Regional distributed hydrological modelling and experimental design within HyMeX

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HyMeX workshop, Bologna, Italy, 8-10 June 2010

Objectives of the study and methodology

Objectives

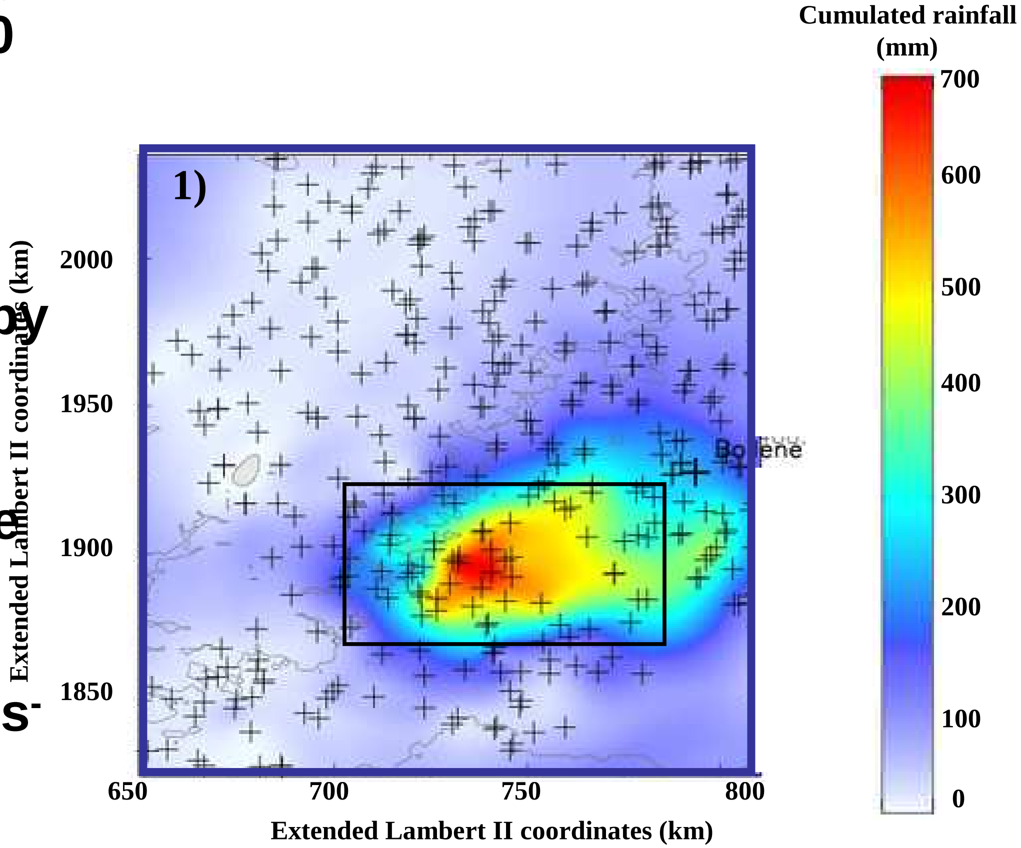
- **Better understanding of the processes generating flash floods focusing on ungauged catchments of a few km^2 to about 100 km^2, identified as the most vulnerable (*Ruin et al., J. Hydrology, 2008*)**
- **Set distributed hydrological models at the regional scale**
- **Use the modelled distributed results to propose an experimental design in the context of the future HyMeX program (http://www.hymex.org)**

Methodology

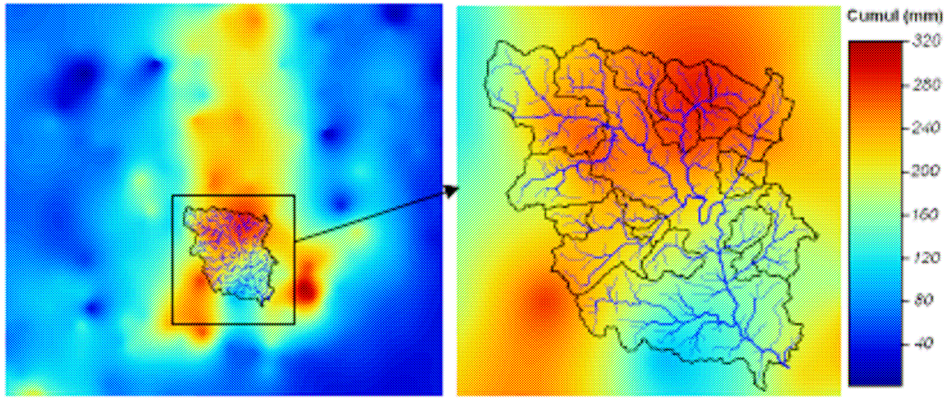
- **Comparison of two distributed hydrological models and sensitivity studies**
- **Impact of initial soil moisture**
- **Focus on soil properties and initial conditions**
- ***Sensitivity to rainfall spatio-temporal variability and to soil variability (Anquetin et al., J. Hydrology, 2010, in revision)***

The September 2002 Gard event

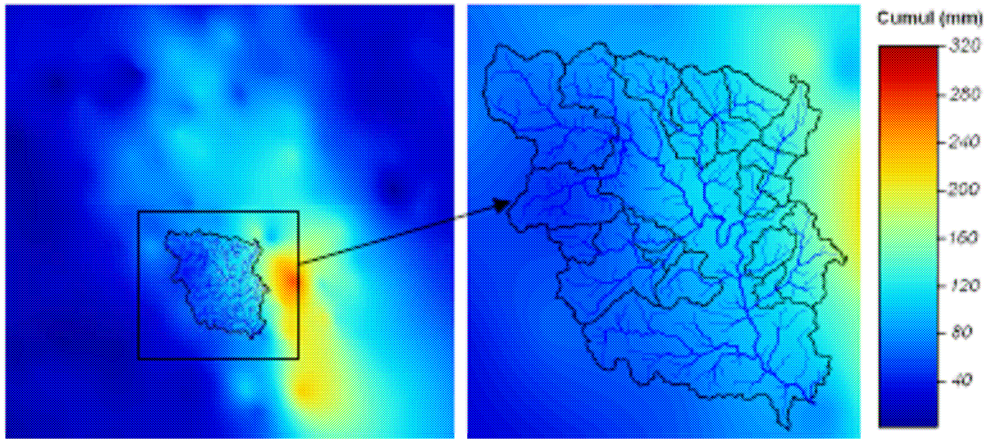
- Unusual large area hitted by the event: more than 20 000 km²
- Maximum precipitation of 610mm in 24h
- More than 3000 km² hitted by more than 200mm in 30h
- Catastrophic flash floods with max specific discharge of up to 40 $m^3 s^{-1} km^{-1}$ as compared to the 10 year return period value of 2 $m^3 s^{-1} km^{-1}$
- 24 casualties
- 1.2 billion damage



