Hydrological processes generating flash floods in a small mountainous Mediterranean French catchment

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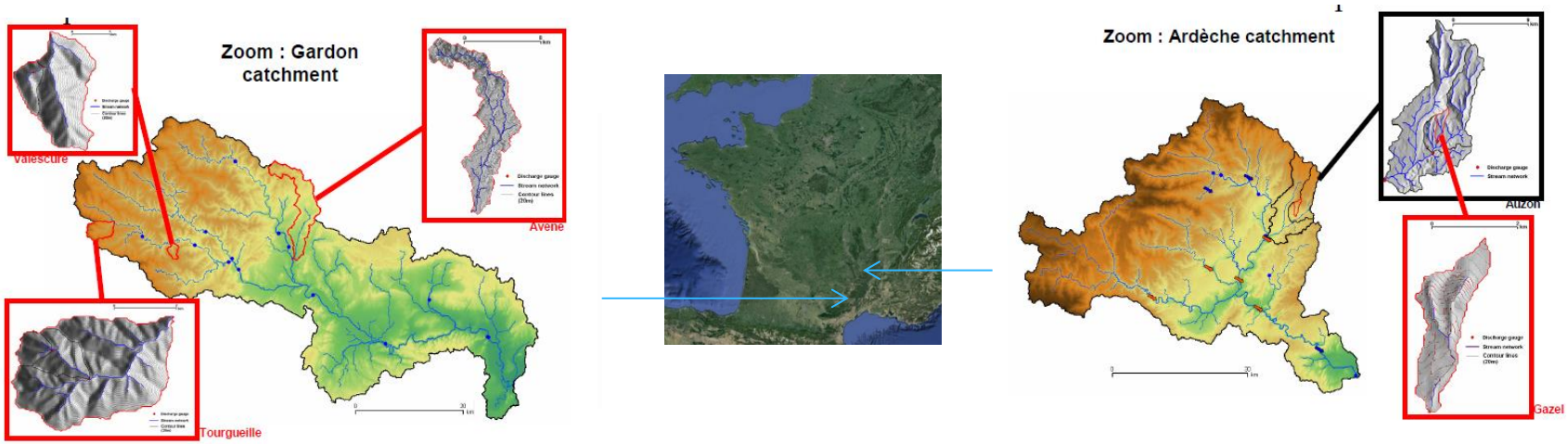
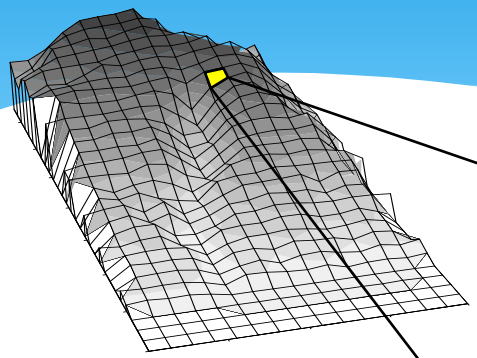
- Flash floods multi-scale modelling : from **hillslope** to regional scales
- Coupling **observation** and **modelling** at hillslope/small catchment scale
- 4 nested systems :
  <u>Valescure (Granite)</u>, Tourgueille (Schist), Avene (partly Karst), Gazel (Marn/basalts)

