Basilisk/Gerris Users' Meeting 2019

Real-time inundation mapping with a 2D hydraulic modeling tool based on adaptive grid refinement : the case of the October 2015 French Riviera flood

G. Kirstetter [1,4], F. Bourgin[2], P. Brigode[1,3], O. Delestre[1,4]

(1) Polytech Nice Sophia, Université Nice Sophia Antipolis
(2) IFSTTAR, GERS, EE, Bouguenais
(3) Université Côte d'Azur, CNRS, OCA, IRD, Géoazur, Nice
(4) Laboratoire de Mathématiques J.A. Dieudonné, Université Côte d'Azur, Nice

Context

- **Climate change : intensification and augmentation of the frequency of rare and extreme events, as flash floods. (*Climate Change 2014: Synthesis Report, IPCC*)**
- **Increasing urban densification leads to increased exposure to flood risk**
- **Extreme weather events can be difficult to predict.**

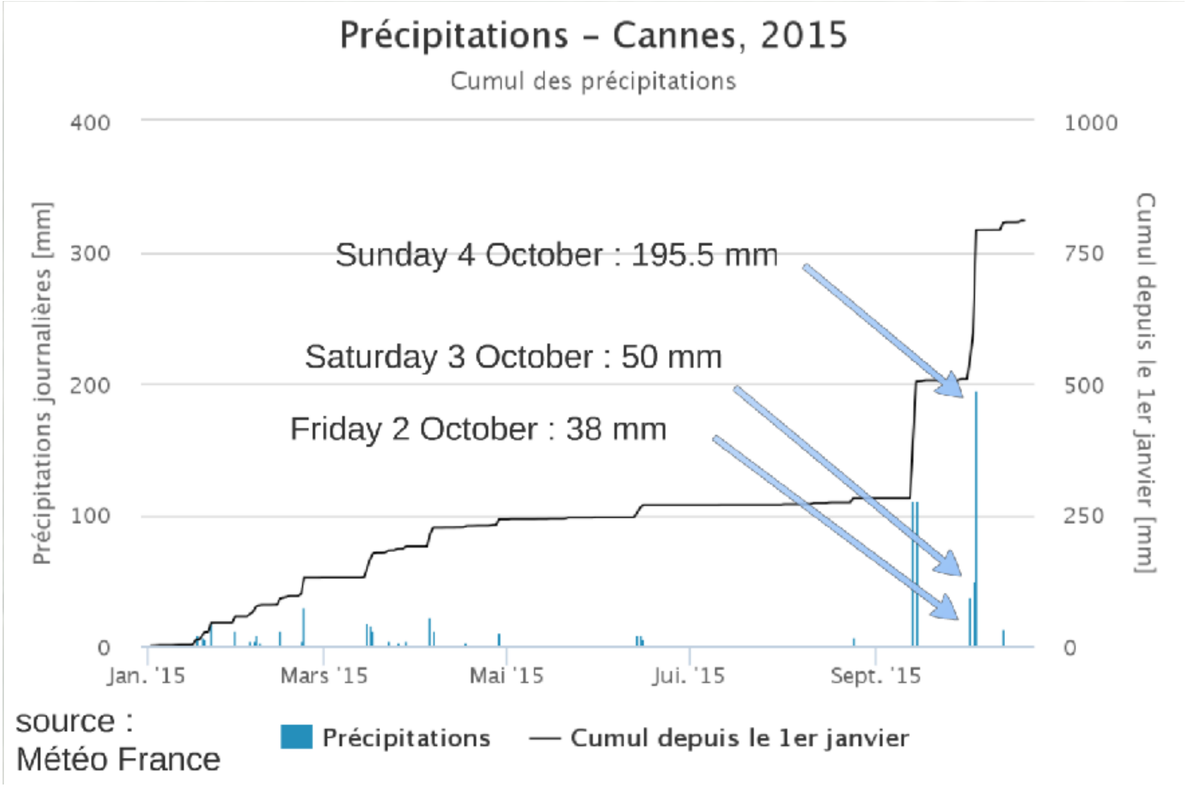
Real-time forecasting tool

- **Climate change : intensification and augmentation of the frequency of rare and extreme events, as flash floods. (*Climate Change 2014: Synthesis Report, IPCC*)**
- **Increasing urban densification leads to increased exposure to flood risk**
- **Extreme weather events can be difficult to predict.**
- **Need a reliable tool to quickly simulate the spread of a flash flood from live weather data.**

The flood of the French Riviera, 03-10-2015

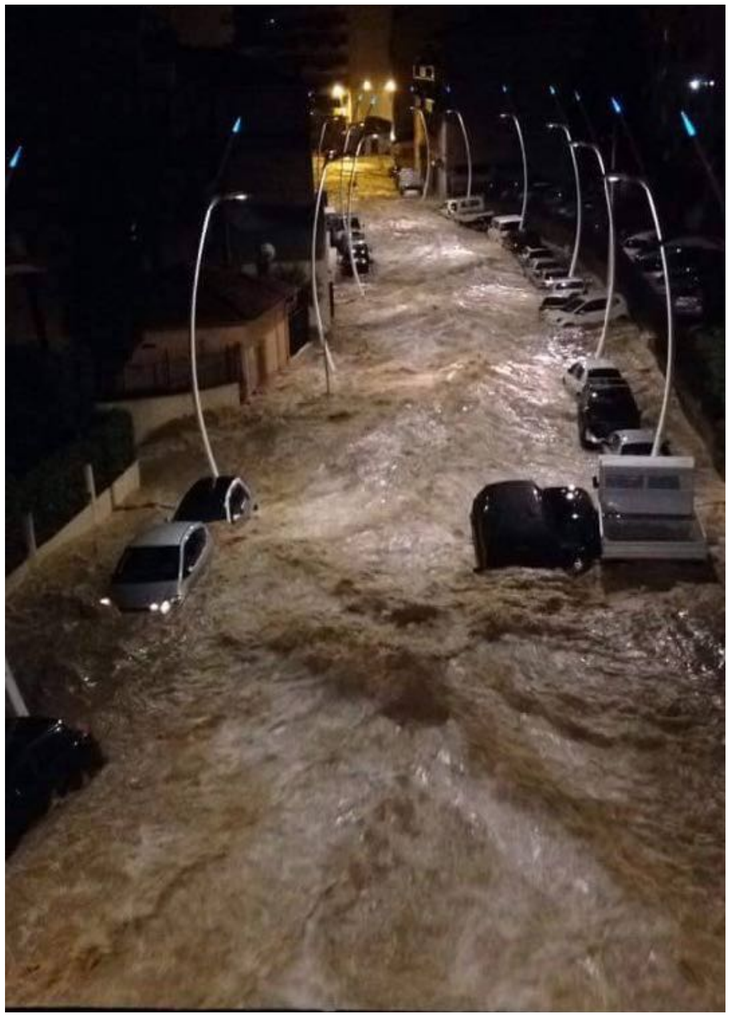
- **On Saturday, October 3, 2015, between 18h and 23h, a heavy rain occurred on the department of Alpes-Maritimes in France: in some places, 200 mm of precipitation accumulation were recorded in less than 3 hours. This exceptional weather event resulted in a huge flash flood, which killed 20 people. The CCR estimated the equipment lost between 500 M€ and 650 M€.**