The 5-6 and 8-9 September 2005 events



September 5-6 2005 Vidourle catchment



September 8-9 2005 Vidourle catchment

Event divided into 3 phases

1) 30h event, more than 200 mm locally (September 5-6)

2) 30h without rainfall

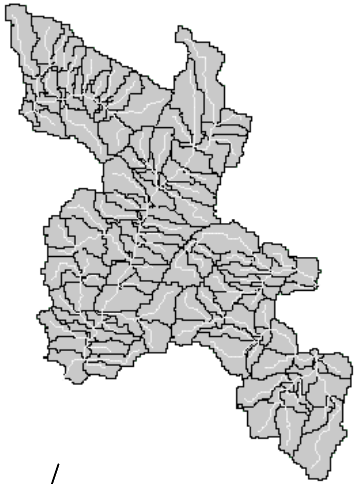
3) 30h event, more than 200 mm locally

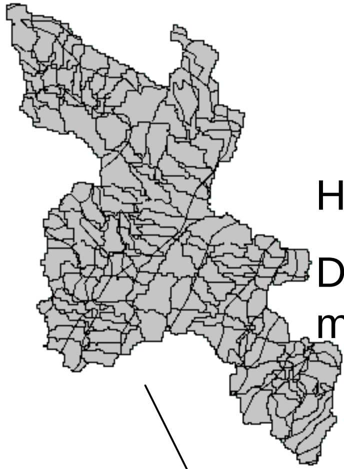
Severe flash floods, especially with the second event.

Used to study the impact of initial soil moisture

CVN model (built within the LIQUID platform)

River network and sub-catchments

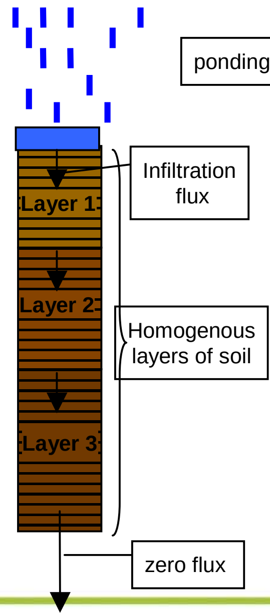




Hydro-landscapes

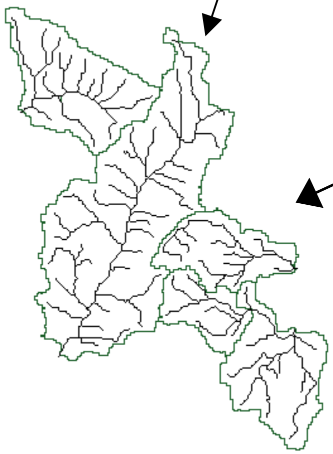
Determined using the soil map for flash flood

Evapotranspiration module (PET, root extraction)



1D Richards' equation module

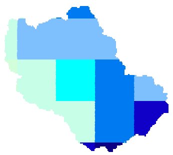
Transfer module of ponding to the river (direct transfer)

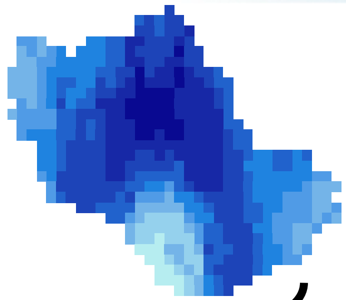


1D kinematic wave module

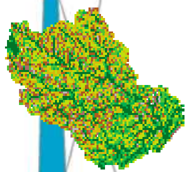
MARINE model (IMFT Toulouse)

Soil moisture

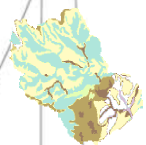




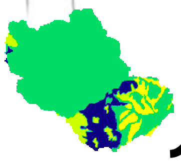
Radar rainfall



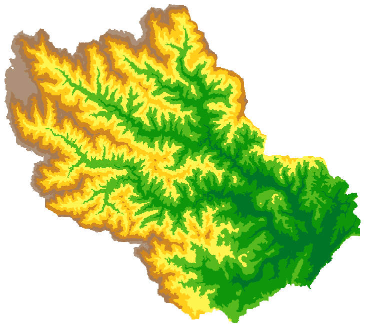
DTM

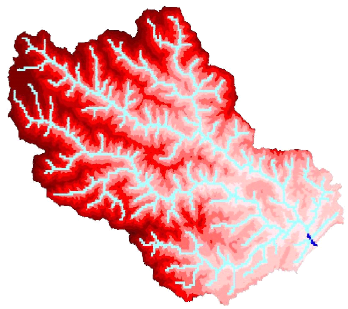


Infiltration

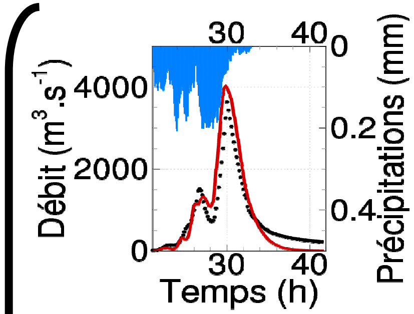


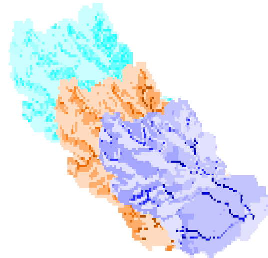
Soil





Point variables





Distributed variables

Infiltration
Green & Ampt

$$\frac{\partial I}{\partial t} = K\left(1 + \frac{(\theta_s - \theta_0)S_f}{I}\right)$$