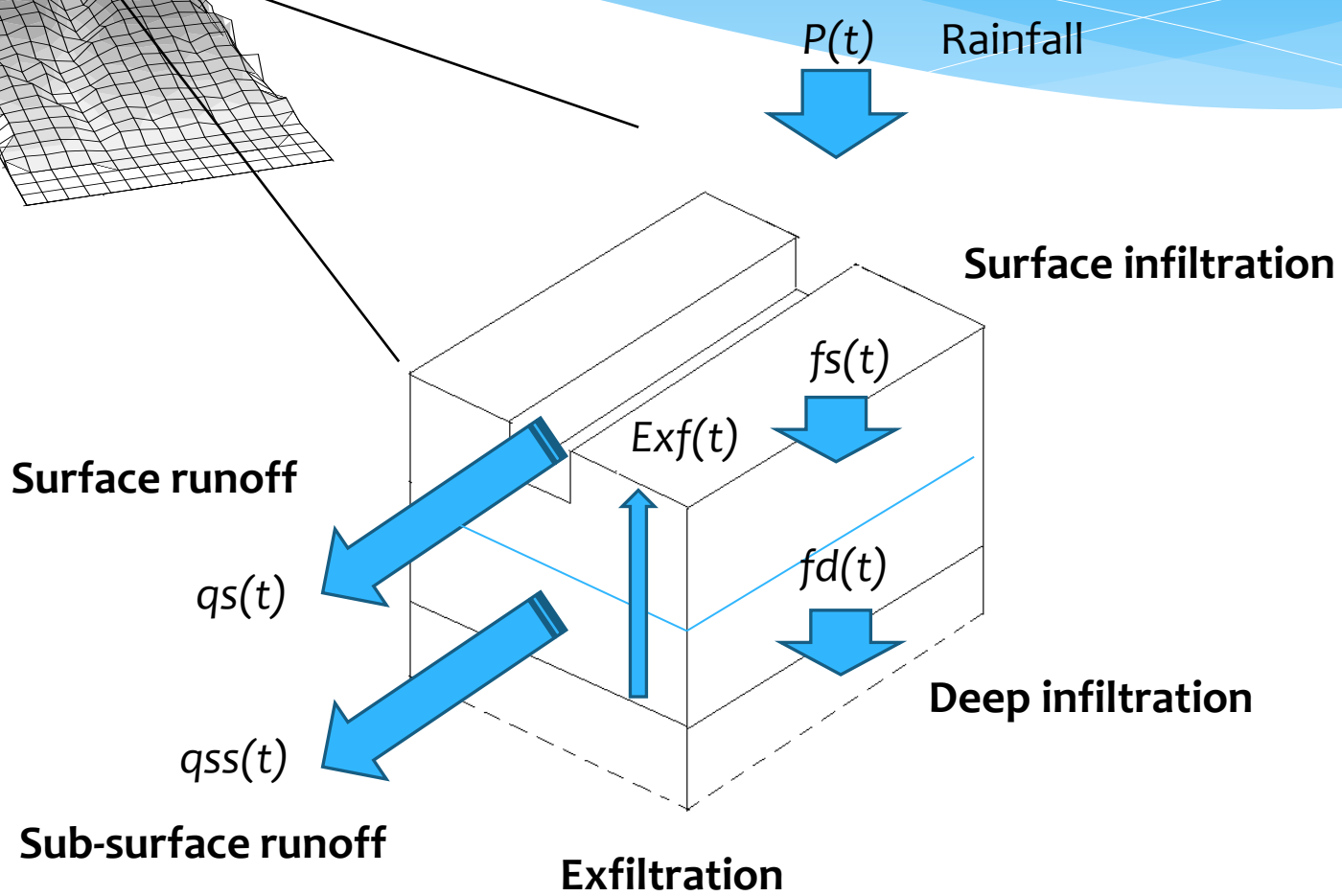


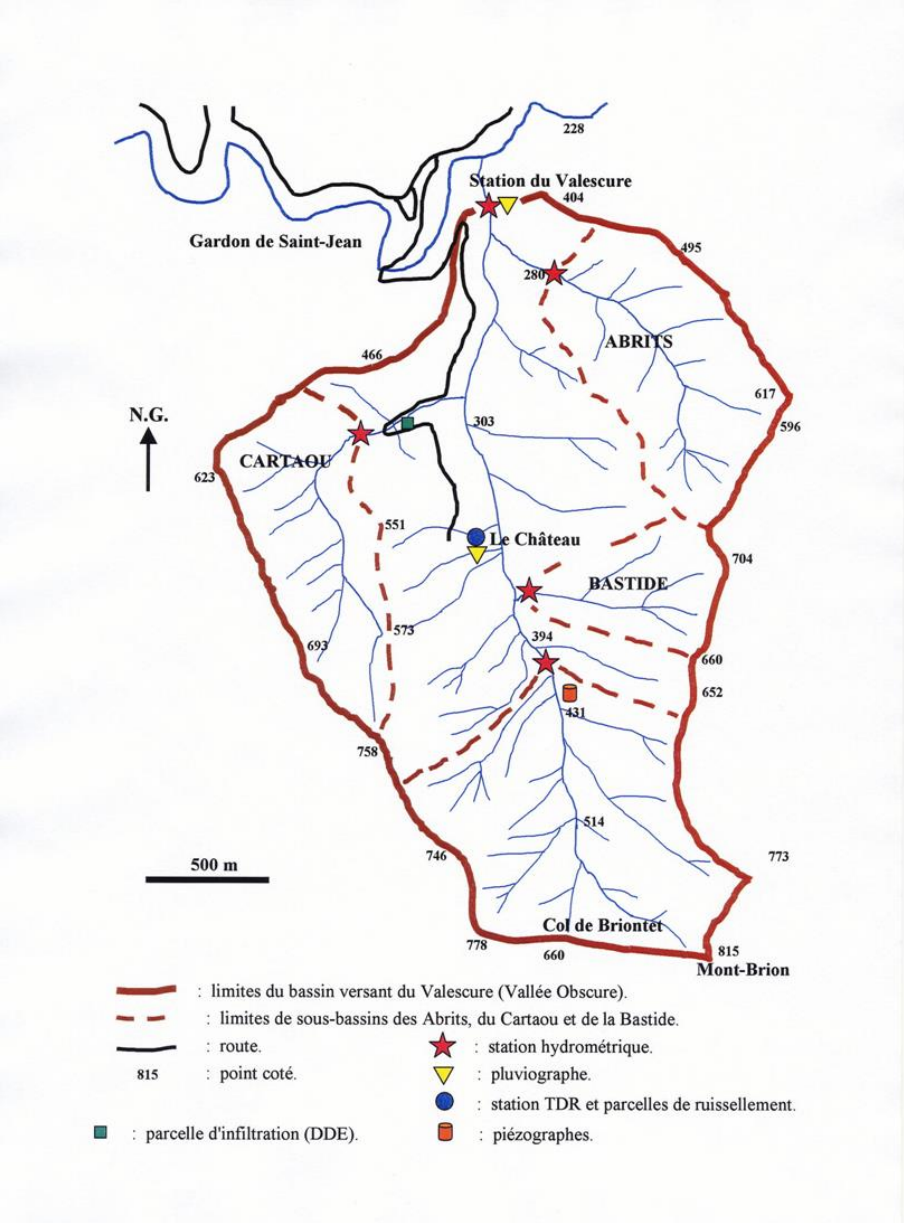
I. Braud, P.-A. Ayral, C. Bouvier, F. Branger, G. Delrieu, J. Le Coz, G. Nord, J.-P. Vandervaere et al., 2014. Multi-scale hydrometeorological observation and modelling for flash flood understanding. Hydrol. Earth Syst. Sci., 18, 3733–3761

How does runoff occur during flash floods ?

- Vertical and lateral fluxes
- Surface/sub-surface fluxes
- From a given saturation state





