Analysis and stochastical modelling of extreme rainfall events

Application in the spanish mediterranean region

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EGU General Assembly 2011 – Vienna 4th April 2011

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- Stochastic multidimensional rainfall model RAINGEN
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- Parameters estimation
- Generation of synthetic events
- Conclusions and outlook

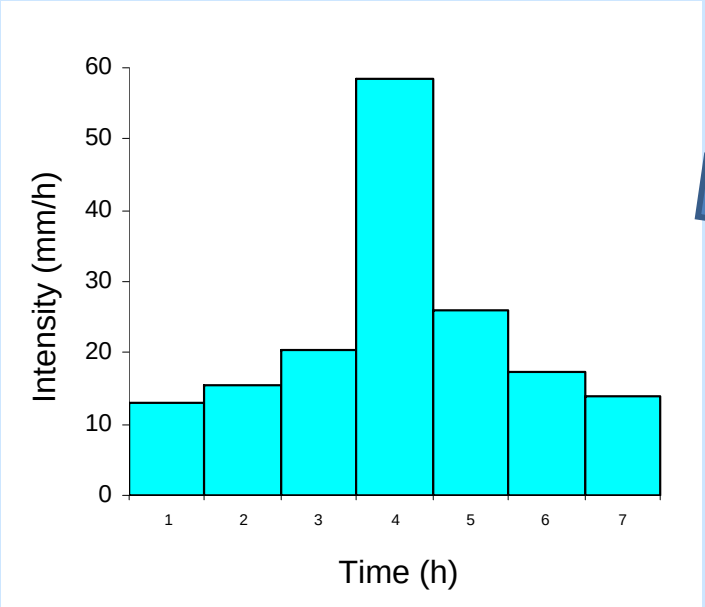
Introduction

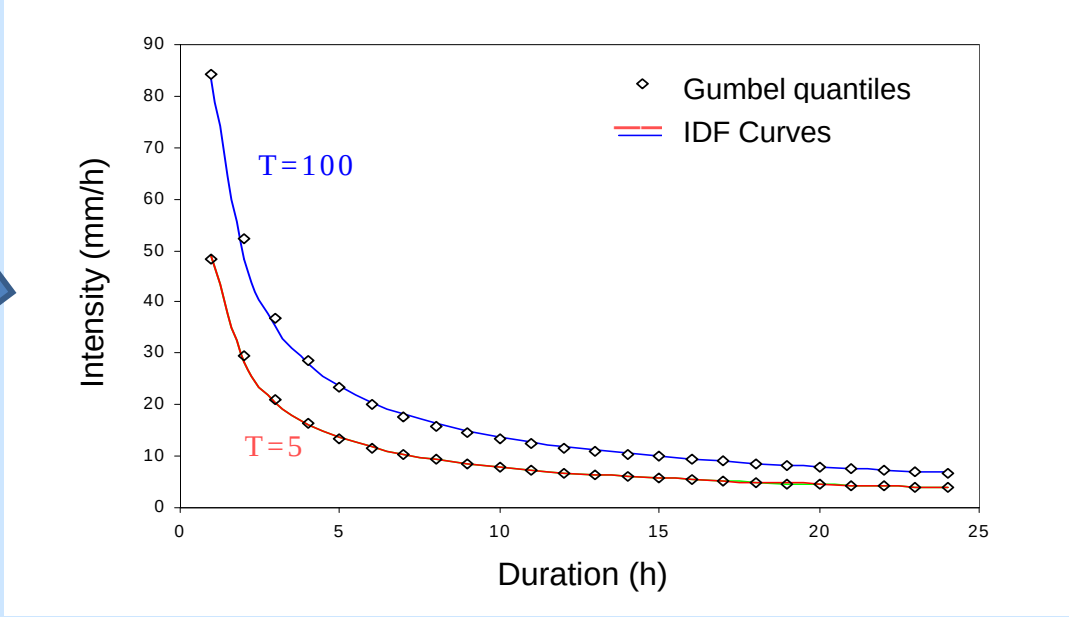
- Master Thesis in the frame of a broader project (*Flood protection strategies in the Marina Alta region*)

- Contribution: generation of the rainfall input, convective extreme events

Introduction

- Classic approach of the design storm – design flood





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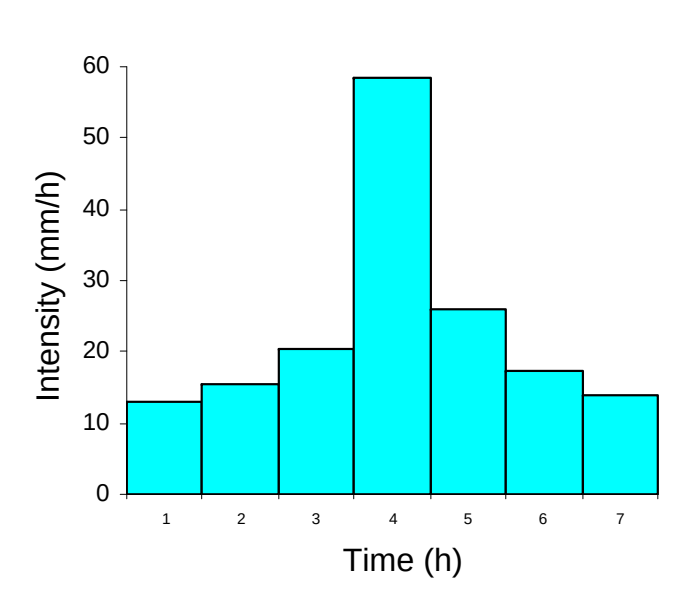

