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From Snow to Sea

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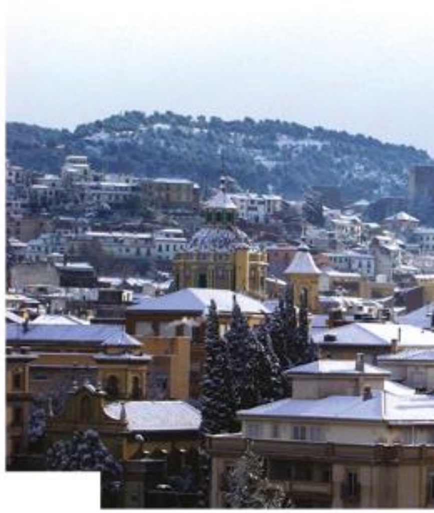

#FromSnowToSea




New Approach to Estimate Extreme Flooding Using Continuous Synthetic Simulation Supported by Regional Precipitation and Non-Systematic Flood Data

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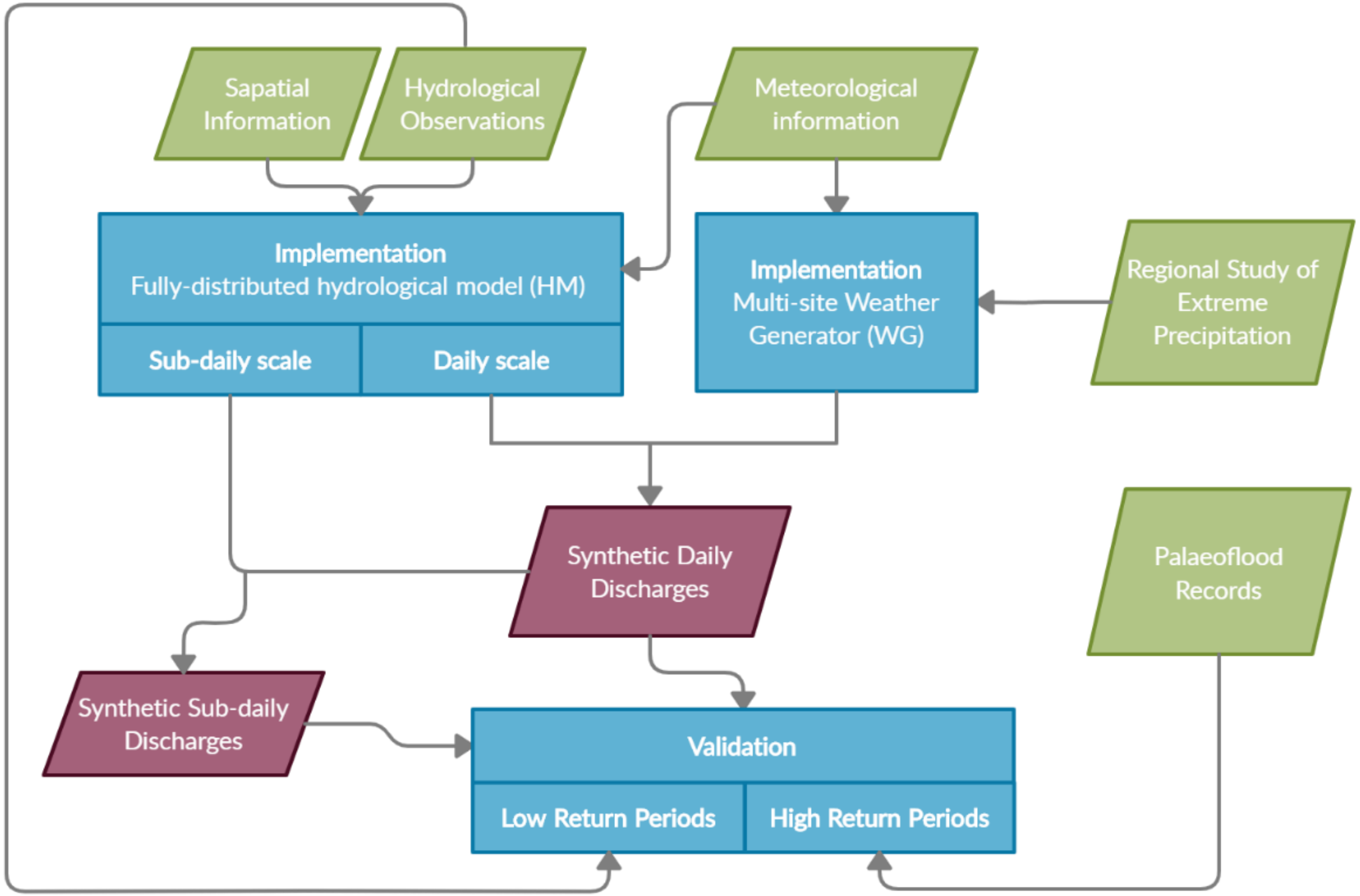
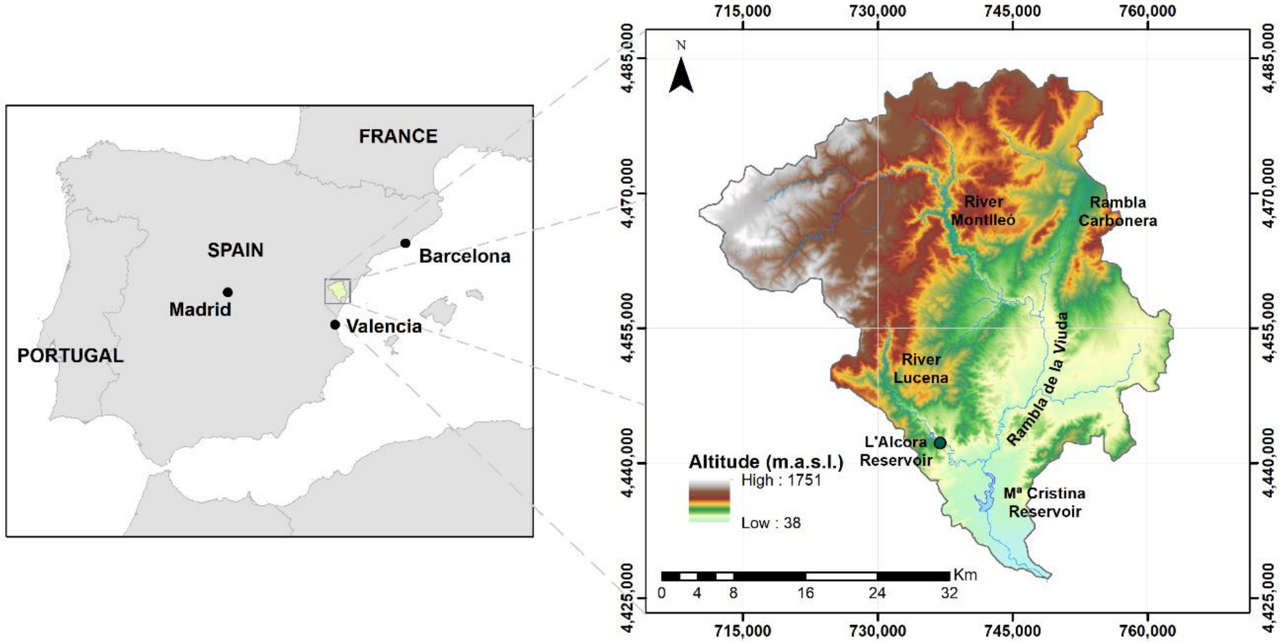
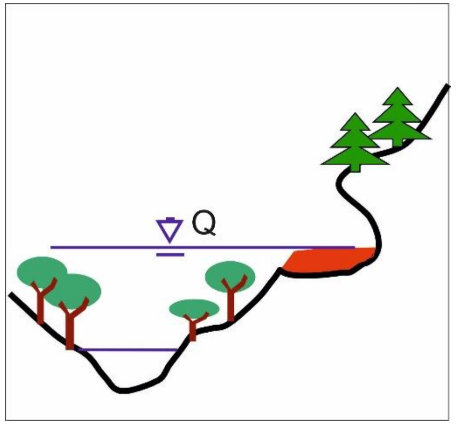
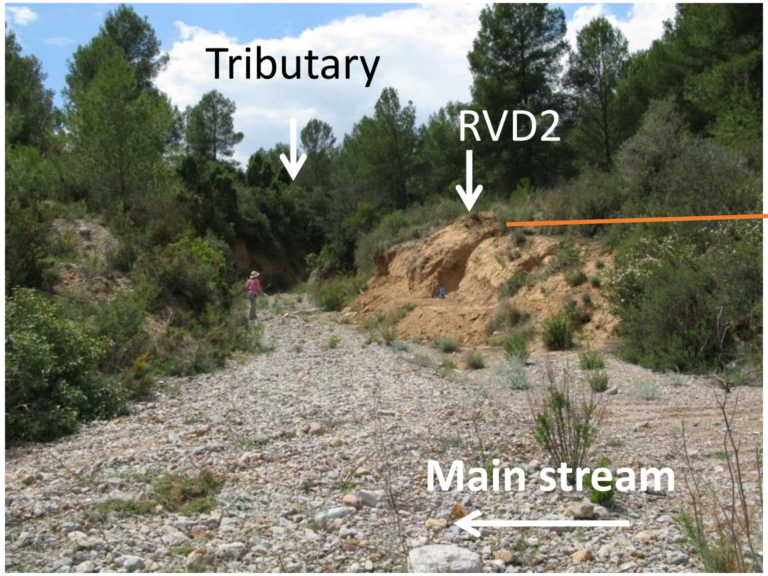

