A perspective on “Radar Hydrology” based on space-time scales

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Outline

- Hydrometeorological risk prediction in the Mediterranean region
- Radar QPE: error models
- Hydrological observation and modelling

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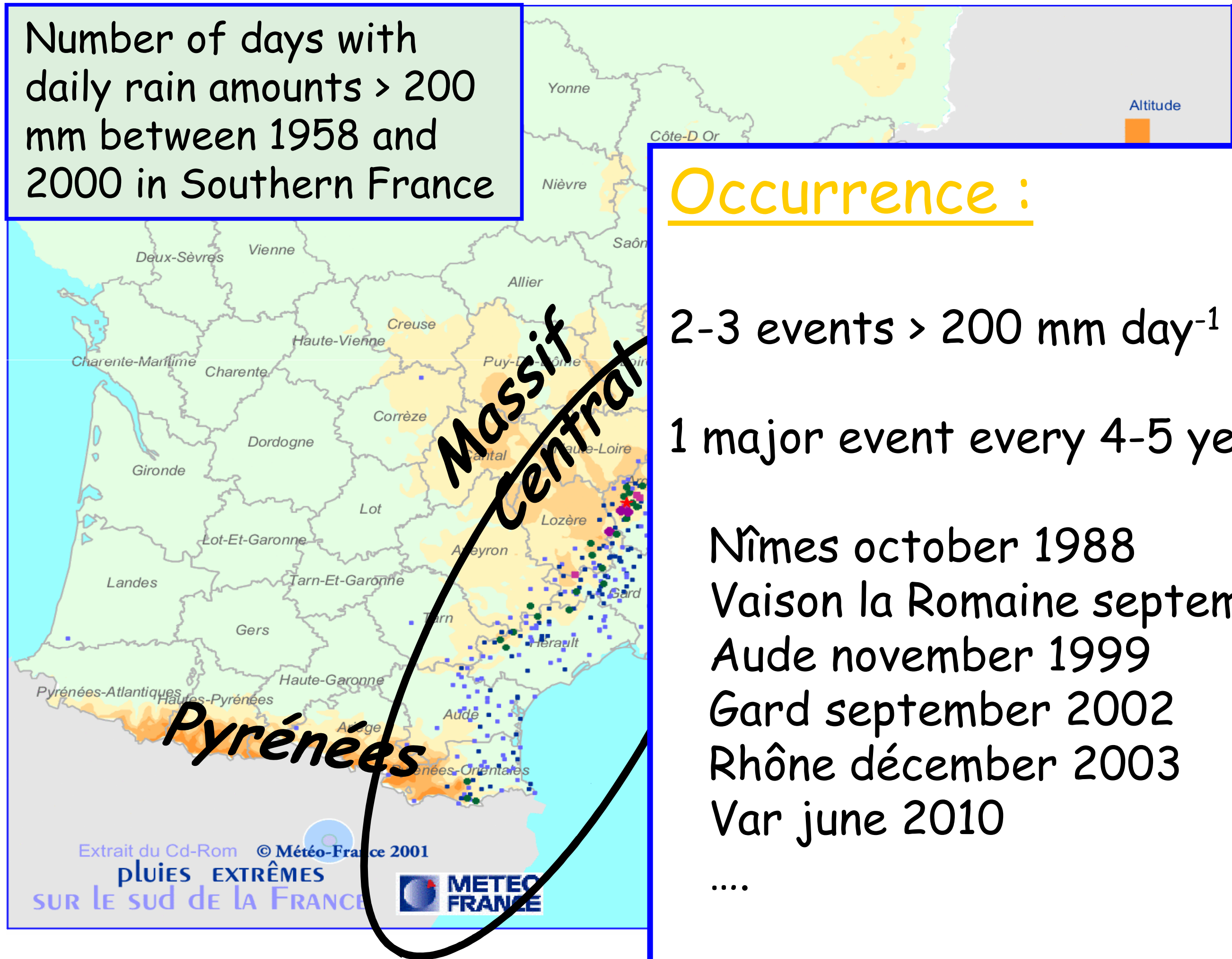
Heavy rain events in France : location and occurrence

Météo France 2001 (CD-rom Pluies extrêmes dans le sud de la France)

Number of days with daily rain amounts > 200 mm between 1958 and 2000 in Southern France



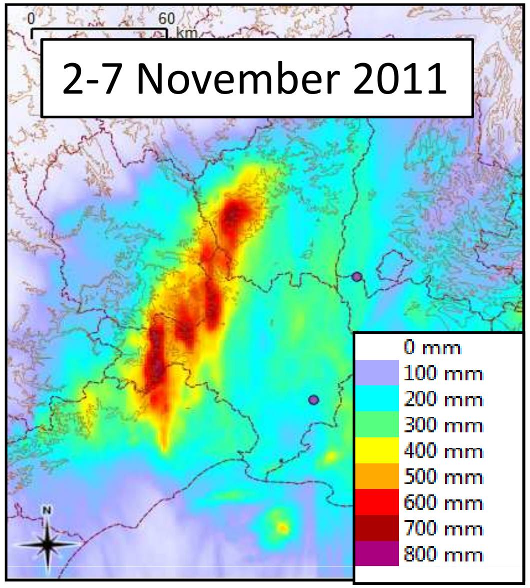
Occurrence :

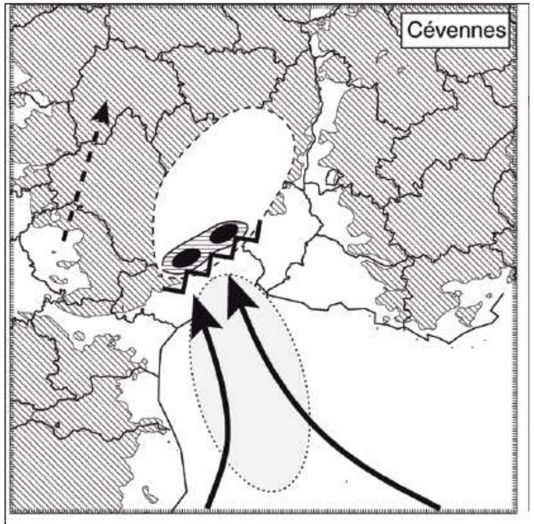
2-3 events > 200 mm day^{-1} per year

1 major event every 4-5 years :

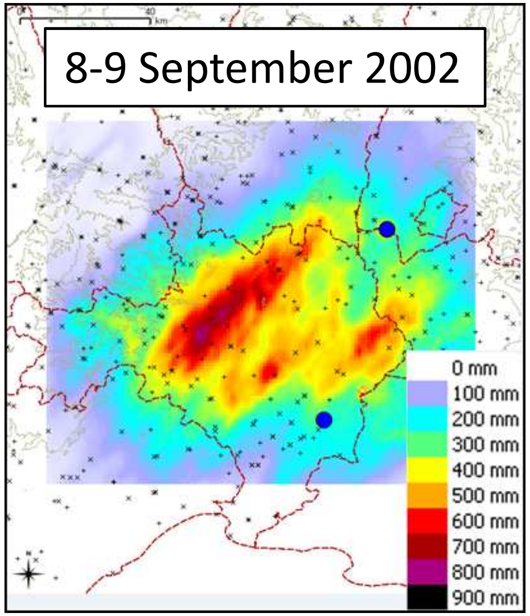
- Nîmes october 1988
- Vaison la Romaine september 1992
- Aude november 1999
- Gard september 2002
- Rhône décember 2003
- Var june 2010
- ....

