Expanding information for flood frequency analysis using a weather generator and distributed hydrological modelling in a Spanish Mediterranean catchment

By:

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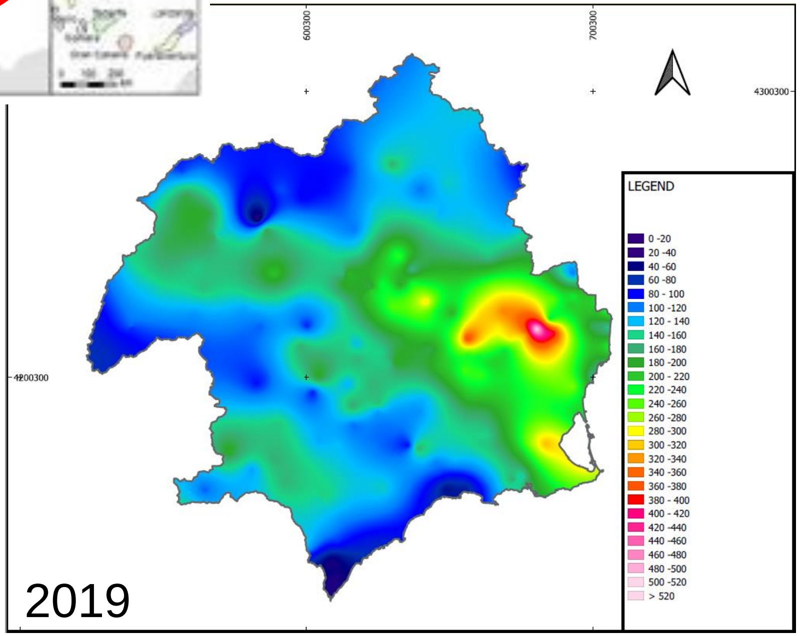
Introduction

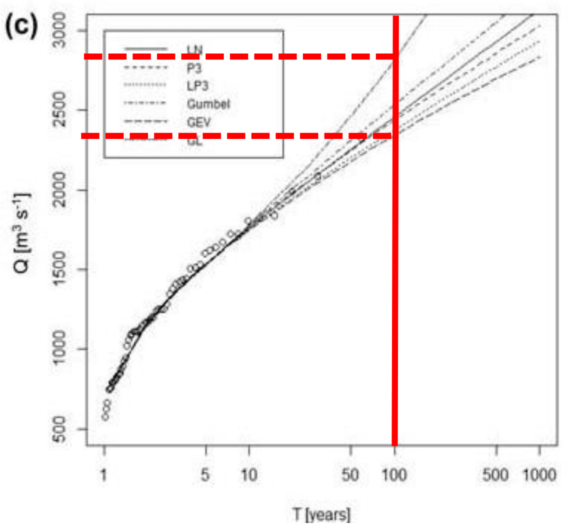
- **Spanish Mediterranean catchments**
  - Semi-arid climate
  - Mesoscale Convective Systems (MCSs)
    - High spatio-temporal rainfall variability distribution
  - Ephemeral rivers
  - Short hydrometeorological records for High T



Complicates even more
Flood Frequency Estimation (high return period flood quantiles)

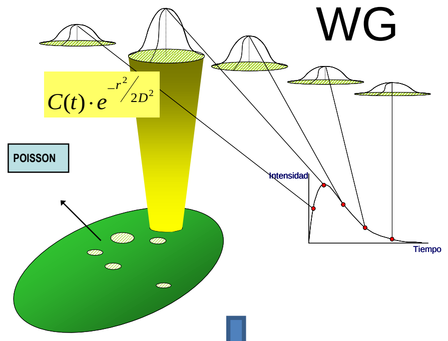
Introduction

- Three main methods to estimate high return period flood quantiles, they can be roughly grouped into the following 3 categories:
  - Statistical or probabilistic (Q_{obs})
  - Deterministic (Design Storm)
  - Hybrid or mixed

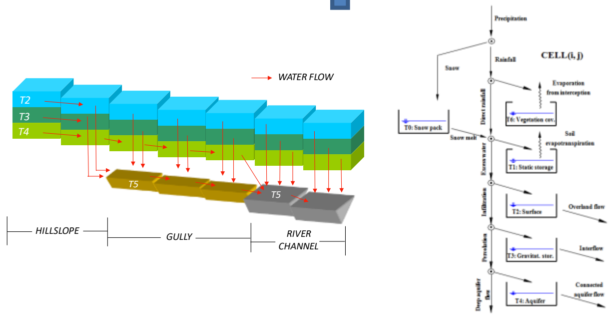


Continuos Simulation

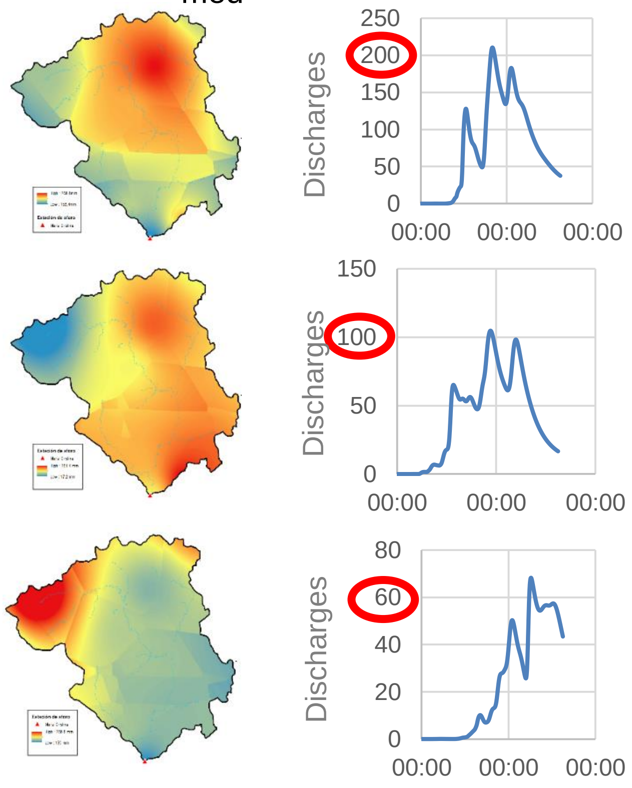
WG



HM



Duration: 78h, P_{med}=169,2mm



To present a new methodology that:

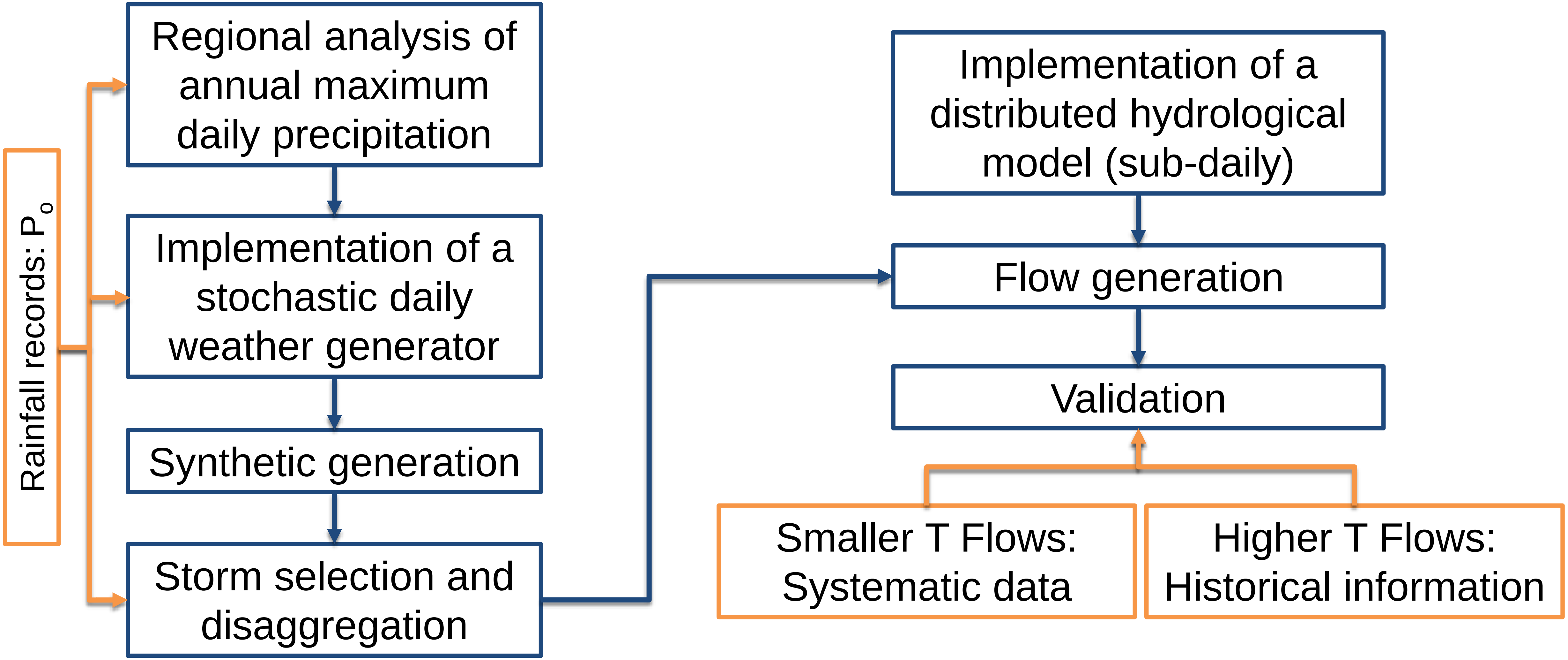
1) integrates different sources of information