Sapatial Information
Hydrological Observations
Meteorological information
Implementation
Fully-distributed hydrological model (HM)
Sub-daily scale
Daily scale
Implementation
Multi-site Weather Generator (WG)
Regional Study of Extreme Precipitation
Synthetic Daily Discharges
Palaeoflood Records
Synthetic Sub-daily Discharges
Validation
Low Return Periods
High Return Periods

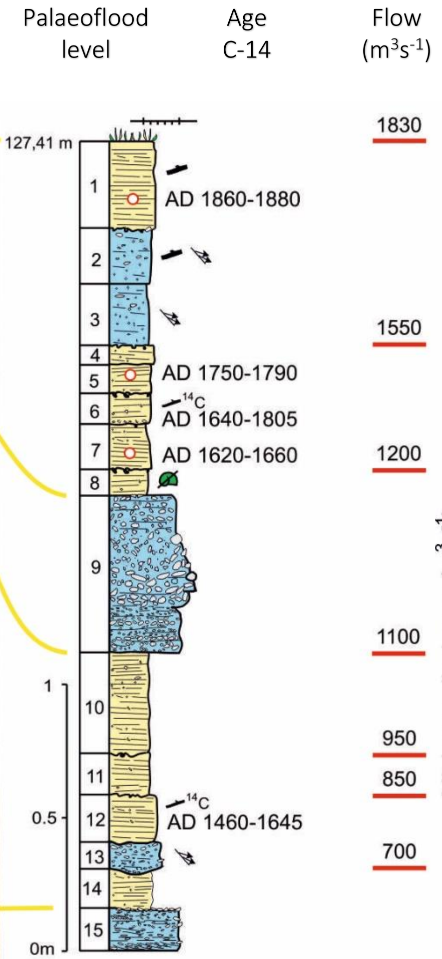
- **Rambla de la Viuda**: ephemeral rive
- Approx. area: 1,500 km^2
- Semi-arid Mediterranean climate
- Annual mean precipitation: 550 mm
- High precipitation variability
- Two reservoirs (Mª Cristina y Alcora)