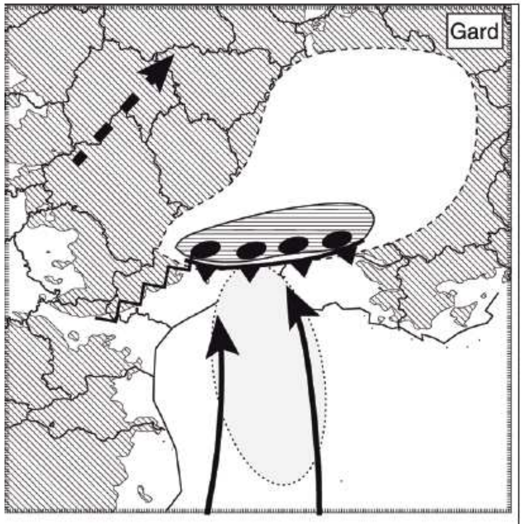
A variety of convective systems





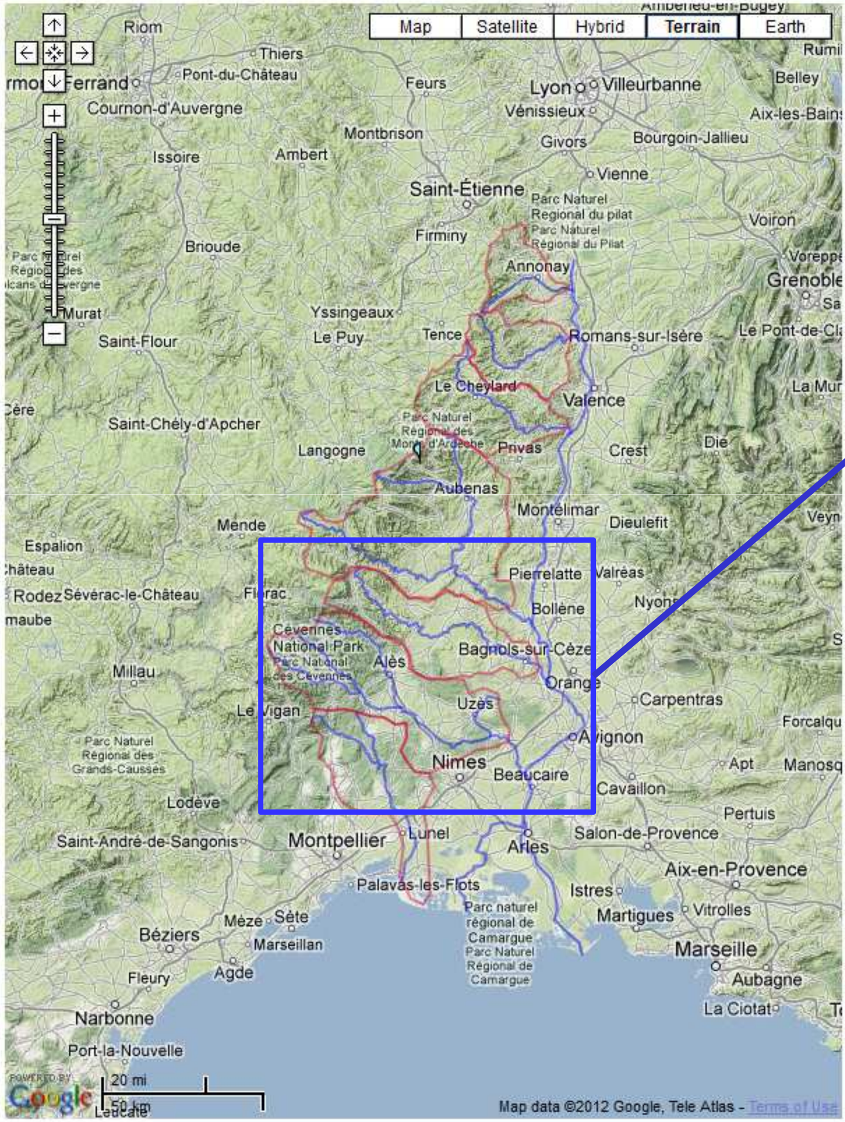
- Long lasting events
- Shallow / banded convection
- Orographic forcing





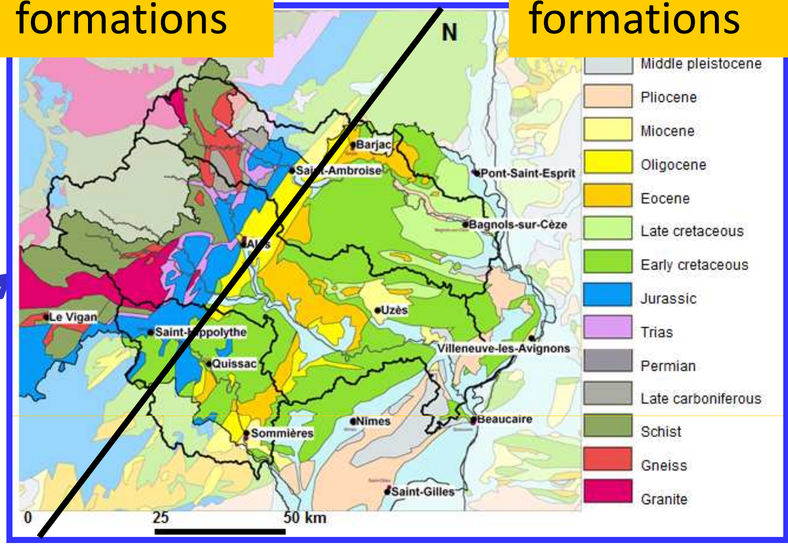
- V-shaped Mesoscale Convective Systems
- Deep convection
- Stationarity, dynamic forcing (cold pool)

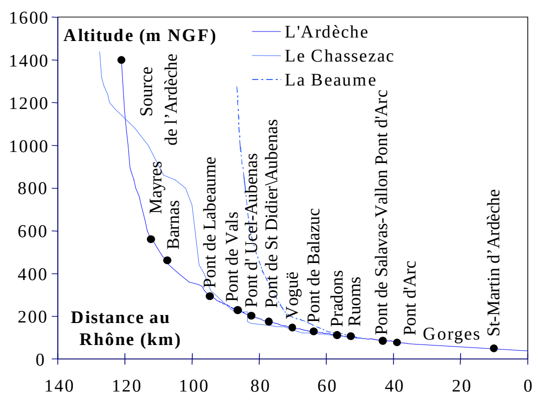
Geomorphological features of the Cévennes watersheds