Subsurface
Darcy law

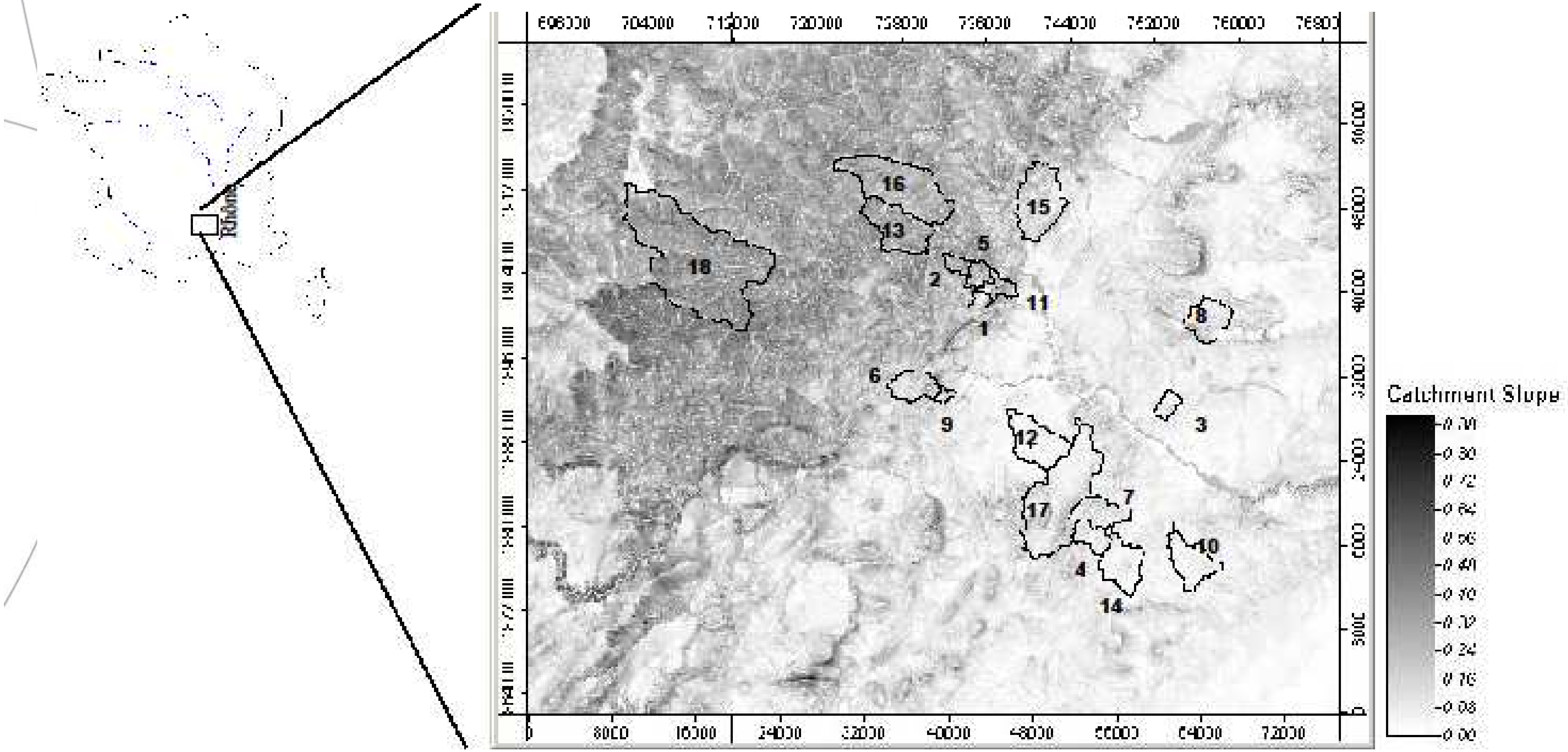
$$Q_{out} = T(\theta)\,grad(h)\,dx$$

$$T(\theta) = T_0 \exp\left(-\frac{\theta_s - \theta}{m}\right)$$

Overland flow
River network
Kinematic wave

$$\frac{\partial h}{\partial t} + \frac{\sqrt{S_0}}{n}\frac{5}{3}h^{2/3}\frac{\partial h}{\partial x} = p - i$$

September 2002: studied catchments: 2.5 to 99 km²

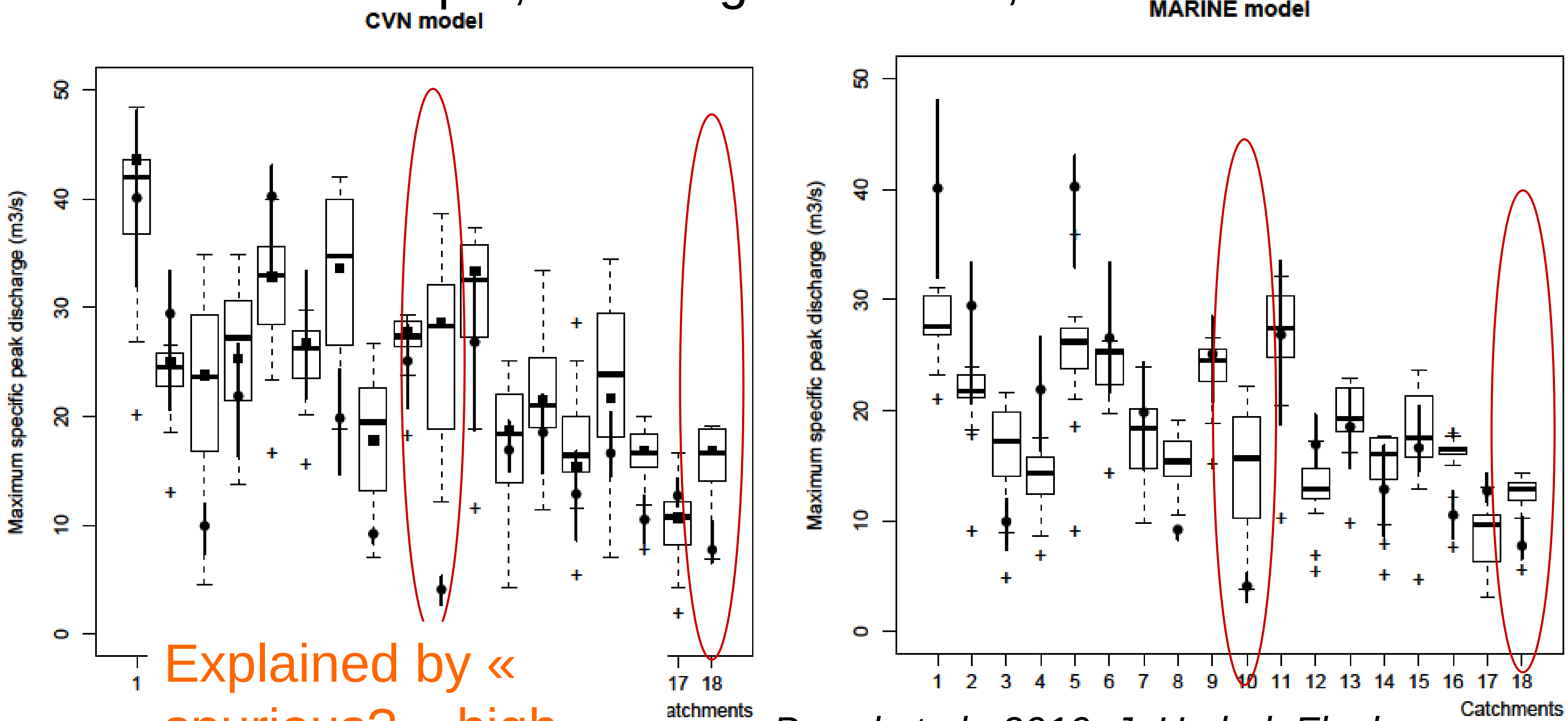


Forcing: Radar data 1 km^2, 5 minutes

Observations: Maximum peak discharge from post-flood field survey: water marks, estimation of roughness and velocity, Manning equation