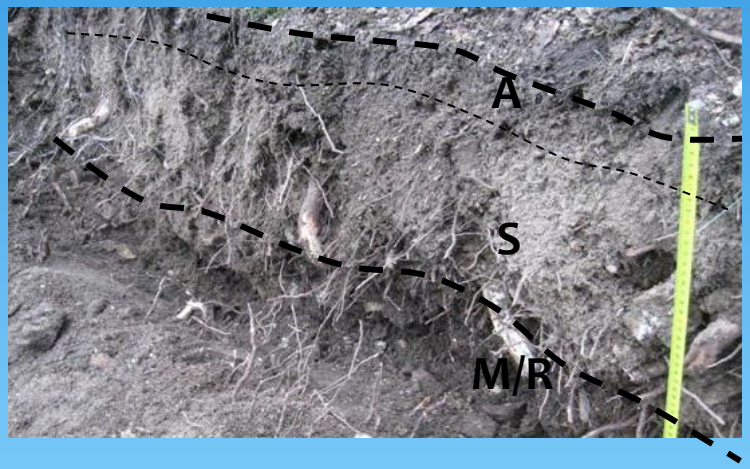


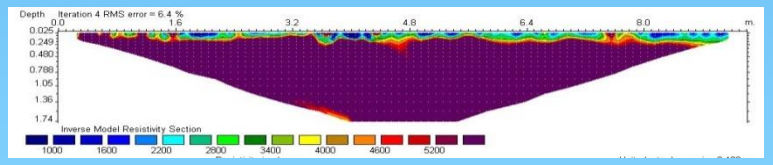
Valescure nested catchments

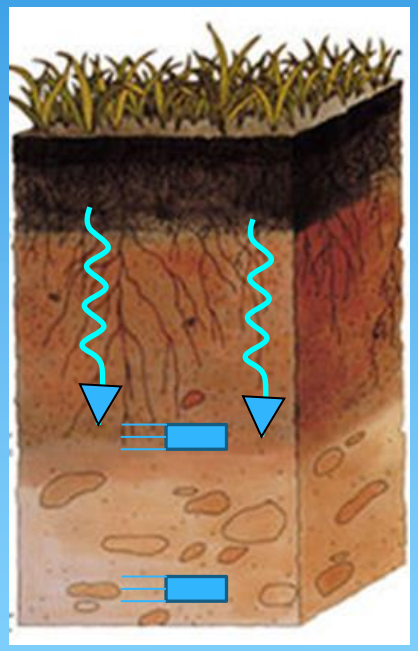
from 0.4 to 3.9 km2
Geology : granite
Median slope : 30°
40 rainfall events since 2005 > 100 mm/24h
Max discharge = 16 $m^3.s^{-1}$ = 4 $m^3.s^{-1}.km^2$

Soil depths and hydrodynamics

- Pits, electrical resistivity & mechanical survey (> 40 spots)
- Inverse modelling of water content (> 40 spots)







40 cm

Le Bourgeois PhD

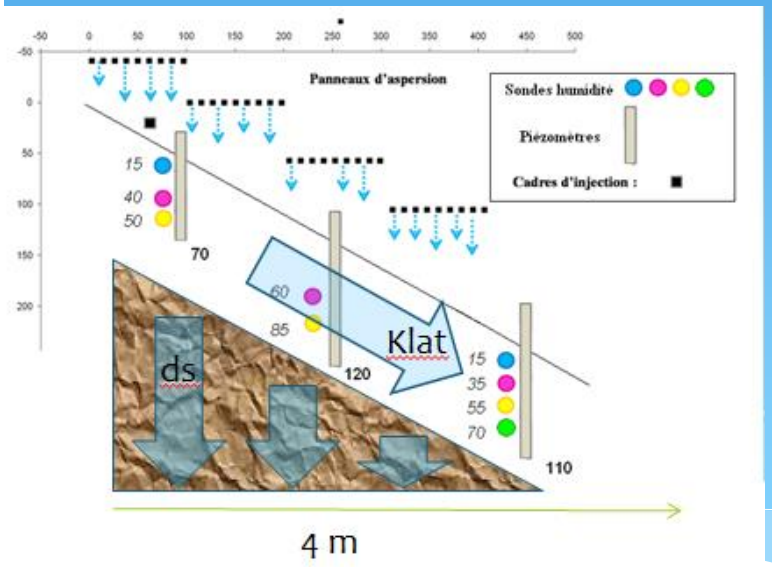
Mean soil depth = 40 cm
Ranges between 0 and 100 cm (log-normal)

Soil mean values

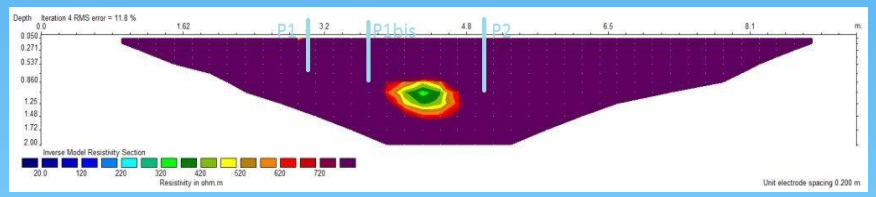
θ_r,	θ_s,	α,	N,	K_s
0	0.45	0.4	1.3	> 500

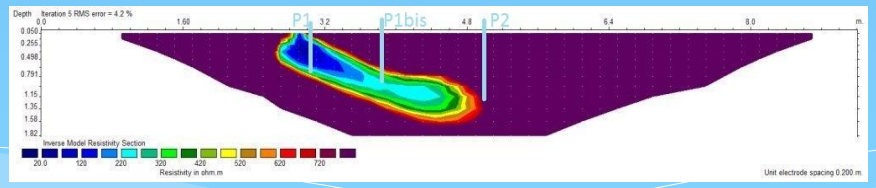
Sub-surface fluxes

- 10-m² plots (x4)
- Natural and artificial rainfalls
- Lateral conductivity Klat
- Deep permeability ds