Primary Era formations

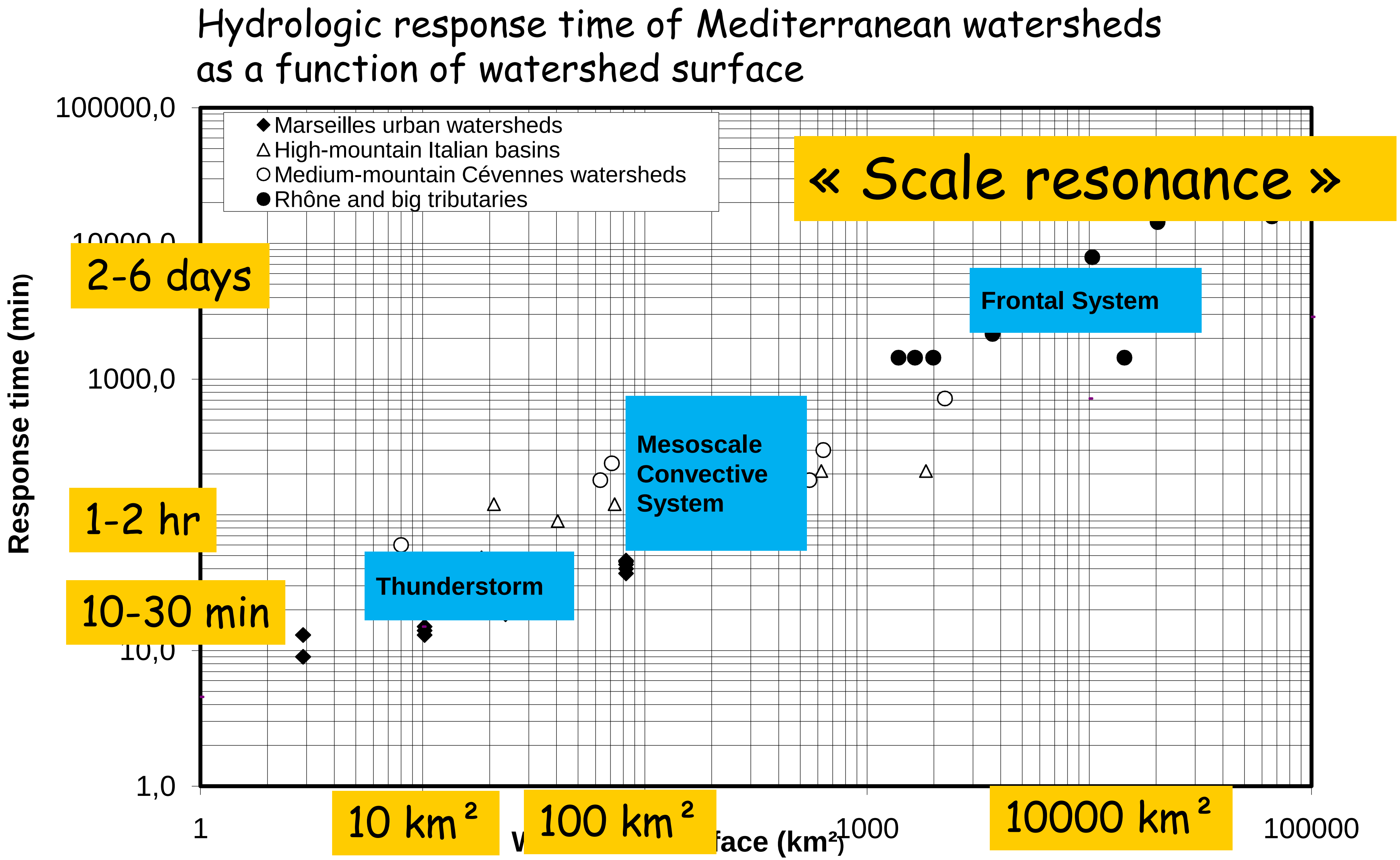
Sedimentary formations



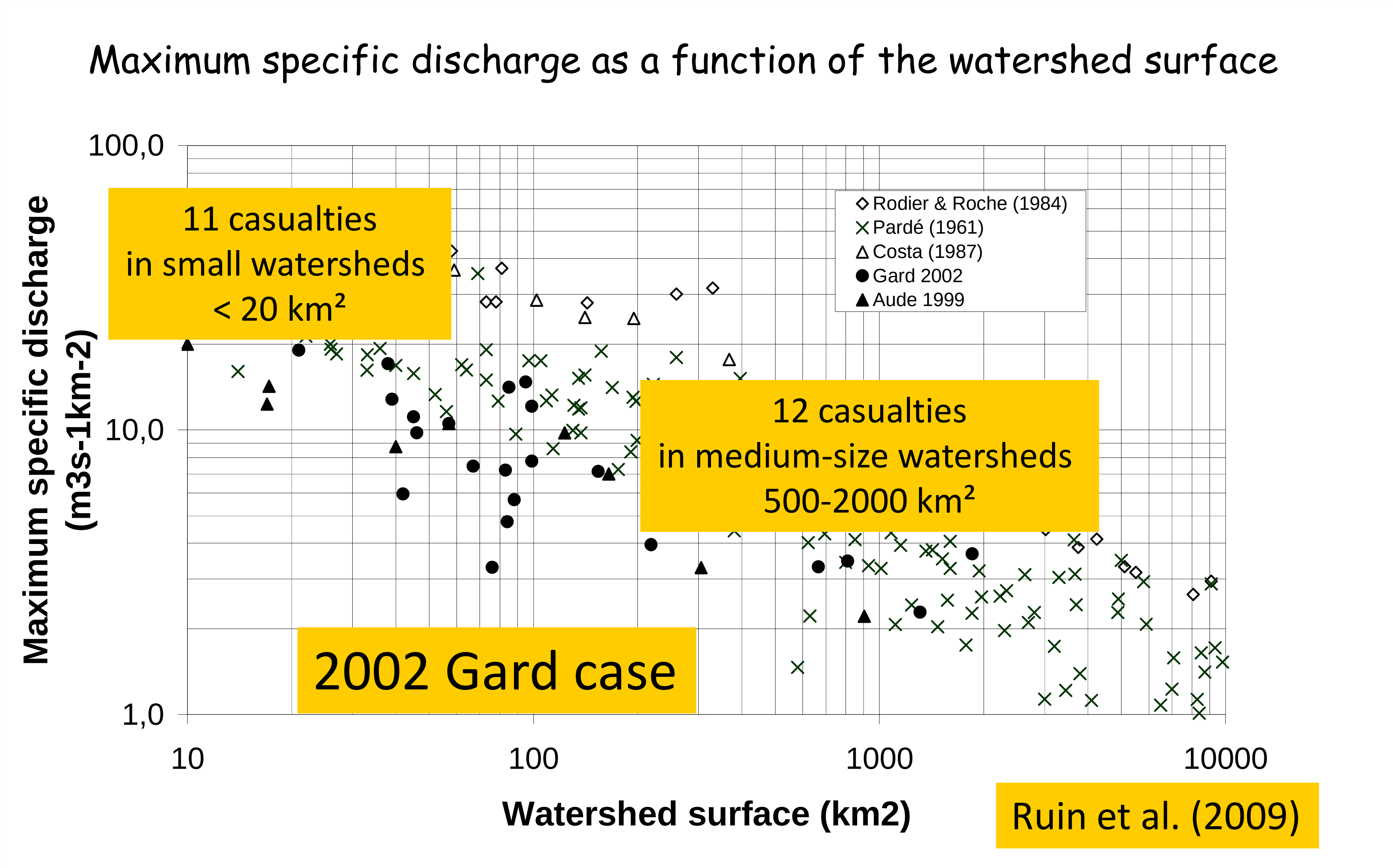


steep slopes karst gorges

Hydrological response: time to peak



Severity of the hydrological response



We should be able to predict HPEs and the associated flash-floods and floods over a **wide range of spatial scales (local to regional)** and to communicate the warnings and alerts with **appropriate lead times** to the end-users.

« Prediction for Ungauged Basins »
« Change of scale problem »

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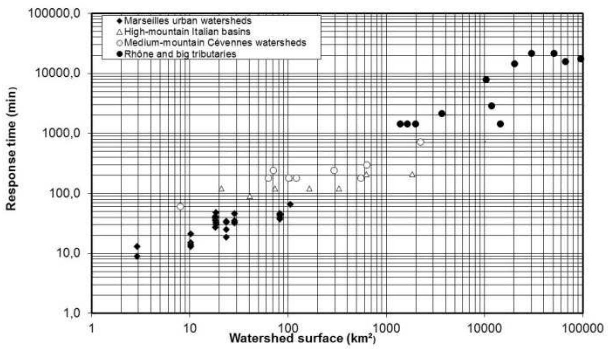
Required space-time resolution of rainfall measurements

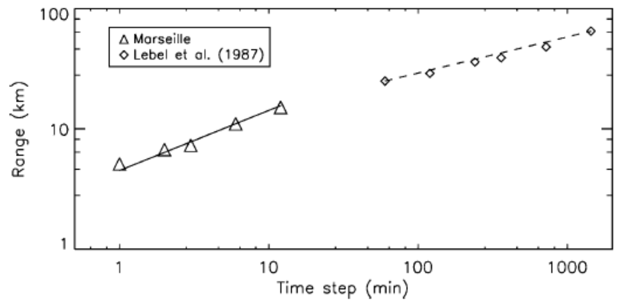
Time to peak



$$\Delta t = T_p/3 = 1.1\, A^{0{,}75}$$

(min) (km²)

Rainfall decorrelation distance



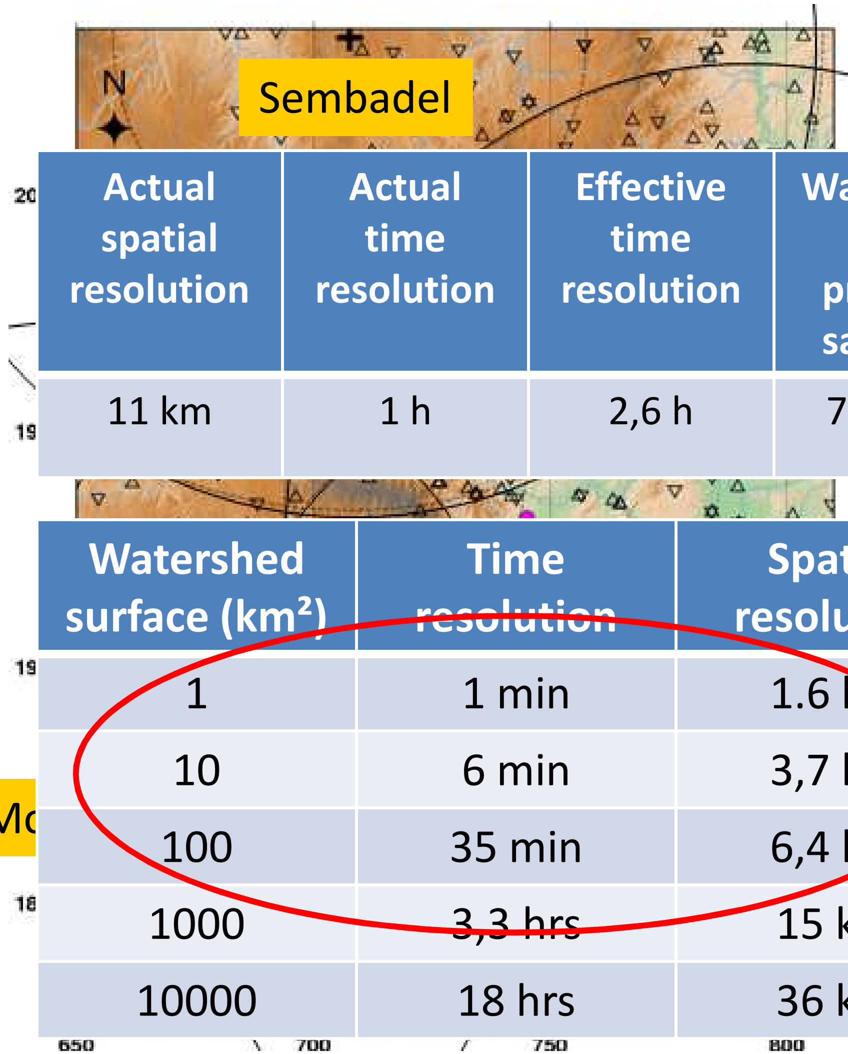
$$1 < \Delta t < 20\, min: \quad \Delta r = \frac{R}{3} = 4{,}5\, \Delta t^{0{,}5}$$

$$1 < \Delta t < 24\, hrs: \Delta r = \frac{R}{3} = 25\, \Delta t^{0{,}3}$$

Watershed surface (km²)	Time resolution	Spatial resolution
1	1 min	1.6 km
10	6 min	3,7 km
100	35 min	6,4 km
1000	3,3 hrs	15 km
10000	18 hrs	36 km

Lebel et al. (1987); Berne et al., (2004)

Rainfall observation system of the OHM-CV



Actual spatial resolution	Actual time resolution	Effective time resolution	Watershed scale properly sampled
11 km	1 h	2,6 h	735 km²

Watershed surface (km²)	Time resolution	Spatial resolution
1	1 min	1.6 km
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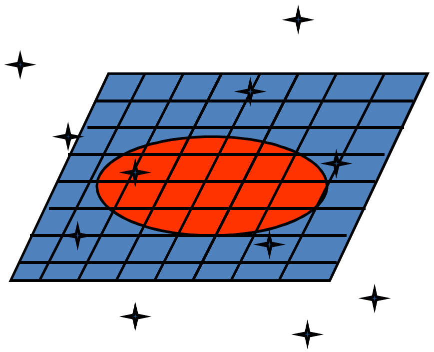
1000	3,3 hrs	15 km
10000	18 hrs	36 km

32000 km²; 0-1800 m asl
1 hour : 250 raingauges
24 hours : 400 raingauges
2 S-band radars
2 C-band radars
2 disdrometers
11 meteo-GPS stations