- **Rain accumulation for the year 2015 : 25% of the annual rain fall in few hours.**
- **Rainfall intensity reaches 100 mm per hour**
- **National annual mean = 690 mm**



source : Météo France

The flood of the French Riviera, 03-10-2015

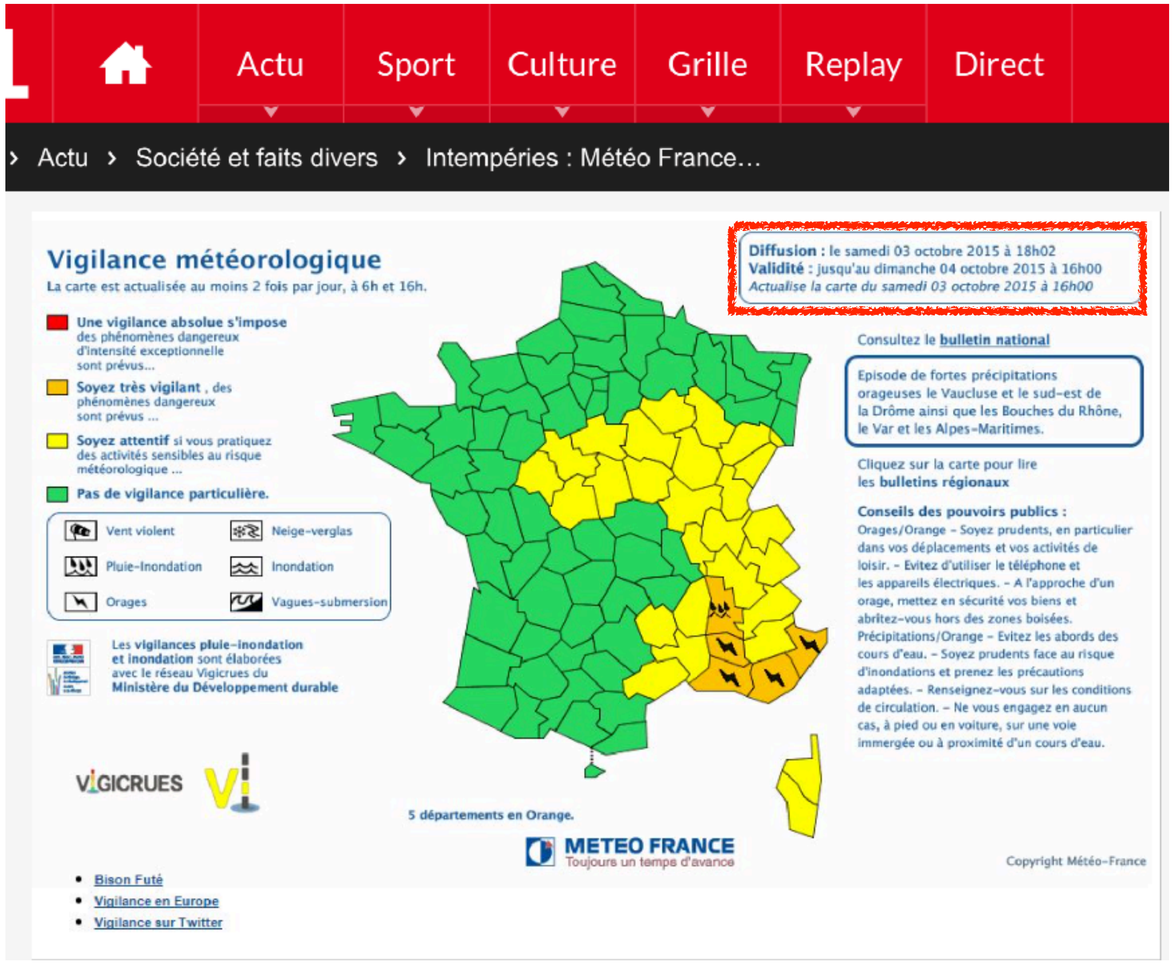


Town-center of Cannes in the night of the 3 October 2015
Source : Facebook Nice-Matin