Sensitivity of maximum specific discharge

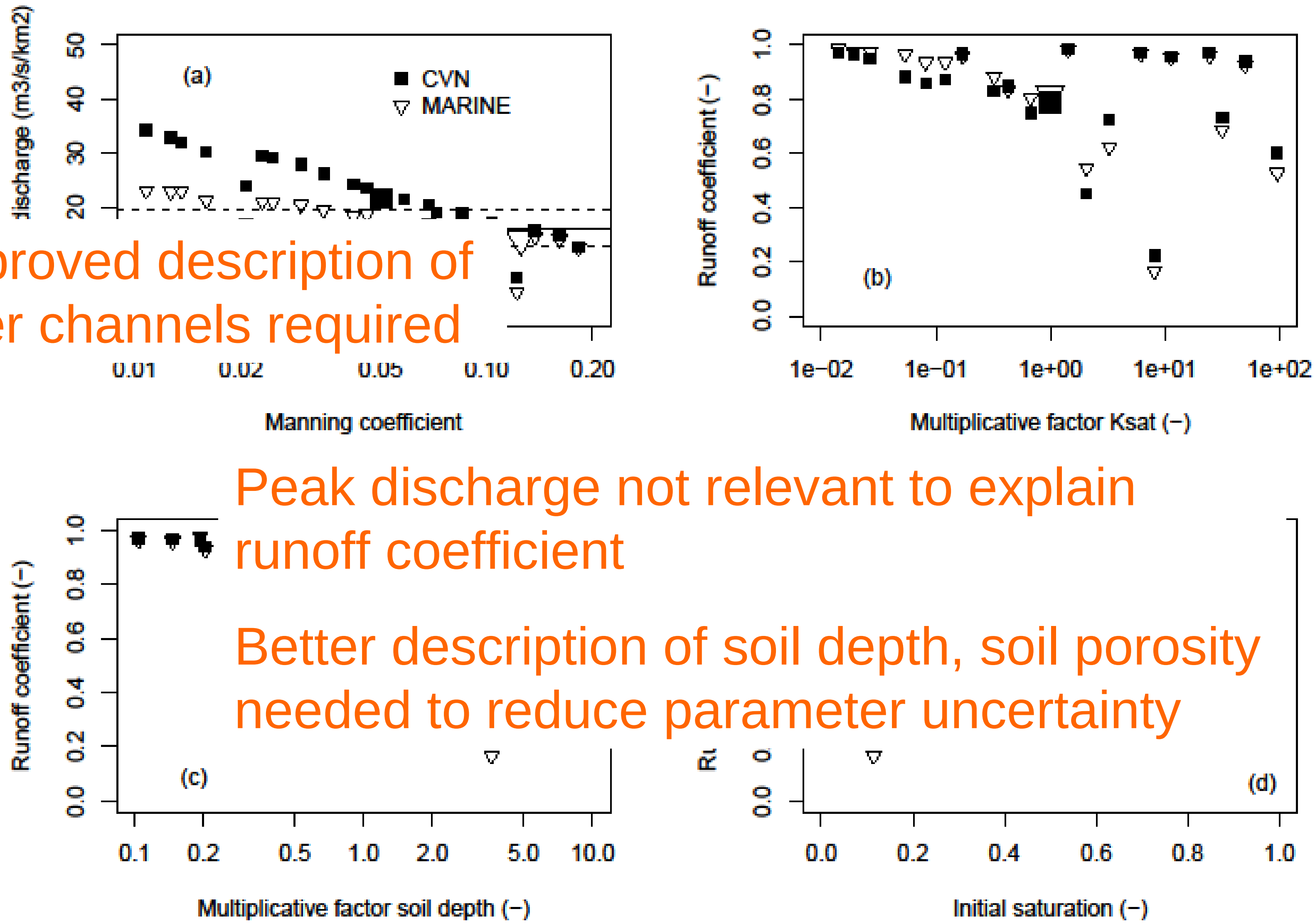
Latin hypercube method: 20 simulations, Multiplicative factor for Ks; Multiplicative factor for soil depth; Manning coefficient; Initial saturation



Explained by « spurious? » high rainfall intensities > 100 mm hr^{-1}

Braud et al., 2010, J. Hydrol. Flash Flood special issue, in press

Sensitivity study



Improved description of river channels required

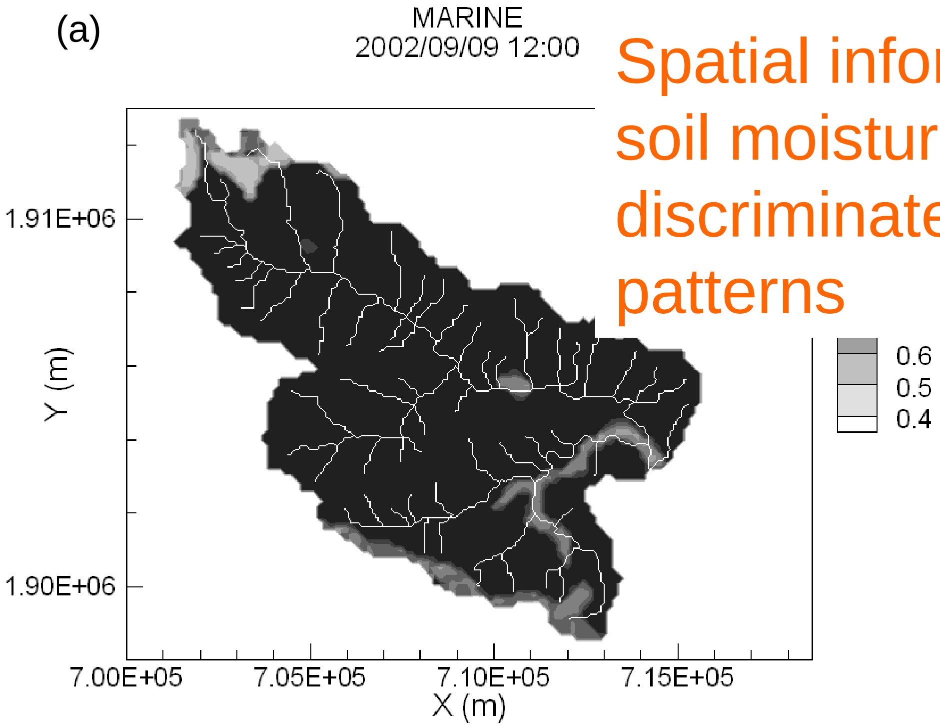
Peak discharge not relevant to explain runoff coefficient