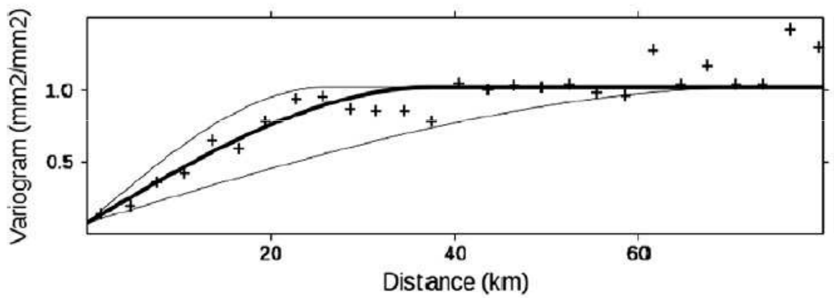
Error model: reference rainfall derived from raingauge data



True unknown rainfall

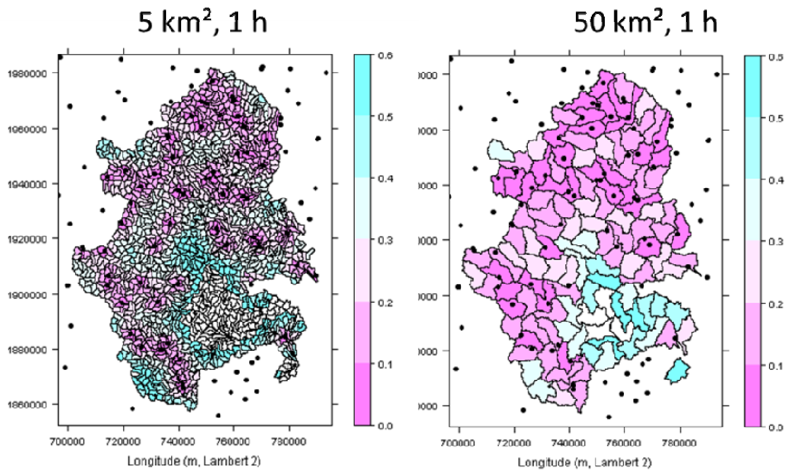
$$R_{AT}(\underline{x},t) = \frac{1}{A}\frac{1}{T}\iint_{A,T} R(\underline{u},v)\,d\underline{u}dv$$

Radar QPE



$$R^*_{AT}(\underline{x},t) = \frac{1}{N_A}\sum_{i=1}^{N_A} R^*_T(a_i,t)$$

Reference rainfall:
Ordinary Kriging of raingauge values



Linear estimator: $R^{ref}_{AT}(\underline{x},t) = \sum_{i=1}^{N_g} \lambda_i\, G(\underline{x_i},t)$

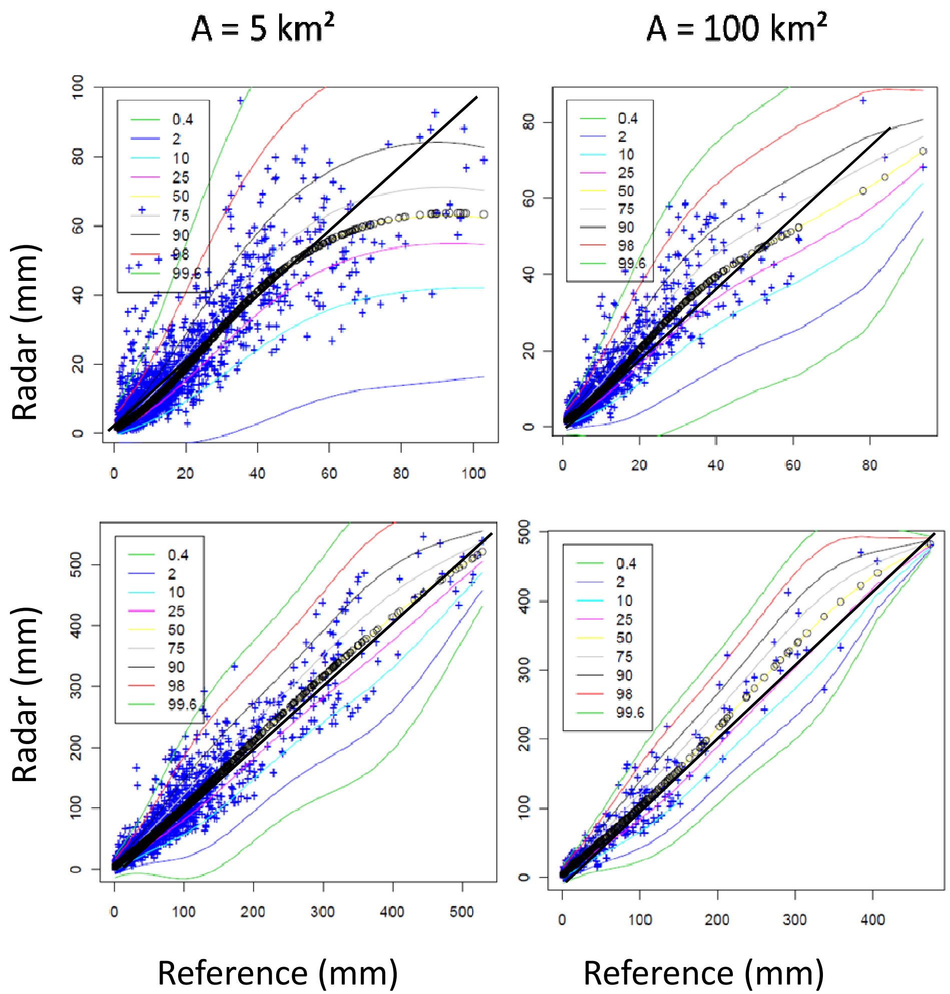
Estimation variance: $E(R^{ref}_{AT}(\underline{x},t) - R_{AT}(\underline{x},t))^2$

Assessment of the OHM-CV rainfall re-analyses

- Our best radar data processing: 4-radar mosaic/ GC / screening and VPR…)
- Optimization of a single Z-R relationship /event

$\Delta t = 1\ hr$

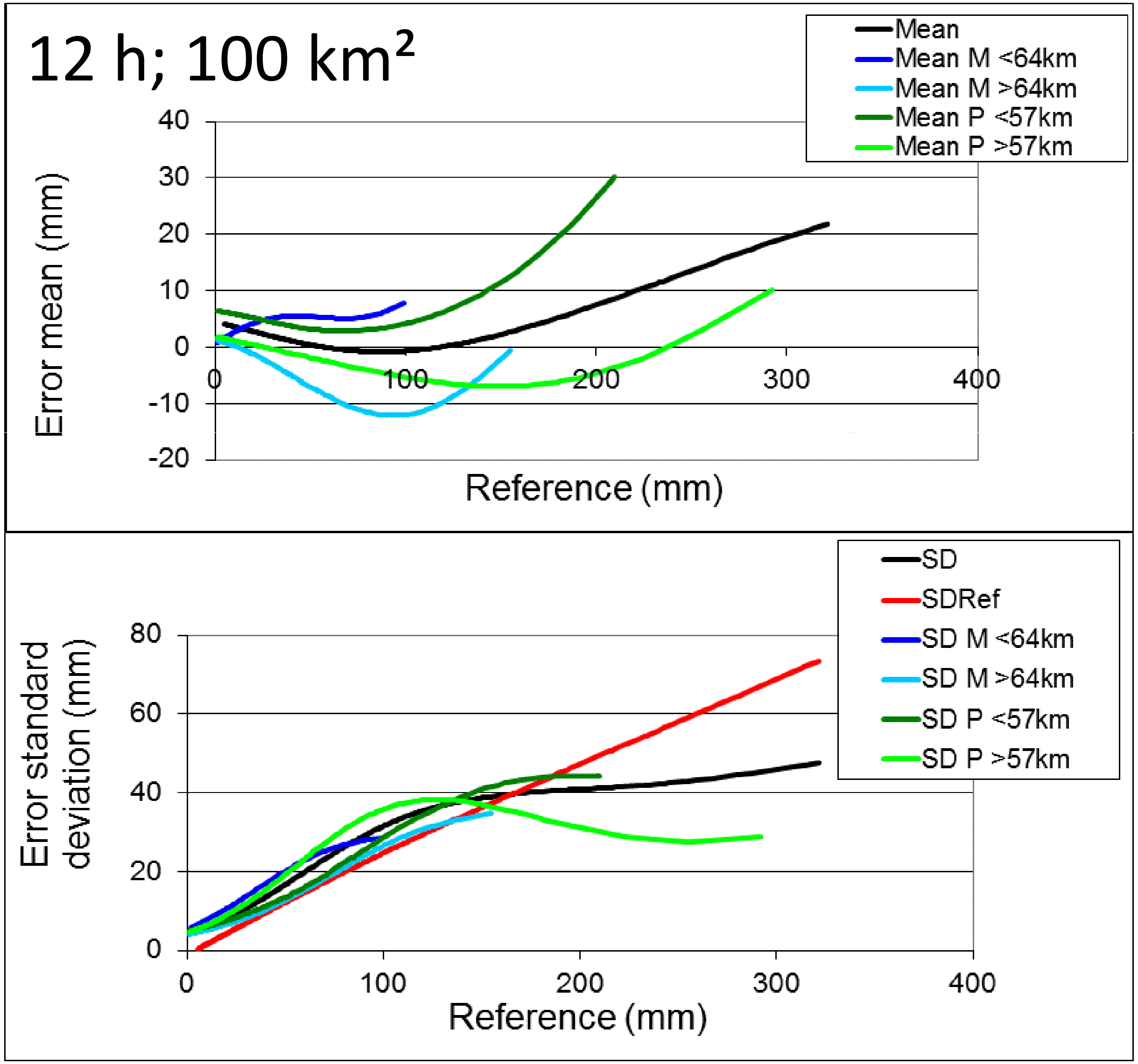
$\Delta t = 12\ hr$

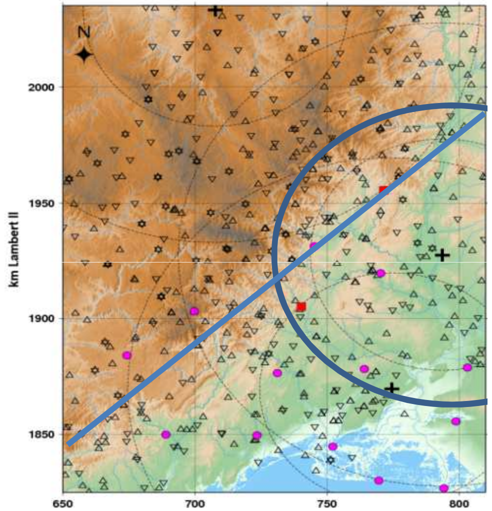


Conditional analyses of the radar – reference rainfall using the **GAMLSS framework** (Rigby & Stanisopoulos 2004)

