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STOCHASTIC EXTREME RAINFALL SIMULATIONS AROUND MONTPELLIER

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Key words: Extreme-value theory; Space-time Pareto processes; Stochastic simulation; Heavy rainfall events.

Abstract : To better manage the risks of destructive natural disasters, impact models can be fed with simulations of extreme scenarios to study sensitivity to temporal and spatial variability. We propose semi-parametric stochastic simulation of realistic spatio-temporal extreme fields using a moderate number of observed extreme space-time episodes to generate an unlimited number of extreme scenarios of any magnitude. Our framework draws sound theoretical justification from extreme value theory, building on generalized Pareto limit processes. For illustration on hourly gridded precipitation data in Mediterranean France, we calculate risk measures using extreme event simulations for yet unobserved magnitudes.

MOTIVATION

Heavy rainfall events have a considerable human and economic impact
Requirement of a wide catalogue of realistic extreme rainfall scenarios in order to lead impact studies
But scarcity of observed extreme episodes
Reconstructing spatial forcing scenarios as close to reality as possible is essential
Study of rainfall-induced flood risk in urban areas

High-dimensional rainfall data-set

Rainfall is one of the most complex meteorological processes

- Reanalysis data-set= Radar signals + precipitation totals from gauges.
- Hourly rainfall totals (mm).
- 10914 cells covering a 133,2 kms x 104,3 kms area in Mediterranean France.
- Years: from 1997 to 2007.

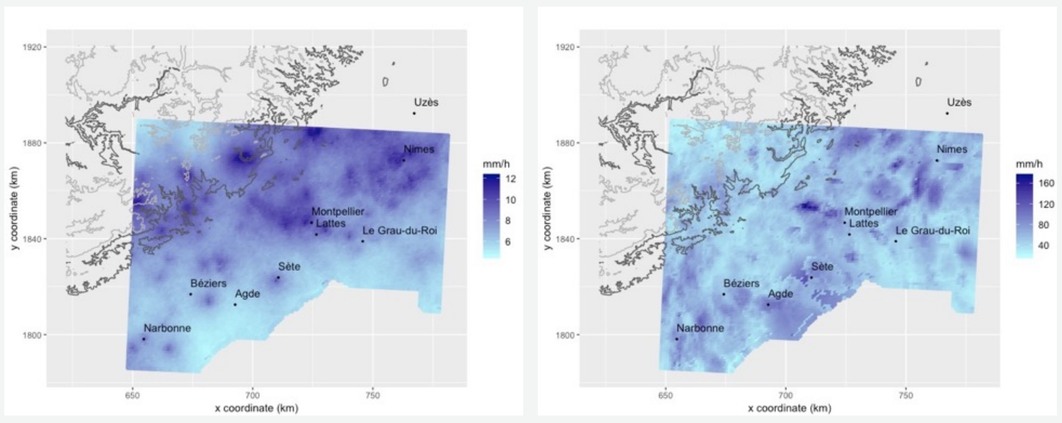


Figure 1. Empirical return levels at 98 % (left panel) and maxima (right panel) of hourly precipitation intensities for each grid cell in our study area from 1997 to 2007.

How to define extreme episodes?

Extreme rainfall episodes could be
- localized with high intensity and lasting a few hours
- long-lasting events with moderate intensities affecting large areas

- Using a cost-functional depending on: the nature of the considered phenomenon, on the data set, on the objective of the study.
- Cost-functional in a space-time window exceeds a threshold u.
  Examples: mean, accumulation, maximum.
- Cost-functional over u: h consecutive hours with precipitation, in average, always above u.

Step 1 : Selection/extraction of extreme episodes from data

Episode	Spatio-temporal mean	Spatial maximum
1st	2005-09-06 12:00:00	2005-09-06 14:00:00
2nd	1999-09-03 07:00:00	1999-09-13 23:00:00
3rd	2001-07-05 14:00:00	1999-08-28 11:00:00
4th	2006-10-12 12:00:00	1999-09-03 04:00:00
5th	2005-09-09 07:00:00	2001-07-05 18:00:00
6th	2003-11-16 02:00:00	2006-10-11 15:00:00

Table 1. Starting times of the most extremes episodes extracted by considering two cost functionals.

But observed extreme episodes are rare by definition !

