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A simple model for low flow forecasting in Mediterranean streams

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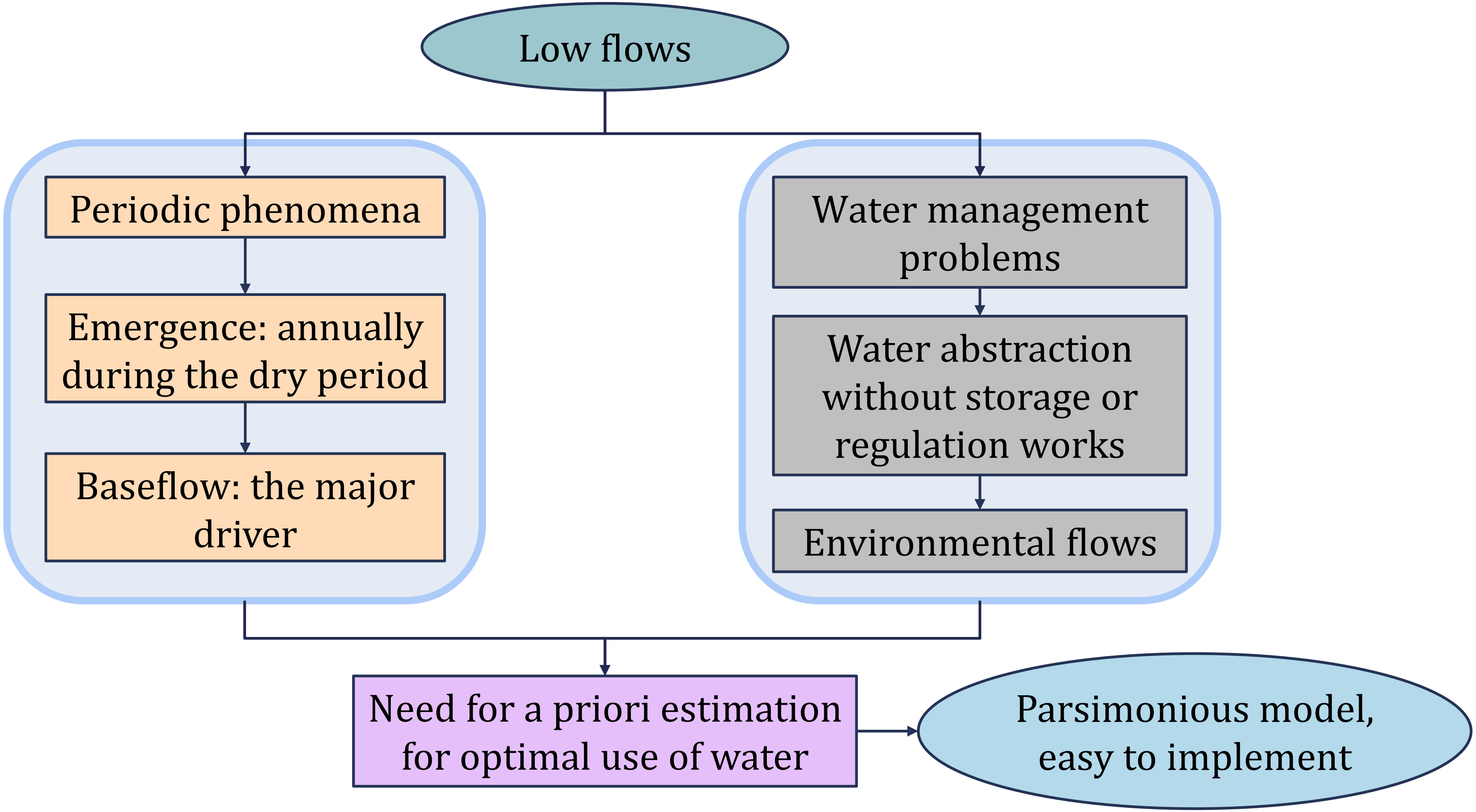
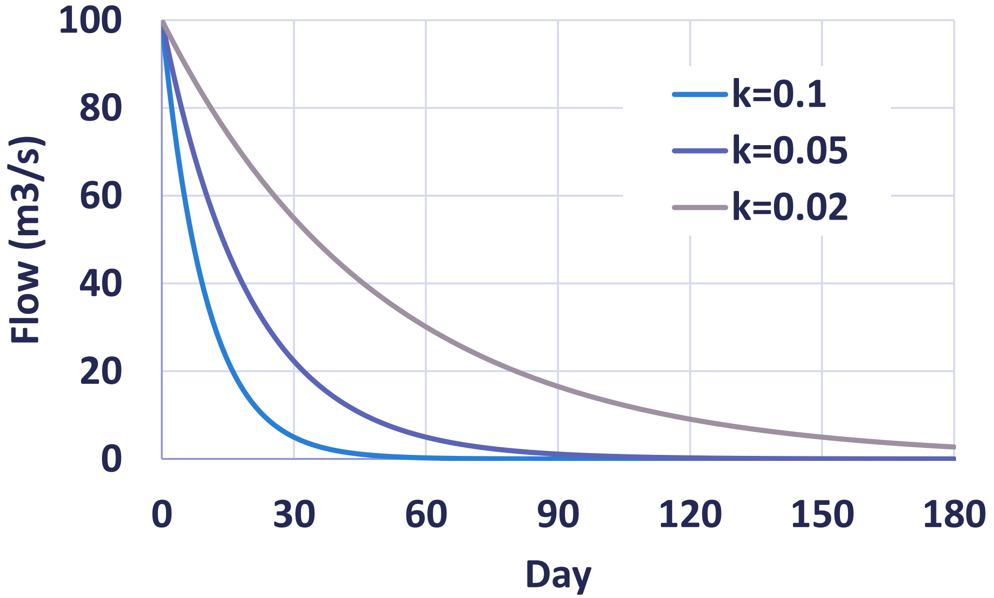
Low flows and water management

