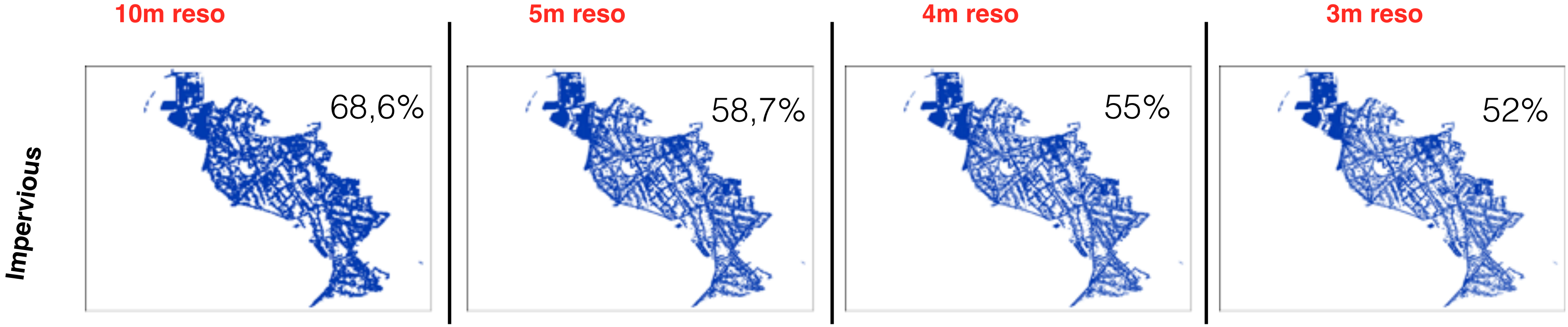


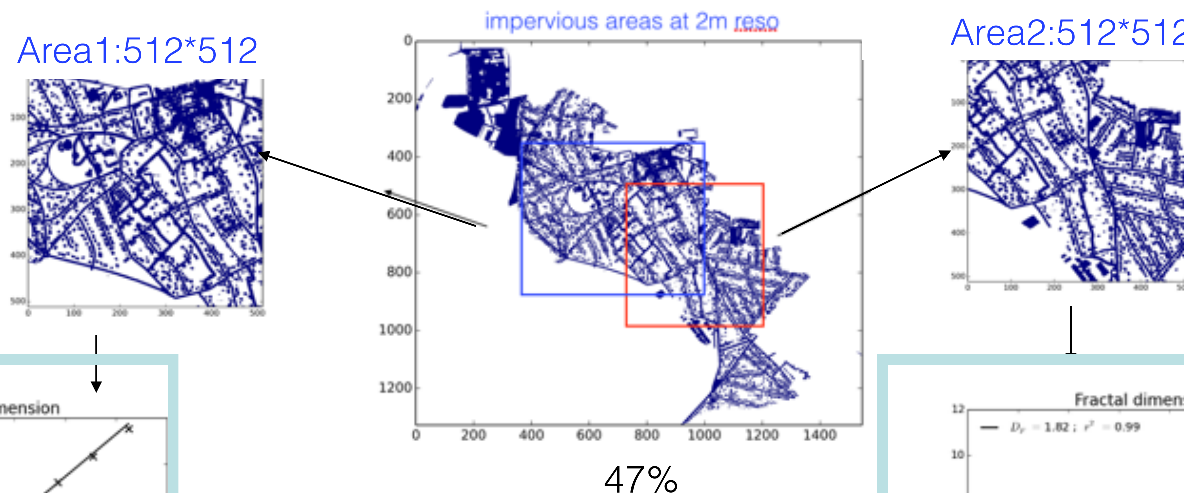
2 048m

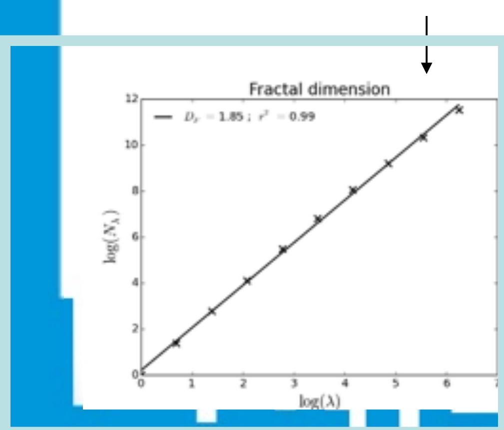


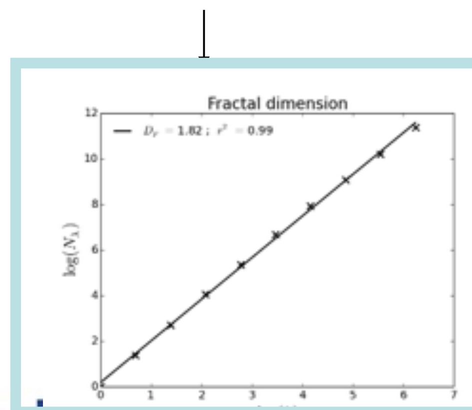
Abbes, 2014)

Impervious “coefficient”?