Requirement of a wide catalogue of realistic extreme rainfall scenarios

Solution → Stochastic simulations

Our procedure draws sound justification from asymptotic theory for threshold exceedances with a strong probabilistic interpretation

Step 2 : Stochastic simulations

Selected Episodes from data (Step1) + Extreme Value Theory / Pareto processes [1] → [2] Stochastic extreme rainfall scenario simulation

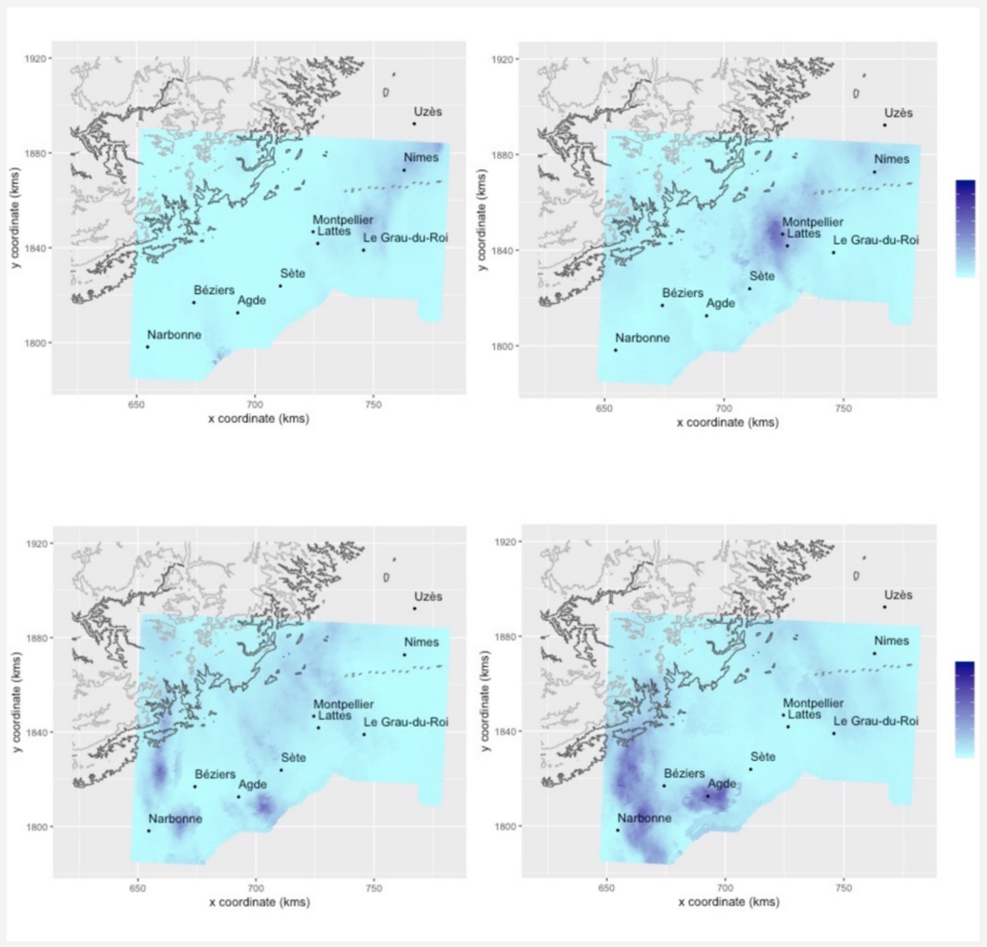


Figure 2. Uplifted episodes based on the spatio-temporal mean associated to the first extreme episode (from 2005-09-06 16:00:00 to 2005-09-06 19:00:00). We consider spatio-temporal neighborhoods of 15 kms and 12 hours, respectively.

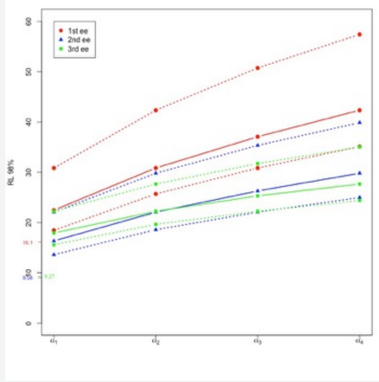


Figure 3. Return level at 98 % are computed for the original episode and for each uplifted episode, where we first aggregate values respectively for each spatial grid cell by taking its temporal average over the 12 hours. The legend indicates the extreme episode (ee). For each episode, the lines correspond to different uplifting levels using the 0.25-, 0.5- and 0.75-quantile (from bottom to top). The considered cost-functional is the spatio-temporal mean:

$$\ell(\dot{X}^*; s, t) = \frac{1}{|\mathcal{N}(s,t)|} \sum_{(z,k)\in\mathcal{N}(s,t)} \dot{X}^*(z,k).$$

Outlook :
- Hydraulic simulations of a rainfall-induced urban flood using extreme forcings
- Construction of a space-time stochastic rainfall generator geared towards extreme events

[1]. de Haan, L. and Ferreira, A. (2006). Extreme Value Theory. An Introduction. Springer Series in Operations Research and Financial Engineering. Springer: New York.
[2]. Palacios-Rodriguez, F., Toulemonde, G., Carreau, J. And Opitz, T. (2019). Generalized Pareto processes for simulating space-time extreme events. HAL.