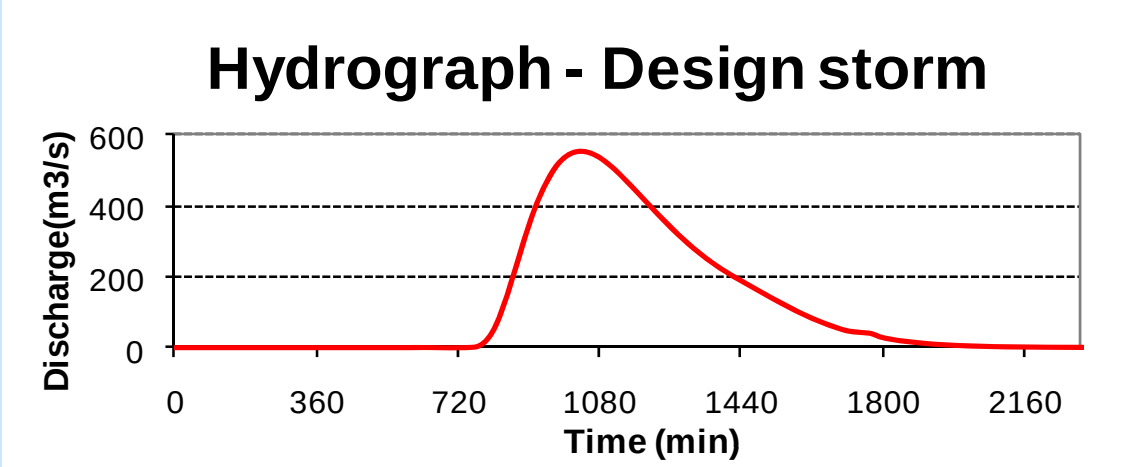

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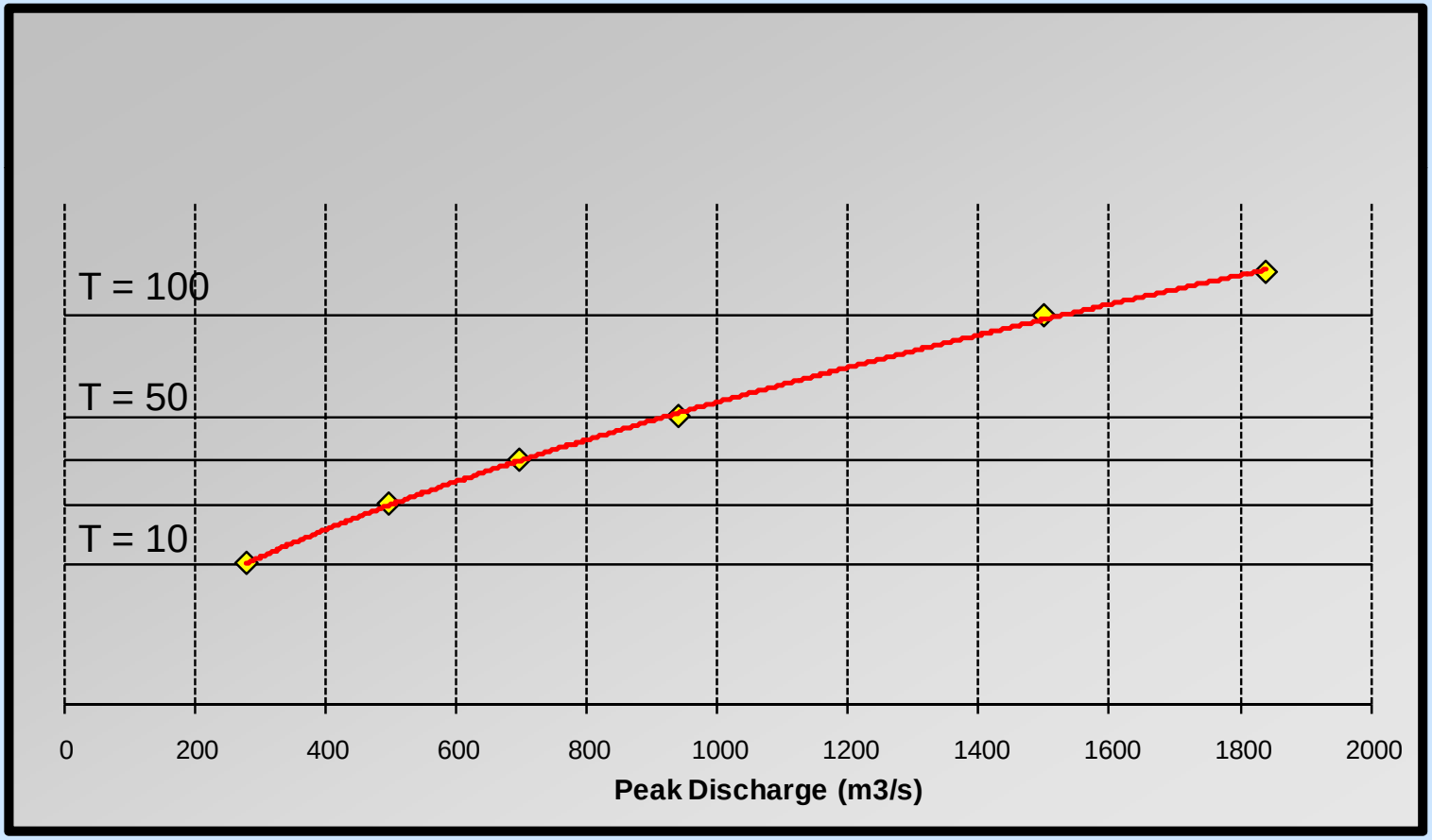
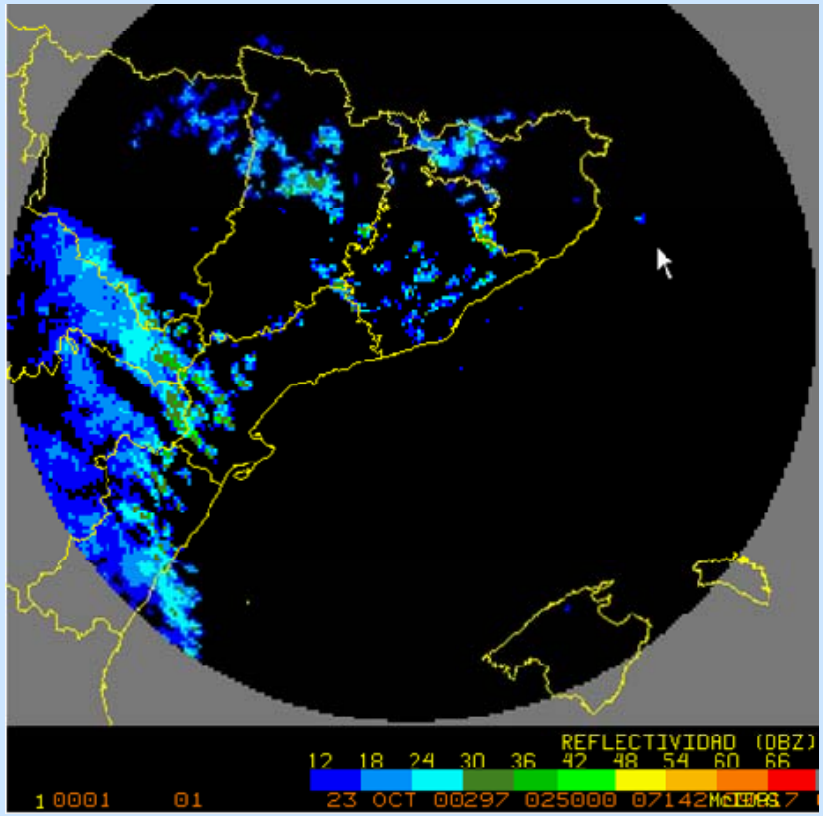


Introduction

- Observed reality – radar



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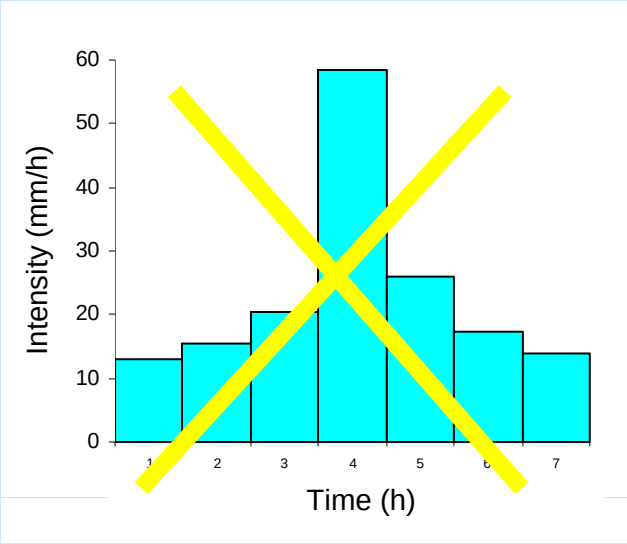