The flood of the French Riviera, 03-10-2015

Biot the 4 October 2015
Source : Facebook Nice-Matin

Anticipate extreme events

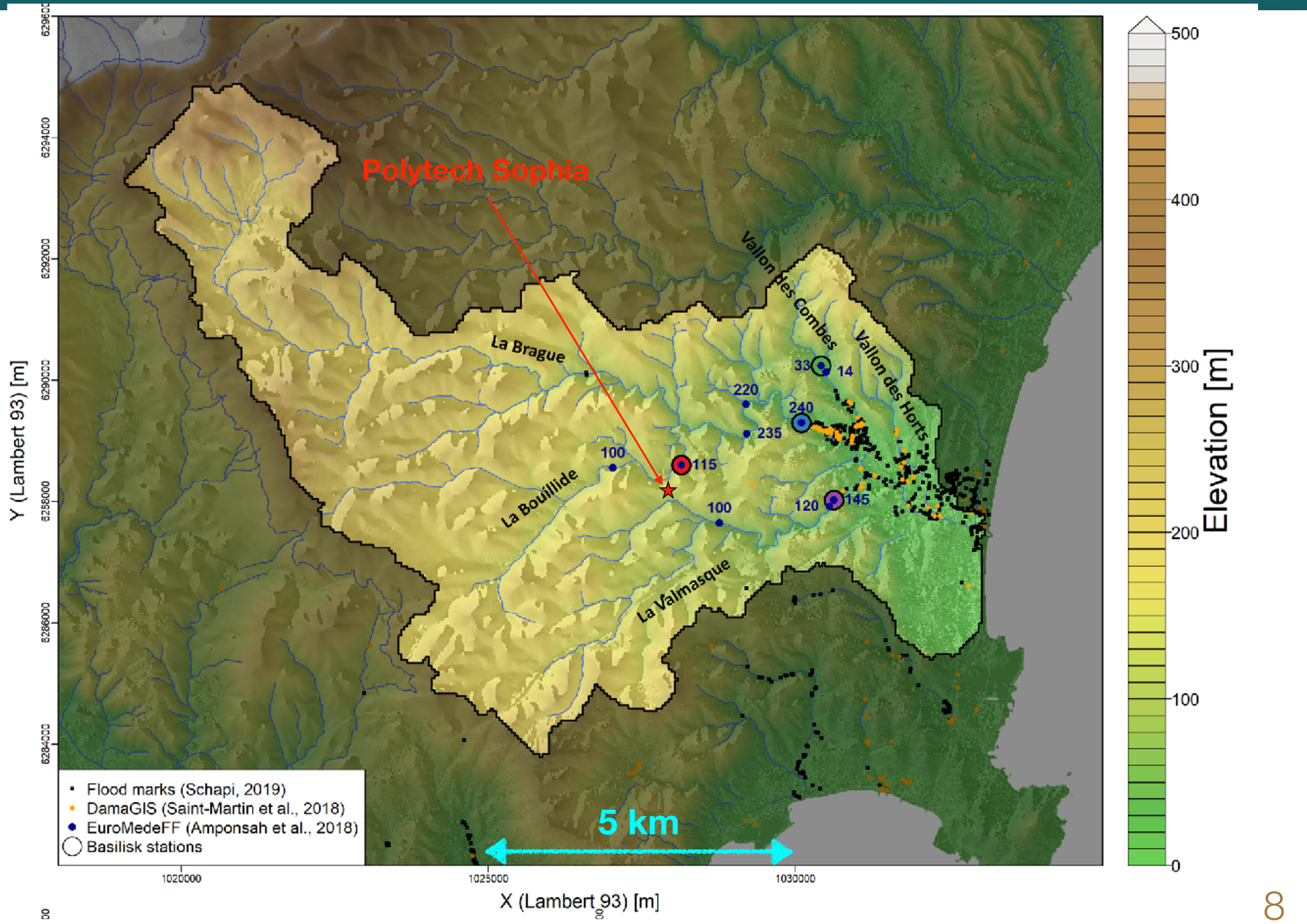


« Rain intensity can reach 40 mm per hour » Weather report of October 3, 2015 at 16:00, Météo-France.

Extreme events are extremely difficult to predict. Need to establish tools that are able to simulate flood in less than one hour.

Case study : Brague River

- **Brague River watershed Area : 68 km²**
- **Estimated peak discharge (Amponsah et al., 2018)**
- **Flood marks (Schapi, 2019)**

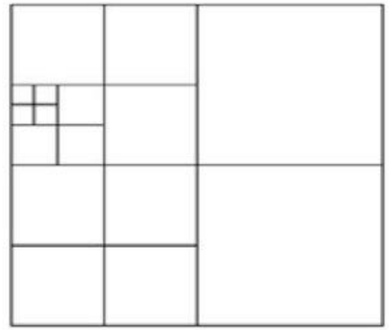


Basilisk : The code

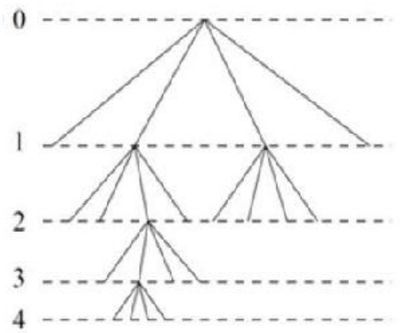
- Basilisk is a Free Software program for the solution of partial differential equations on adaptive Cartesian meshes. It is destined to be the successor of Gerris and is developed by the same authors.

www.basilisk.fr

- 2D Shallow water equations.
- Finite volume method
  - Rieman approximate solver (Kurganov 2002)
  - well-balanced (Audusse et al., 2004)
  - second order in time and space.
- Parallel computation (OpenMP & MPI).
- Adaptive cartesian grid (Quad-tree)