2) generated from hydrometeorological models with an adequate space-time discretization

3) for a proper characterization of the flood frequency analysis of the main variables in the Spanish Mediterranean region

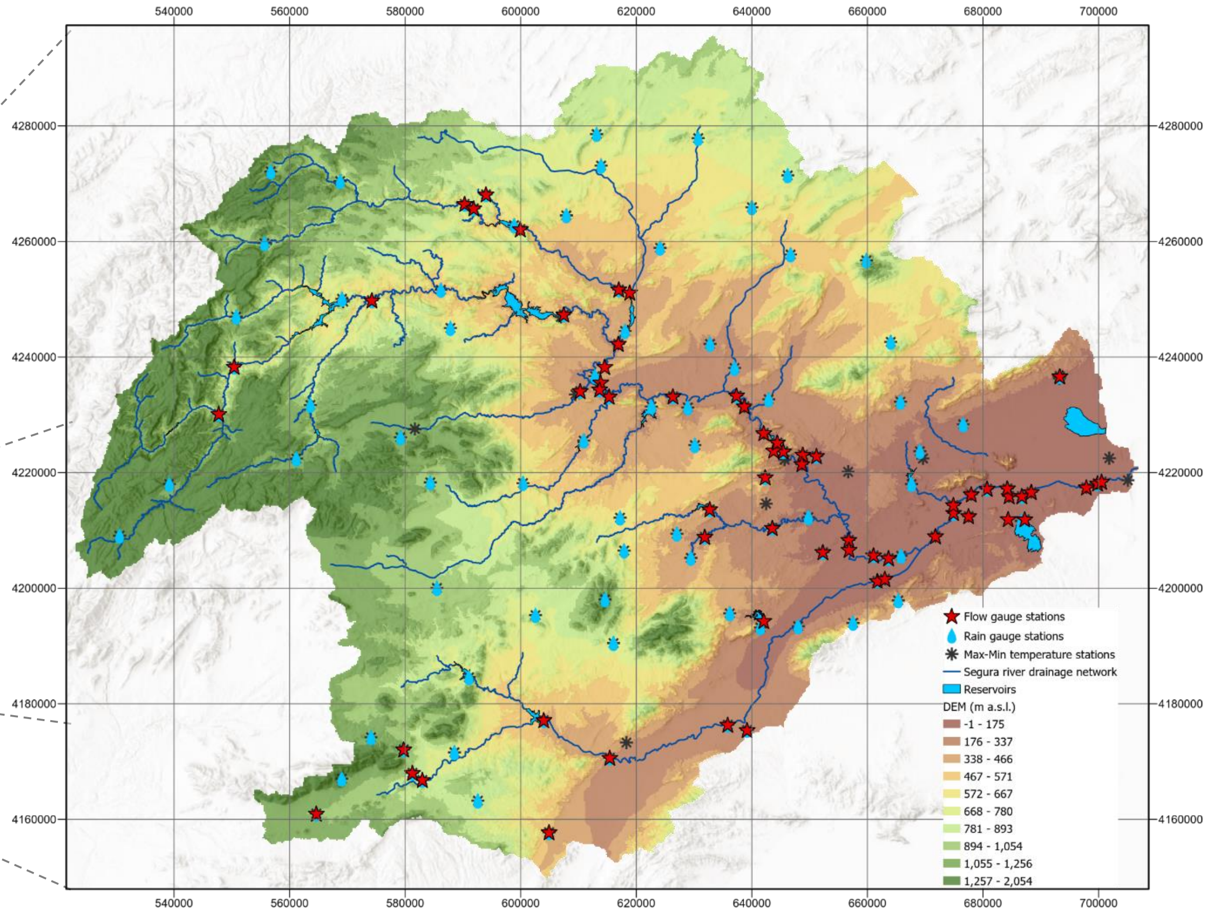
Case Study: Segura River basin

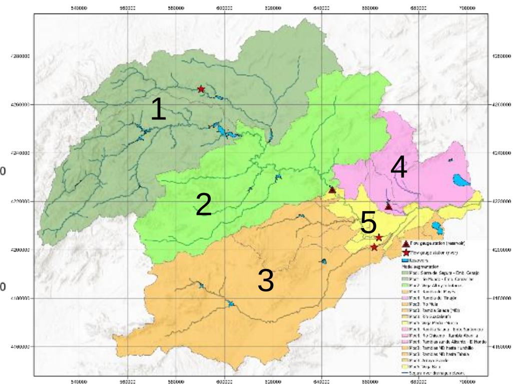
Methodology



Study area

❑ Segura River basin



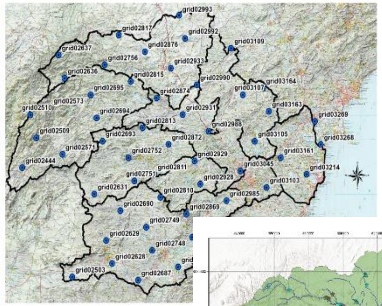


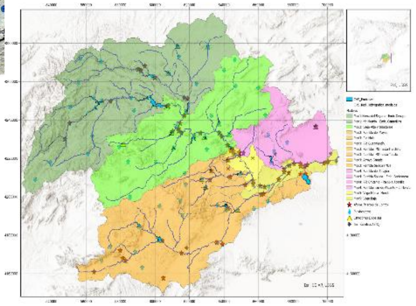
Hydrological model	Geodetic Area (Km^2)
1	5,099.12
2	3,635.68
3	4,378.96
4	1,295.45
5	646.63
Total catchment area	15,055.84

16 Reservoirs
56 River transfers

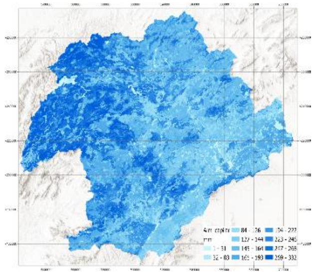
Study Area: hydrometeorological and spatial information

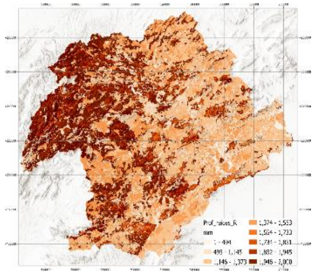
- River basin Water Authorities: 49 rain gauges and 83 flow gauges
- State Meteorology Agency (AEMET): 273 daily rain gauges
- SPAIN02-V2 (1951-2015)(*Herrera et al., 2016; Kotlarski et al., 2017*): 52 grids