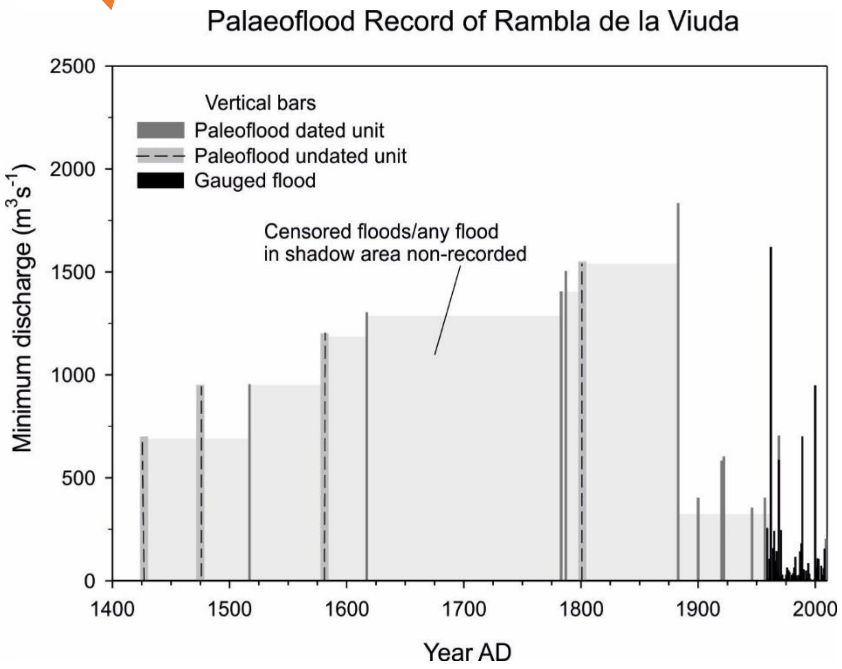
Flow calculated from the sediment depth



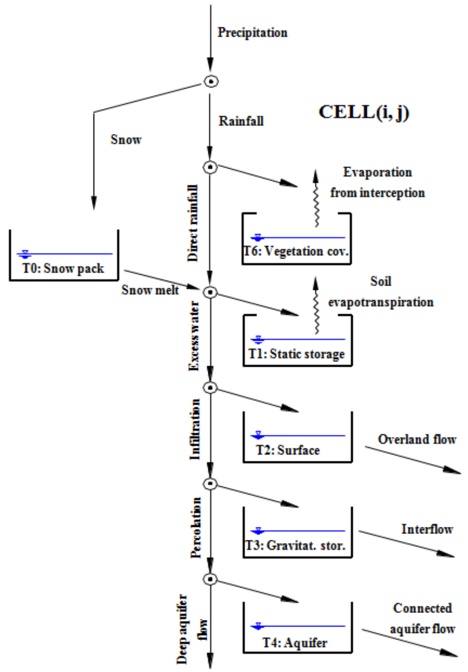


PALAEOFLOODS: Extreme flood flow records from the recent past

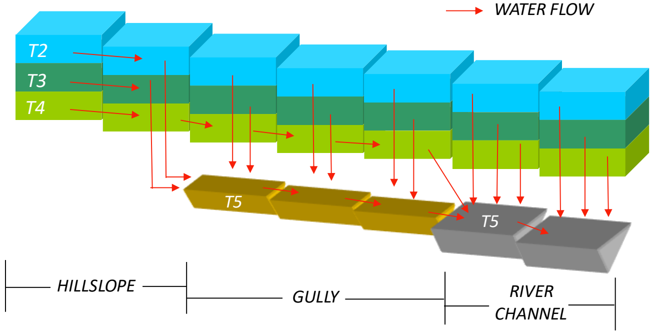
R. Viuda: 500 years on record



- Developed by our group since 1994 (version 9 on the web)
- Conceptual (tank structure) model, with **physically based parameters**
- **Distributed** in space
- **Parsimonious**: 9 parameters for hydrologic sub-model
- **Integral** model: water resources, floods, sediments, dynamic vegetation, crop production, N-C cycle, … and more to come!
- Incorporates an **split effective parameter structure** (*Benito and Francés, 1995; Francés et al., 2007*)



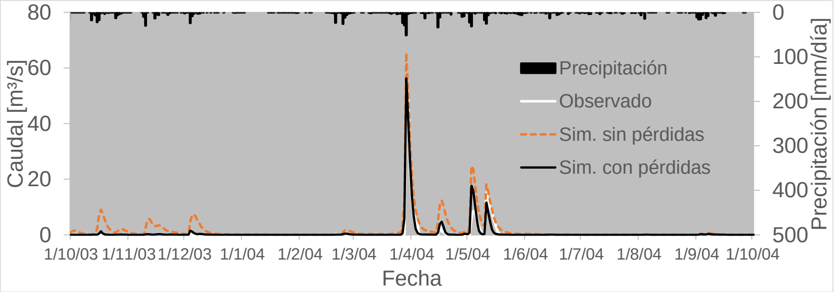
Conceptual schema of the TETIS model at cell scale