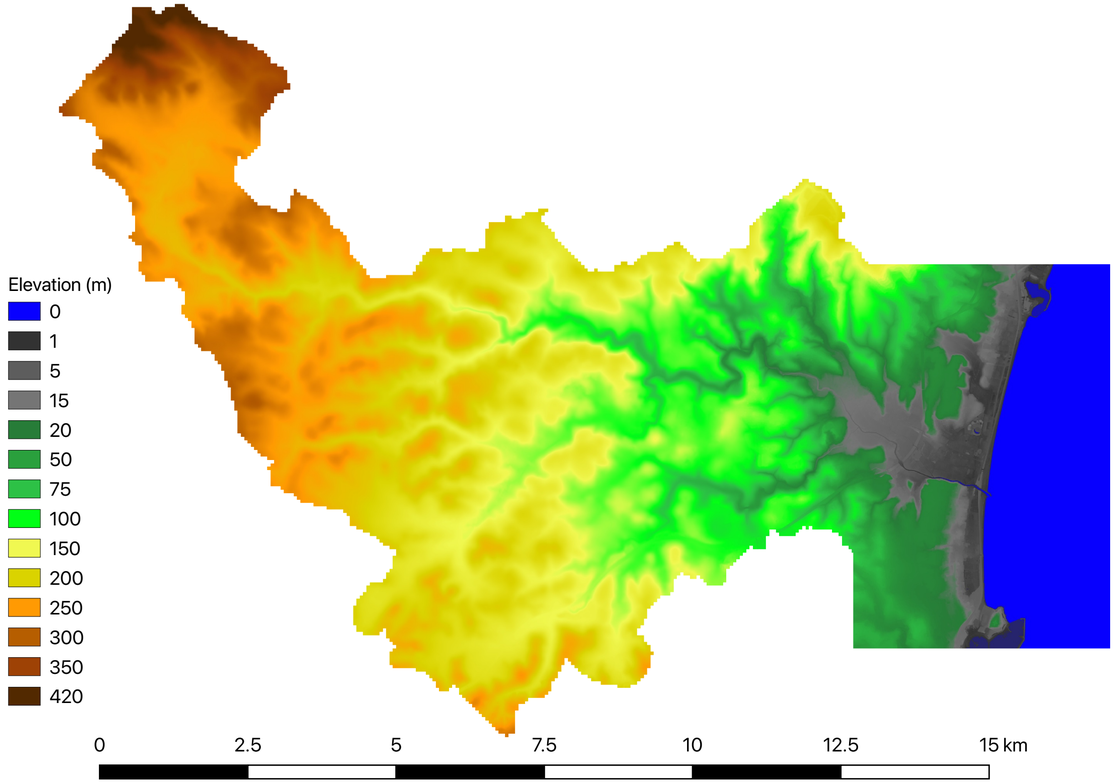
(a) Quadtree Mesh



(b) Logical Structure

Topography

- 1 meter DTM (IGN) aggregated at 4 m (maximal resolution of simulations)
- The right boundary is a lake filled with fully simulated water allowing an optimally modeled exit condition
- Whole Brague watershed
- DSM added (Digital Surface Model)



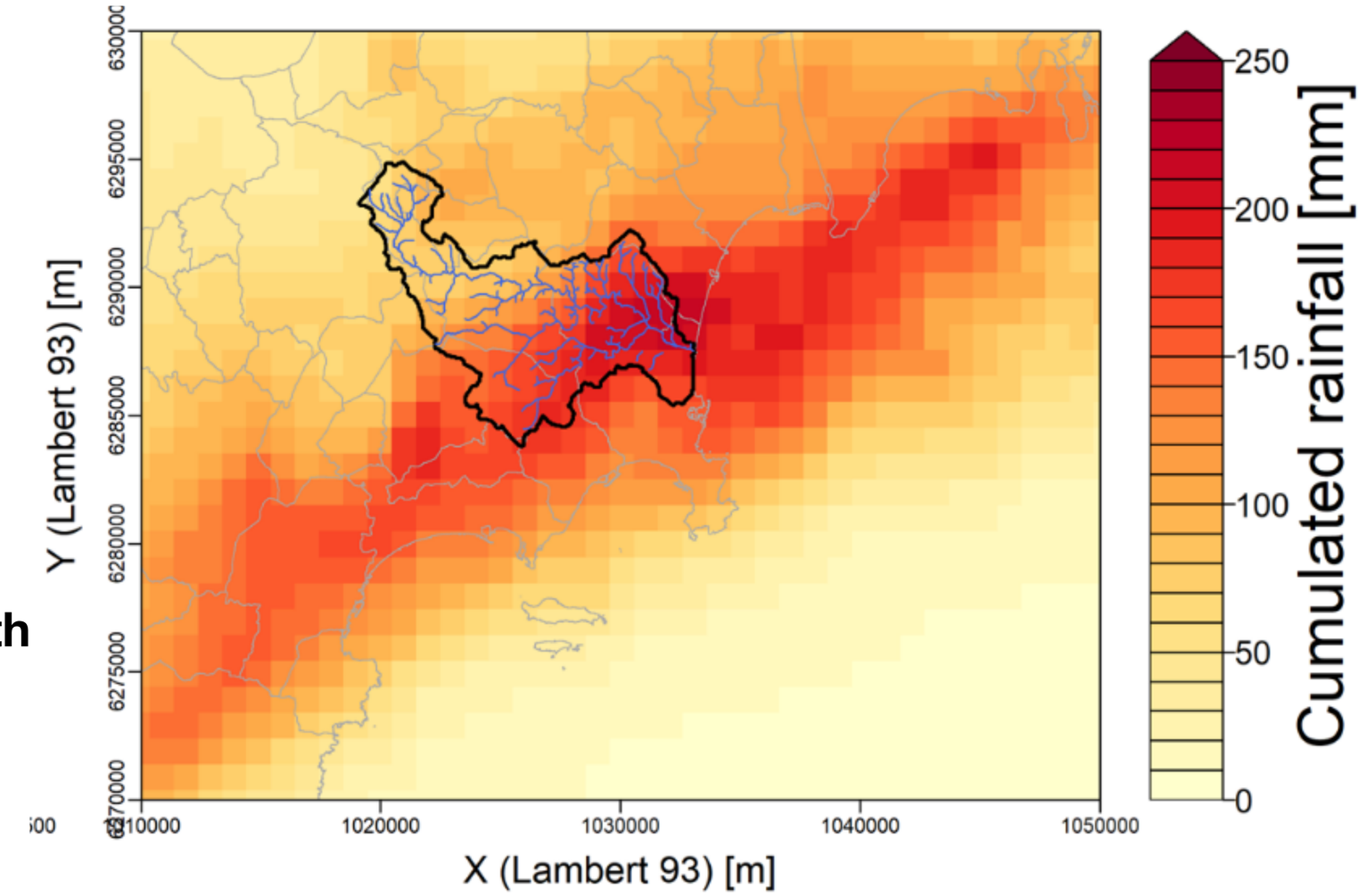
Precipitation & Overland flow

Rainfall from Météo-France :

- **Panthere Radar-data**
- **1km x 1km**
- **Temporal resolution : 5min**

Overland flow :

- **SCS Production function with a uniform value of CN = 70**
- **Uniform Manning value for friction : n = 0.05**



Mesh Adaptative Refinement

- **Published in Popinet (2011)**
- **Threshold of 20 cm fixed on the water height field**
- **Compute the mean of the field on the 4 children cells and compare it to the value of the parent cell**

