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


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(2) EMA, Ecole des Mines d'Alès;
• Flash floods multi-scale modelling: from hillslope to regional scales
• Coupling observation and modelling at hillslope/small catchment scale
• 4 nested systems: Valescure (Granite), Tourgueille (Schist), Avene (partly Karst), Gazel (Marn/basalts)

How does runoff occur during flash floods?

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

Rainfall

Surface infiltration

Surface runoff

Deep infiltration

Sub-surface runoff

Exfiltration
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 m³.s⁻¹ = 4 m³.s⁻¹.km²
Soil depths and hydrodynamics

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

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

Soil mean values

\[ \theta_r, \theta_s, \alpha, N, K_s \]

<table>
<thead>
<tr>
<th>Value</th>
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<tbody>
<tr>
<td>0</td>
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<tr>
<td>0.45</td>
</tr>
<tr>
<td>0.4</td>
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<tr>
<td>1.3</td>
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<td>&gt; 500</td>
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Le Bourgeois PhD
Sub-surface fluxes

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

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
\[ \delta i = H_o (\theta_s - \theta_i) \]

Kinematic wave
Surface runoff
\( K_r, \lambda \)

Darcy sub-surface runoff
\( q_{ss}(t) = K_{lat}.F(t).tg(\beta) \)

Deep infiltration
\( f_d(t) = d_s.F(t) \)

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

- $\theta_s = 0.50$, $Kr = 3 \text{ m}^{1/3} \text{ s}^{-1}$, $\lambda = 10 \text{ m}$
- Uniform soil depth $Ho = 0.70 \text{ m}$
- $Klat = 3 \text{ m.h}^{-1}$
- $ds = 0.3 \text{ j}^{-1}$
- $\theta$ calibrated = 0.05-0.35

Nash criterion distribution

Nash criterion = 0.93

Nash criterion = 0.78
Is it realistic?

1/ Agreement with field experiments?
- OK for $K_{lat}=3 \text{m} \cdot \text{h}^{-1}$, $ds=0.1 \text{j}^{1}$
- Initial water deficit related to base flow
- Soils depths are higher in the model (0.70m)

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

Suggests that weathered area plays a role in water storage?
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

- 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