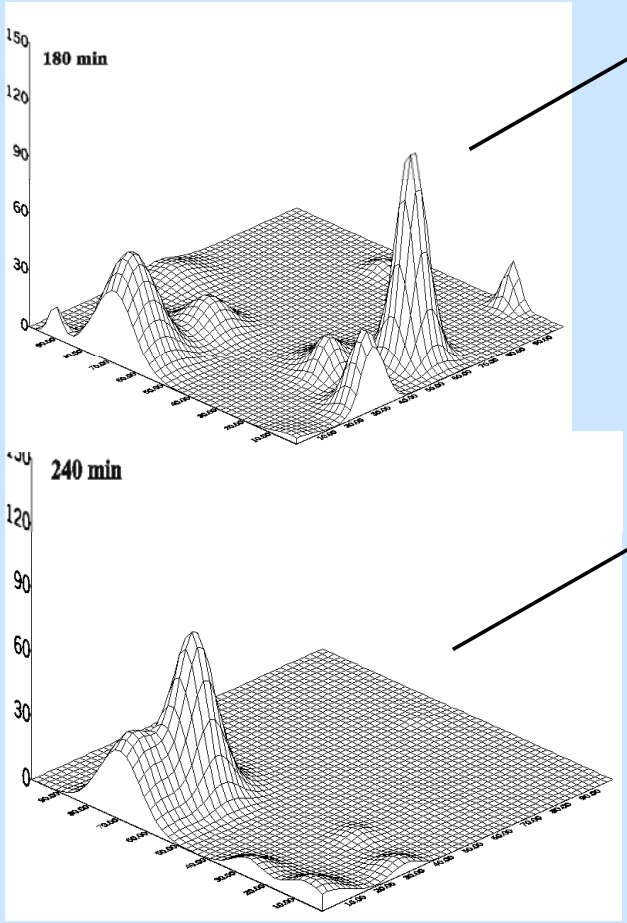

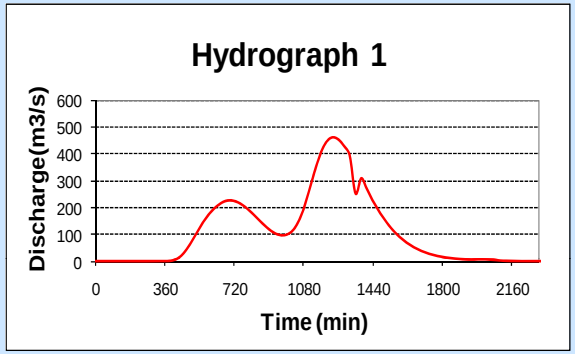

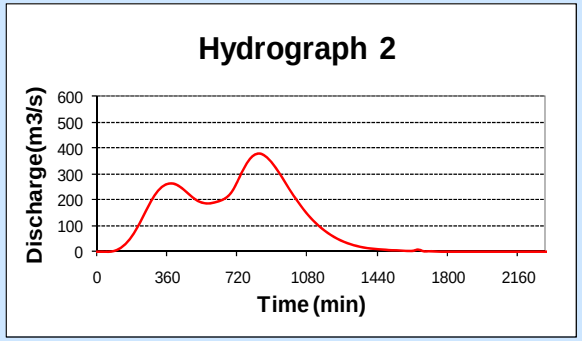

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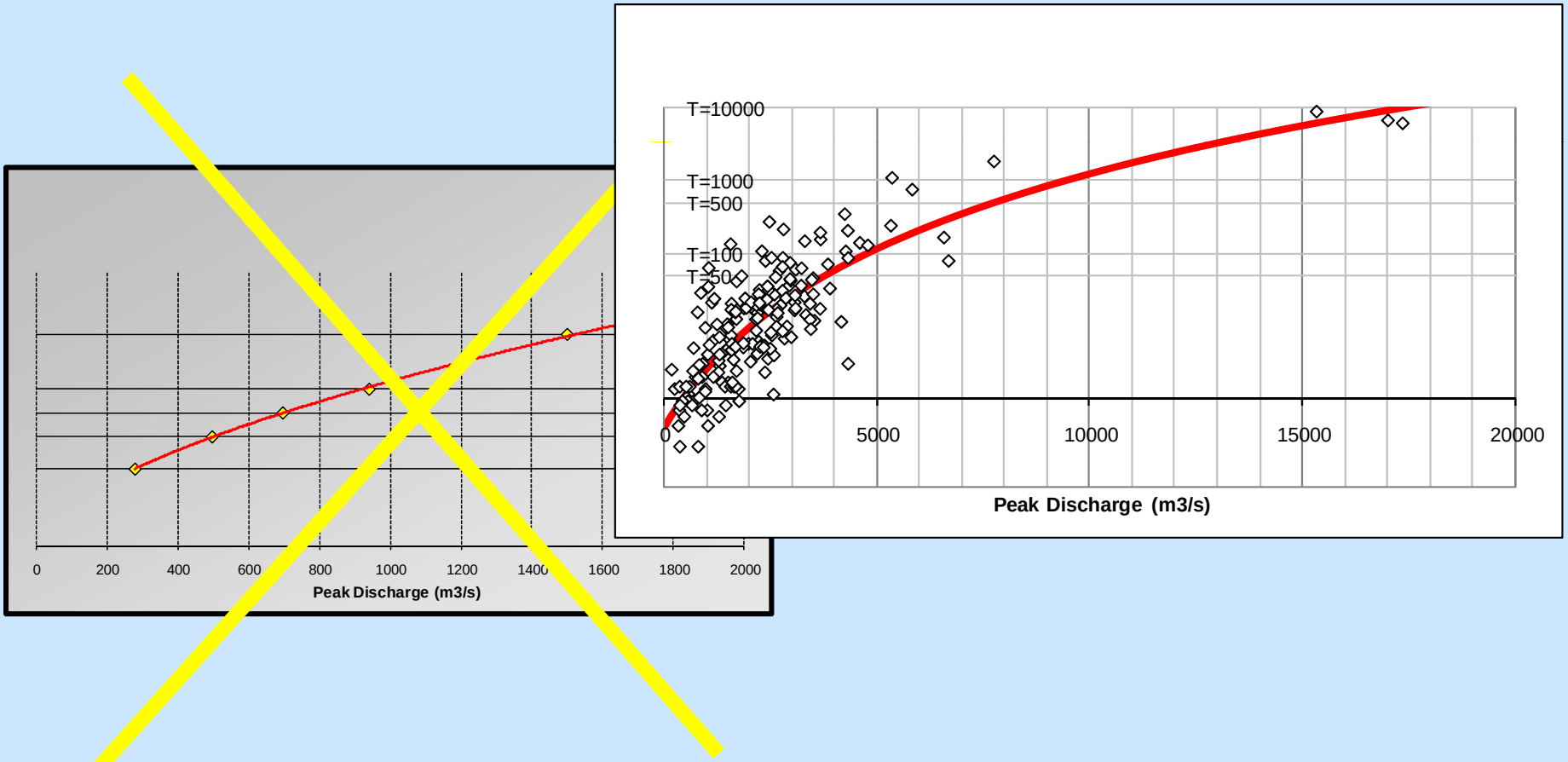

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Introduction

- Model requirements
  - Realistic spatial and temporal rainfall distribution, similar to observed patterns
  - Ability to generate high return period events
  - Connection to distributed rainfall-runoff models

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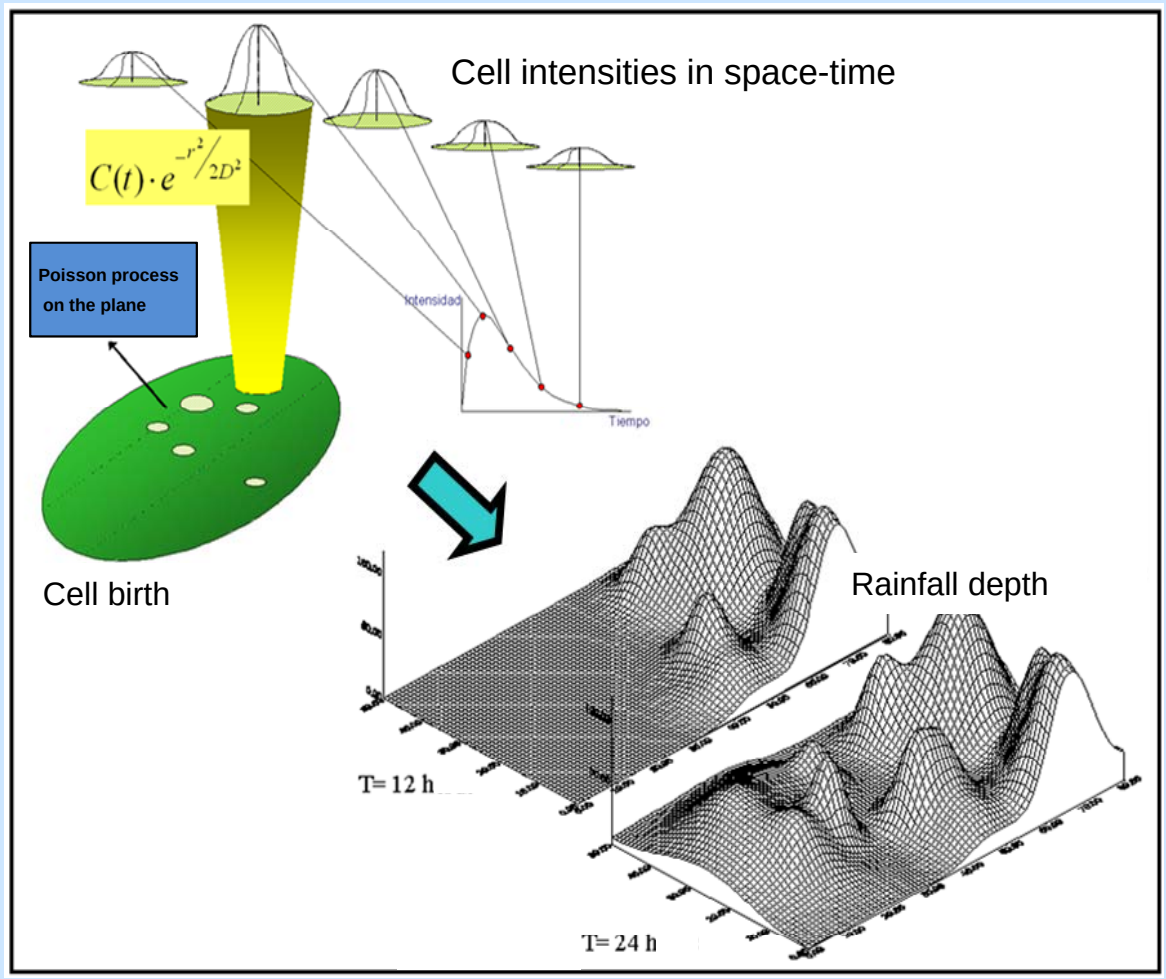
RAINGEN Model

- Event based
- Stochastic model
- Multidimensional
- Convective cell as rainfall generating unit
- Random birth in time and space
- Spatial and temporal attenuation of cell intensity



$$C(t) \cdot e^{-r^2/2D^2}$$

Poisson process on the plane

Intensity

Time

$$C(t^*) = i'_0 \cdot t^* \cdot e^{-\varphi \cdot t^*}$$

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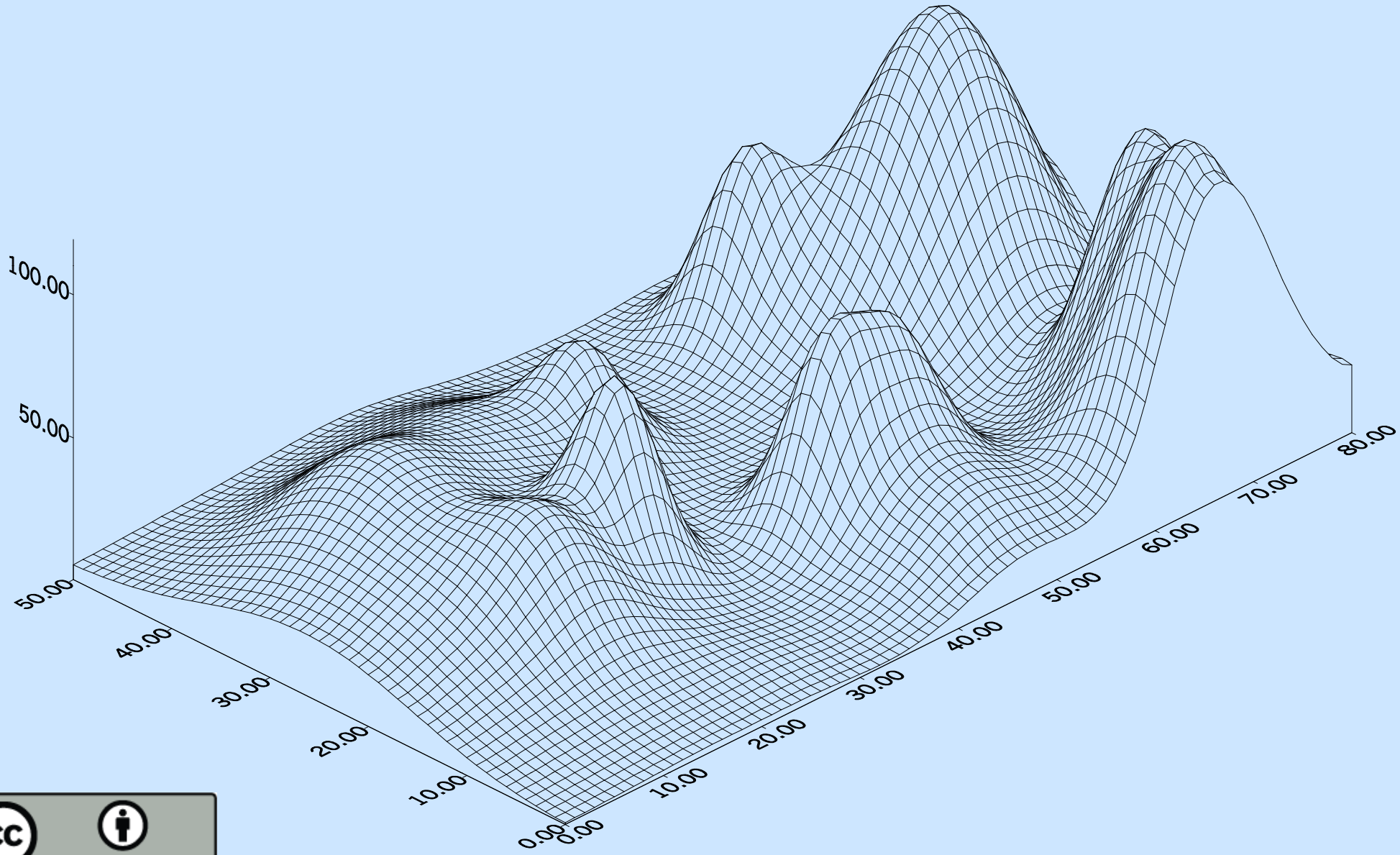
FWF Der Wissenschaftsfonds.