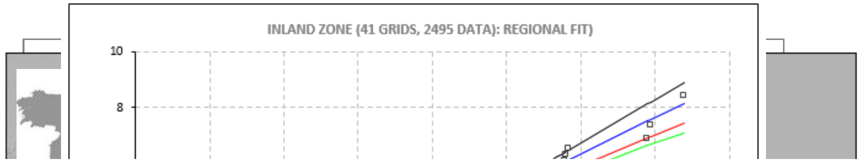


- Segura River basin Water Authority
- Spanish National Geographic Institute http://centrodedescargas.cnig.es/
- SoilGrids250m *(Hengl et al., 2017)* y 3D Soil Hydraulic Database *(Tóth et al., 2017)*
- CORINE https://www.ign.es/web/resources/docs/IGNCnig/OBS-Ocupacion-Suelo.pdf
- SIOSE https://www.siose.es/
- European Soil Data Centre https://esdac.jrc.ec.europa.eu/





Regional study of annual max. P_d



- Definition of elementary grid cells
- Analysis of rainfall records (≥ 30yrs)
- Generation of equivalent data series in each grid
- L-moments estimation
- Discordance analysis
- Homogeneity analysis
- Selection of regional cdf
- Local quantiles

(Hosking & Wallis, 1993, 1997)
(Dalrymple, 1960)

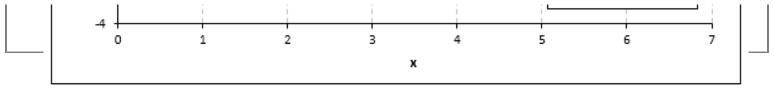
$$X_{i,T} = X_{R,T} \cdot \overline{X_i}$$

where $X_{i,T}$ is the quantile of return period T at location i,

$X_{R,T}$ is the regional quantile of return period T

$\overline{X_i}$ is the mean of the registered data at location i.

Area	Regional GEV Parameters			Dimensionless quantiles for different T (yrs)					
	x_0	α	β	10	25	50	100	200	500
INLAND	0,811	0,311	-0,031	1,535	1,856	2,100	2,348	2,601	2,943
COAST	0,749	0,355	-0,118	1,663	2,126	2,506	2,914	3,357	3,998



Weather generator GWEX

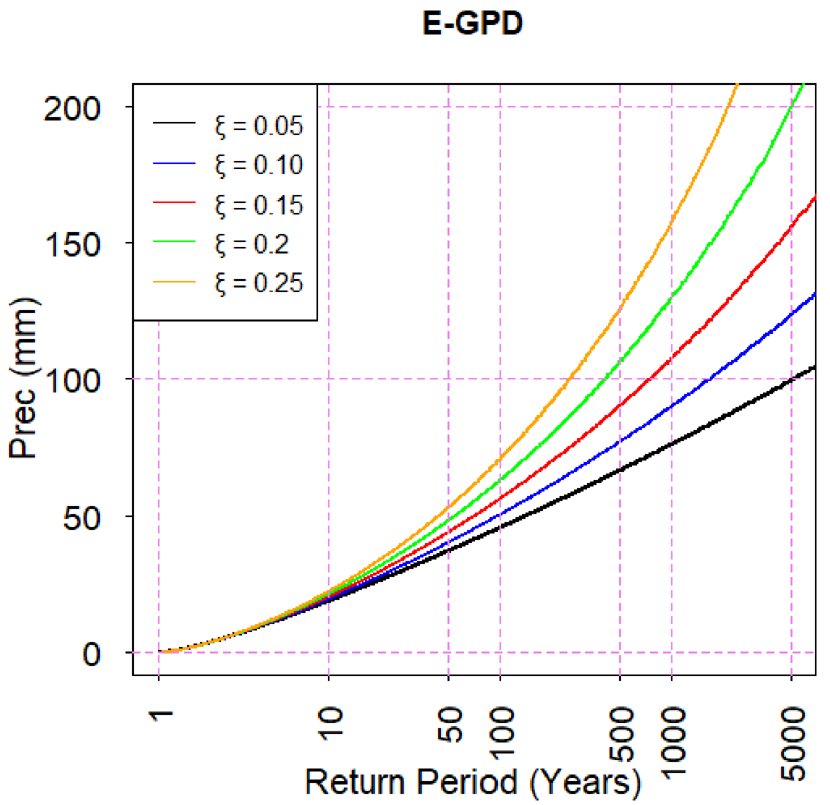
- **GWEX** *(Evin et al., 2018)*
  - Multisite Weather Generator focused on extreme events
  - Precipitation amounts: Extended Generalized Pareto Distribution (E-GPD) (*Papastathopoulos and Tawn, 2013*)

$$F(x;\lambda) = \left[1 - \left(1 + \frac{\xi x}{\sigma}\right)^{-1/\xi}\right]^{\kappa}$$