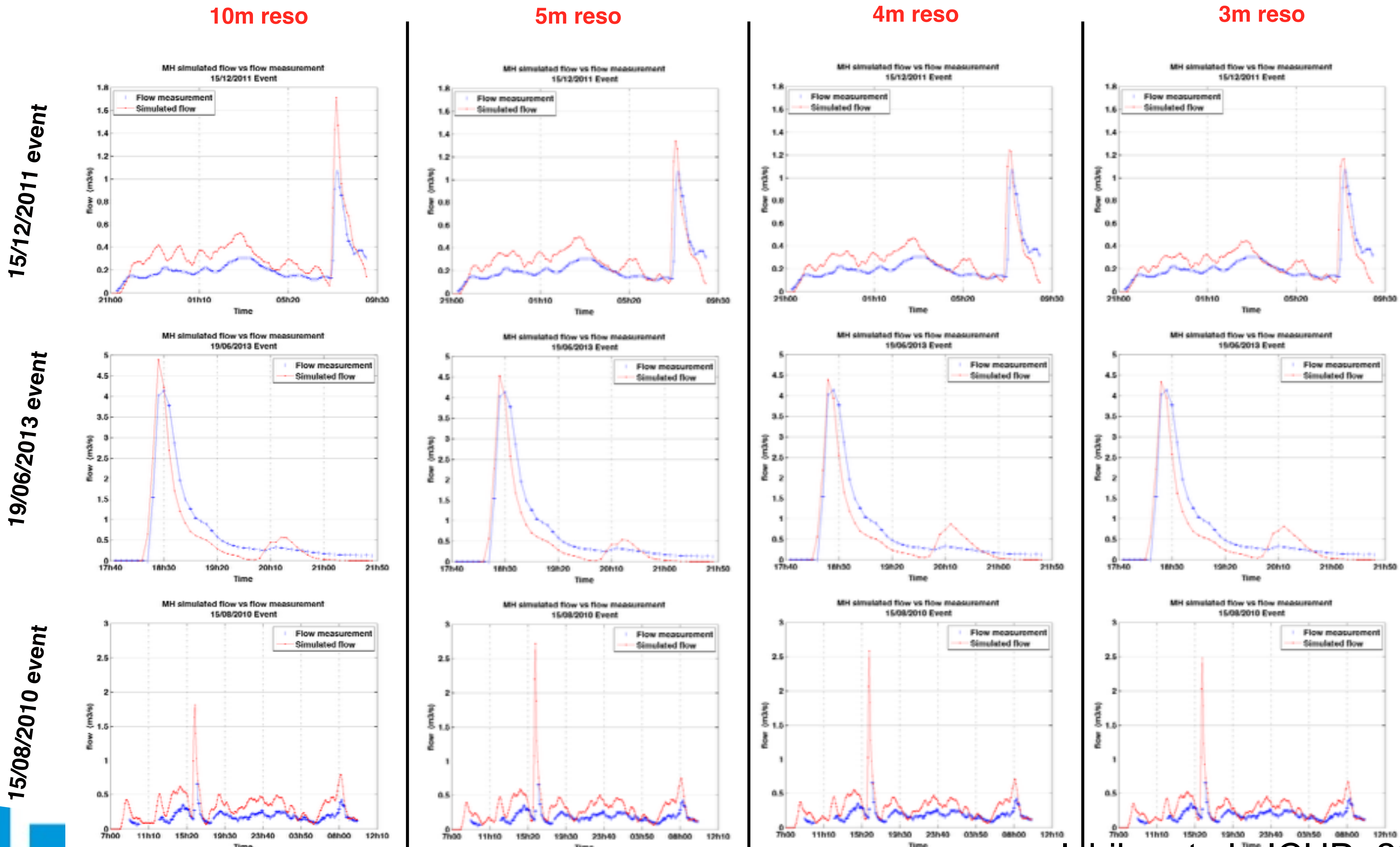






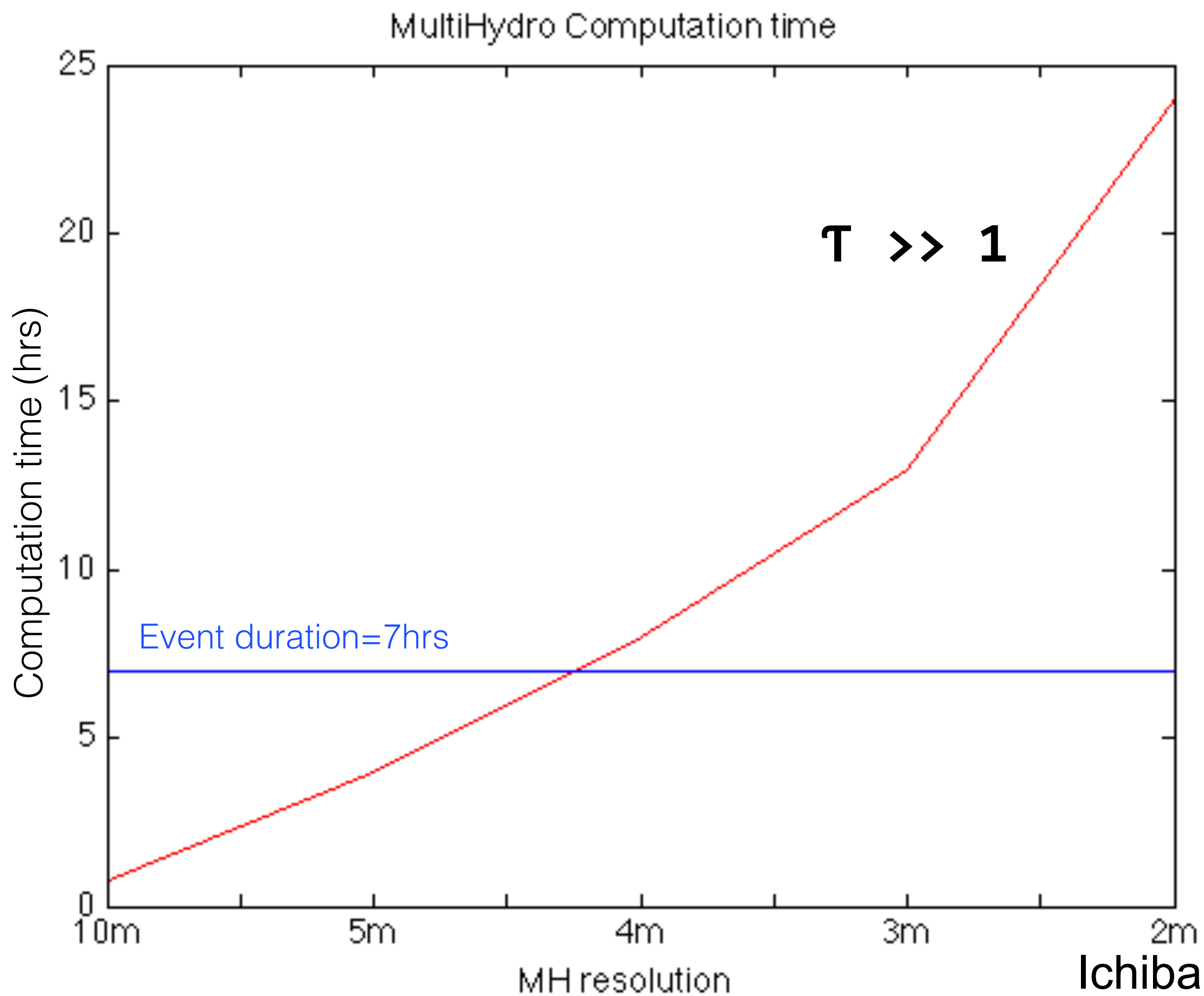
Ichiba et al., ICUD, 2014

Response and scales



Ichiba et al., ICUD, 2014

Time and memory

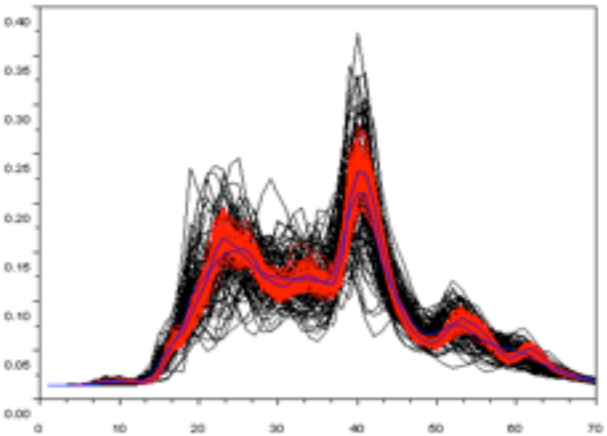