- Multi-temporal ERT and tracing

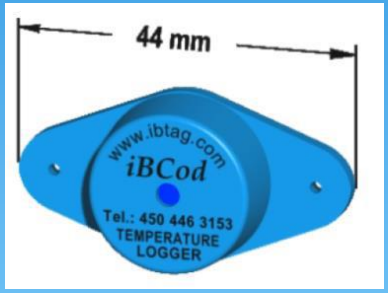


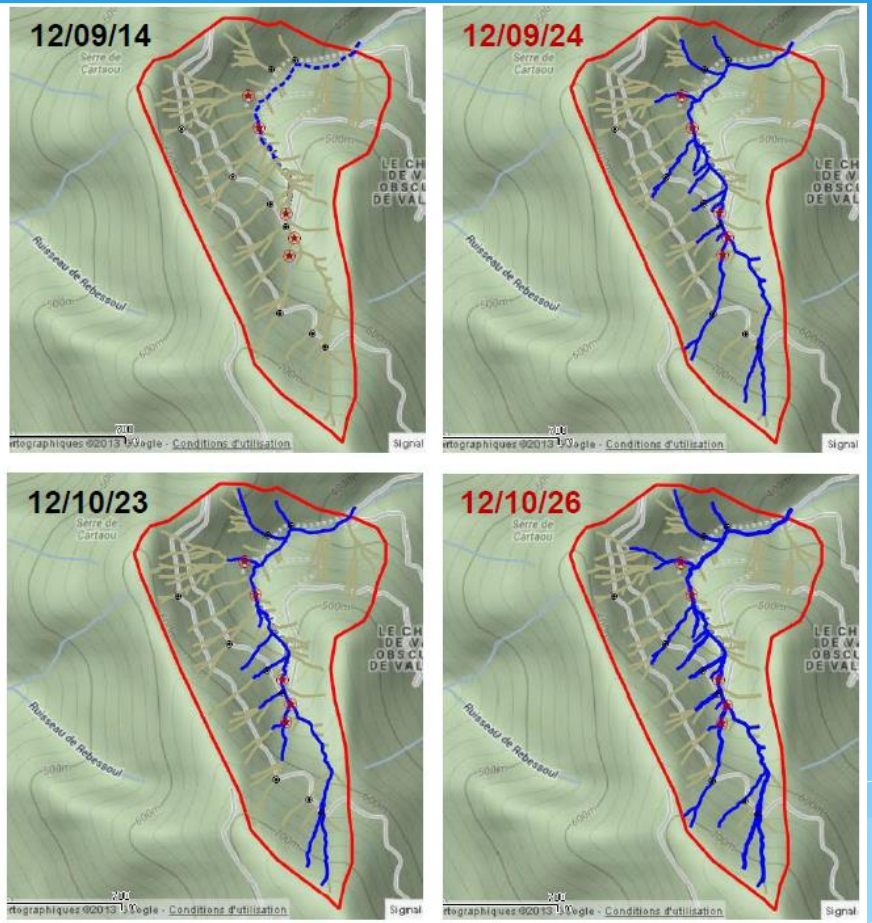


In first approximation, estimation of Klat = 1-5 m.h^{-1}, ds = 0-1 d^{-1} …..

Active network extension

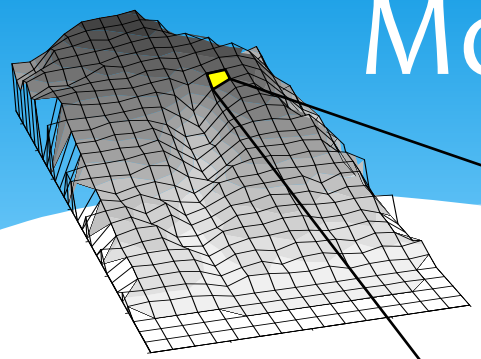
- Event scale
- Where is there flow, or not ?

