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](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 hit by the event: more than 20,000 km²
- Maximum precipitation of 610 mm in 24h
- More than 3,000 km² hit by more than 200 mm in 30h
- Catastrophic flash floods with max specific discharge of up to 40 m³ s⁻¹ km⁻¹ as compared to the 10 year return period value of 2 m³ s⁻¹ km⁻¹
- 24 casualties
- 1.2 billion damage

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The 5-6 and 8-9 September 2005 events

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

1D kinematic wave module

Transfer module of ponding to the river (direct transfer)

Homogenous layers of soil

Layer 3

Zero flux

Layer 2

Infiltration flux

Layer 1

Hydro-landscapes

Determined using the soil map for flash flood

Evapotranspiration module (PET, root extraction)

1D Richards’ equation module

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The MARINE model (IMFT Toulouse) is illustrated in the diagram. It includes components such as radar rainfall, soil moisture, and infiltration. The mathematical equations for infiltration and subsurface flow are shown:

\[
\frac{\partial I}{\partial t} = K \left( 1 + \frac{(\theta_s - \theta_0) S_I}{l} \right) 
\]

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

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

The model integrates various processes such as soil moisture, infiltration, subsurface flow, and overland flow to simulate hydrological dynamics. The diagram also shows the integration of DTM (Digital Terrain Model) and point variables into the model framework.
September 2002: studied catchments: 2.5 to 99 km²

**Forcing:** Radar data 1 km², 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

Explain by « spurious? » high rainfall intensities > 100 mm hr\(^{-1}\)

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

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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
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
Impact on the initial soil storage deficit

Soil depth more important than Ks for initial conditions
Crieulon (Logrian) catchment – Sensitivity of the hydrograph

Ks more important than soil depth for the simulation of discharge
● Which consequences in terms of required observations for
  ▪ Model hypotheses validation?
  ▪ Model assessment?
Hillslope scale: test of various hypotheses

Characterization
- Hydraulic properties of bedrock
- Tracers
- Hydro-geophysics

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

Soil hydraulic properties
- Soil depth, soil porosity
- Tracers (water pathways)

Impermeable bedrock

Surface flow

Subsurface flow, Macropores

Infiltration
Catchment scale

Gauged catchments

Ungauged catchments

New gauging stations (LS-PIV, water height)

Radar data

Soil moisture (in situ, remote sensing), piezometers

Typology of sub-catchments

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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)

Hillslope hydrology (water flow paths)
Closure of the water balance
Detailed models

Gardon de Saint Jean (200 km²)

Change of scale problem
Distributed hydrometry
Remote sensing
Catchment typology

Gardon (2000 km²)
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)

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Photos : CG30
Soil depth sensitivity analysis (Depth*0.2 → Depth*5)

Ks sensitivity analysis analysis (Ks*0.2 → Ks*50)

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