Kirstetter et al. (2010); Delrieu et al. (2012)

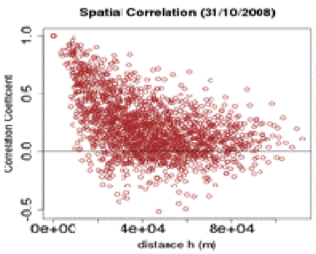
Conditional mean and standard deviation of the errors

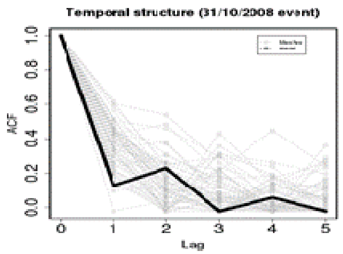




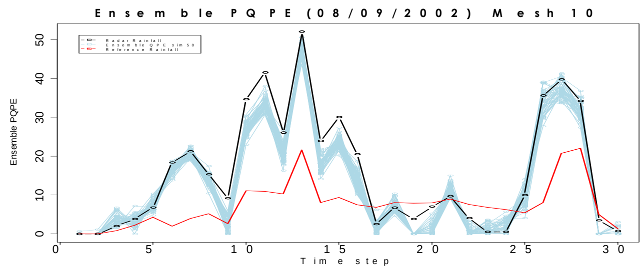
Toward probabilistic radar QPEs

Spatial and temporal correlation

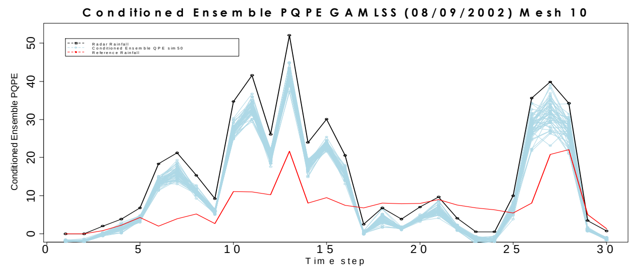




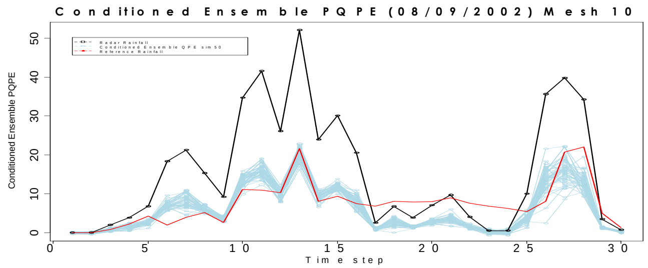
100 km², 1 hour



Conditioned by $\mu(\Delta)$
and $\sigma(\Delta)$ estimated globally
over the region of interest



Conditioned by
$\mu(\Delta|R)$ and $\sigma(\Delta|R)$
estimated globally
over the region of interest



Conditioned by
$\mu(\Delta|R)$ estimated
locally and $\sigma(\Delta|R)$
estimated globally

Germann et al. (2009); Partheni and Delrieu, this conf.

The radar error structure is complex

- rain-rate dependent
- space-time scales dependent
- location (range) dependent
- rain-type dependent

We are limited in our willing to provide radar error models useful in hydrology by the reference rainfall problem

- micronets, microwave links?
- work on estimation variance of merged products through geostatistical or Bayesian techniques; introduce some physics

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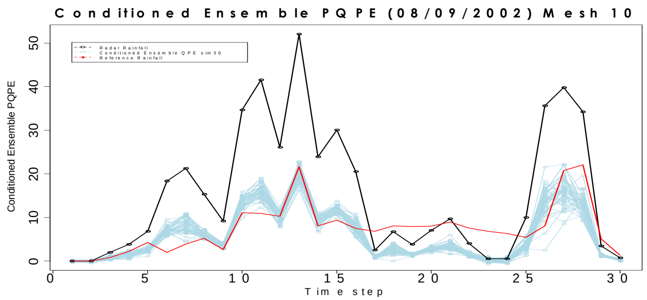
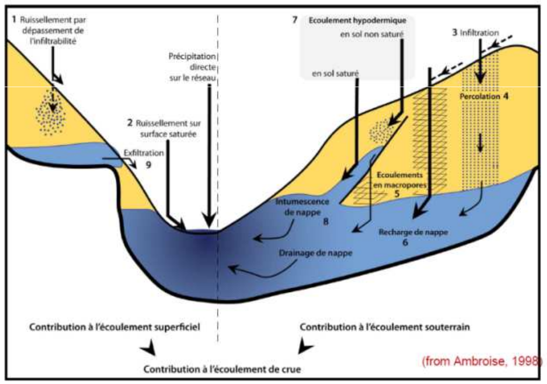
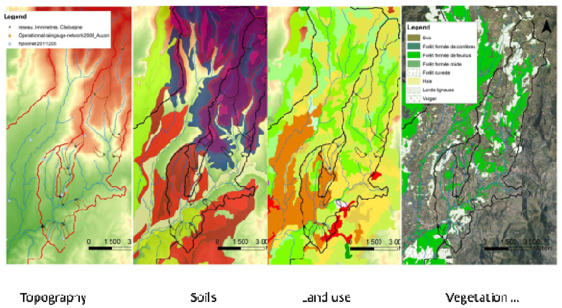




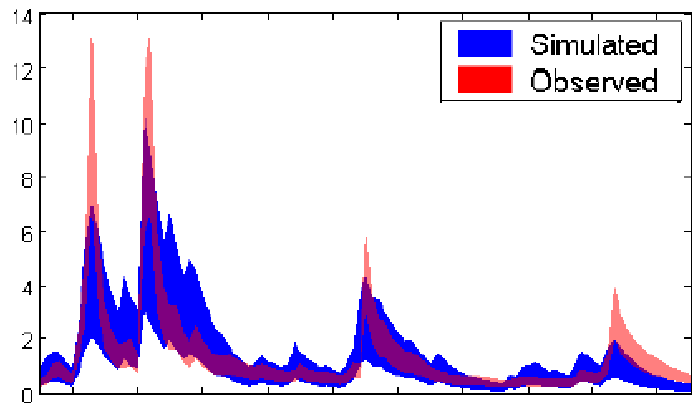


Hydrological modelling:

- Processes complexity
- Observability problem of the sub-surface
- Numerous landscape descriptors

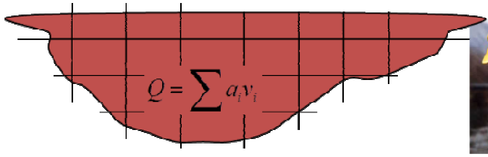
- Spatial discretization
- processes representation (and selection?)

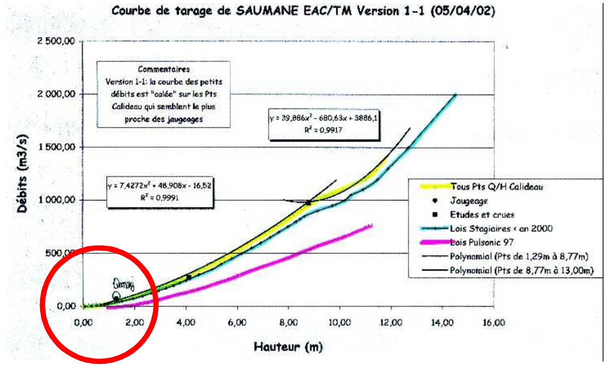
- Input-output uncertainties
- Structural and parametric uncertainties