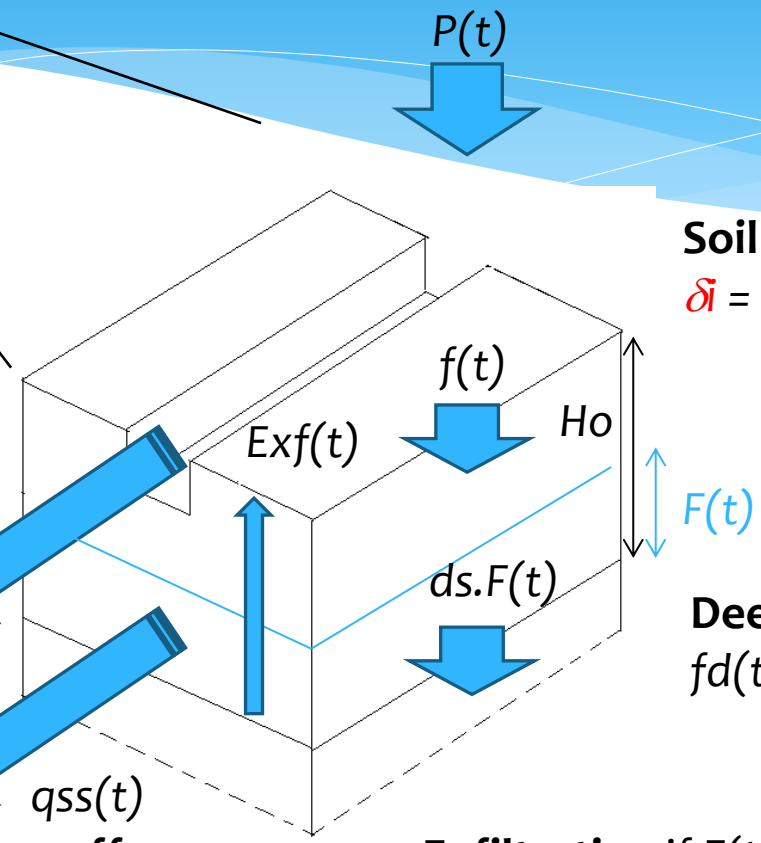




Flow mainly concentrated in the gullies

Modelling flood processes





Soil storage capacity

$\delta i = Ho.(\theta s - \theta i)$

Kinematic wave

surface runoff

Kr, λ

Deep infilration

$fd(t) = ds.F(t)$

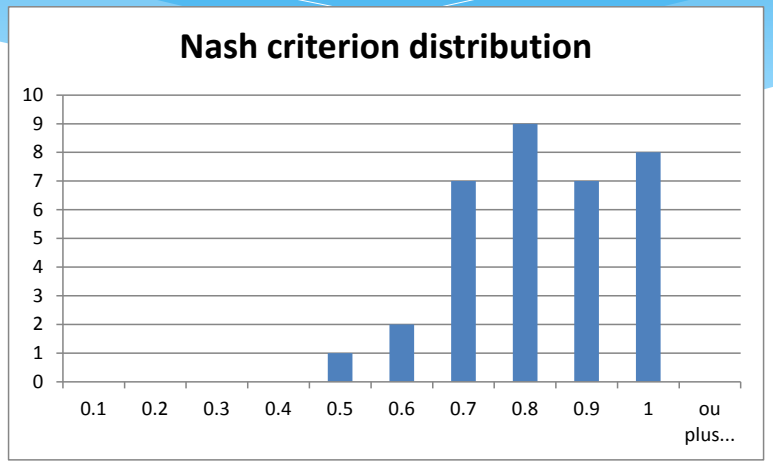
Darcy **sub-surface runoff**

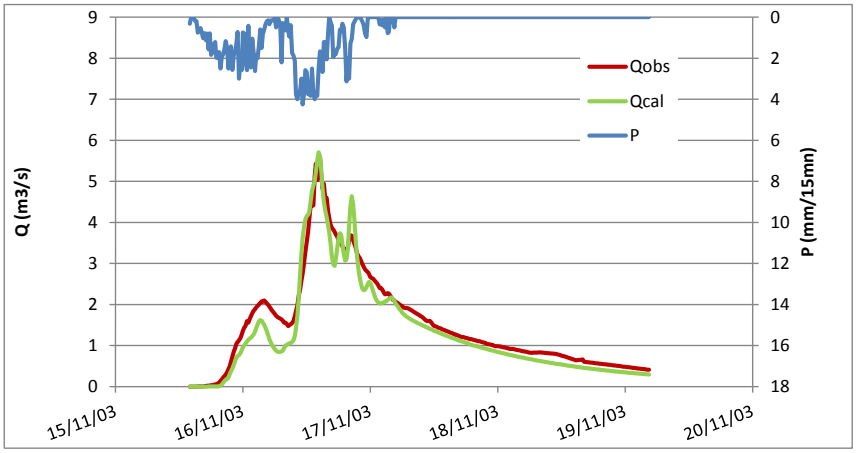
$qss(t) = Klat.F(t).tg(\beta)$