Vienna Doctoral Programme on Water Resource Systems



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RAINGEN Model

- Summary of model parameters
  - Cell birth
    - Spatial (Poisson) λ
    - Temporal (Erlang) n,β
  - Cell intensity
    - Maximum (Exponential) $E[i_0]$
    - Spatial structure (Gamma) δ,θ
    - Temporal structure φ

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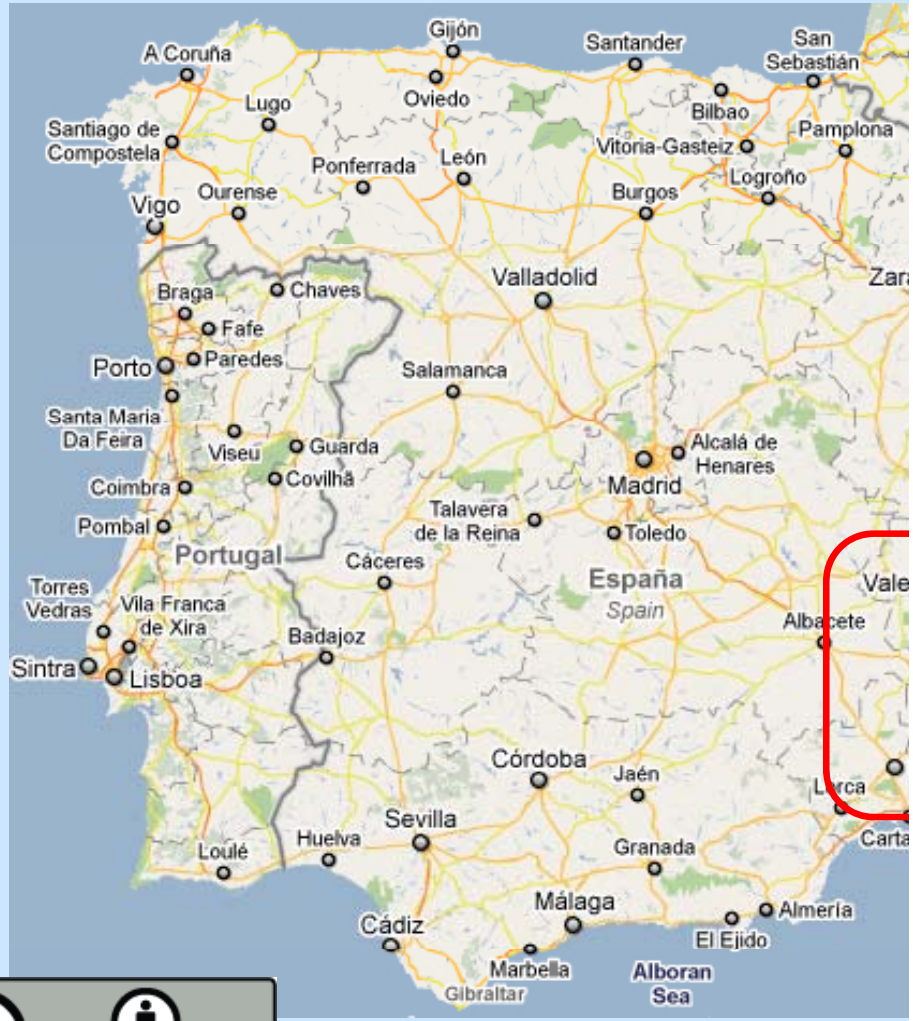
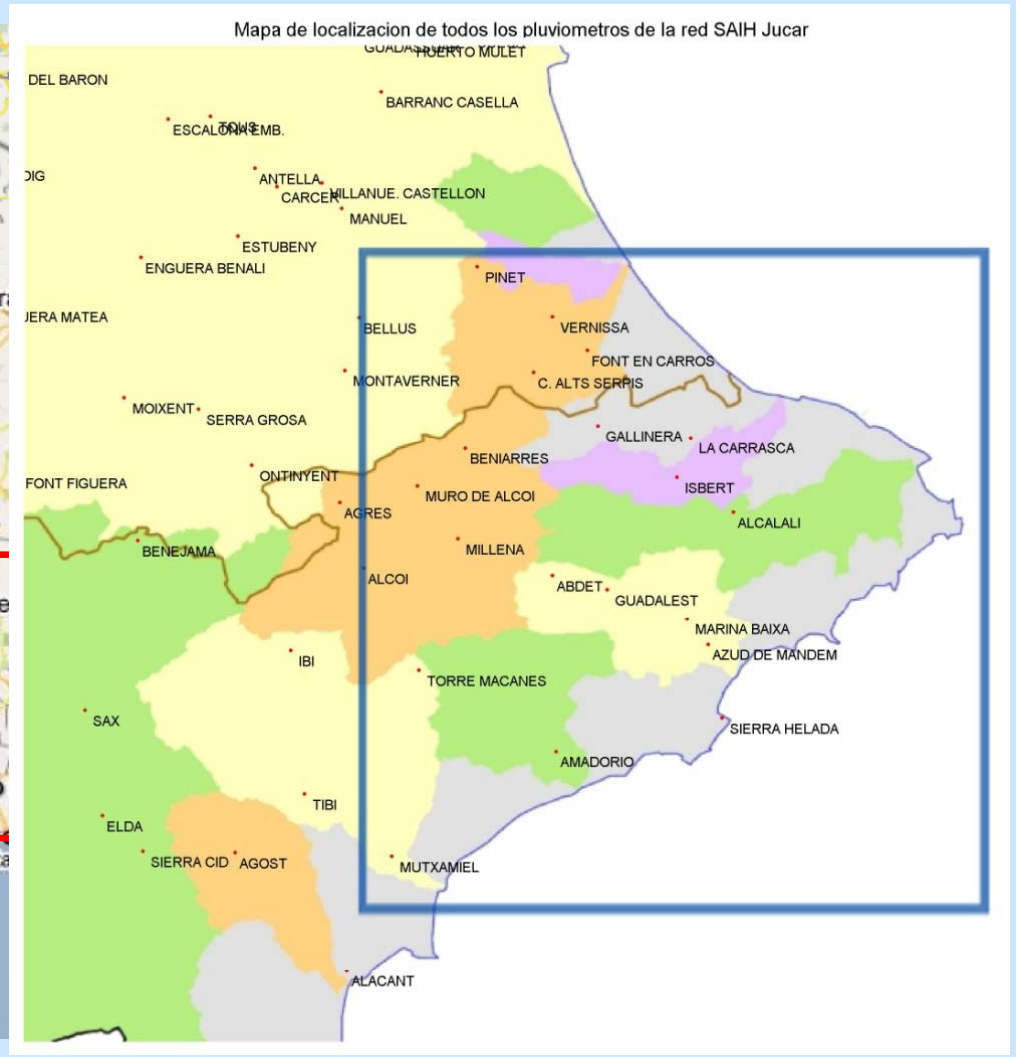
Events analysis