Better description of soil depth, soil porosity needed to reduce parameter uncertainty

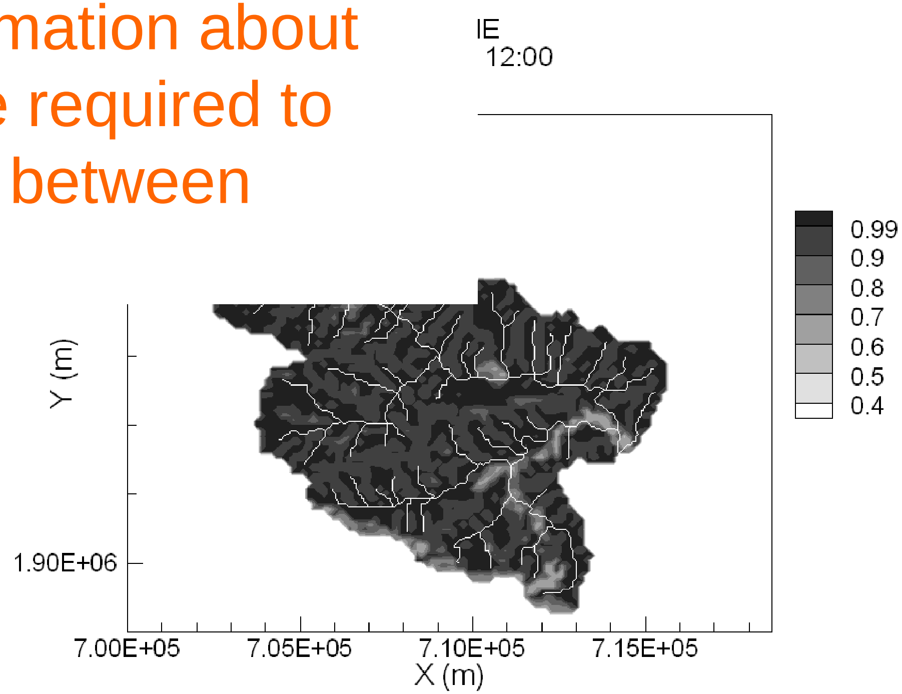
Impact of including lateral sub-surface flow

Without sub-surface flow: saturation patterns related to soil water capacity variability

With sub-surface flow: a second saturation patterns related to the river network



Spatial information about soil moisture required to discriminate between patterns



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Sciences, eaux & territoires

Impact of initial soil moisture (September 2005)

- Long term simulations of the water balance (19 months before the event)
- Use of SAFRAN reanalysis from Météo-France
- Sensitivity to saturated hydraulic conductivity and soil depth
- Evaluation of the difference in initial soil storage deficit before the event
- Simulation of the event