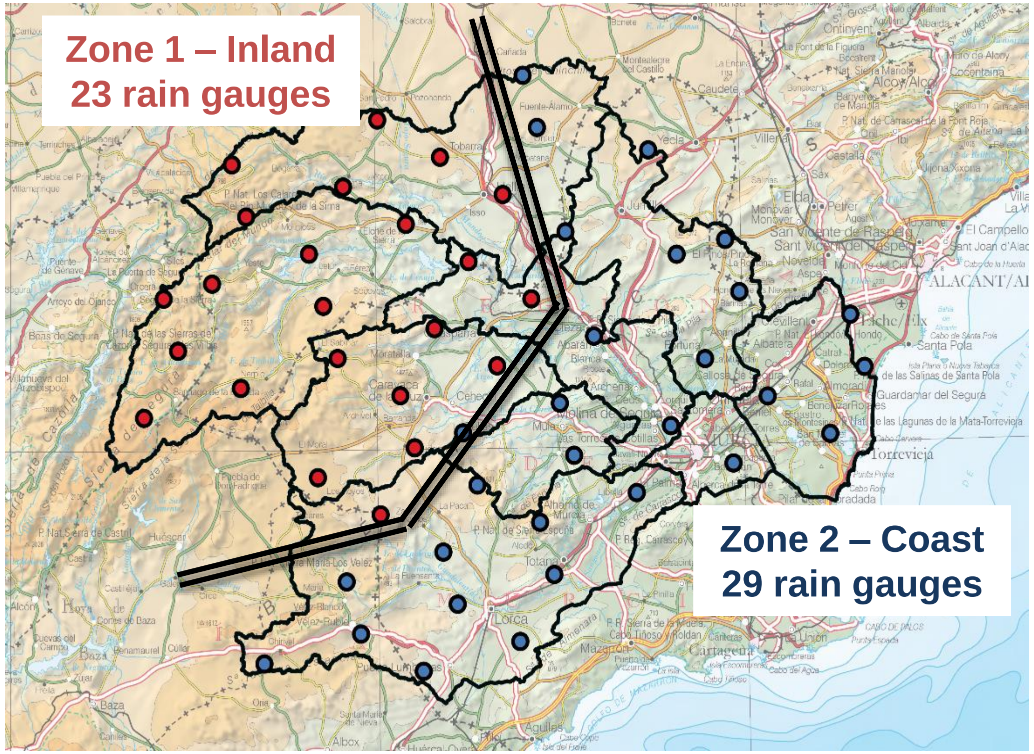
σ → Scale Parameter

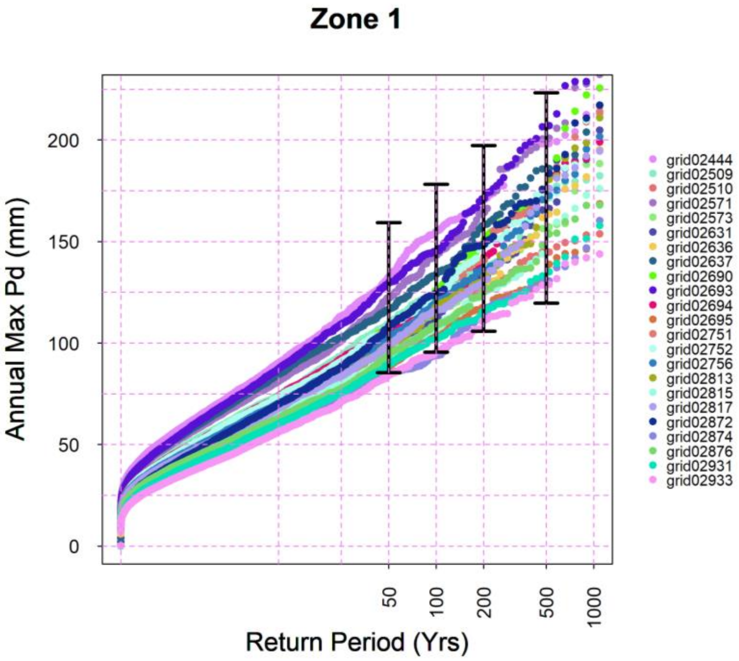
κ → Transf. Parameter

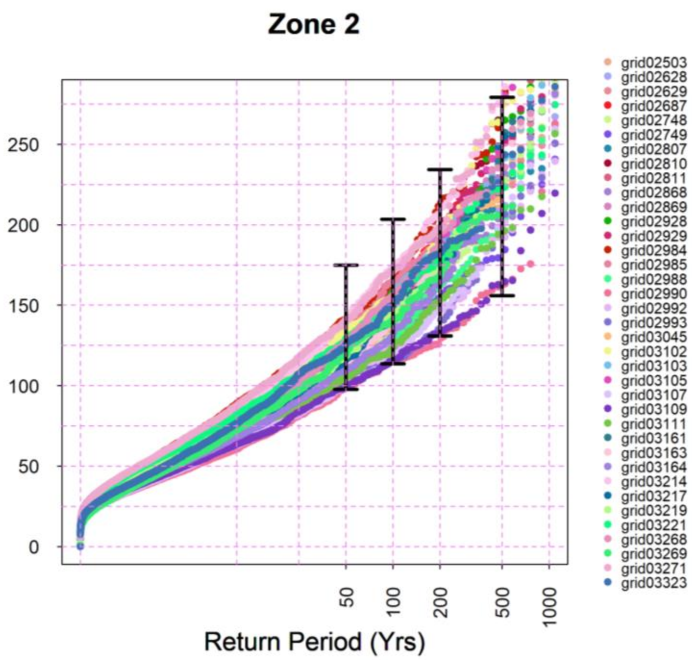
ξ → **Shape Parameter (directly affecting the upper tail)**



Weather generator GWEX - Implementation







	Zone 1 (Inland)	Zone 2 (Coast)
JFMAM	0.08	0.16
JJA	0.1	0.08
SOND	0.16	0.23

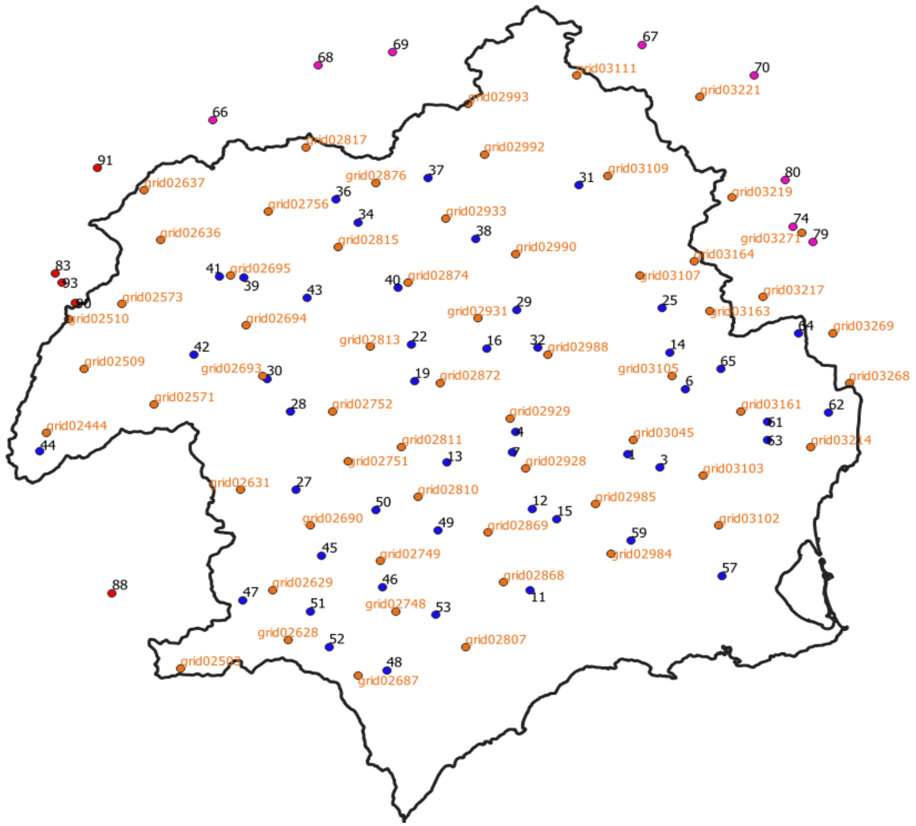
Storm selection and rainfall disaggregation

- Storm Selection
  - 9 sub-catchments + entire catchment
  - 200 biggest storms of each
  - Different date: 698 events

- Disaggregation
  - Spatial-Method of Fragments (MOF)

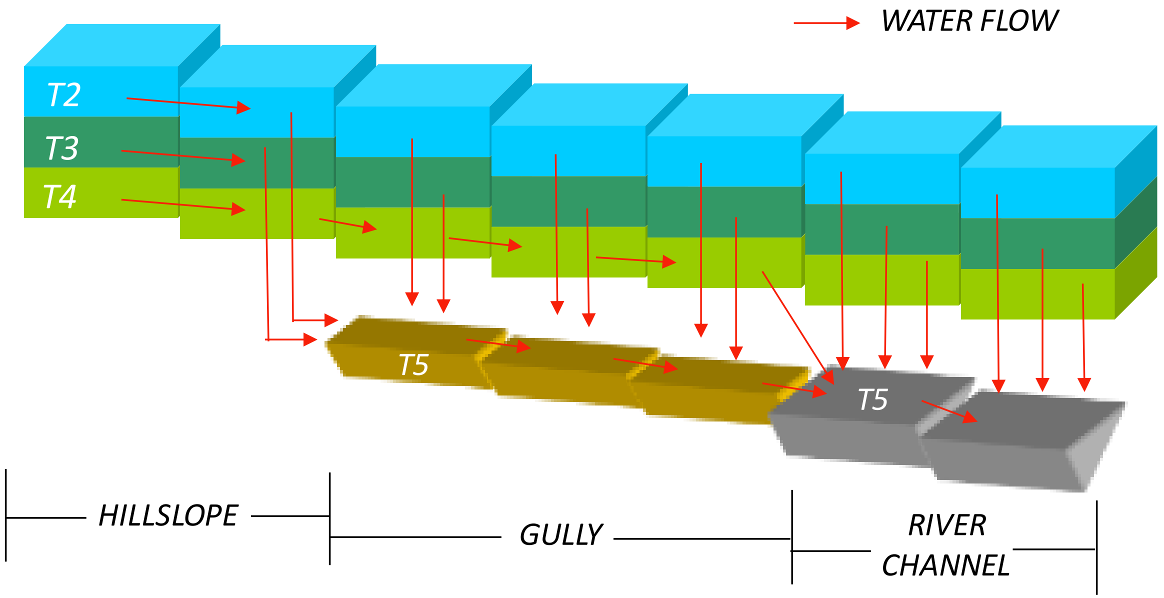
  (Breinl & Di Baldassarre, 2019)