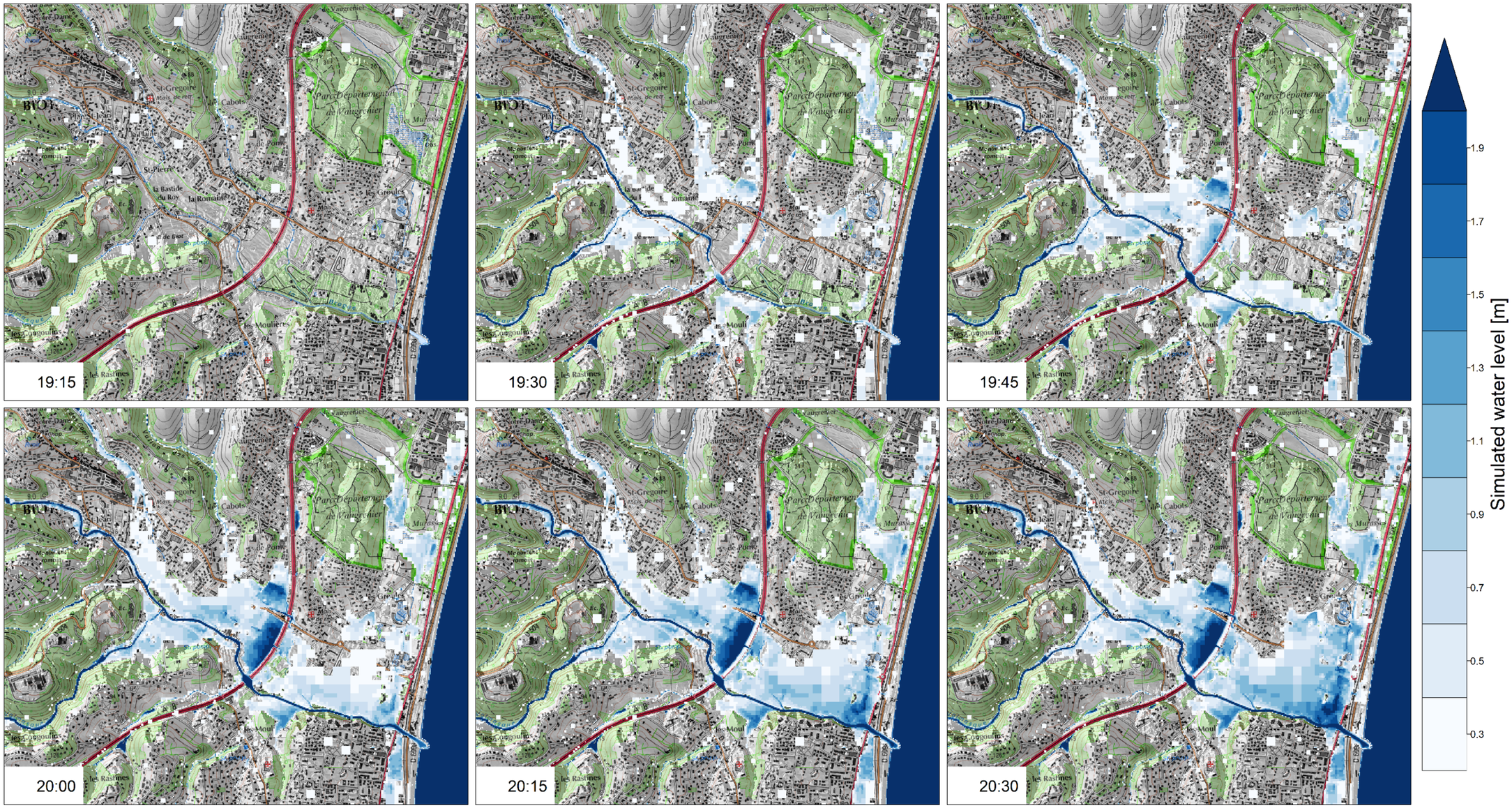
  If difference > threshold => Refinement
- **Same at one superior level of refinement to coarse the cells.**

#Simu	Minimal size	nb of cells in cartesian
1	16 m	1 048 576
2	8 m	4 194 304
3	4 m	16 777 216