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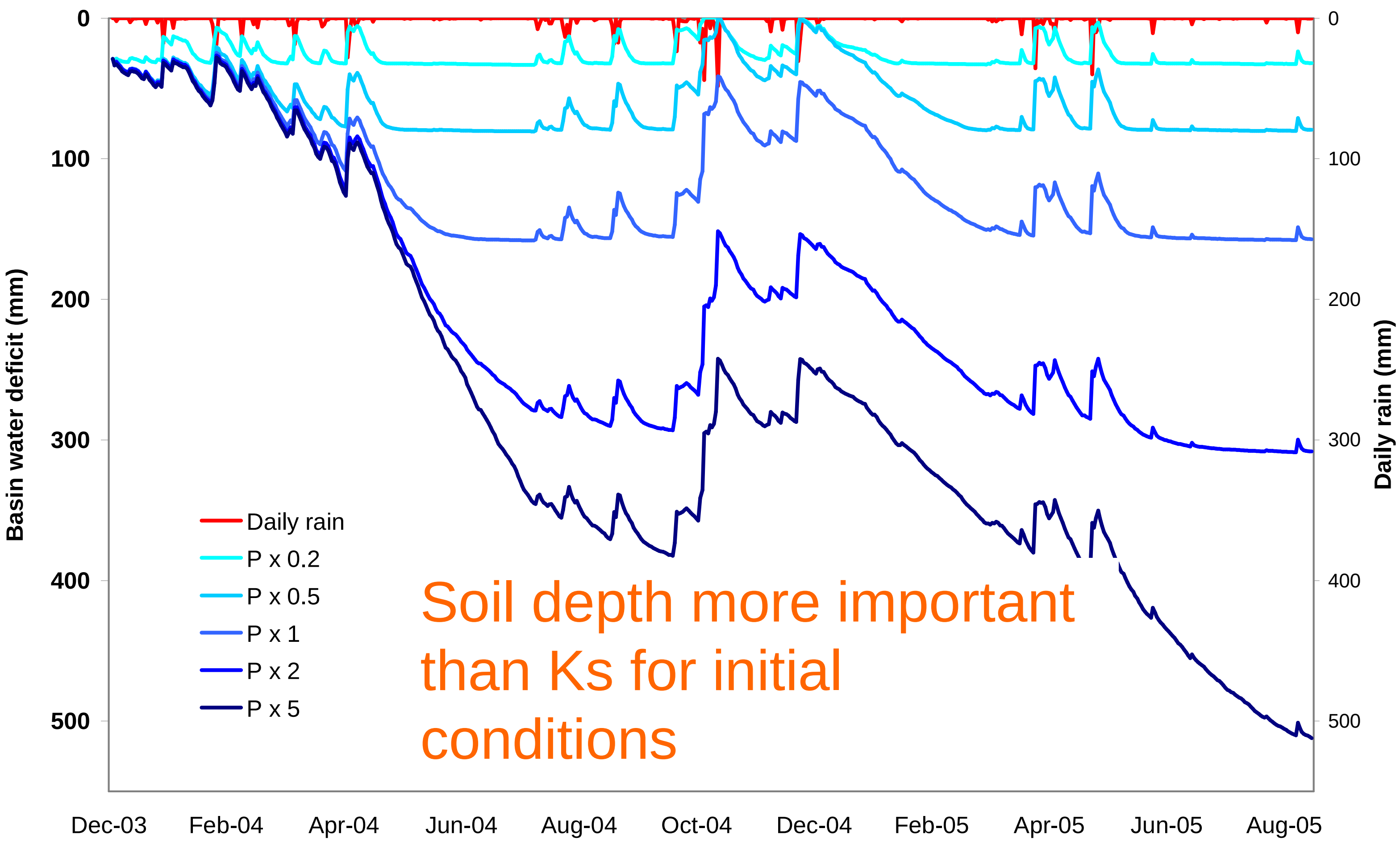
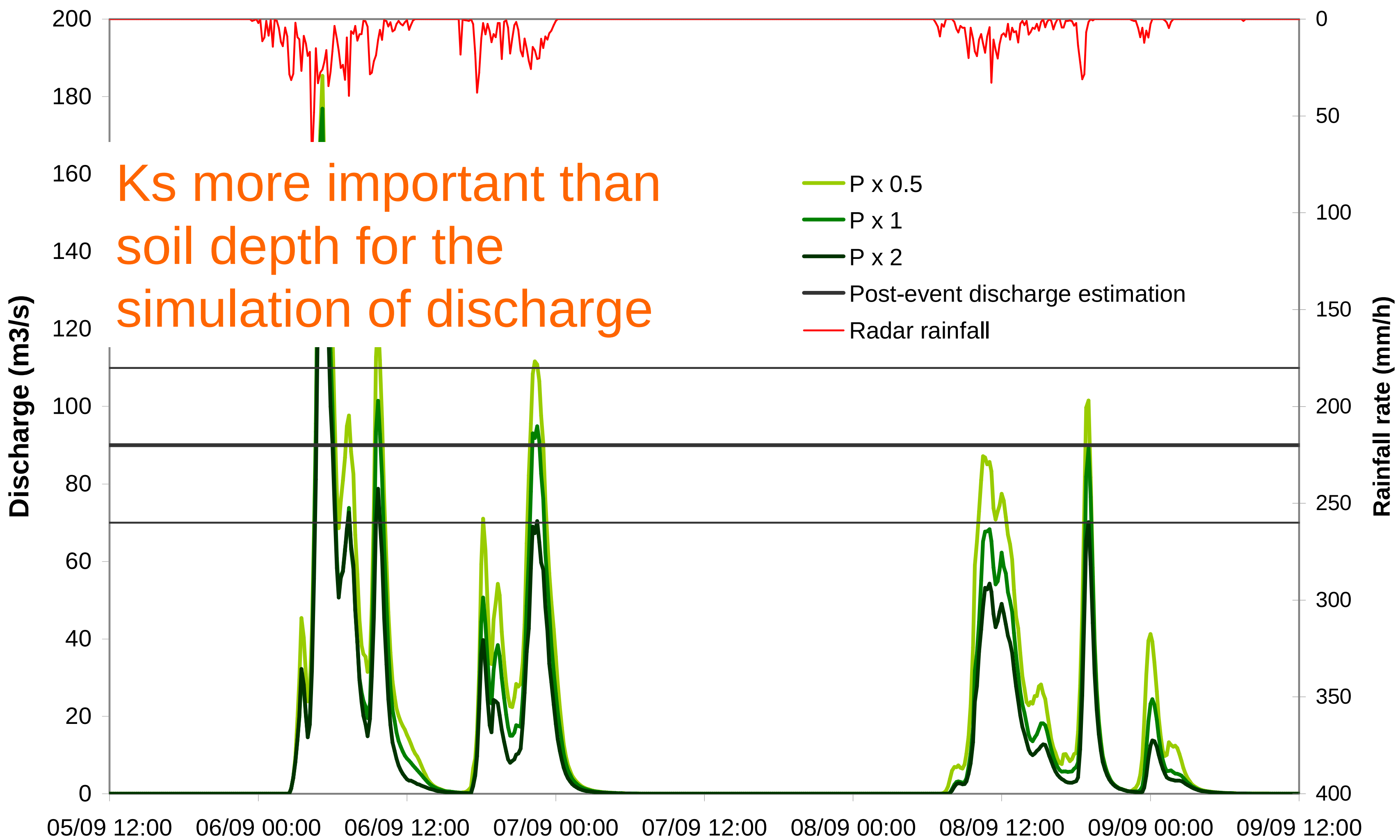
Impact on the initial soil storage deficit



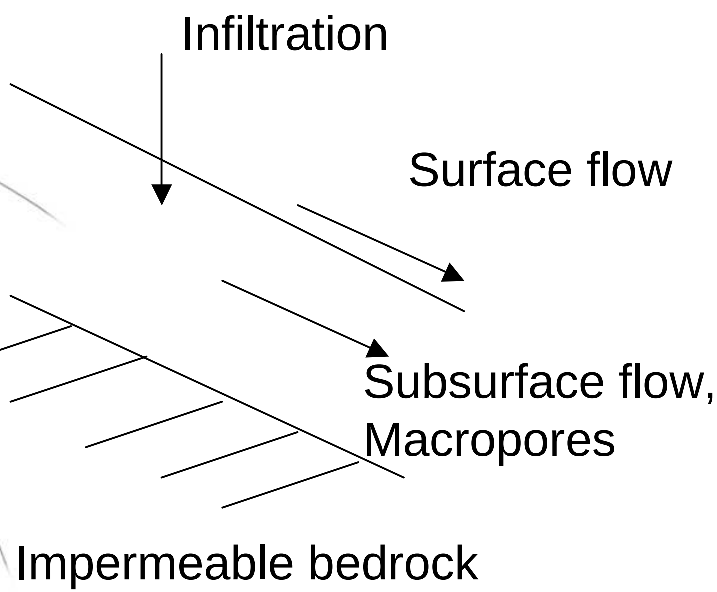
Soil depth more important than Ks for initial conditions

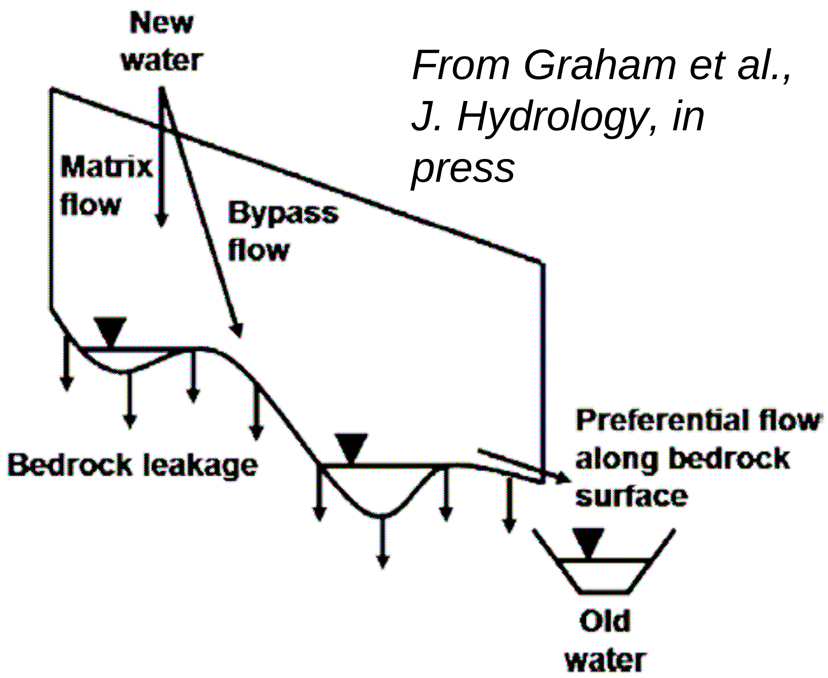
Crieulon (Logrian) catchment – Sensitivity of the hydrograph



- **Which consequences in terms of required observations for**
  - Model hypotheses validation?
  - Model assessment?