Exfiltration if $F(t) > \delta i$

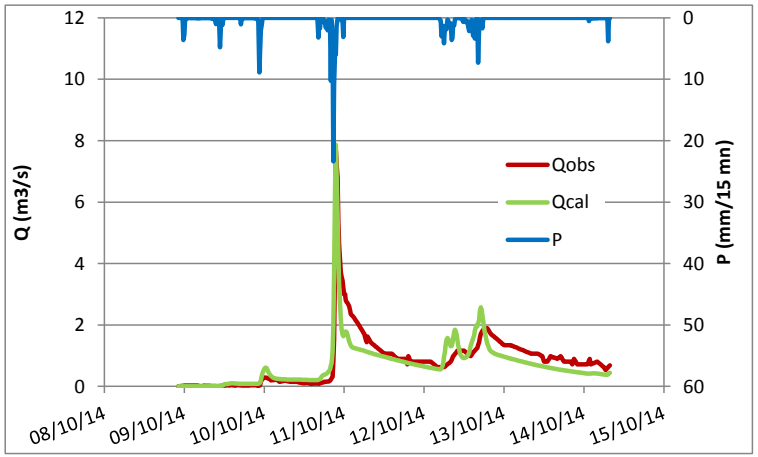
Results

- θs = 0.50, Kr = 3 $m^{1/3}.s^{-1}$, λ = 10 m
- Uniform soil depth Ho = 0.70 m
- $Klat$ = 3 $m.h^{-1}$
- ds = 0.3 j^{-1}
- θi calibrated = 0.05-0.35





Nash criterion = 0.93

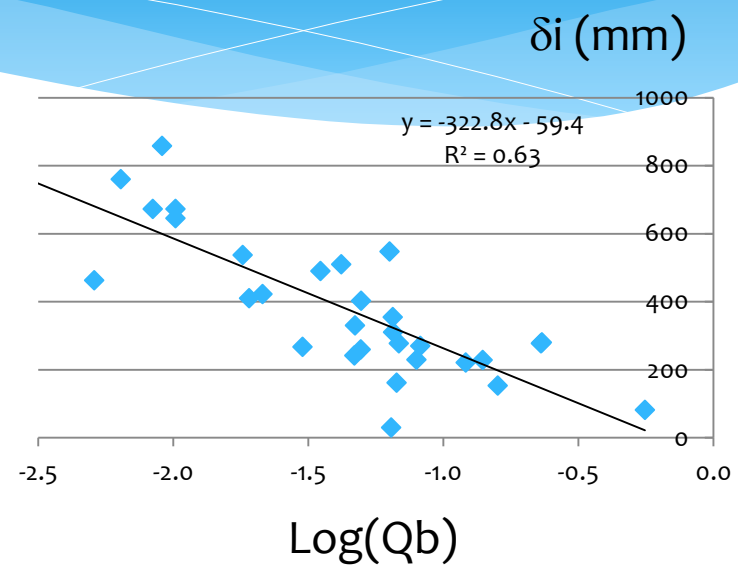


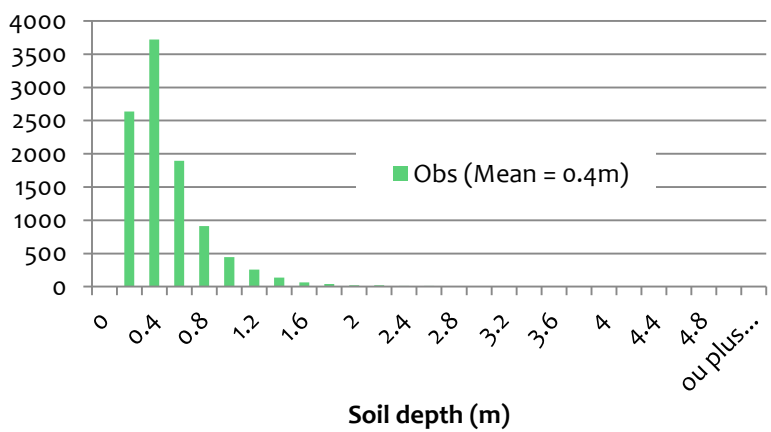
Nash criterion = 0.78

Is it realistic ?

1/ Agreement with field experiments ?