- Validation
  - Torrentiality Factor (FT) *(I. Carreteras 5.2)*



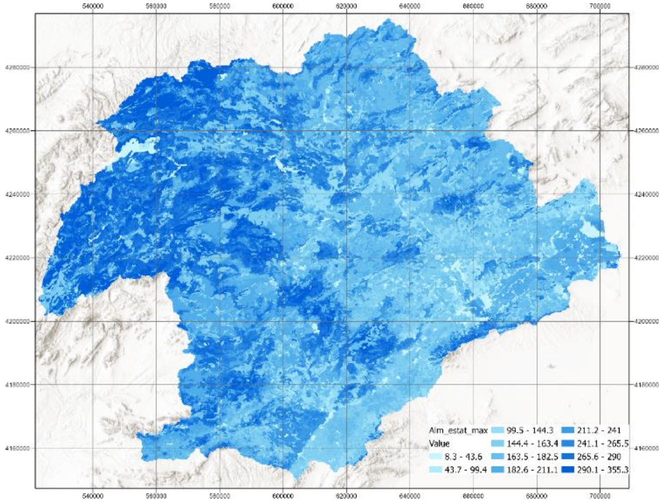
TETIS eco-hydrological model

- **Distributed** in space:
  - Reproduces the spatial variability of hydrological cycle
  - Uses all spatial information available
  - Gives results at any point

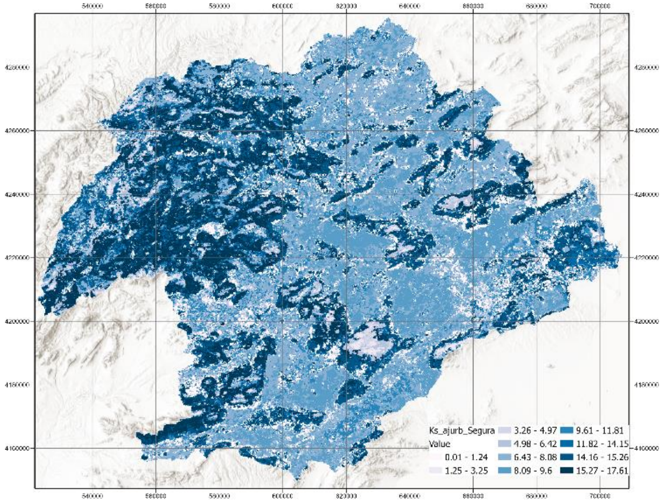


TETIS eco-hydrological model

- Incorporates an **split effective parameter structure** *(Benito and Francés, 1995; Francés et al., 2007)*



✖ FC1

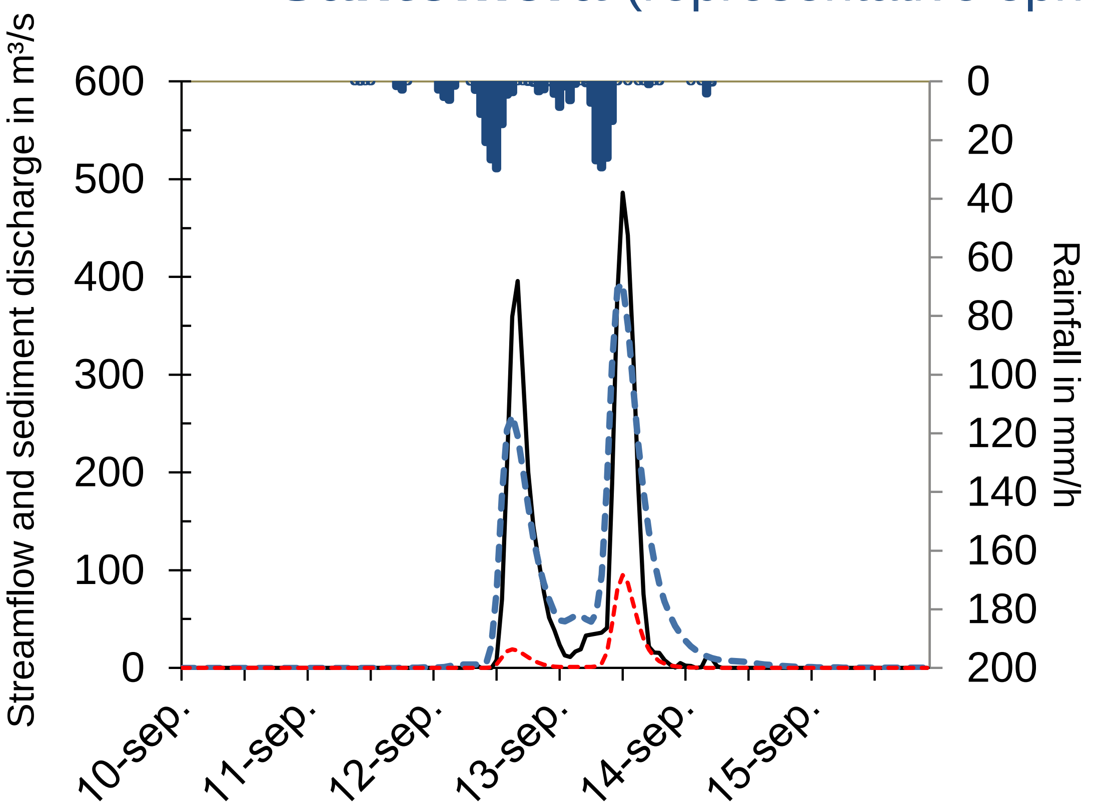


✖ FC2 …

- Significant reduction of the number of variables to be calibrated => facilitates model calibration stage
- Maintains the spatial pattern of the parameter maps
- Powerful **automatic calibration** algorithm

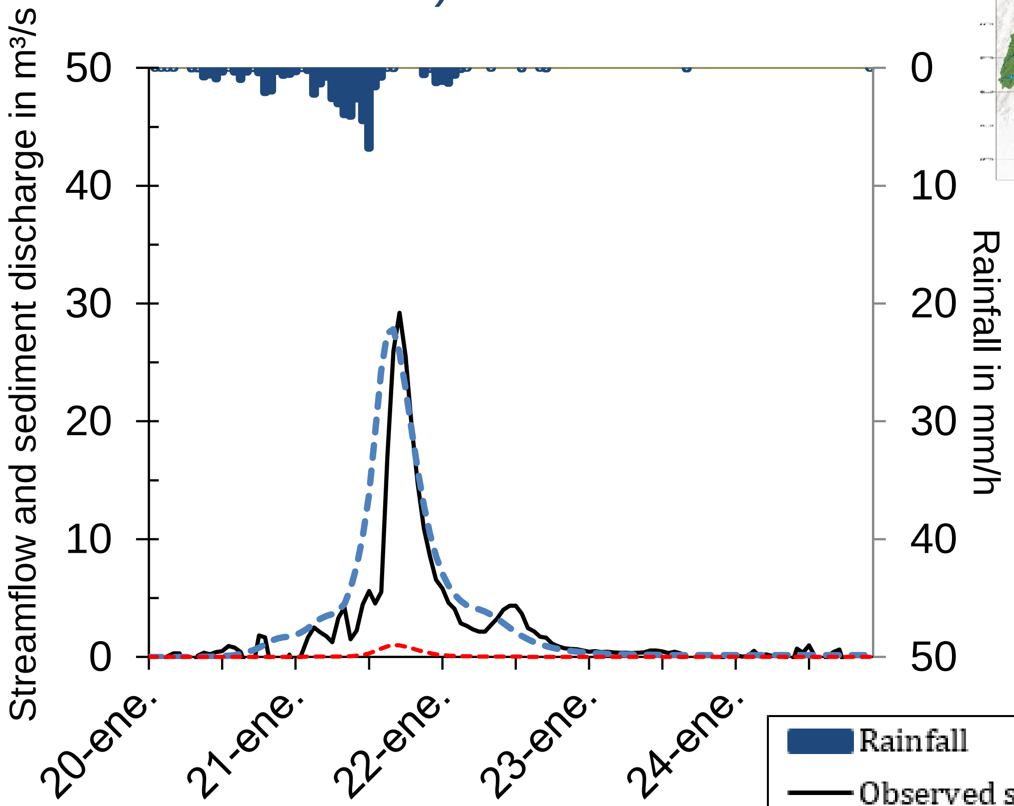
Implementation of TETIS model

Santomera (representative ephemeral torrential river)