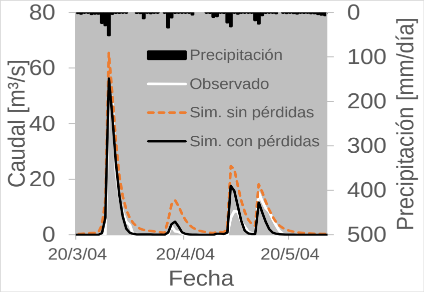


- **Calibration (daily scale):**

  Mª Cristina (2003-2004)

  NS = 0.930

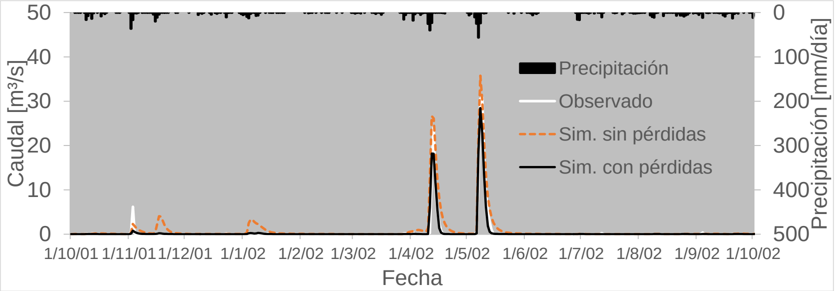


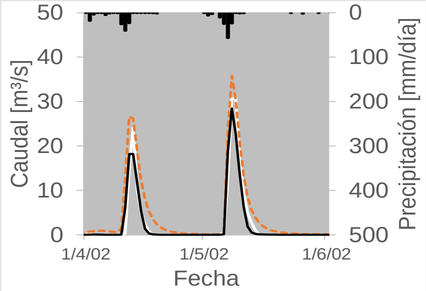


- **Temporal validation:**

  Mª Cristina (2000-2001)

  NS = 0.928

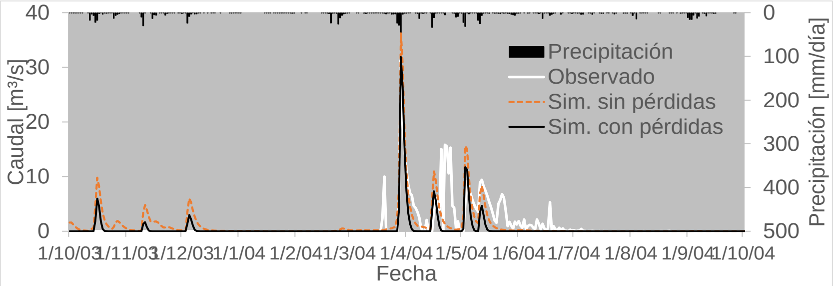


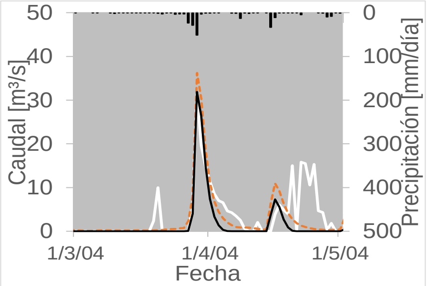


- **Spatial validation:**

  Vall d'Alba (2003-2004)