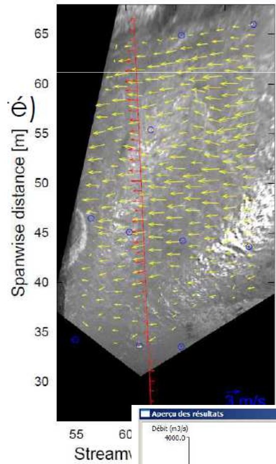
Monitoring of flooding rivers

Unfeasibility of conventional techniques during floods

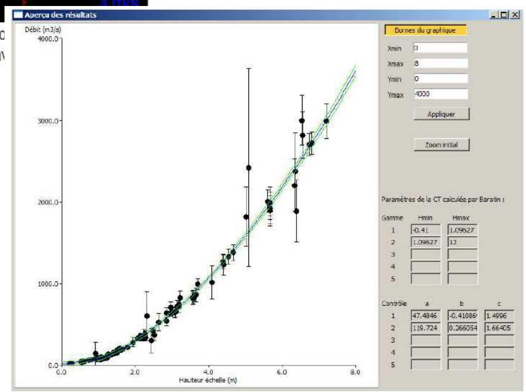




Need to develop « non-contact » gauging techniques



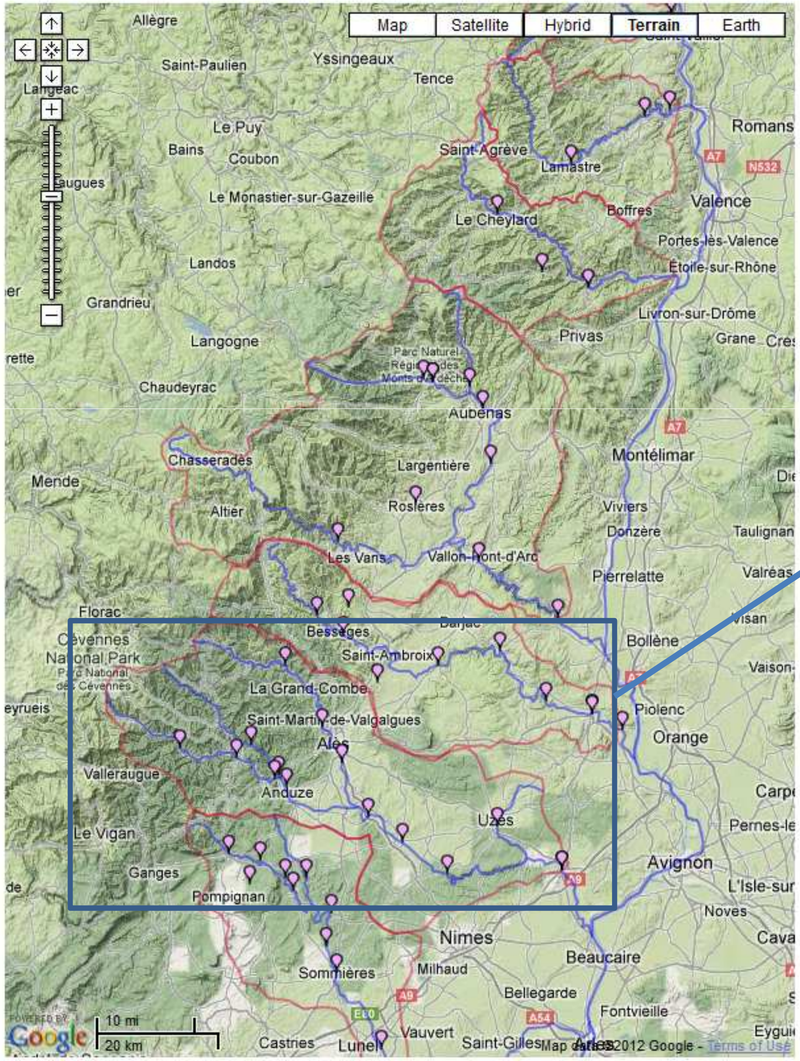
Need to improve rating curves (hydraulic modelling + gauging uncertainty accounting)

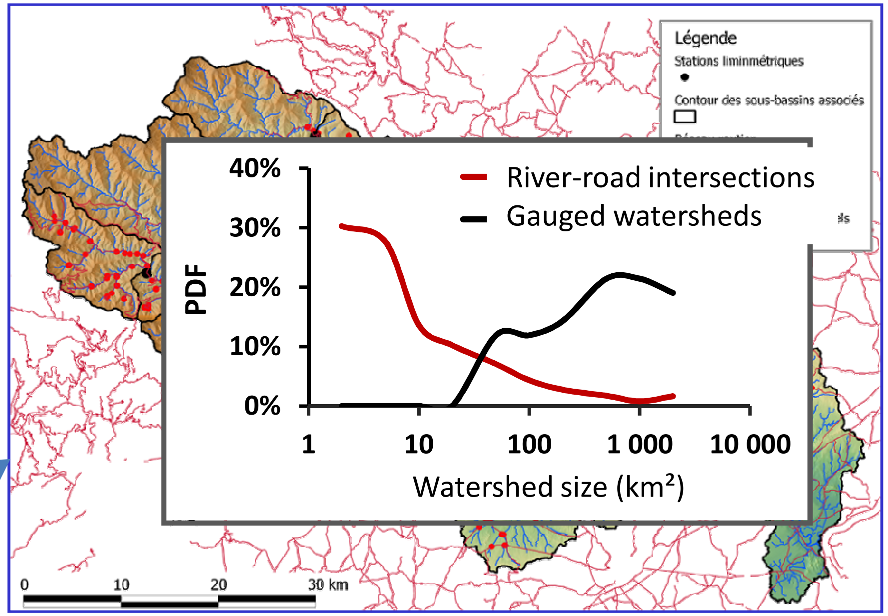


Le Coz et al.

Streamgauge network density

45 stream gauges in the OHM-CV





O. Vannier

- Post-event surveys
- A team/network of local observers?

Hydrological models, example 1: TOPMODEL

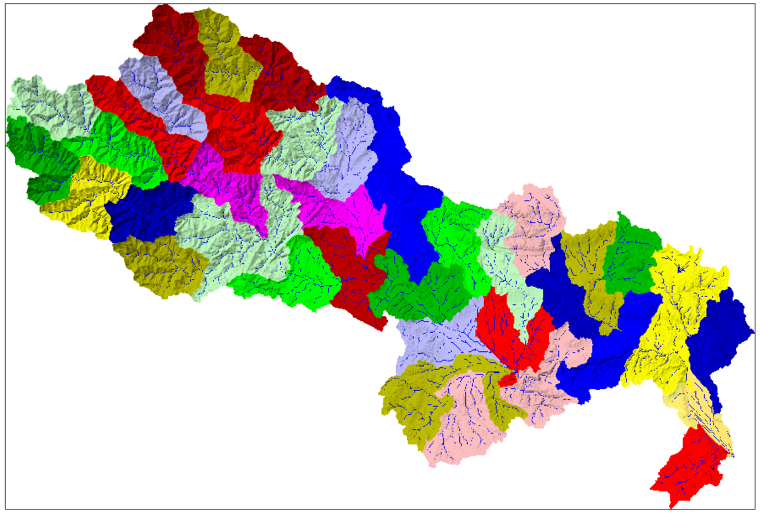
“topographic similarity”

Runoff production:
sub-surface lateral flow and saturation excess overland flow
Runoff transfer:
Geomorphological unit hydrograph

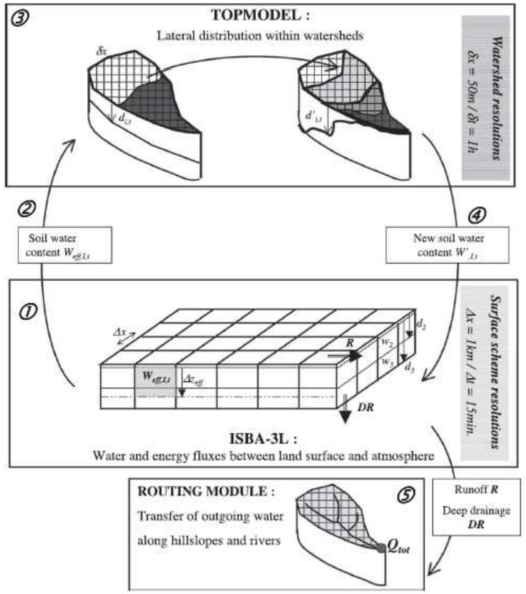
« Parcimony »: 4 parameters

1) nTopmodels
Hydrological meshes of ~constant area

2) ISBA-TOPMODEL
Coupled land surface – hydrological model



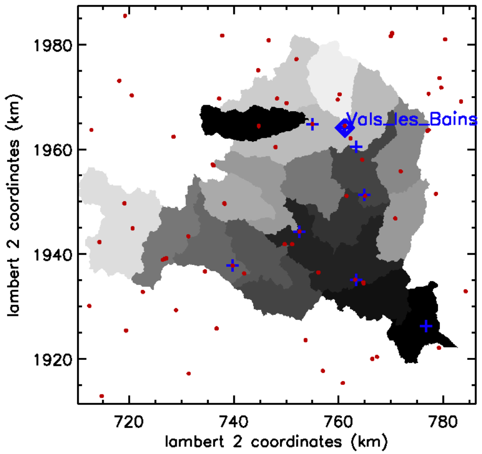
Le Lay and Saulnier (2009)