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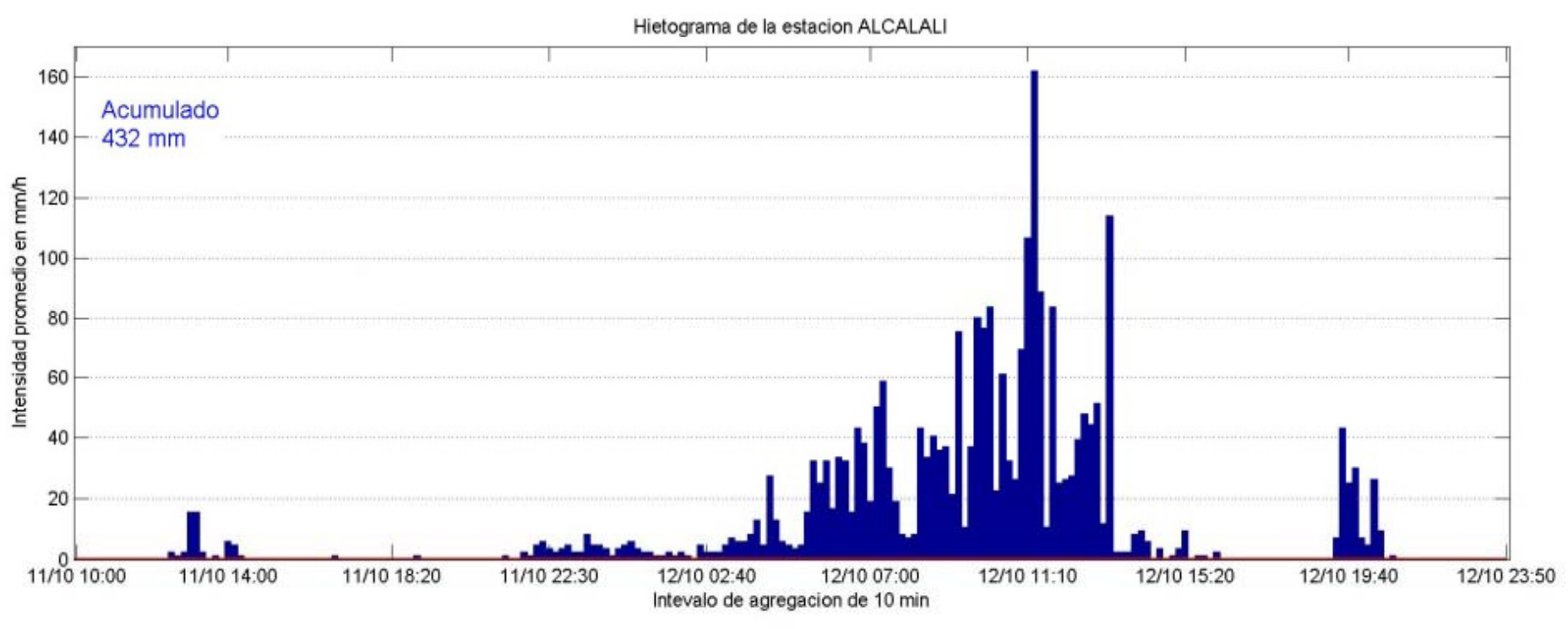
Events analysis

- Event selection

- 11-12 November 1999
- 23-25 October 2000
- 14-16 February 2001
- 6-8 May 2002
- 15-16 April 2003
- 17 November 2003
- 11-12 October 2007
- 9 October 2008
- 27-29 September 2009

Events analysis

- Data record



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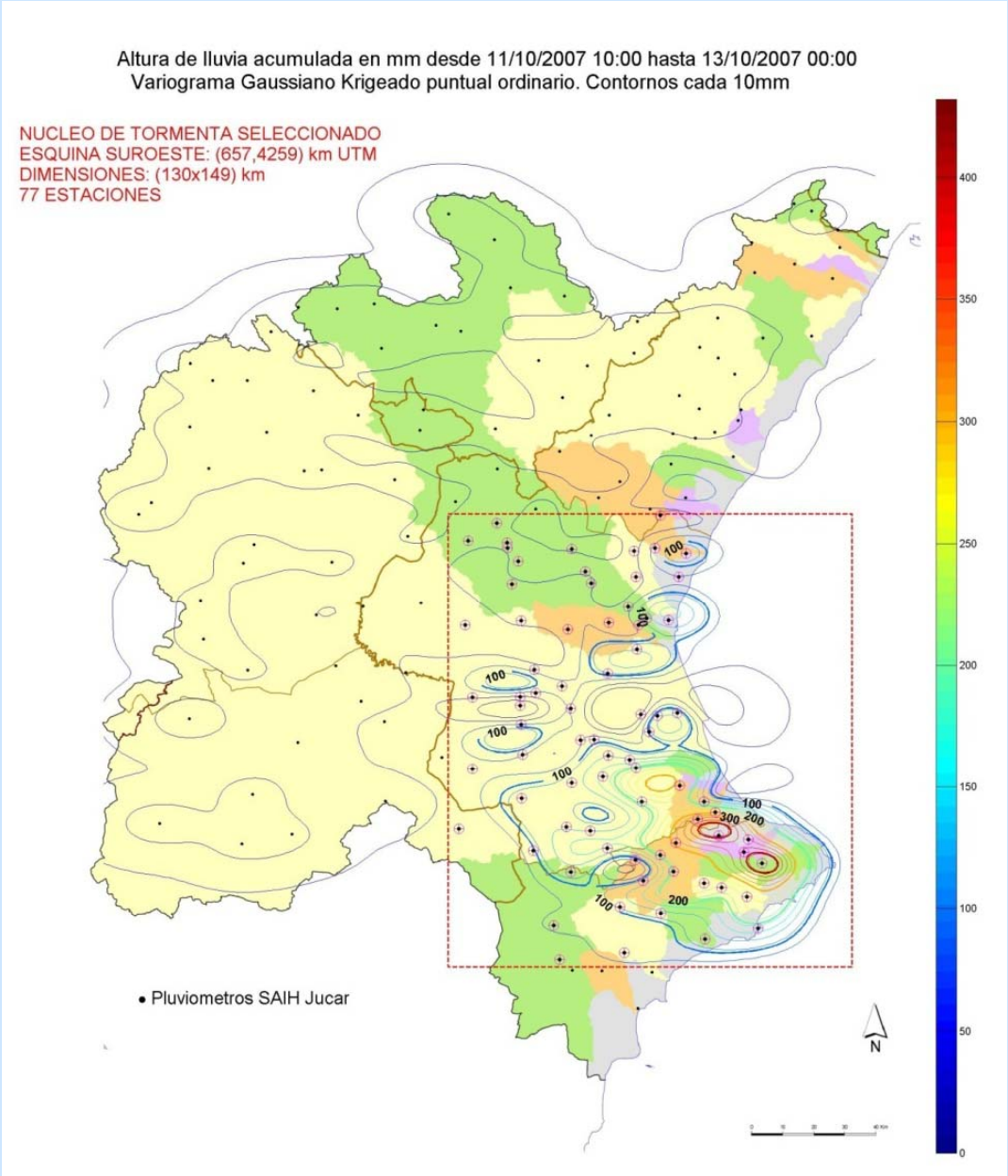
Events analysis

- Event visualization (kriging)
- Total rainfall depth and averaged intensities
- Selection of storm area



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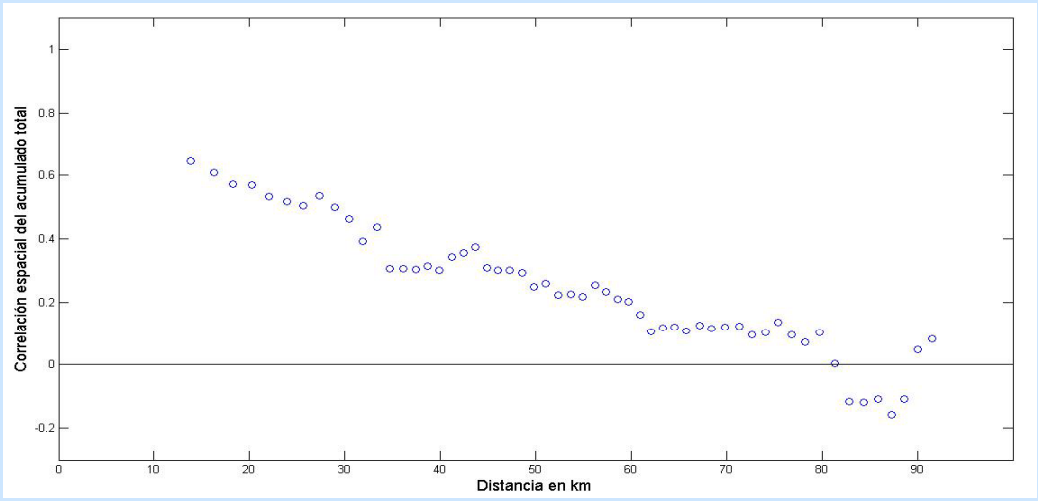
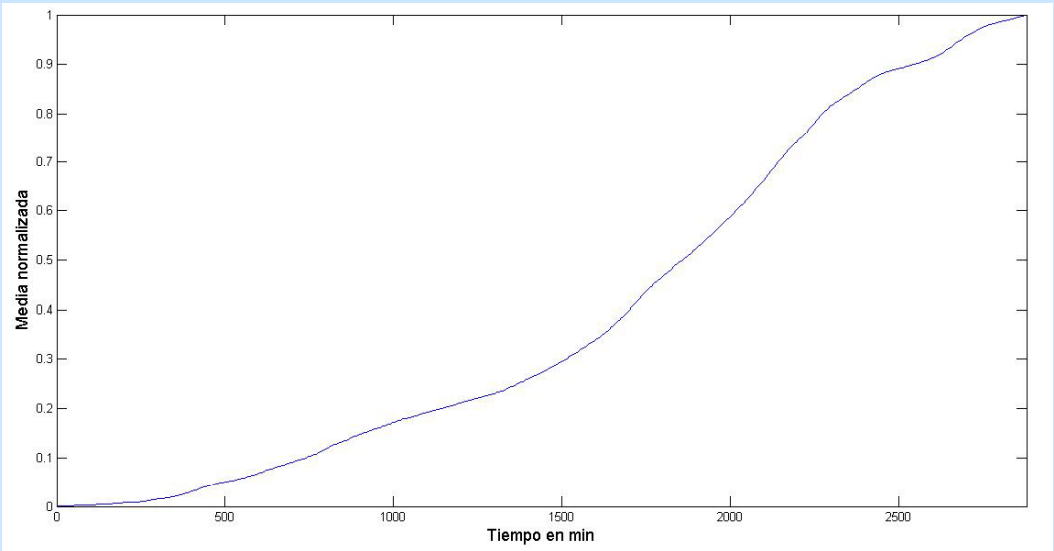
Events analysis