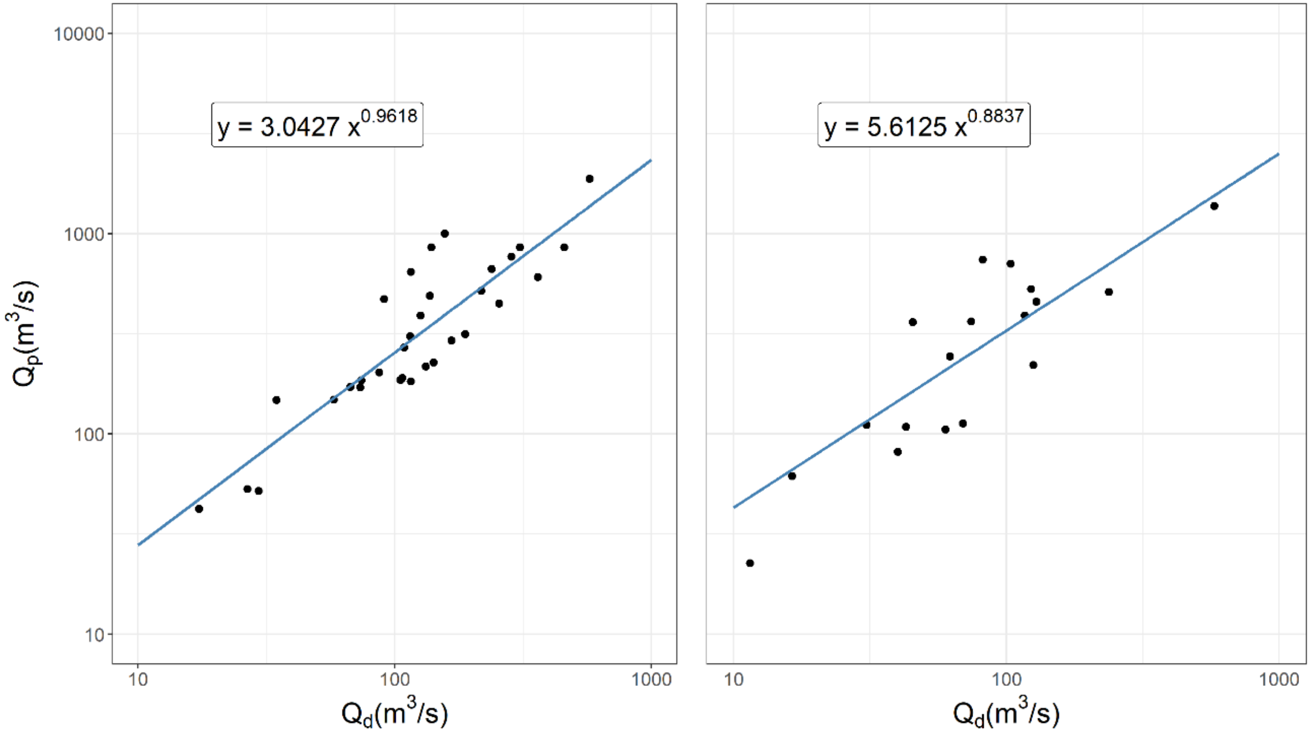
  NS = 0.428



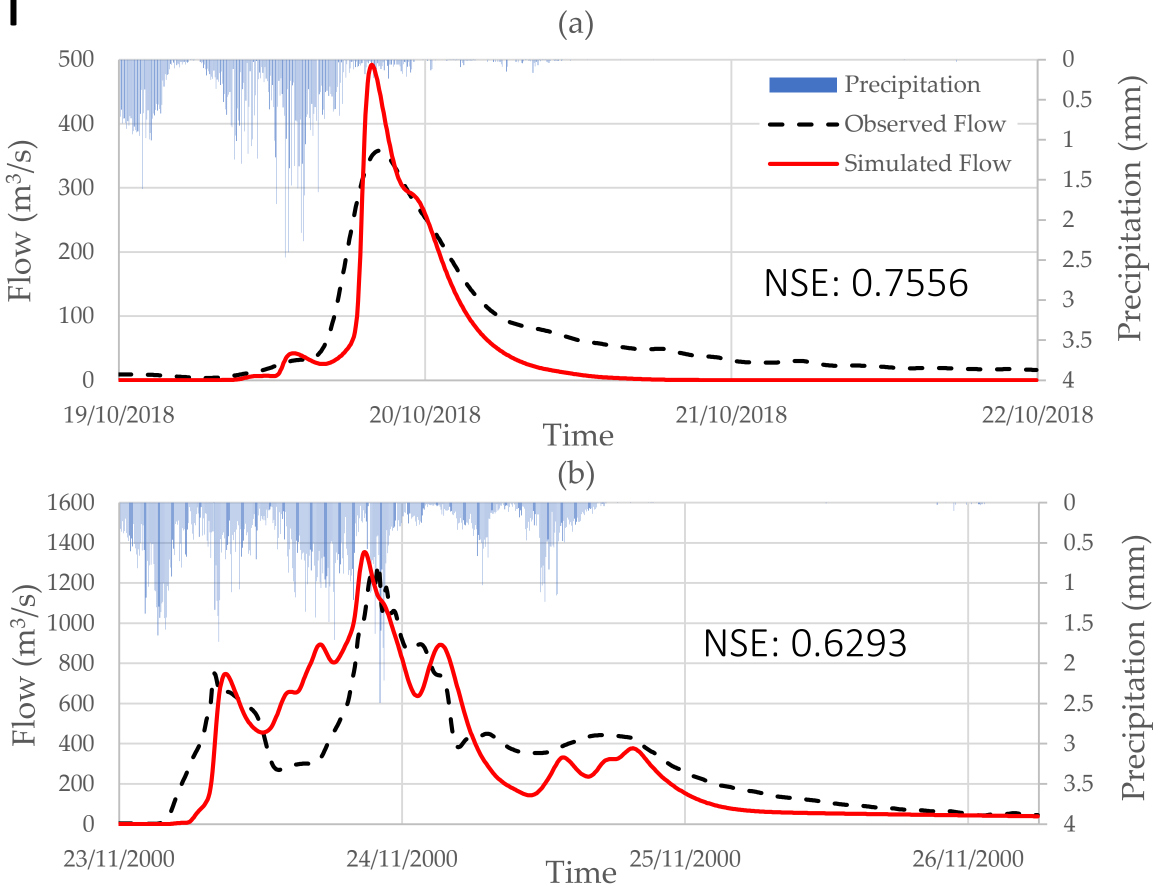


(Correcting time lag and y transmission losses)