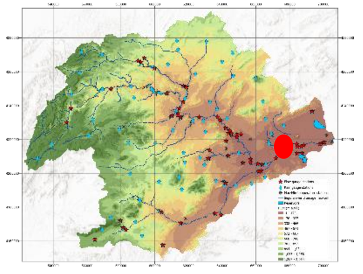
Calibration: 2019

NSE = 0.82



Validation: 2020

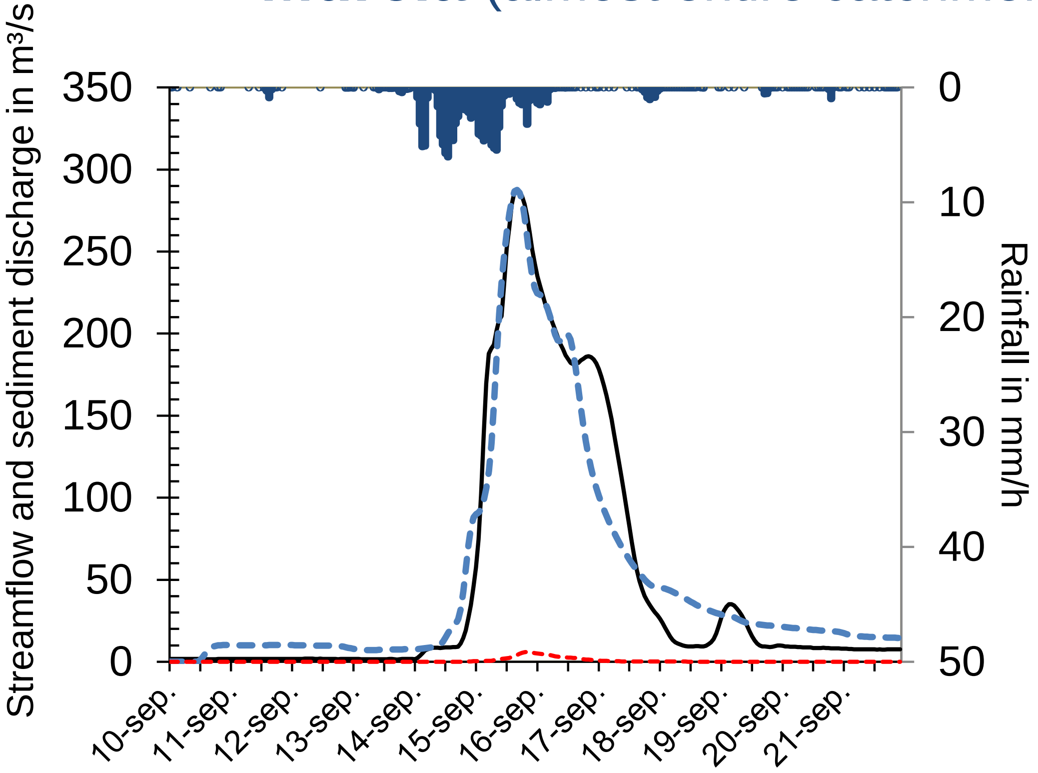
NSE = 0.71



Area: 148.6 Km^2

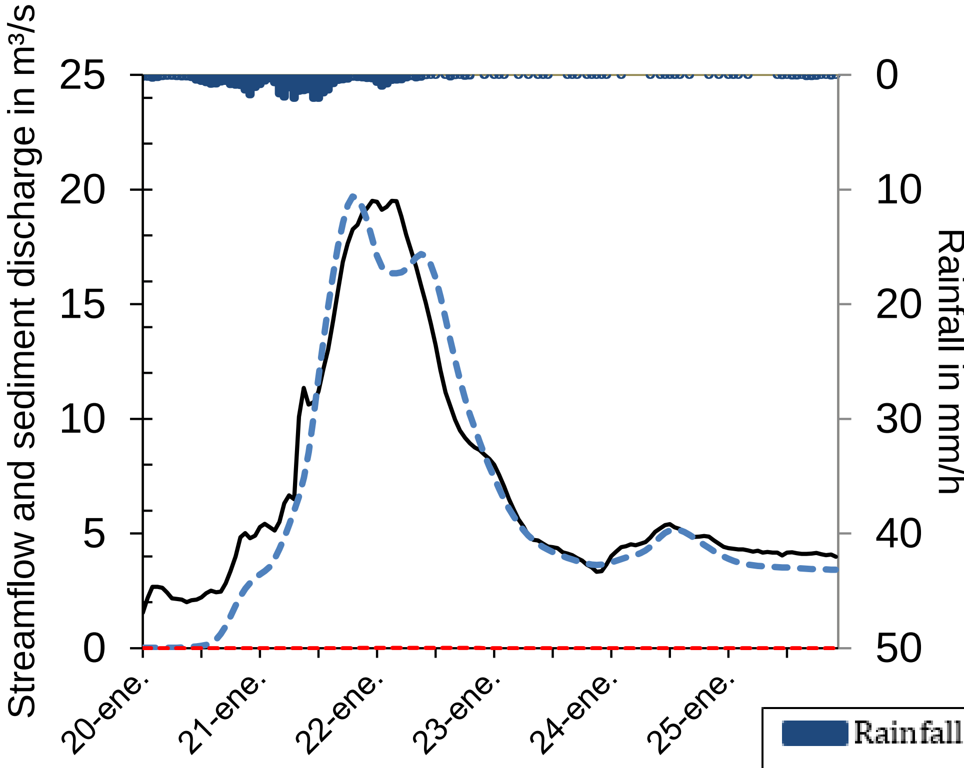
Implementation of TETIS model

Murcia (almost entire catchment)