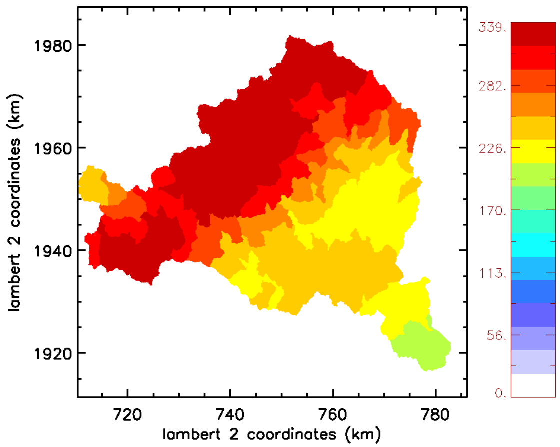


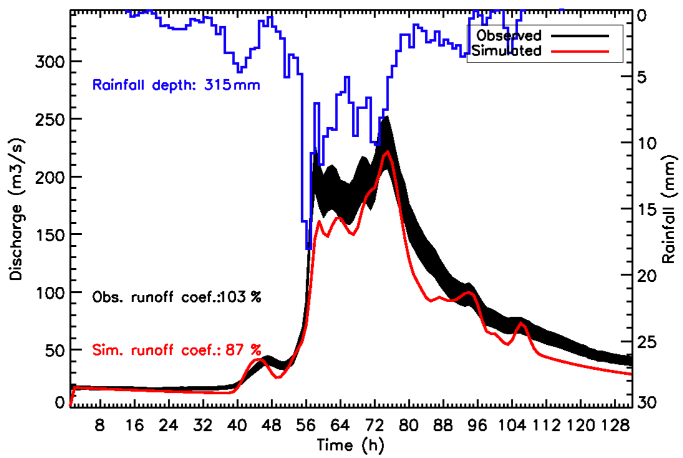
Vincendon et al. (2009)

Spatial assessment of n-Topmodels

The 2003 flood in the Ardèche catchment







Limitations:

- Data-calibrated
- Initialization?

Qualities:

- uniform spatial parameterization works reasonably well
- sensitivity to the rainfall spatial distribution

Le Lay and Saulnier (2009); Bonnifait et al. (2009)

Hydrological models, example 2: CVN

"Landscape similarity"

Landscape discretization (~0.5 km²)

Based on topography and soil maps

Spatialized forcings:

- Radar-raingauge rainfall
- Evapotranspiration (based on soil and vegetation maps)

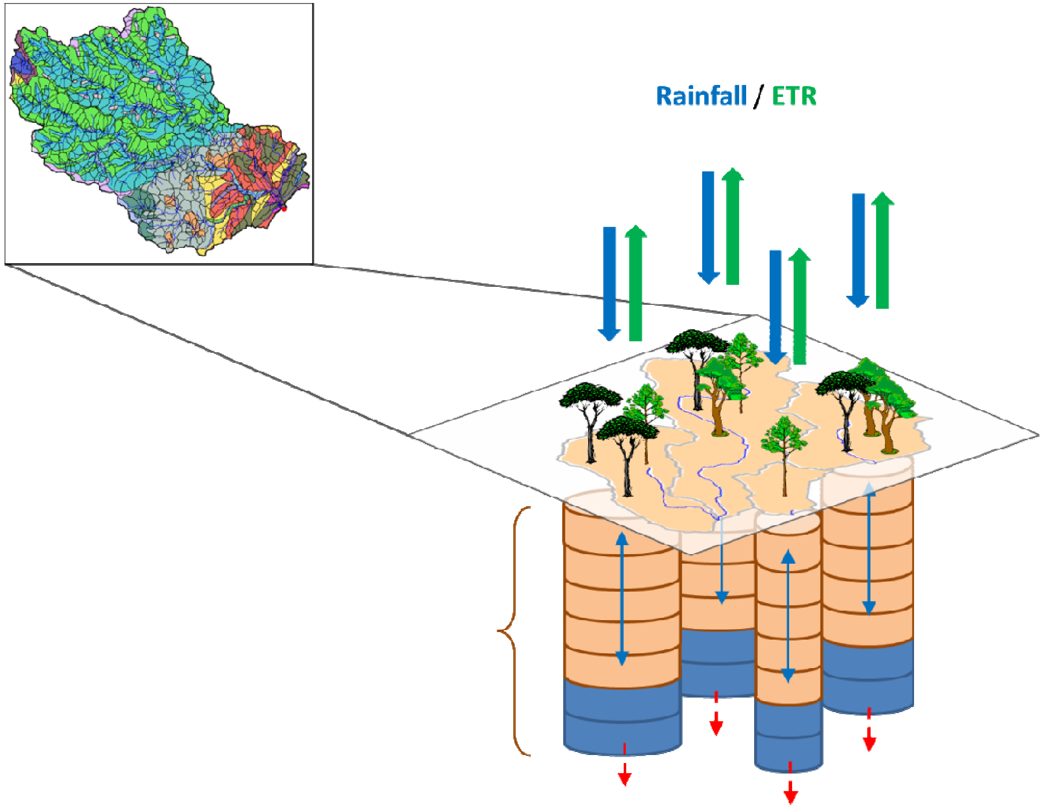
Runoff production:

Vertical transfer of water in the soil

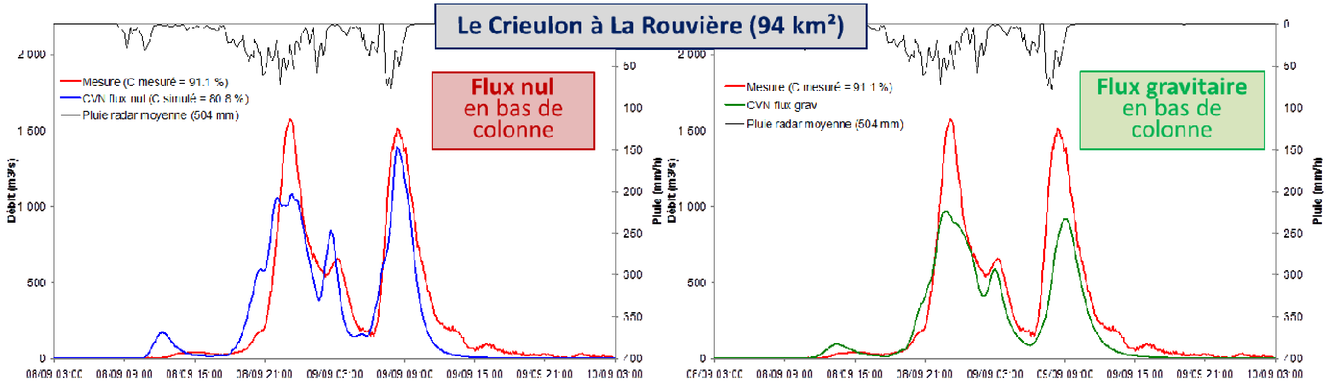
- use Solve Richards 1D
- use h(Θ) et K(Θ) relations (Brooks & Corey) for the various layers

Runoff transfer:

- Ponding sent directly to the river network
- Transfer with kinematic wave equation



Braud, Anquetin, Vannier et al.

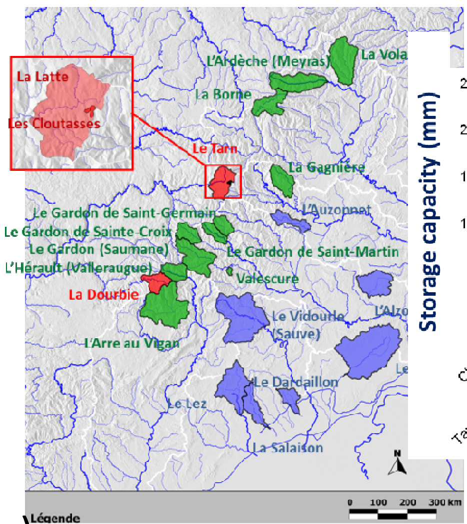


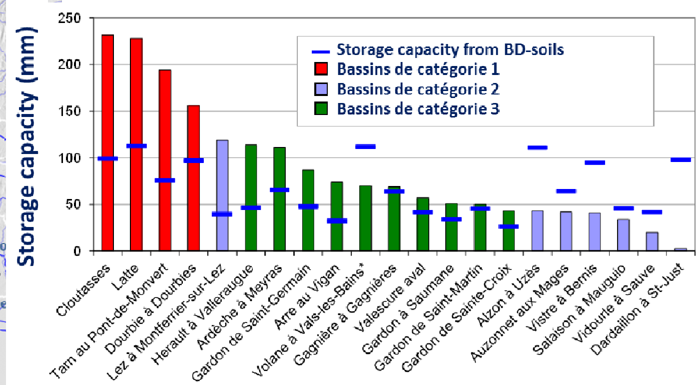
Qualities:

- Best use on spatialized data
- Physically based water transfer
- Continuous modelling
- No data-calibration

Limitations:

- Hydrological relevance of soil maps
- some process representations are lacking so far (sub-surface lateral flow)