- Implementation of Sub-daily Hydrological Model

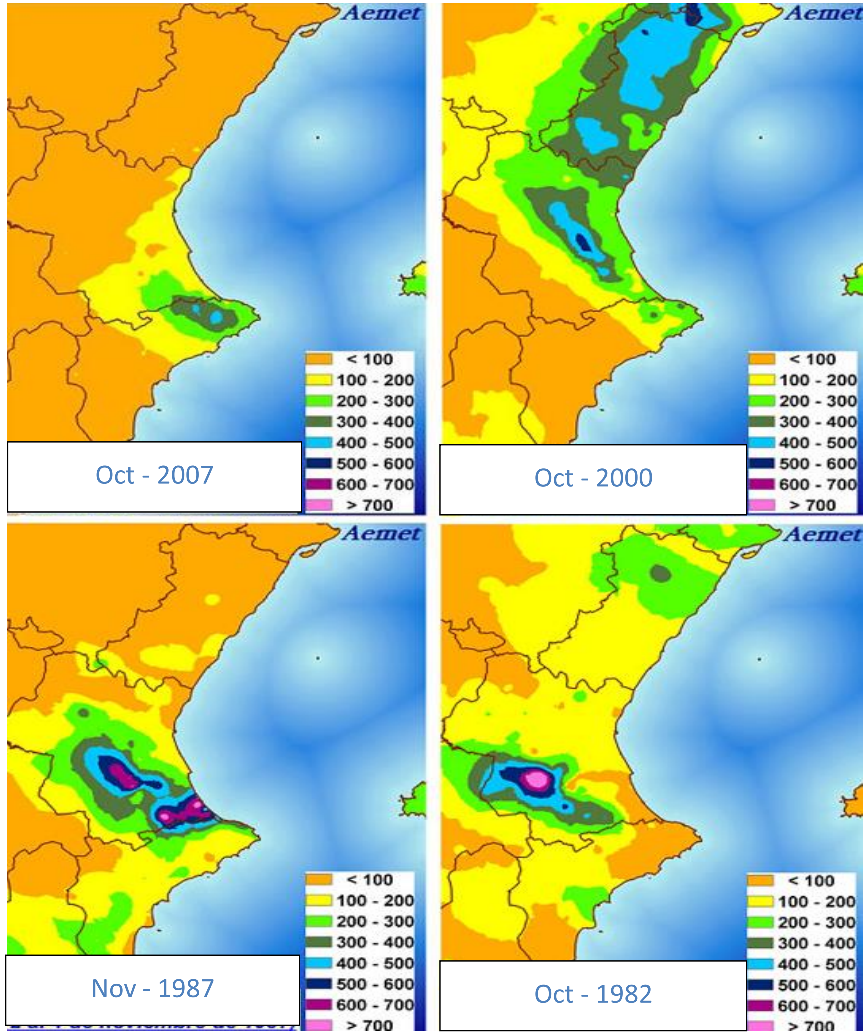


Potential regression between daily (Qd) and simulated peak discharges (Qp) at palaeoflood sites: Left, Rambla de la Viuda NS site; Right, Montlleó NS site



Observed and simulated sub-daily hydrographs for the calibration in the 2018 event (a), and temporal validation in the 2000 event (b) at Maria Cristina dam

- Precipitation regime clearly influenced by (mesoscale convective events)
  - Low frequency precipitation events
  - Every 7-8 years on average
  - Huge amounts of precipitation (up to 900mm in 24h)
  - Over periods of time lasting between 2-3 days
  - Autumn months (SON)
  - **COMPLEX PHENOMENA**



- Multisite Weather Generator: **GWEX** (Evin et al., 2018)
  - At-site occurrence: *p-order* Markov chain
  - Spatial dependence of the precipitation states is modeled using an unobserved Gaussian stochastic process
  - Amounts of precipitation are modelled by using: a tail-dependent spatial distribution and an autocorrelated temporal process
  - Marginal distribution: Extended Generalized Pareto Distribution (E-GDP) -> **heavy-tailed**

$$F(x;\lambda) = \left[1 - \left(1 + \frac{\xi(x)}{\sigma}\right)_+^{-1/\xi}\right]^k, x > 0$$