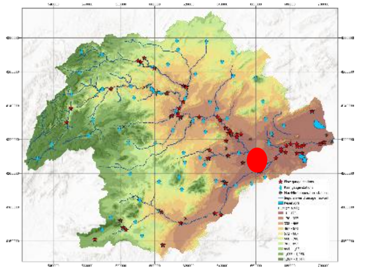
Calibration: 2019

NSE = 0.93



Validation: 2020

NSE = 0.91



Area: 9,874.1Km^2

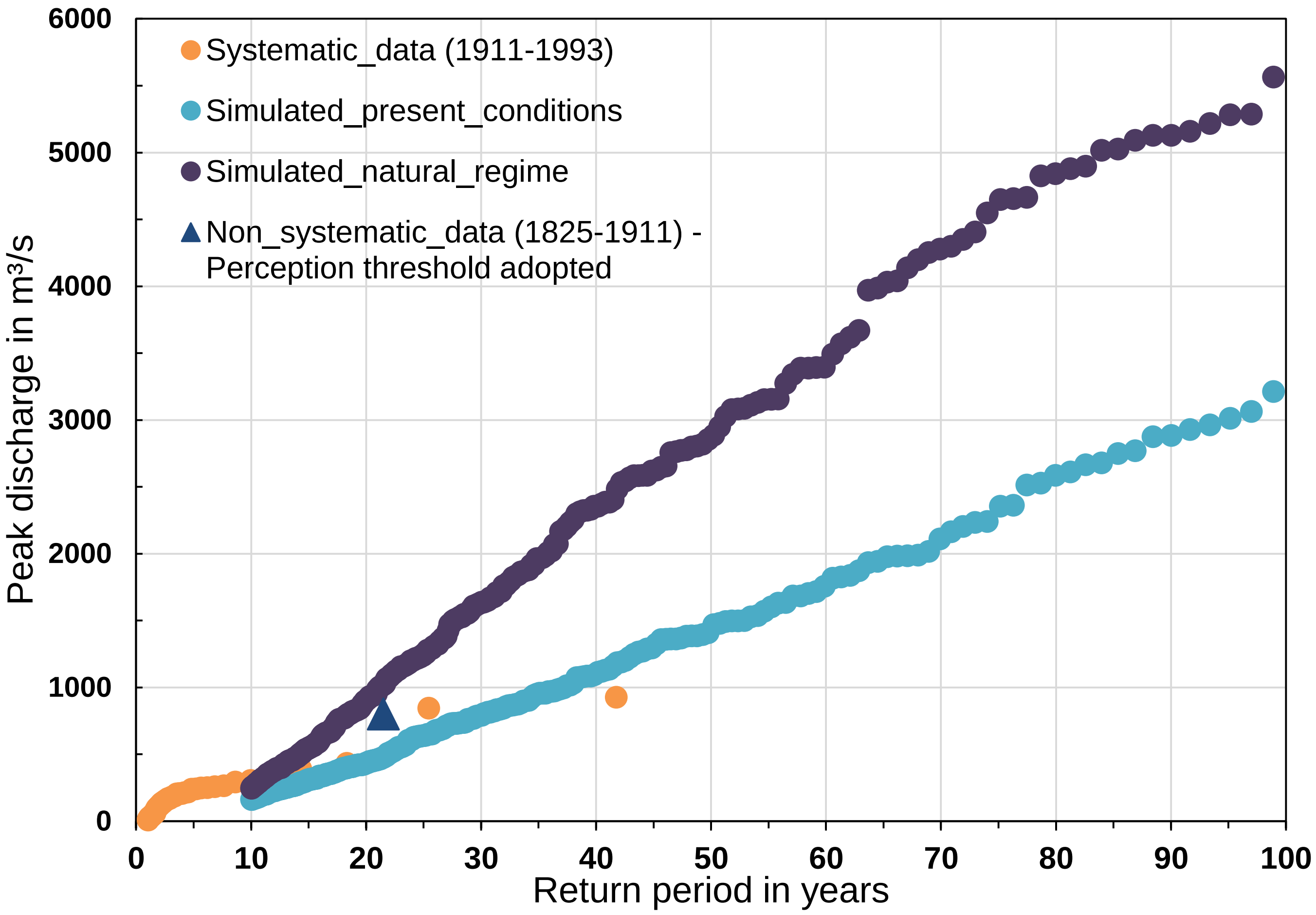
Flood frequency analysis

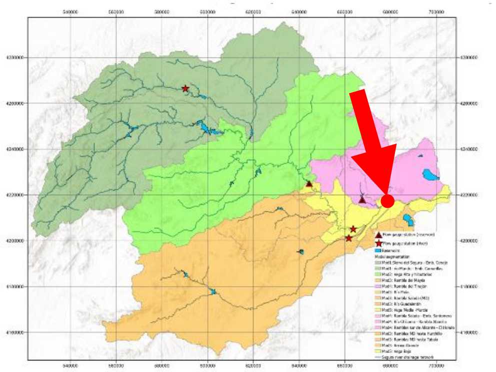
Orihuela
Segura River
Floodplain

$$F_i = \frac{i - \alpha}{N + 1 - 2\alpha}$$

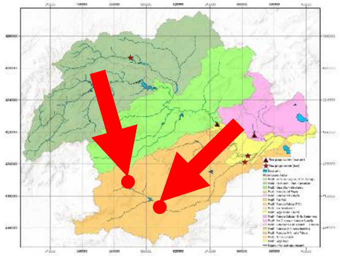
$\propto = 0.44$ (*Cunnane, 1978*)
$N = 5000$

500 flood events
(Annual peak flows)