Hillslope scale: test of various hypotheses





From Graham et al., J. Hydrology, in press

Soil hydraulic properties

Soil depth, soil porosity

Tracers (water pathways)

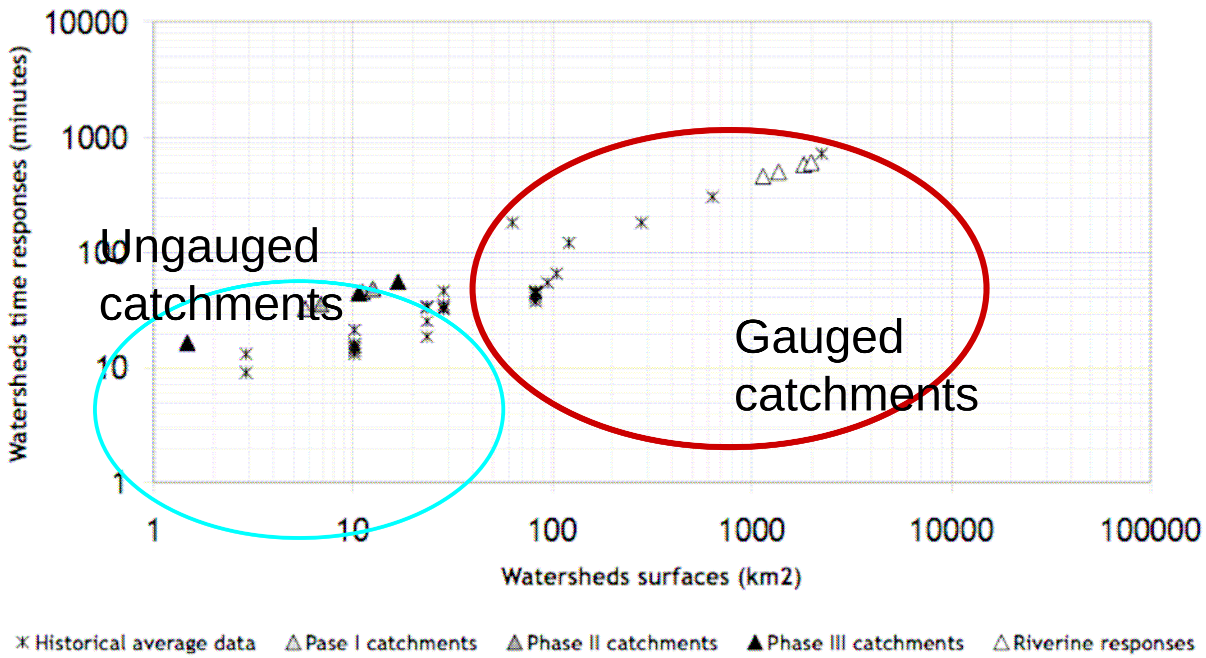
Characterization

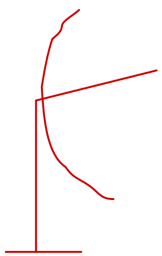
Hydraulic properties of bedrock

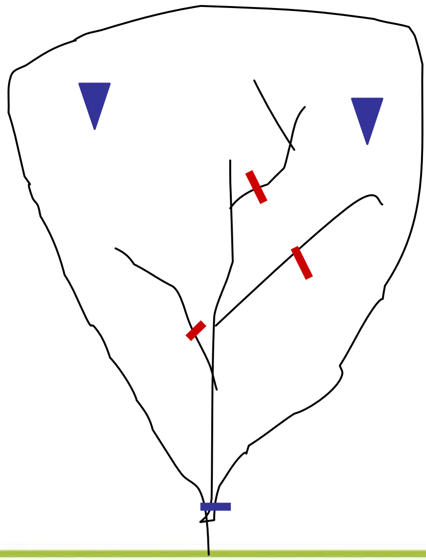
Tracers

Hydro-geophysics

Catchment scale







New gauging stations (LS-PIV, water height)

Radar data

Soil moisture (in situ, remote sensing), piezometers

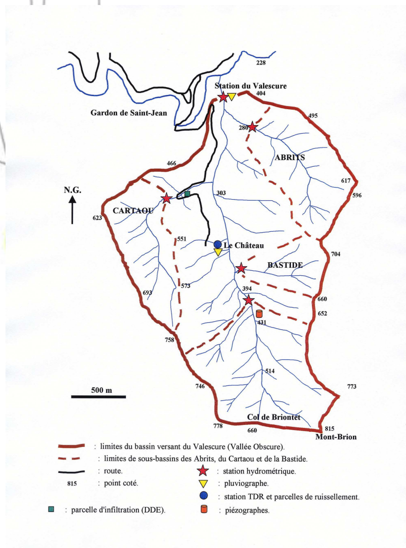
Typology of sub-catchments

Conclusions in terms of observation requirements

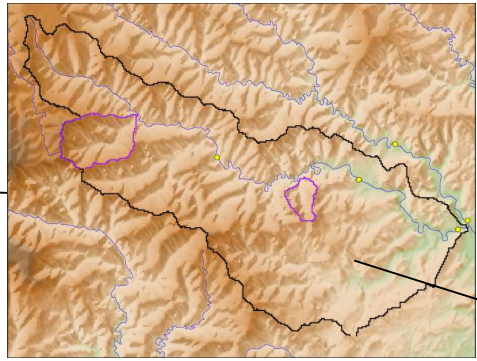
- Still needs to improve rainfall radar data accuracy (space and time)
- More information needed about soils (different variables for pre-event and event periods)
  - Soil depth, porosity
  - Soil hydraulic conductivity
  - Imperviousness of bedrock
- Multi-scale observation strategy to improve process knowledge and tackle the change of scale problem