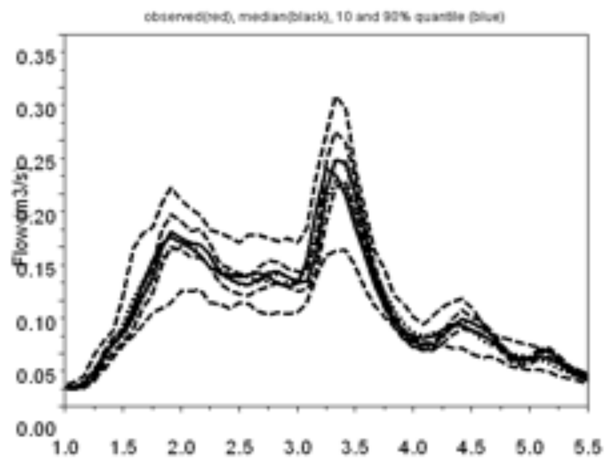
+ instability problems !

Ichiba et al., ICUD, 2014

Sewer response to small scale variability

1000 realisations of multifractal downscaling

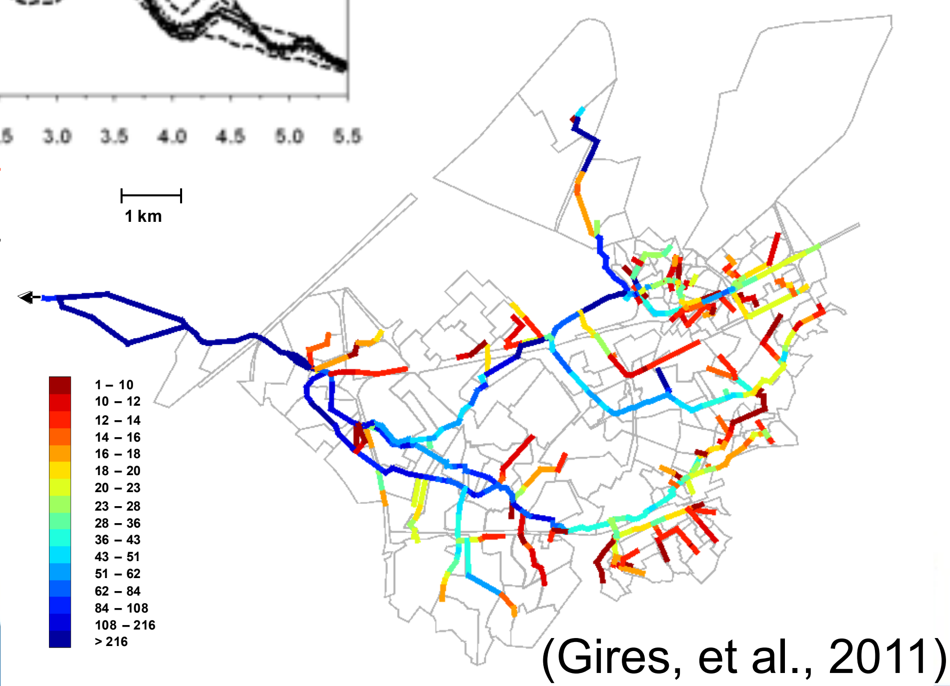