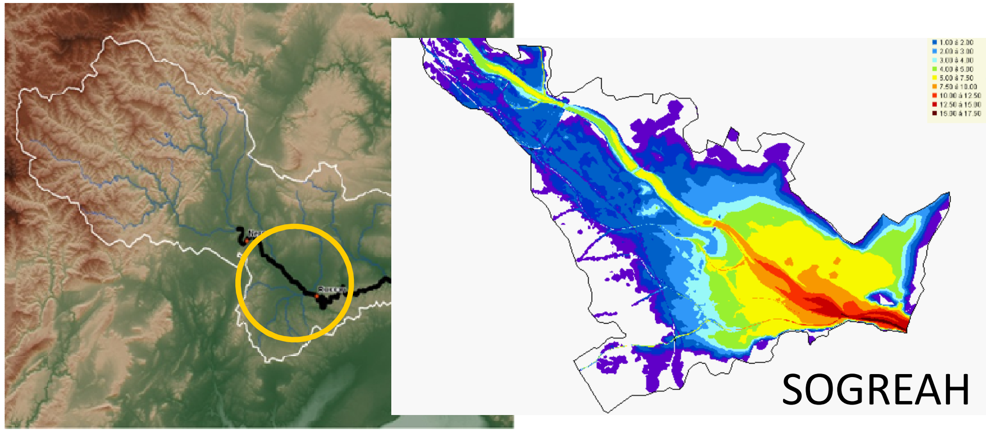


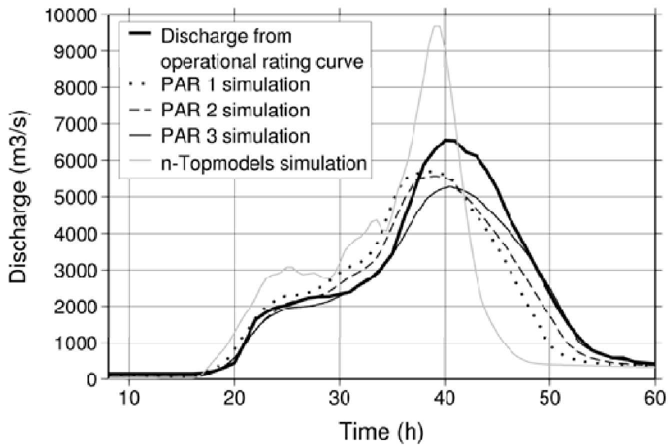


PhD thesis of O. Vannier

Geomorphological controls:

Gardonnenque plain + Gardons gorges during the Gard 2002 flood





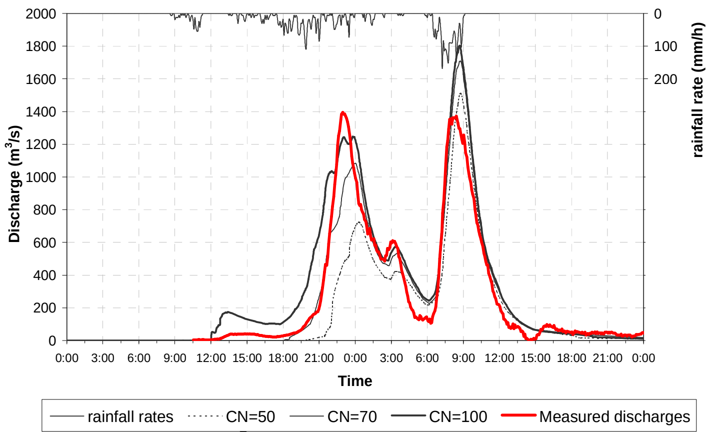
Bonnifait et al. (2009)

→ Coupling hydrologic and hydraulic models

Geological controls:

Crieulon, Bge de la Rouvière (93 km²) :

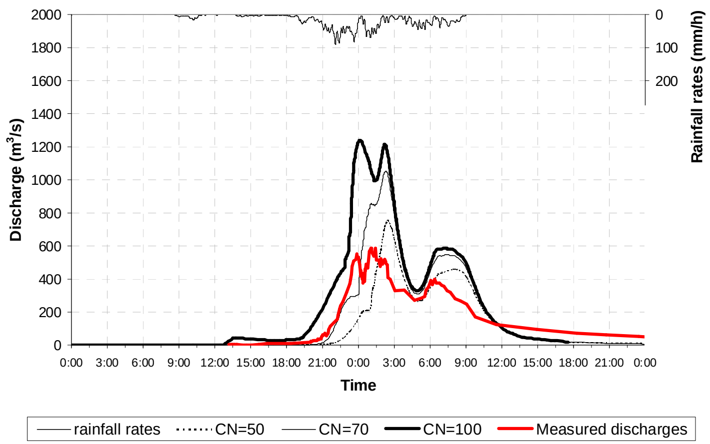
Marls and non karstic limestones



→ Solution?

Vidourle, Bge de Conqueyrac (86 km²) :

Karst

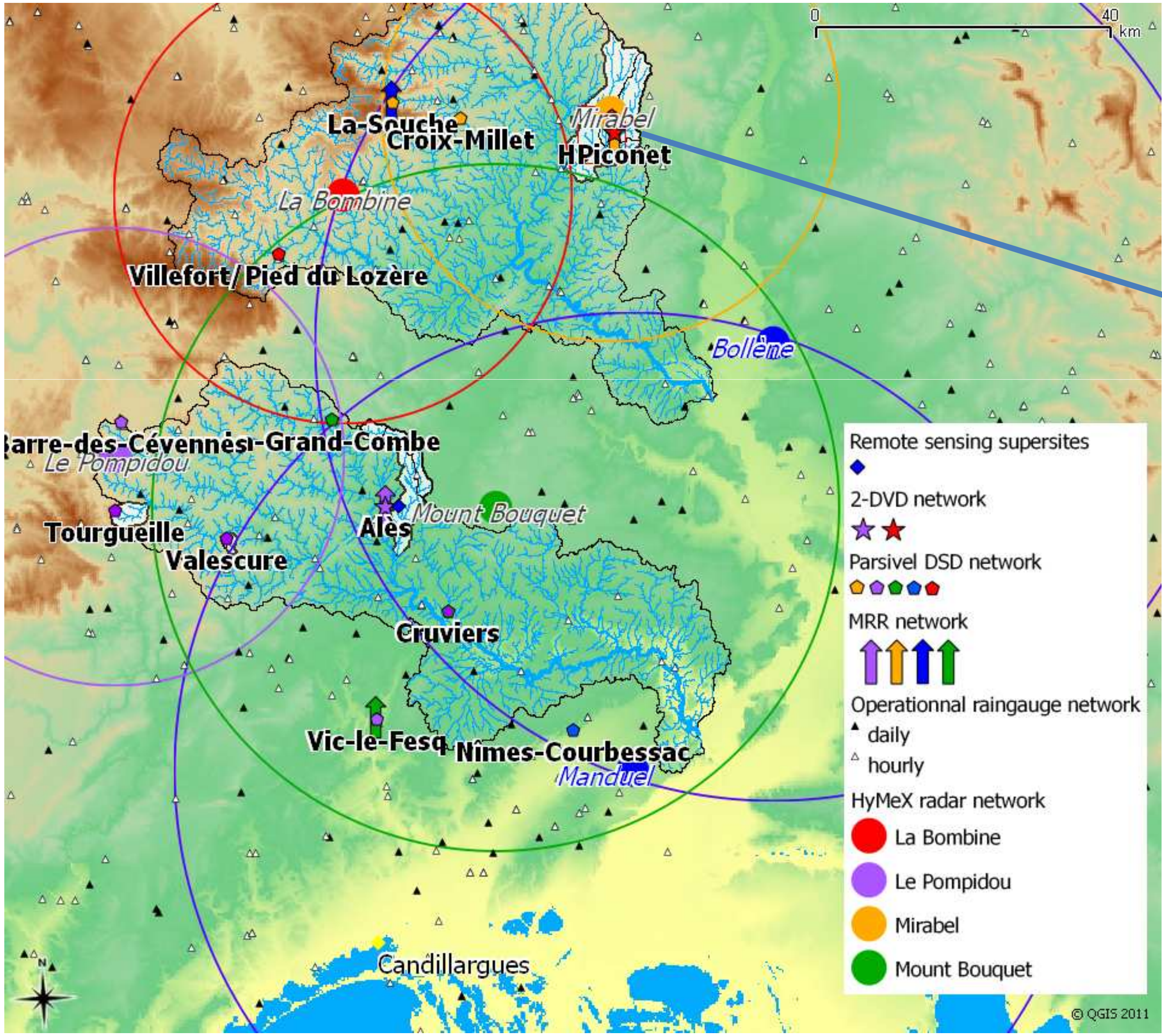


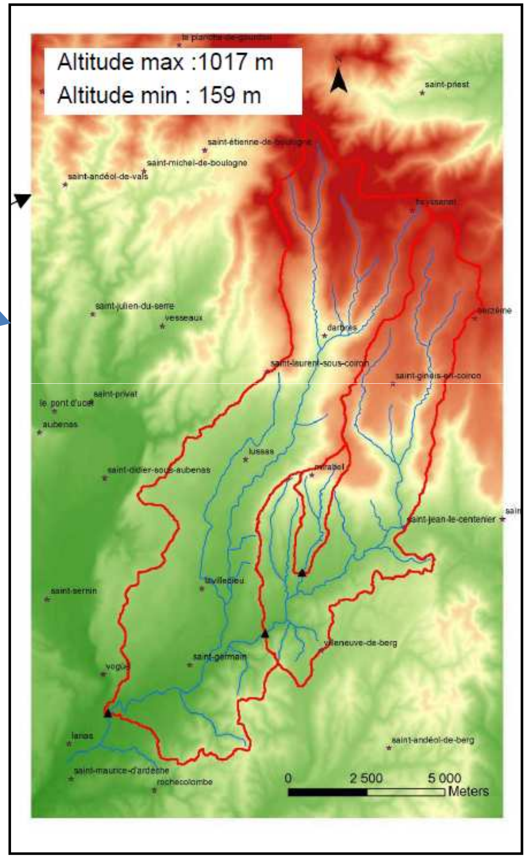
Gaume et al. (2004)

Coming work within HyMeX/FloodScale projects

Investigate the « missing scales »:

- Reinforce the rainfall observation system
- Study hydrological processes for a series of Cévennes landscapes





Thank you!