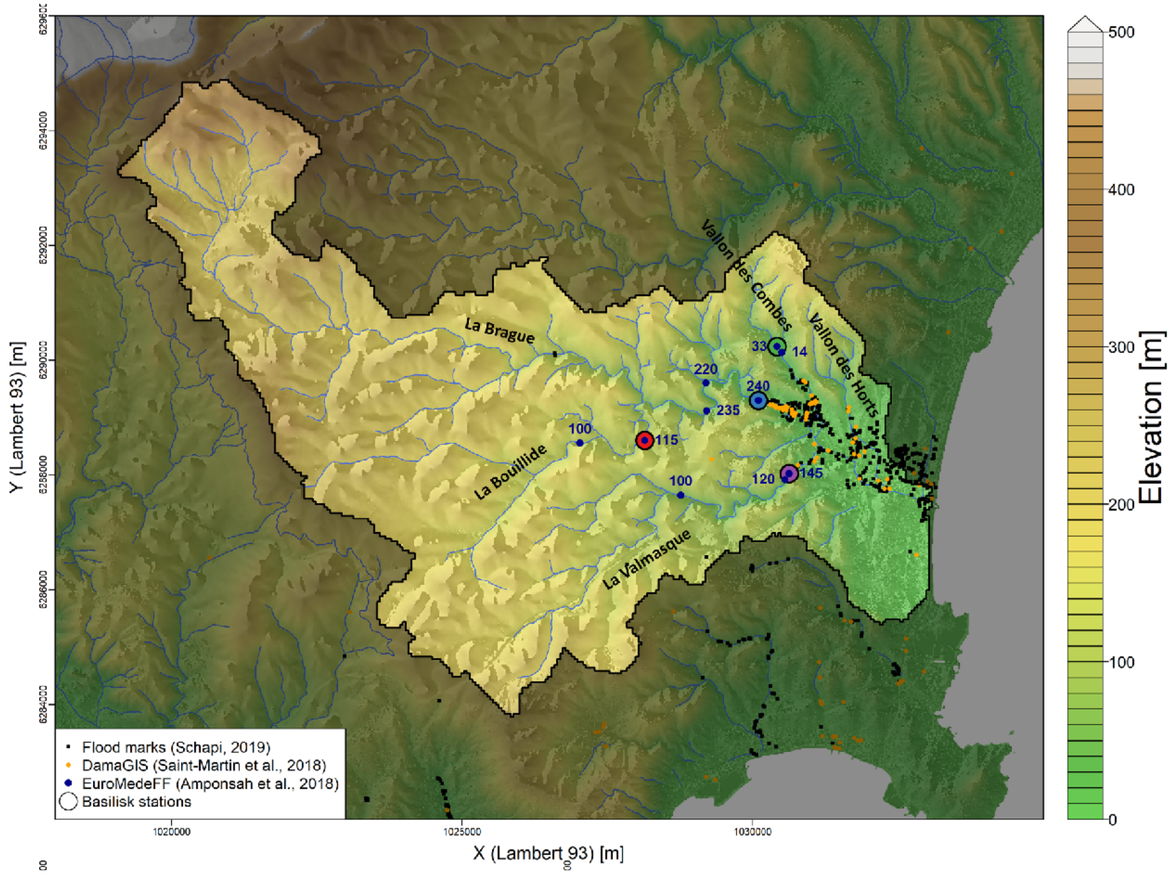
Simulation : Water height

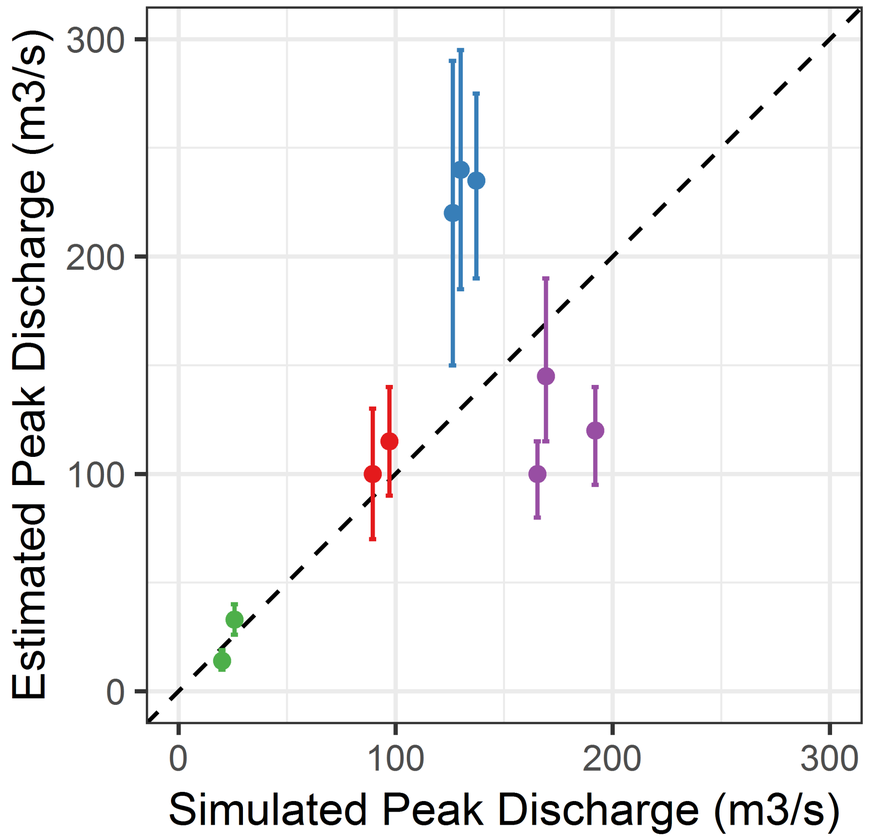
Movie : Water depth.
Color scale : Red > 1 m
Minimum cell size = 8 m

Simulation : Flood extent



Simulation : Peak discharges

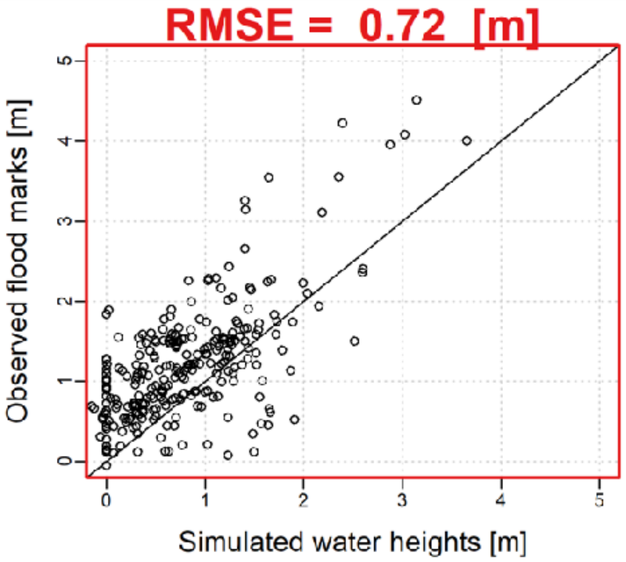


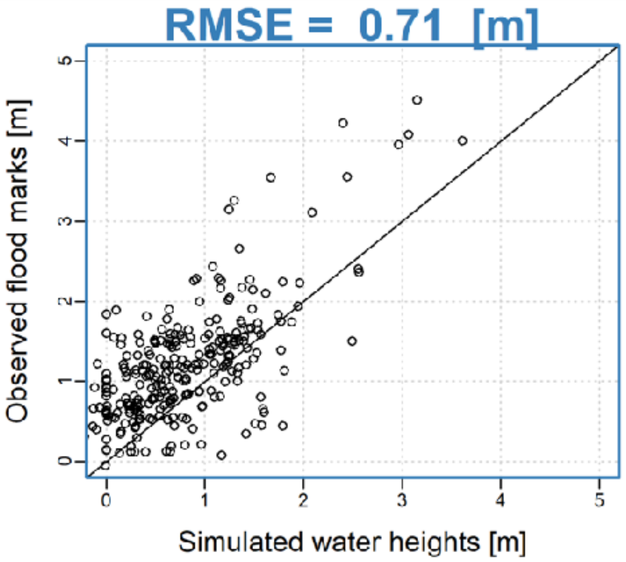


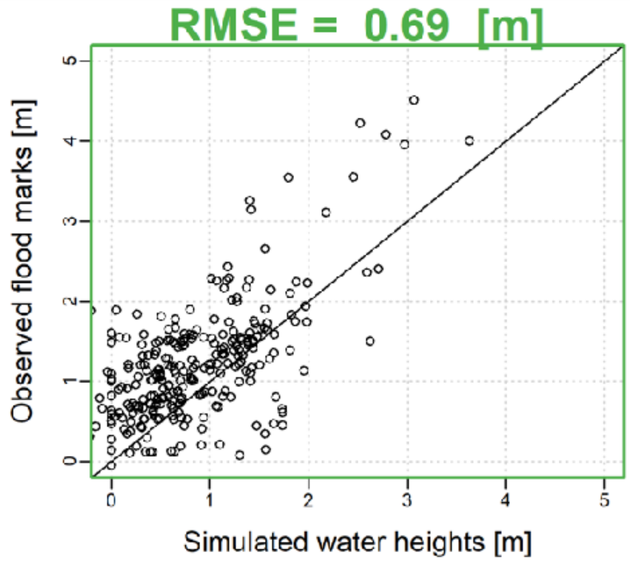
Discharge at « La Bragues » near Biot is under-estimated