    - Parameter estimation

σ, κ, — From observations

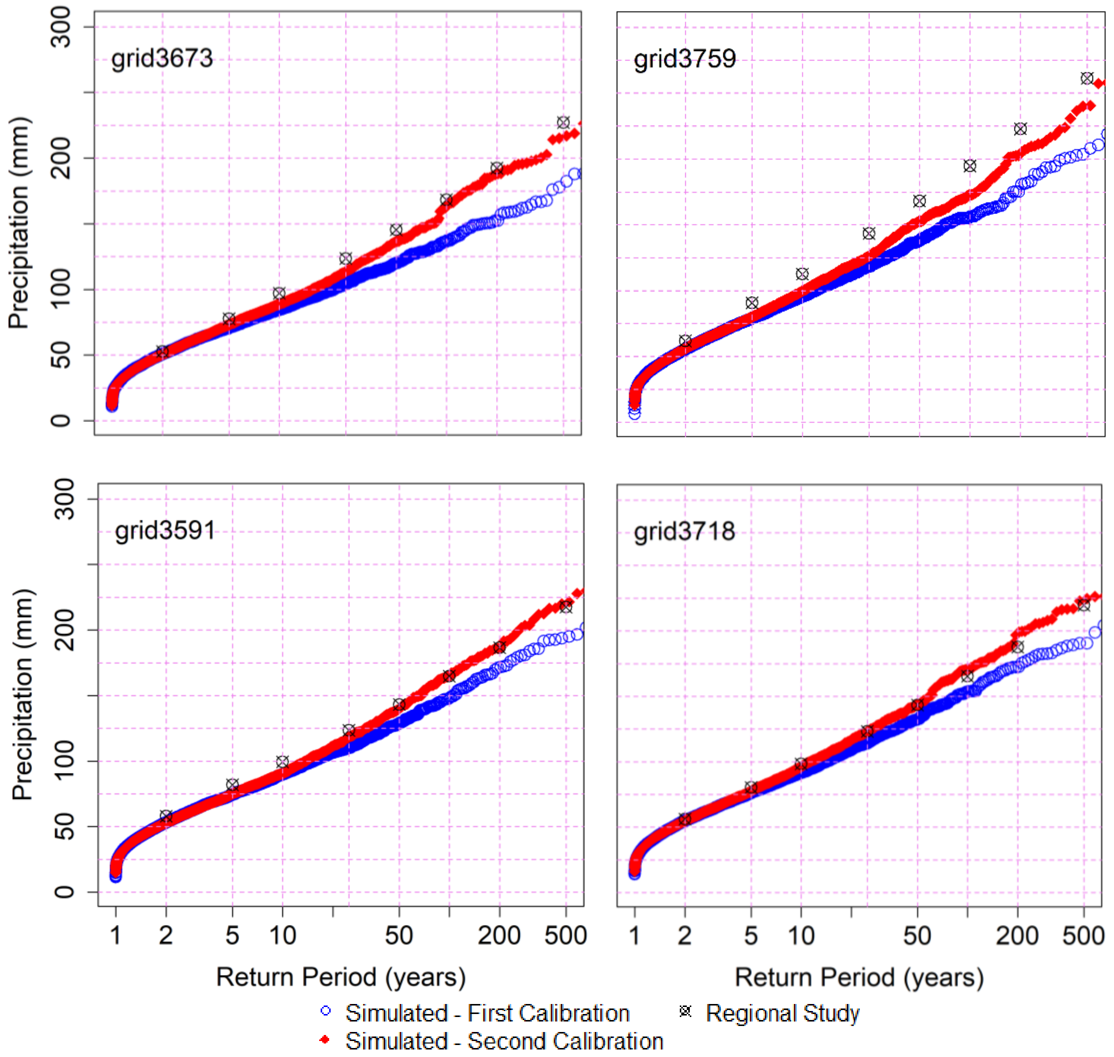
ξ, — From more robust studies

(Evin et al., 2018)

  - **3-day aggregation**

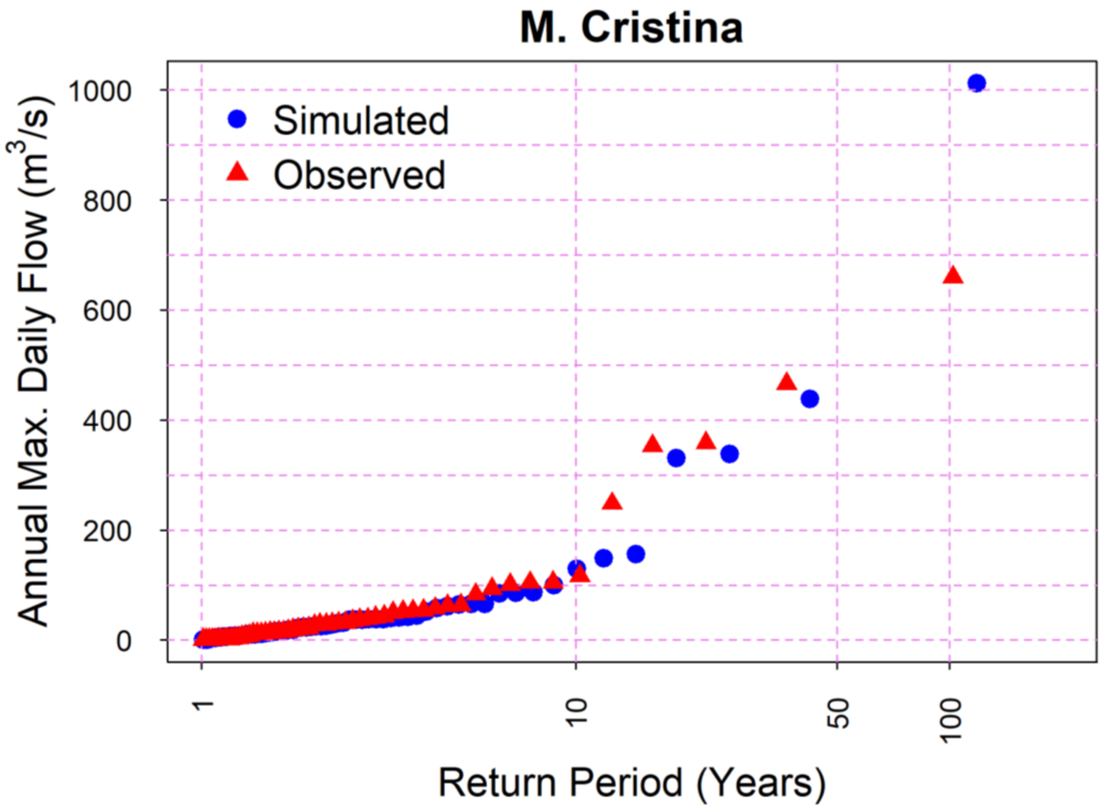
- First calibration=> Observed precipitation from Spain02-v5: 66 years
  - Validation with regional analysis of daily max. precipitation *(CEDEX, 1994)*
    - Updated values with Spain02-v5 observations

❑ Second calibration => Shape parameter ξ fit:
    - Two populations:
      - Autumn months (SON) => To calibrate (minimising RMSE)
      - Rest of months