- Event duration
- Expected value of the final rainfall depth
- Variance of the final rainfall depth
- Spatial correlation of the final rainfall depth
- Normalized mean function





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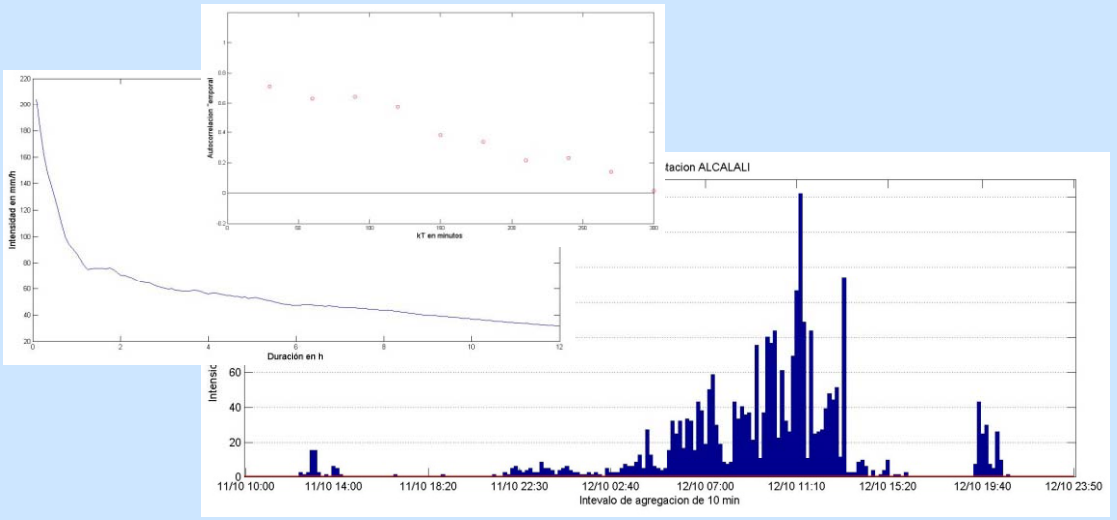
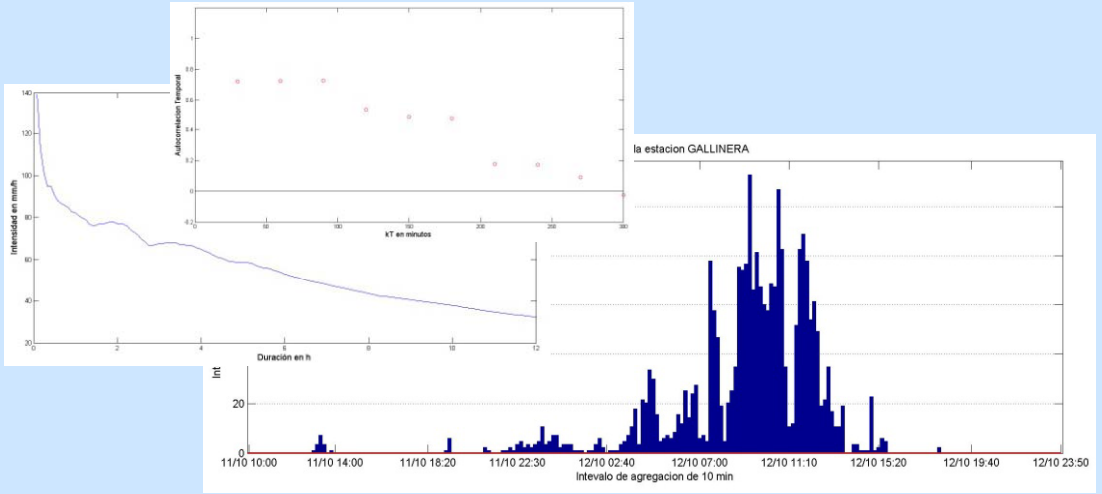
Events analysis

- 4 most representative stations
- Empirical ID curves
- Temporal autocorrelation function





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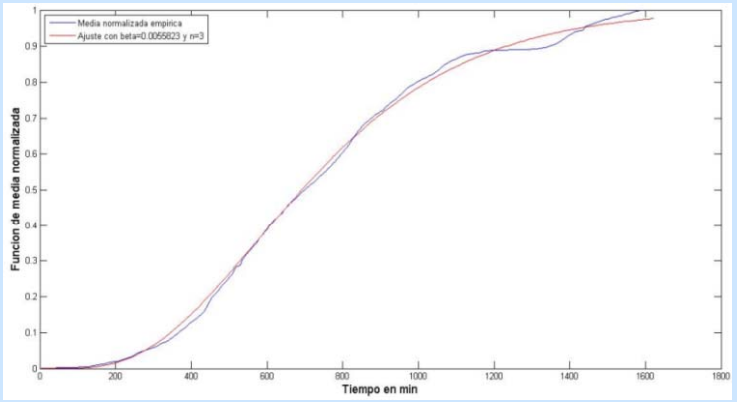
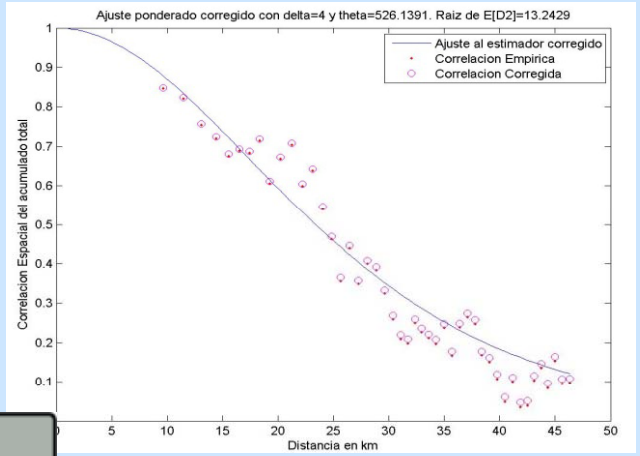
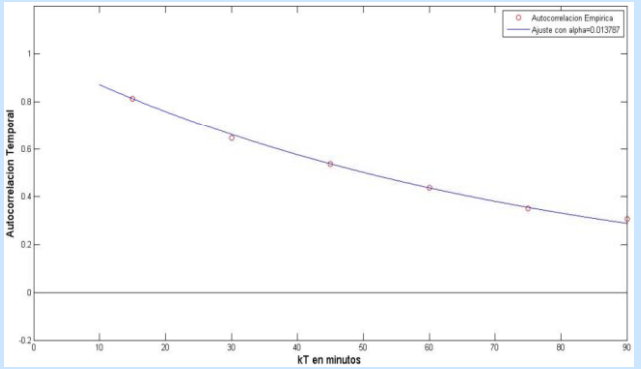
Parameter Estimation

- Analytical expressions of the moments derived from the model
- Method of moments







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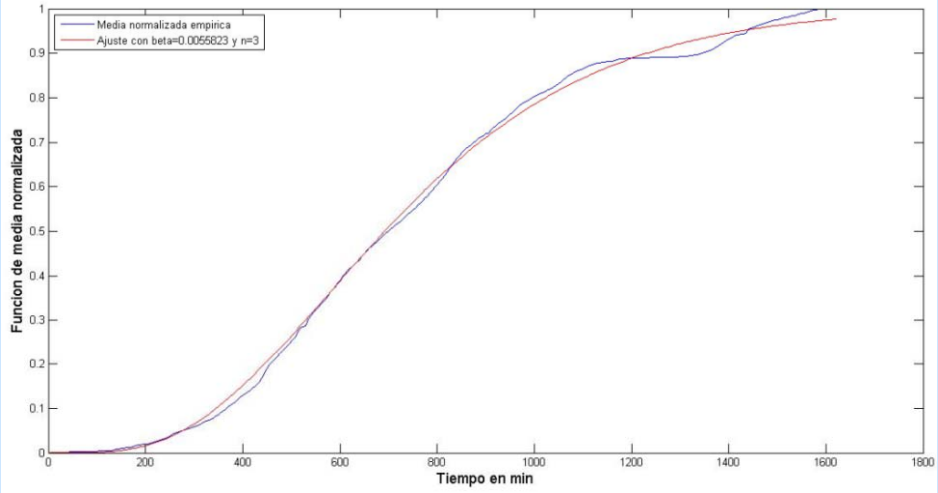
Parameter Estimation