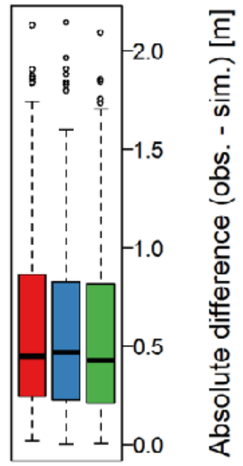
Good prediction of peak discharges

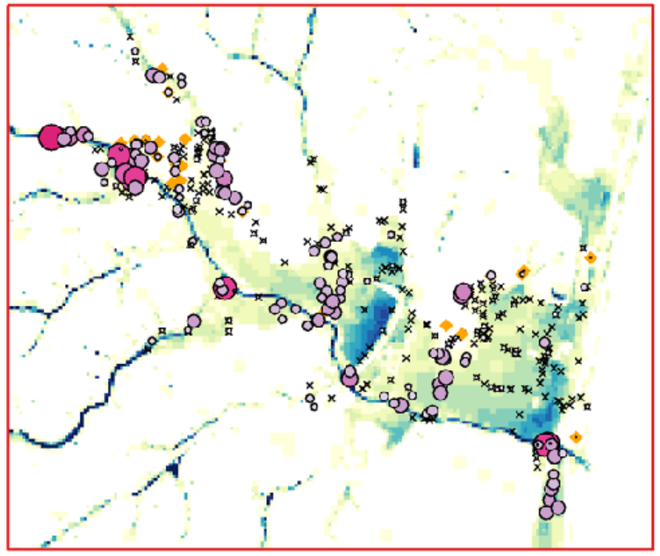
Simulation : Water Depths

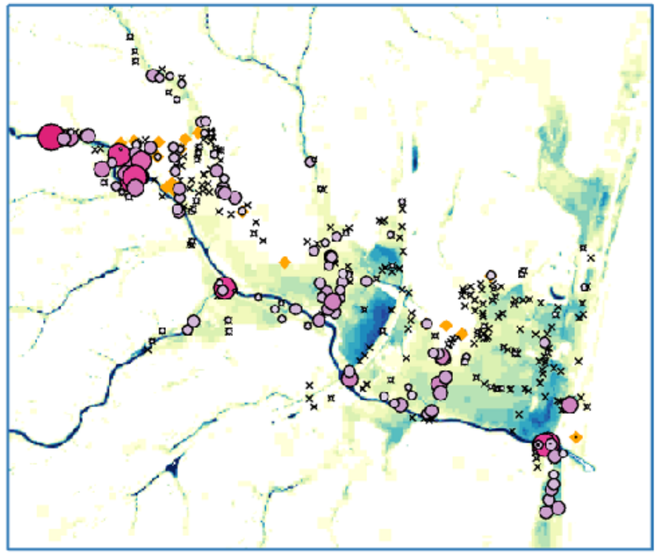


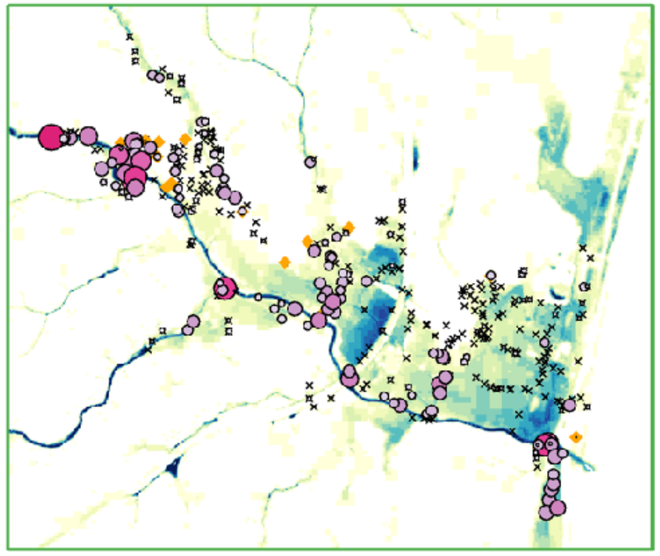


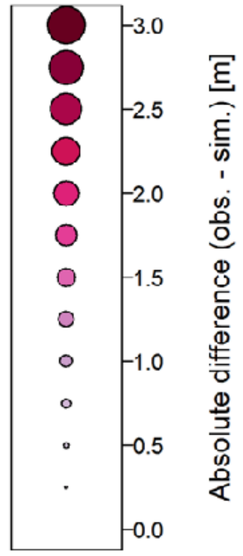










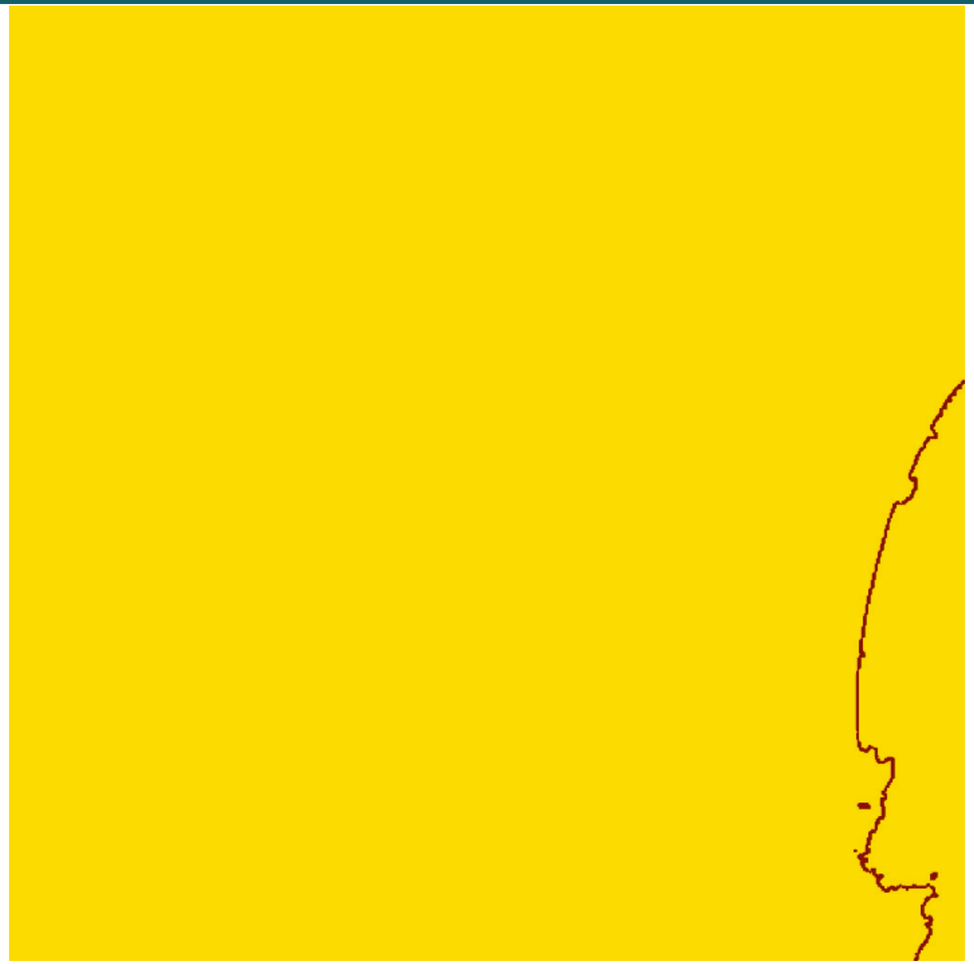


Cell size : 16 m
I = 89.5%

Cell size : 8 m
I = 91.8%

Cell size : 4m
I = 93.9%

Simulation : Adaptative refinement



Movie : Level of refinement
Minimum cell size = 8 m. (Level 11)
Maximal cell size = 64 m (Level 8)

Numerical

#Simu	1	2	3
Minimal size	16 m	8 m	4 m
nb of cells in cartesian	1 048 576	4 194 304	16 777 216
Computationnal time (32 cores)	1009 s	3411 s	10 210 s
nb of cells at the end	98 845	149 407	225 184
Maximal nb of cells	100 000	162 000	255 000