1000 downscaling realisations: 1km -> 125 m

1000 downscaling realisations: 8 km -> 125 m

Estimates of peakflow quantile increases due to small scale variability



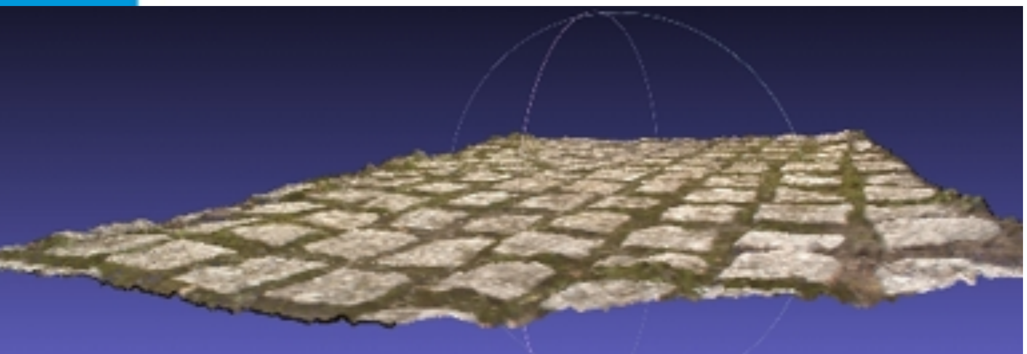
(Gires, et al., 2011)

HR only by brute force ?