- Normalized mean function



$$\mu(T,\varphi,\beta,n)=\frac{E[h(T,\boldsymbol{z})]}{E[h(\infty,\boldsymbol{z})]}=1+\frac{(-1)^n\beta^{n+1}\varphi}{k^{n+1}}\left[T+\frac{1}{\varphi}+\frac{n+1}{k}\right]e^{-\varphi T}-$$
$$-\frac{\varphi^2\beta^n}{k^2n!}\left[T^n+\sum_{j=1}^{n}\frac{\prod_{i=0}^{j-1}(n-i)}{\beta^j k^j}\left(\sum_{q=0}^{j}(-1)^q(q+1)\beta^q k^{j-q}\right)T^{n-j}\right]e^{-\beta T}$$

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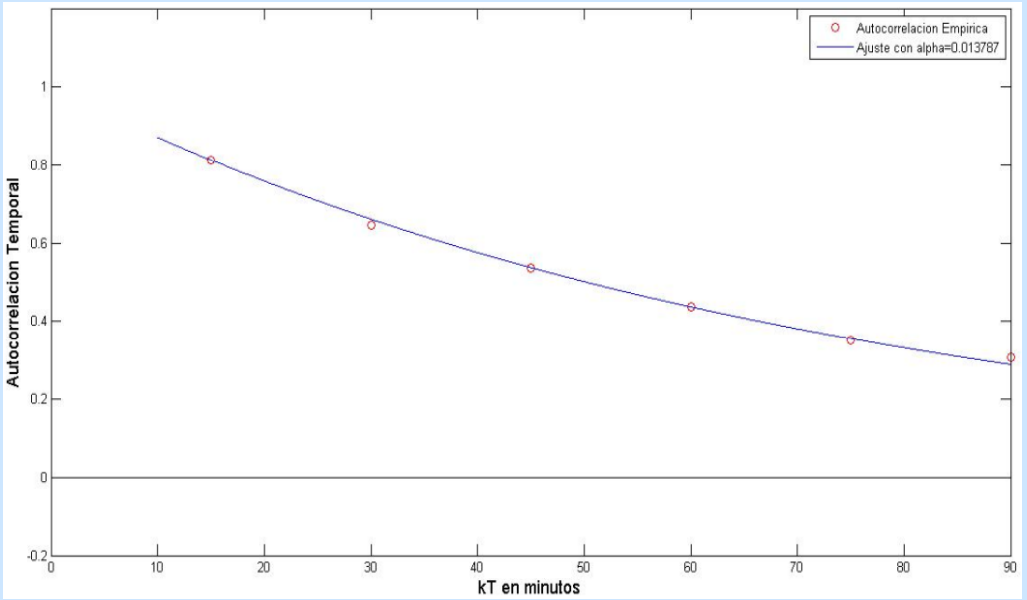
Parameter Estimation

- Temporal autocorrelation function



$$\frac{Cov\left[\xi^{(T)}(t,\boldsymbol{z});\xi^{(T)}(t+kT,\boldsymbol{z})\right]}{Var\left[\xi^{(T)}(t,\boldsymbol{z})\right]} == e^{-\alpha\cdot kT}$$

$$\varphi = e \cdot \alpha$$

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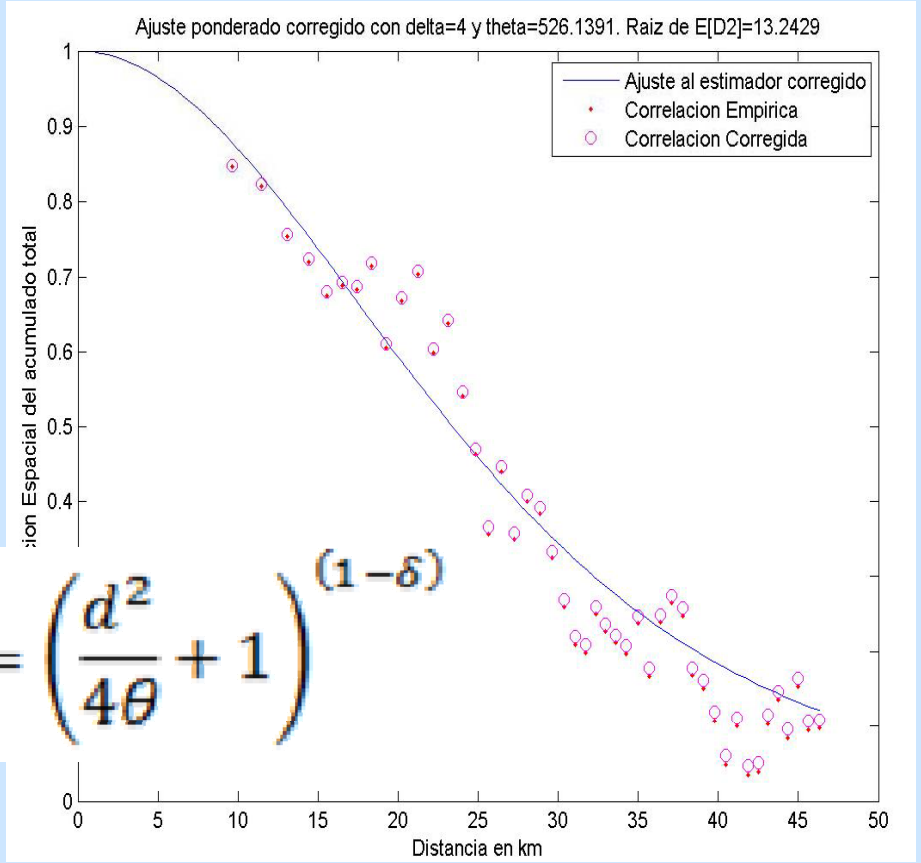
Parameter Estimation

- Spatial correlation function



$$\rho(d) = \frac{Cov[h(\infty, \boldsymbol{z}_1); h(\infty, \boldsymbol{z}_2)]}{Var[h(\infty, \boldsymbol{z})]} = \left(\frac{d^2}{4\theta} + 1\right)^{(1-\delta)}$$

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Parameter Estimation

$$\lambda = \frac{1}{2\pi E[D^2]} \frac{(E[h(\infty, \boldsymbol{z})])^2}{\hat{Var}_C[h(\infty, \boldsymbol{z})]}$$

$$E[i_0] = \frac{\alpha}{2\pi\lambda E[D^2]} E[h(\infty, \boldsymbol{z})]$$

Parameter Estimation

- Values of the estimated parameters

EVENTO	δ	θ	λ	α	β	n	E[i_o]
		km^2	km^{-2}	min^{-1}	min^{-1}		mm/min
NOV_99	6.95	574.04	1.602E-03	2.177E-02	5.582E-03	3	1.08
OCT_00	1.50	48.41	6.157E-03	1.531E-02	1.467E-03	1	0.65
FEB_01	3.45	186.38	4.399E-03	1.167E-02	2.500E-03	2	0.38
MAY_02	8.40	1011.14	1.205E-03	8.889E-03	3.967E-03	6	1.09
ABR_03	2.10	3.01	1.043E-01	1.451E-02	5.494E-03	4	0.84
NOV_03	3.40	55.58	8.256E-03	2.503E-02	4.942E-03	2	0.86
OCT_07	4.35	863.68	1.127E-03	2.080E-02	7.685E-03	6	1.45
OCT_08	4.40	606.05	1.283E-03	5.544E-02	2.278E-03	1	2.46
SEP_09	2.30	383.75	1.118E-03	6.052E-02	3.228E-03	5	3.19

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Events generation

- Rectangle 60x65 km
- Resolution 1x1 km

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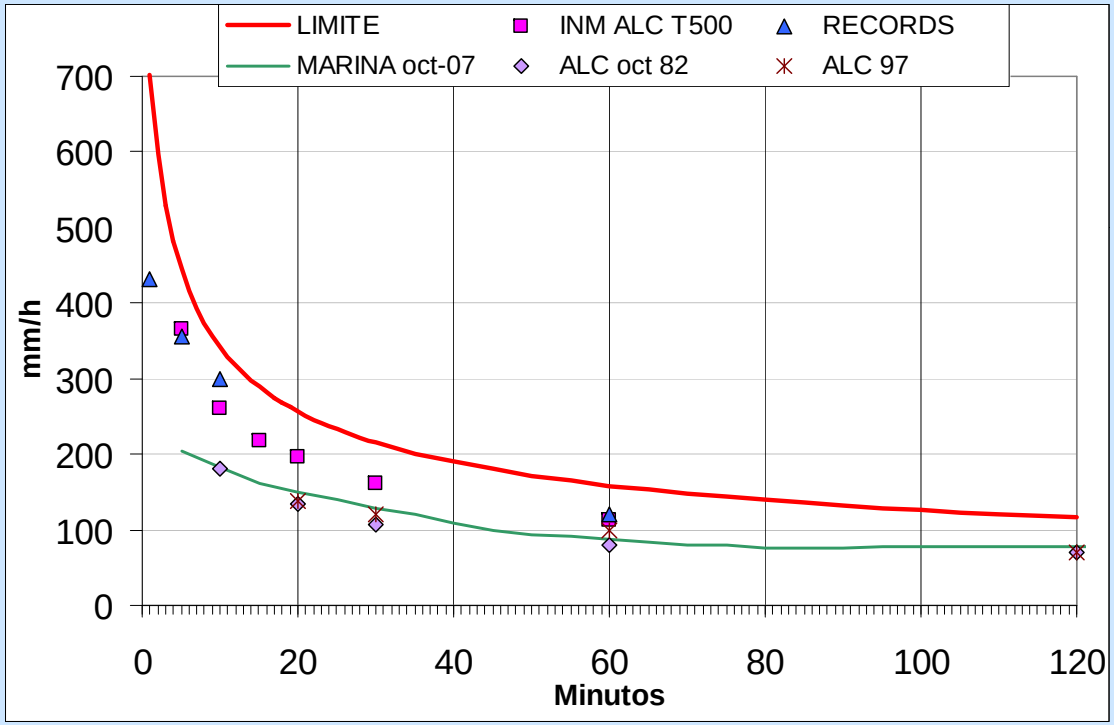
Events generation