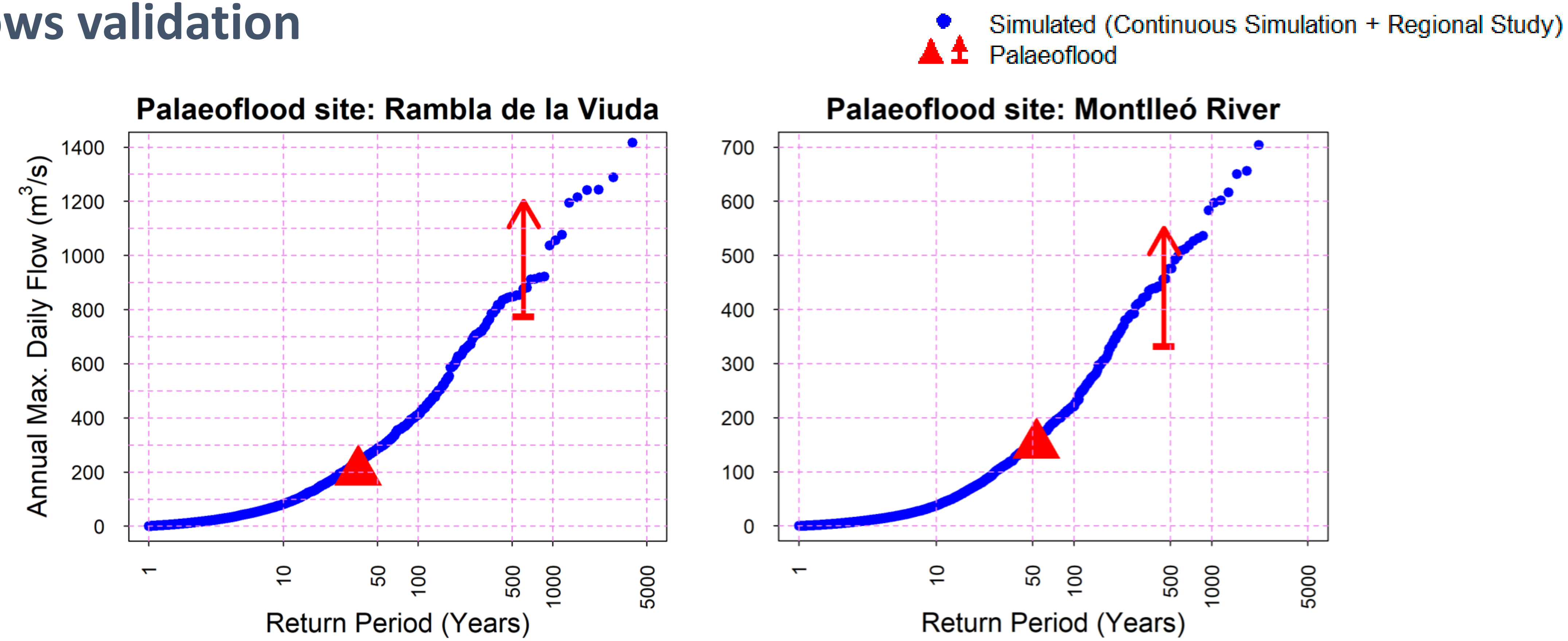


Low T Flows Validation

- Plotting positions at Maria Cristina Dam of the observed flows (SAIH) and the simulated flows with the precipitation generated by GWEX



High T flows validation



Plotting positions of the simulated flows with the precipitation generated by GWEX at the locations where the historical and palaeoflood information is available

- The **reliability of flood estimates depends upon long and trustworthy input data series** (i.e., precipitation and/or discharges). Most **ephemeral rivers** worldwide **lack long-term and spatially fully distributed hydrometeorological information**, which leads to **inaccurate estimations of flood quantiles**, especially those associated with **high return periods**

- The use of **continuous stochastic meteorological** models coupled with a **fully distributed hydrological simulation** provide a **realistic approach**, enabling the recreation of **multiple different situations at any point within the catchment**, thus **completing** the **frequency distributions of discharges** along the whole river network

- Yet, though, **long and reliable input data series of precipitation and discharges are necessary** for the correct implementation of the WG and the HM, which in practice are **rarely available**

- Our results show that the **integration** of more **robust precipitation studies** for the **WG implementation** clearly **improve its performance**. In our case, the integration of an **existing regional study of annual maximum precipitation** allowed the reproduction of the high return periods precipitation quantiles, where the bias was more significant

- This **improvement** was **transferred** to the simulation of **discharge data series** with the fully distributed HM. Here, the available **palaeoflood records gave extra flood information** up to **T = 500** years as opposed to the highest quantile of T = 50 years obtained only with the systematic information

- Moreover, these **estimates** are **not limited to the sites** where **flow gauge stations are located or where the palaeoflood information is available.** The fully distributed HM **provides reliable** data on **extreme** flood **discharges at any point** of the catchment

- Finally, **the importance of incorporating two different sources of additional information** in the methodology when trying to estimate extreme flooding **was demonstrated**. Whilst **adding one source of additional information is essential** for a better **calibration** of the WG, adding a **second one allows for the validation of the simulated discharges**, thus improving the robustness of the methodology and providing higher confidence in the flood quantile estimates.

For more information, please see:

- Beneyto, C.; Aranda, J.Á.; Francés Exploring the stochastic uncertainty of Weather Generators' extreme estimates in different practical available information scenarios. *Hydrological Sciences Journal* **2022**. (Under Review)
- Beneyto, C.; Aranda, J.Á.; Benito, G.; Francés, F. New Approach to Estimate Extreme Flooding Using Continuous Synthetic Simulation Supported by Regional Precipitation and Non-Systematic Flood Data. *Water* **2020**, *12*, 3174. https://doi.org/10.3390/w12113174