Conclusion

- **We have simulated the flash flood of the Brague River (Area: 68 km²) in 2D thanks to the adaptive refinement. This simulation was carried out in 20 min for a resolution of 16m, which is compatible with a real-time forecasting.**

- **Adaptive refinement allows us to increase the maximum resolution of our simulations with a better ratio than a 1D simulation**

- **Perspective :**
  - **Whole study on the Refinement criteria**
  - **Inject discharge given by hydrological model to drastically reduce the size of the simulation.**

References

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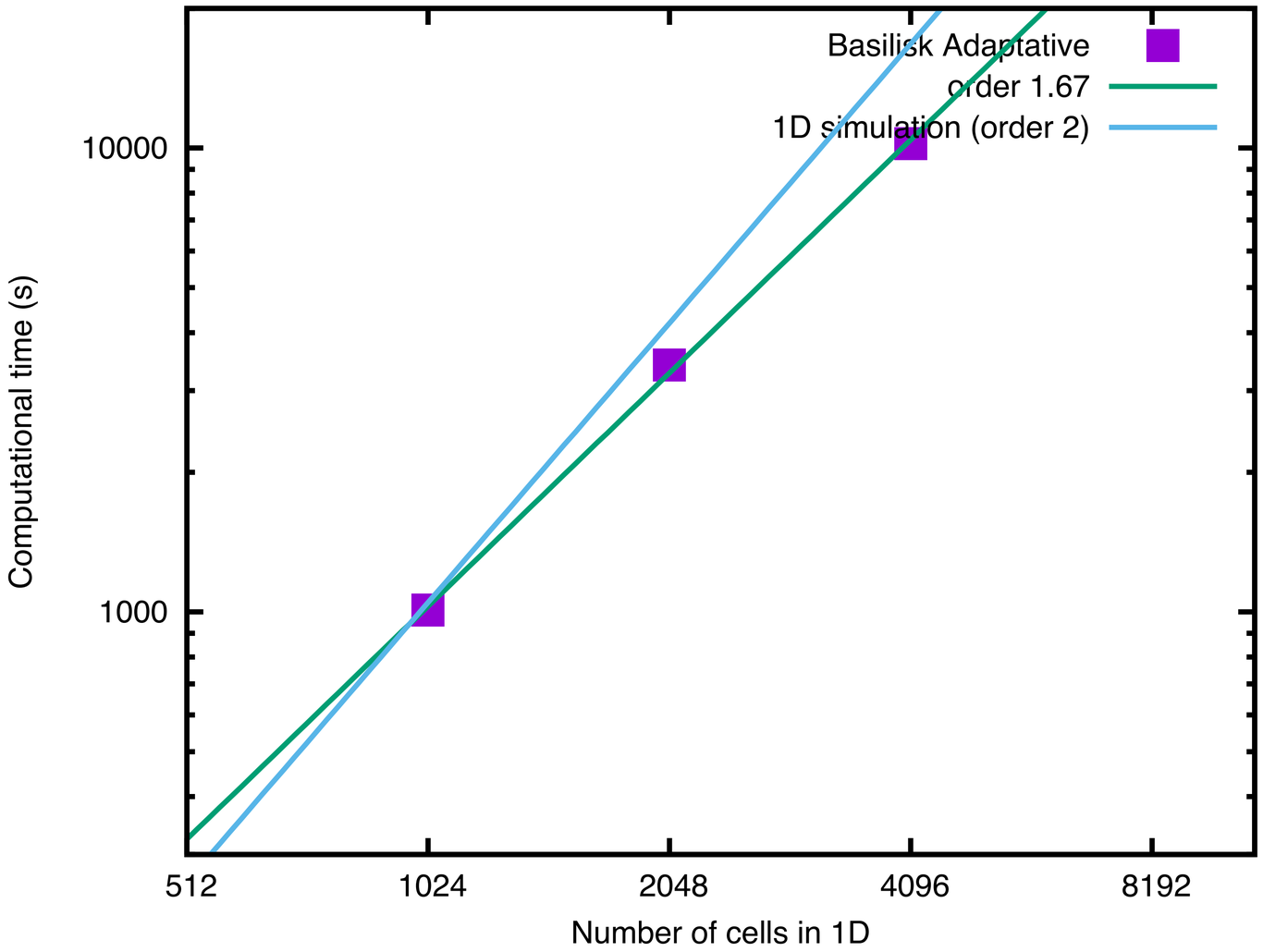
Scalability of computational time



- **Fractal dimension**
- **Better scalability than a 1D simulation**