- Parameters values for the generation
  - Cell birth
    - Spatial (Poisson) λ $[0.0011 ; 0.0083]\ km^{-2}$
    - Temporal (Erlang) $n \in [1 ; 6]$, β $[0.00101 ; 0.00901]\ min^{-1}$
  - Cell intensity
    - Maximum (Exponential) $E[i_0] \in [60.2 ; 150.1]\ {}^{mm}/_{h}$
    - Spatial structure (Gamma) $\delta = 3.81$ and $\theta = 235.12\ km^2$
    - Temporal structure $\alpha \in [0.0801 ; 0.0130]\ min^{-1}$

Events generation

- Pixel scale filter to eliminate storms with unrealistic intensities, physically impossible

- Majorated regional envelope curve (historical intensities records



- approx. 85% pass the filter

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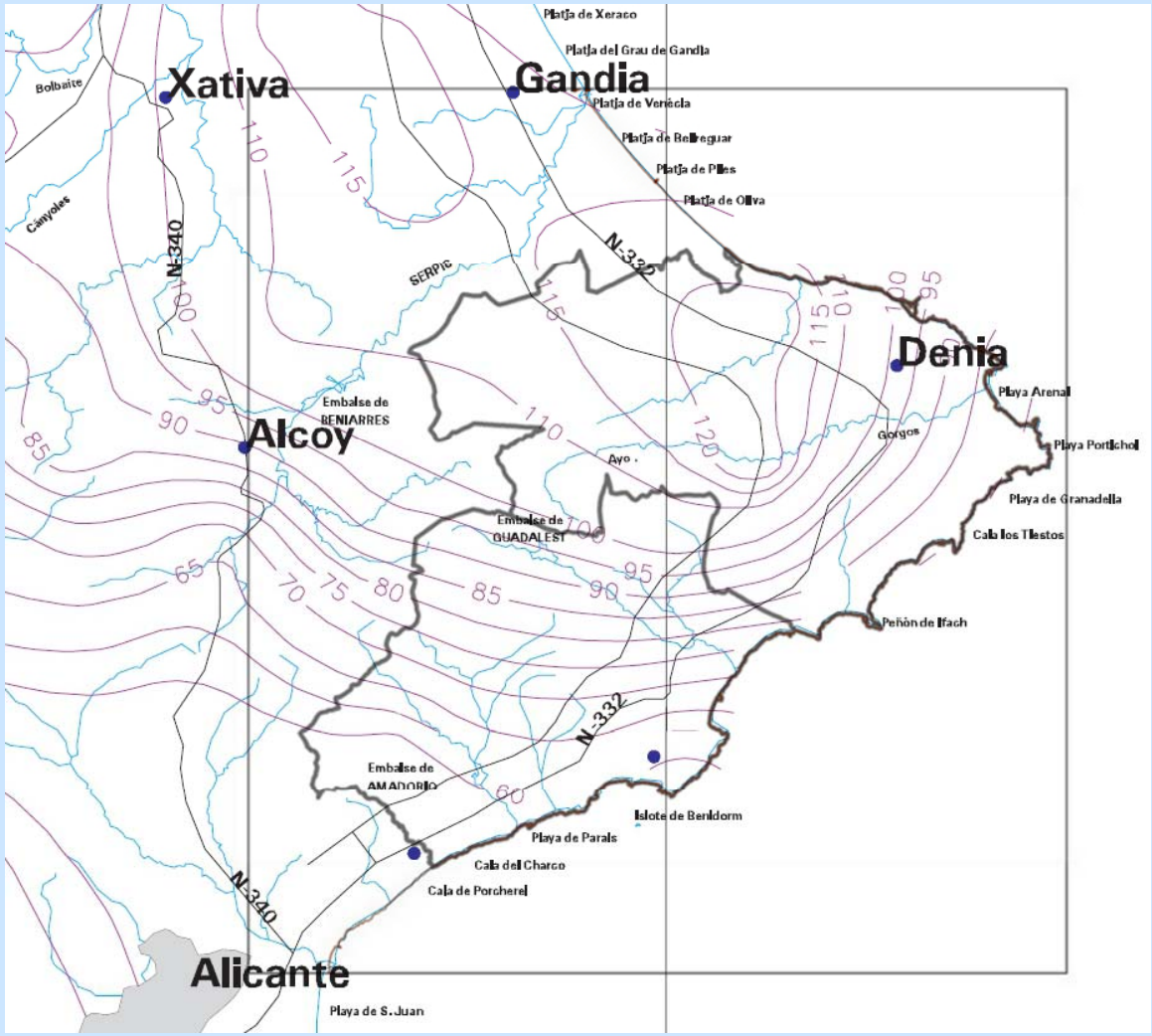
Events generation

- Return period assigned to synthetic storms
- Regional rainfall statistics



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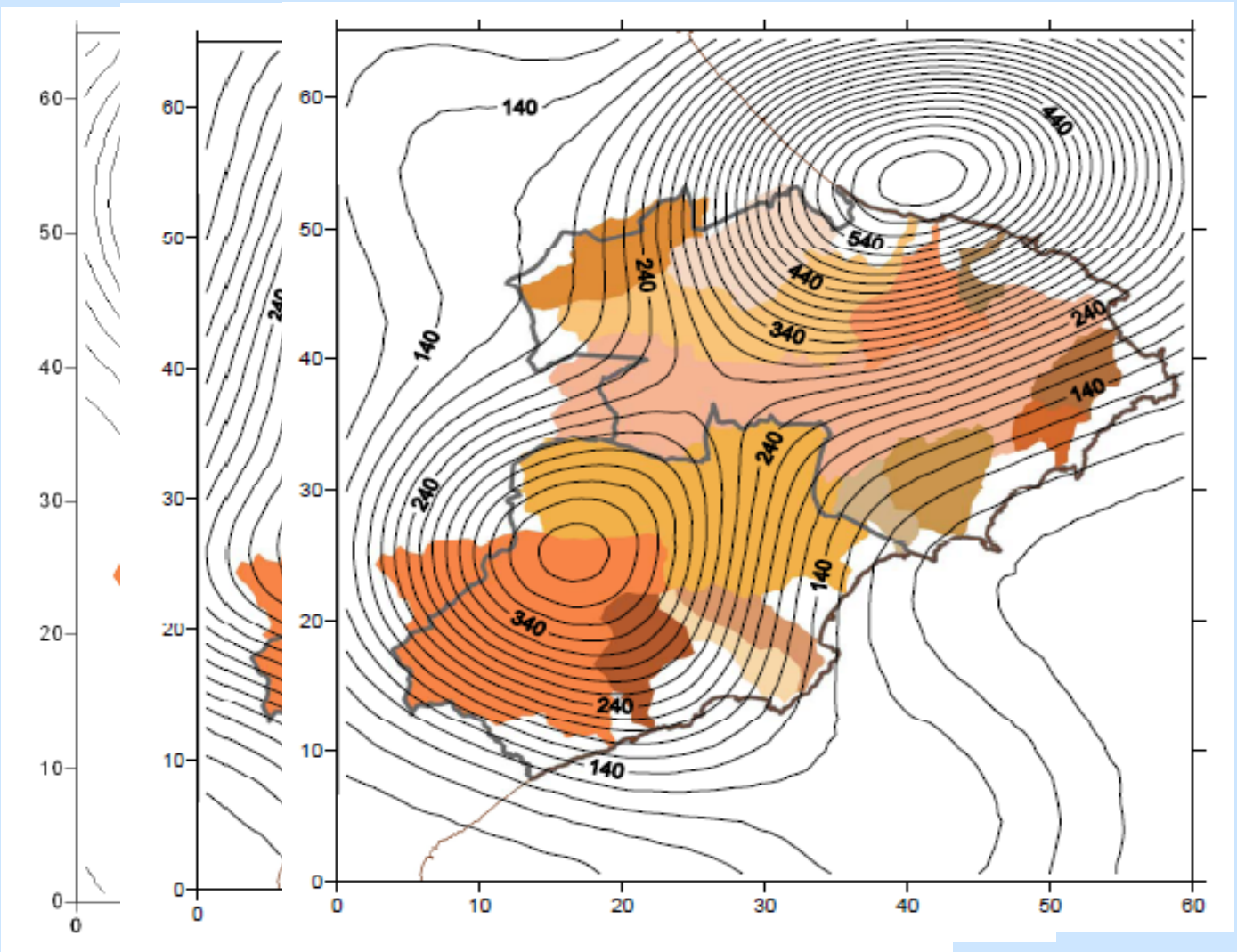
Events generation

- Around 400 storms selected
- Main statistics
- Contour plots
- Format for rainfall-runoff



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Conclusions & Outlook

- The RAINGEN conceptual model reproduces in a satisfactory way the empirical statistics and the observed rainfall patterns
- In every analyzed storm an optimum set of parameters could be found
- Though improbable, the model can generate unreal rainfall intensities (cell clustering)
- Next data source for parameter estimation: RADAR

Thank you for your attention

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