- OK for Klat=3m.h^{-1}, ds=0.1 j^{-1}
- Initial water deficit related to base flow
- Soils depths are higher in the model (0.70m)





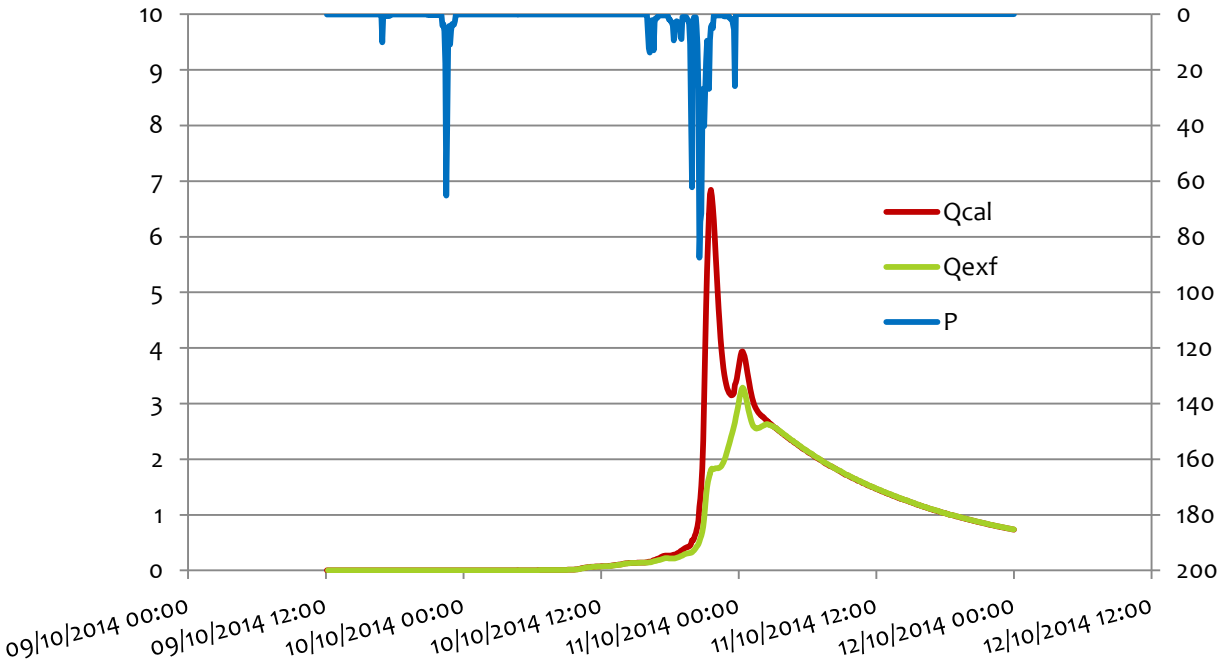
Suggests that weathered area plays a role in water storage ?

2/ How far the model tells the truth ?

- Simplified vadose area processes
- No bedrock fill and spill effect
- Choice of the distribution of soil depths
- (Low) sensitivity to the cell size

What are the dominant processes for runoff ?

- Direct runoff over saturated areas = 25 %, but 70 % at the peak
- Sub-surface exfiltration = 75 %

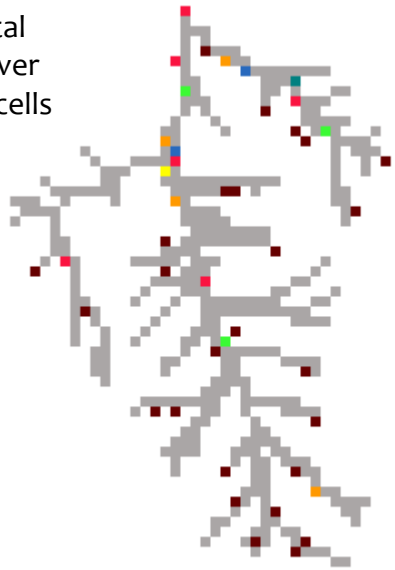


Where does runoff occur ?

In grey, cells that drain more than 1.25 ha (5 cells) = 25% catchment
In colour, (model) saturated cells during 9-11 November 2014

Saturated cells over hydrological network

Hydrological network over saturated cells



- Runoff due to soil saturation
- Soil saturation due to convergence of the sub-surface fluxes
- Surface runoff is mainly due to exfiltration in the gullies

Conclusions / perspectives

- Correct model simulations, in agreement with field observations and measurements
- Soil saturation due to convergence of sub-surface fluxes
- Runoff due to the soil saturation (exfiltration or rainfall)
- Exfiltration in the gullies dominant for runoff generation, except for the peak
- Weathered area maybe plays active role in water storage dynamics
- Still to progress for truth and uniqueness of the solution
  use additional controls : nested sub-catchments, active network extension, geochemistry, change of catchment scale
- To apply for other geology : Tourgueille nested sub-catchments