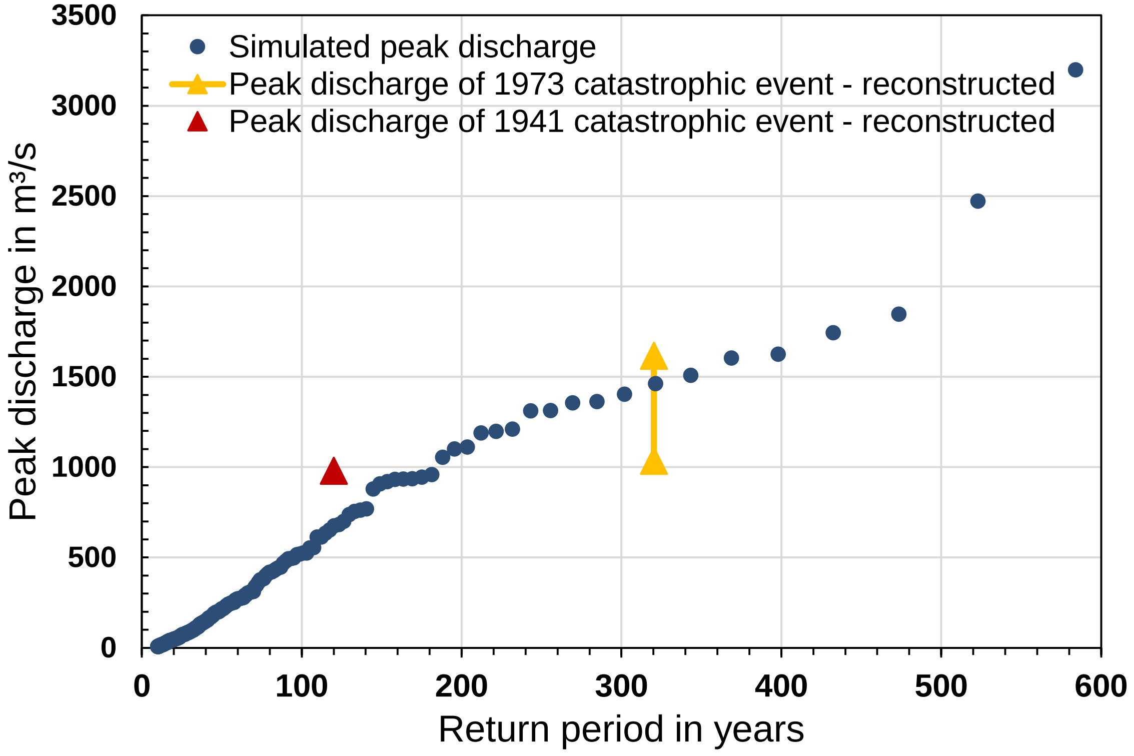


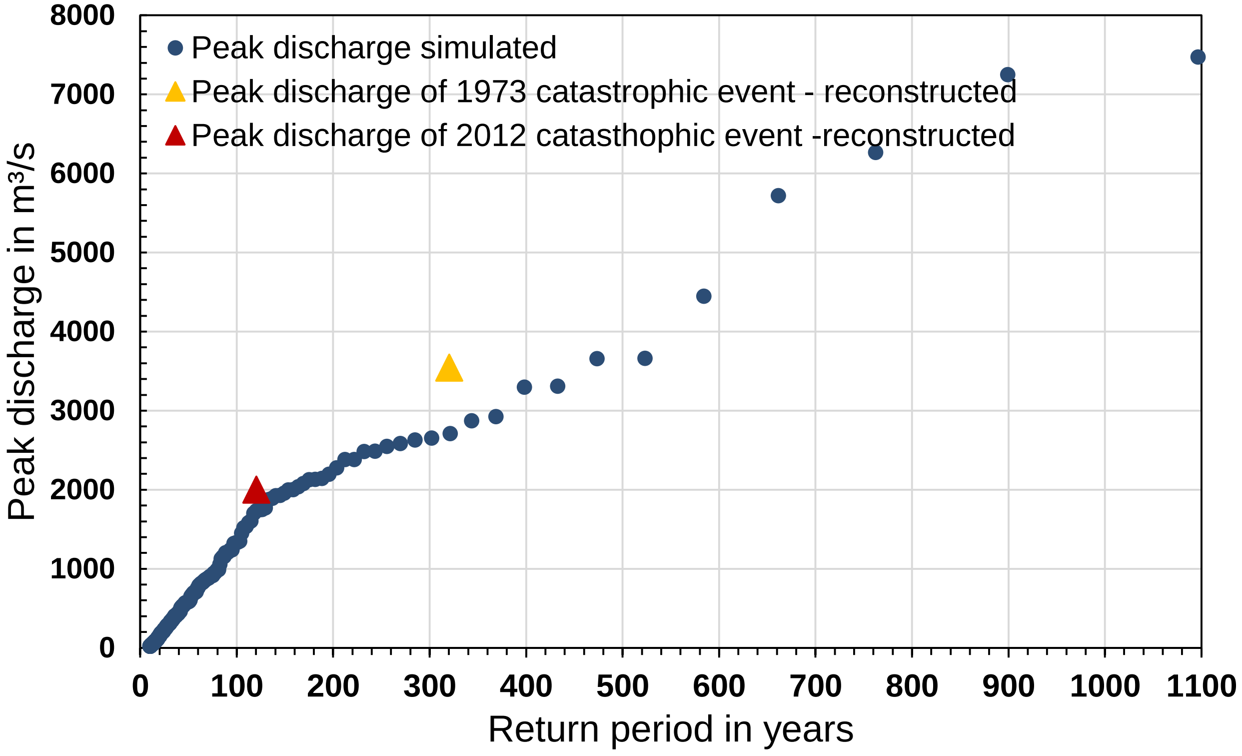
Flood frequency analysis



Valdeinfierno reservoir
Guadalentín river
Headwaters

Puentes reservoir
Guadalentín river
Headwaters

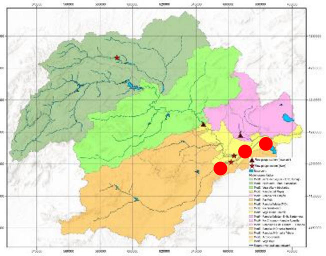


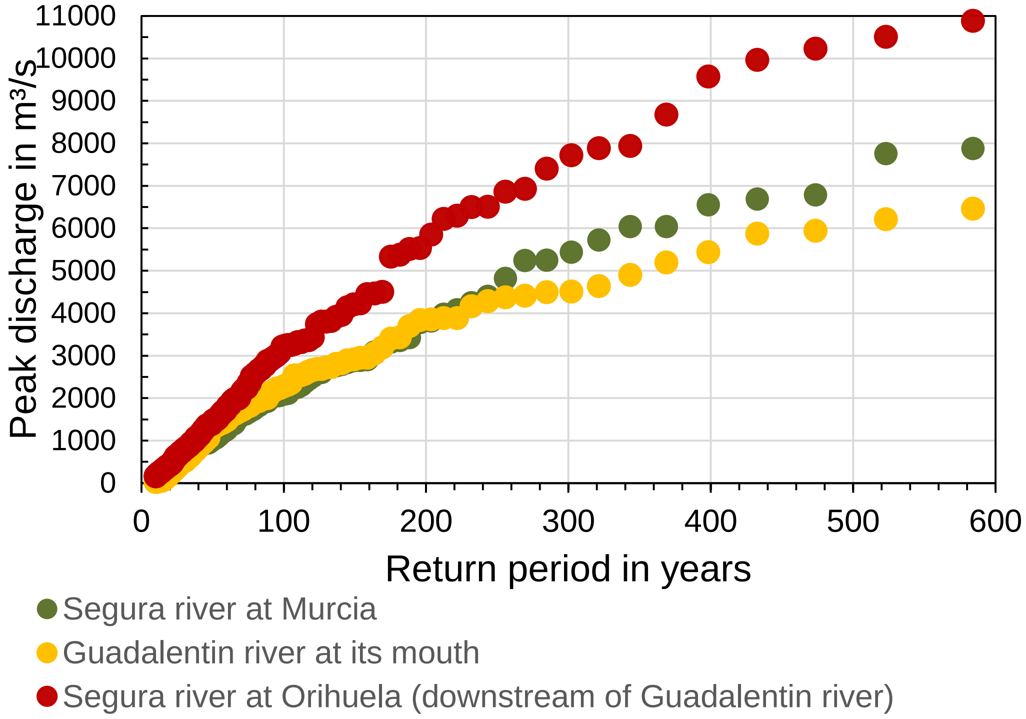


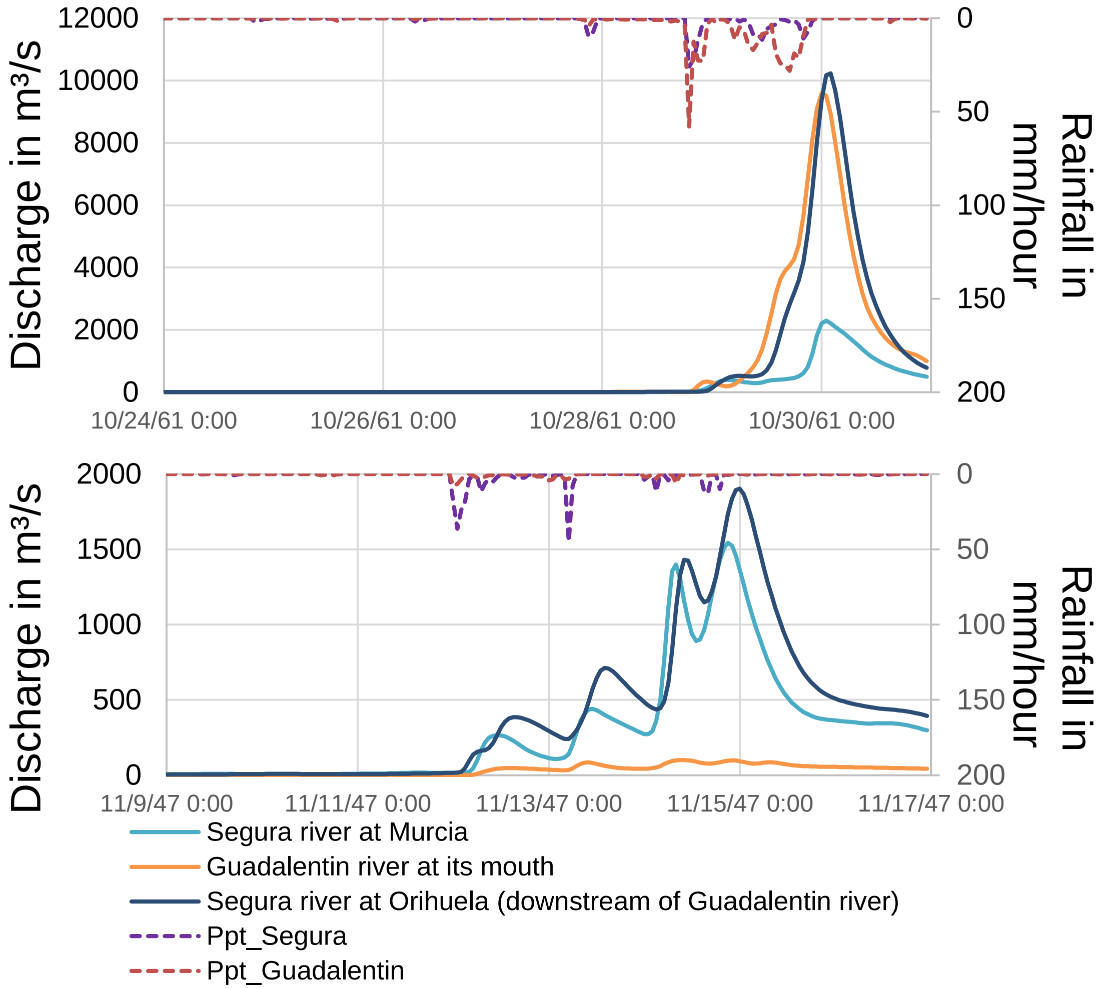
Flood frequency analysis

Practical results

Guadalentín-Segura case







Conclusions

- The spatial-temporal variability of the flood events needs to use a WG in combination with a distributed hydrological model
- Additional information must be incorporated in the WG implementation for an adequate modeling of low frequency quantiles, especially in arid and semi-arid climates where extreme rainfall records are scarce
  - Our proposal is to use a regional analysis of annual maximum daily precipitation
- This methodology has been applied in a strongly altered and considerably large area, with satisfactory results
- The validation with both systematic and non-systematic data shows that the present methodology is capable of reproducing not only ordinary discharges but also extreme peak discharges in different locations of the catchment

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Thank you for your attention!

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