Example of experimental design

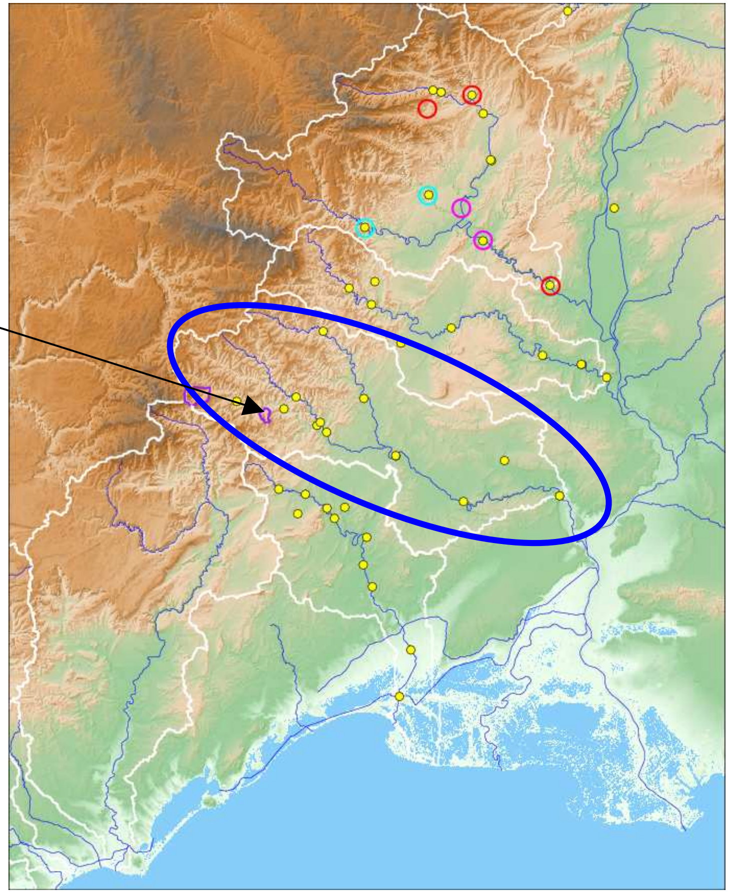
Valescure (5 km²)



Gardon de Saint Jean (200 km²)



Gardon (2000 km²)



Hillslope hydrology (water flow paths)

Closure of the water balance

Detailed models

Change of scale problem

Distributed hydrometry

Remote sensing

Catchment typology

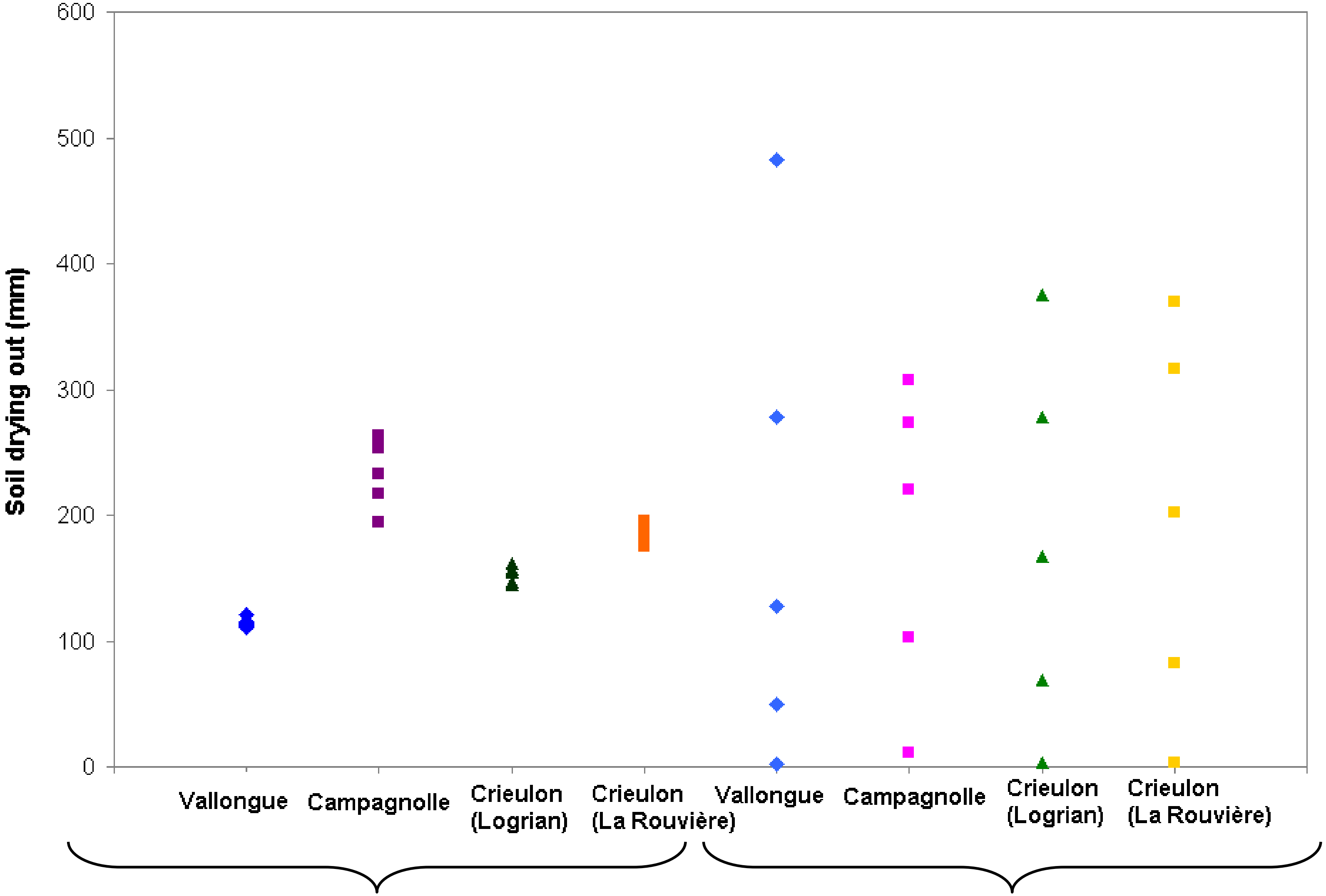
The roman Pont du Gard bridge during the Gard 2002 event (source CG30)

THANK YOU FOR YOUR ATTENTION

QUESTIONS???

The La Rouvière dry dam on the Crieulon (source CG30)

Photos : CG30



Ks sensitivity analysis

(Ks*0.2 → Ks*50)

Soil depth sensitivity analysis

(Depth*0.2 → Depth*5)