Fujitsu *VPP 5000 :   0,3 Teraflops*

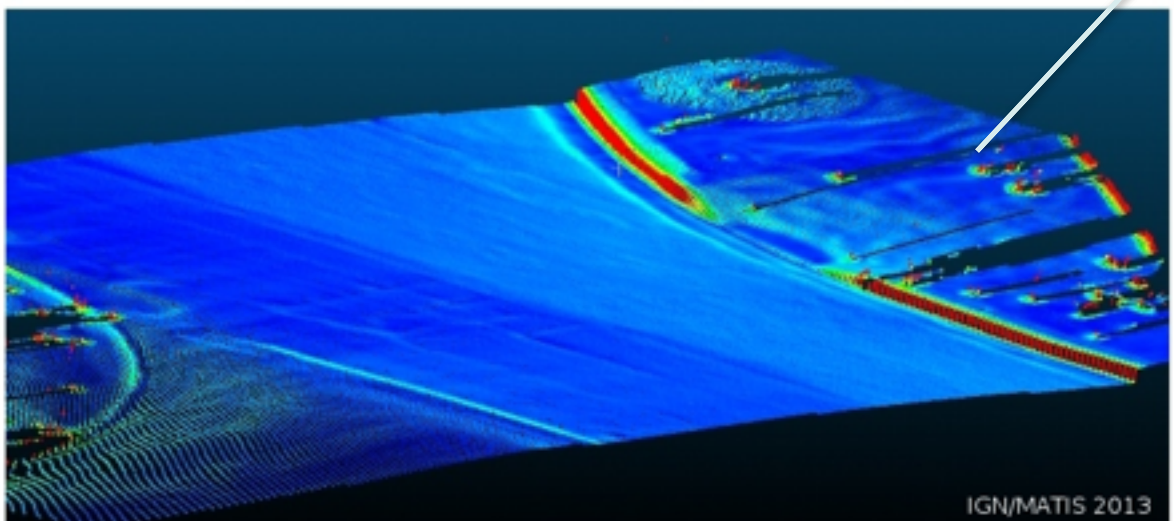
NVDIA GPU*:   1,3 Teraflops*

Which inner scale?

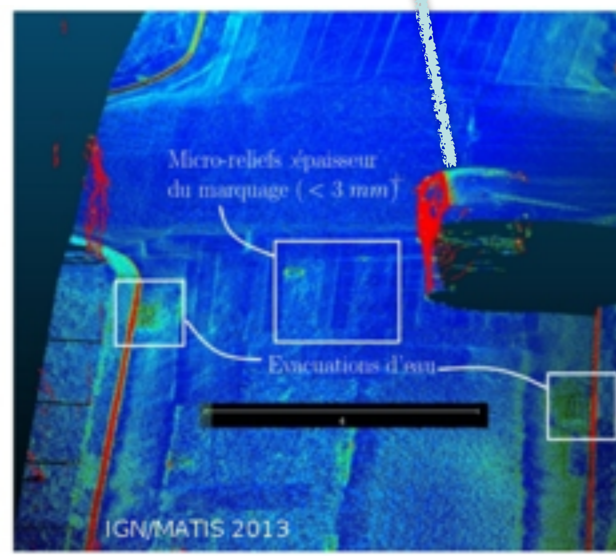


3D surface with resolution > 5 mm (Micmac, IGN)

IGN STEREOPOLIS II mobile mapping system



3D surface with resolution > 1 cm (Micmac, IGN)



Hong, thesis 2014

Conclusions

- HR urban hydrology
  - a PUB issue: processes/understanding vs. parametrisation/calibration
  - models should be easily transportable, scalable and inter-operational

Conclusions

- however, cannot be obtained only by computer brute force
  - scale dependance —> change of observables/ parameters vs. scale truncation
  - across scale stochastics, inc. LR or missing data
  - no strong (functions), only weak convergence (measures)
    - problems with finite differences (particularly explicit ones): Trex, SWWM, V2DT..
    - finite volumes schemes