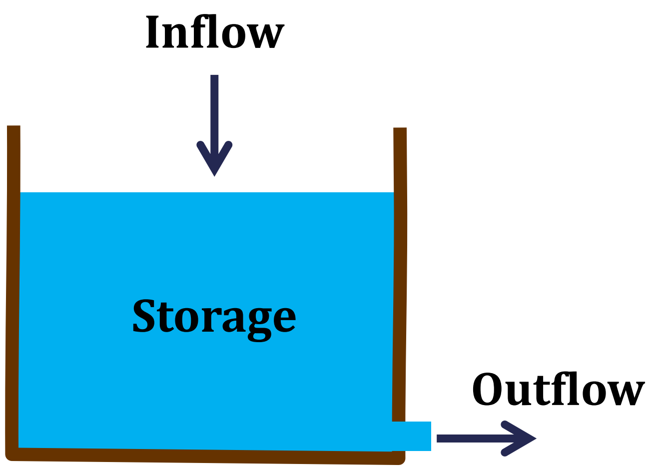


Key assumptions and definitions

- **Rationale**: Baseflow is the key driver of low flows during dry periods, represented as outflow through a linear reservoir.
- **Modeling scheme**: The low flow during the dry-period of a specific year *j* is modelled by an exponential decay:

$$q_{jt} = q_{0j} \exp(-k_j t) \qquad (1)$$





- **Reference time horizon**: April 15th to October 15th
- **Adjusted low flows**: Estimated on the basis of dry-period hydrograph, after filtering and removal of flow maxima.
- **Initial discharge, q_{0j}**: Minimum flow of the first two weeks of April, *a priori* determined according to the observed data.
- **Recession parameter, k_j**: Inferred through calibration, by fitting eq. (1) to adjusted low flow data of year *j*.

Study areas

Salso (Imera) @ Petralia
***A* = 28 km²**
MAF = 0.77 m³/s

Achelous @ Kremasta dam
***A* = 3570 km²**
MAF = 108.0 m³/s

Peristerona @ Panagia bridge
***A* = 77 km²**
MAF = 0.31 m³/s

Xeros @ Lazarides
***A* = 69 km²**
MAF = 0.28 m³/s

Derivation of adjusted low flow data

- Real-world dry period hydrograph ⟶ rising and recession limbs, individual peaks ⟶ **underestimation of recession parameter**
- Extraction of actual low flows from the total hydrograph ⟶ **adjusted low flows**

Smoothing of hydrograph via a numerical filter

↓

Identification of beginning and end of dry period

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Removal of flows above a theoretical upper threshold

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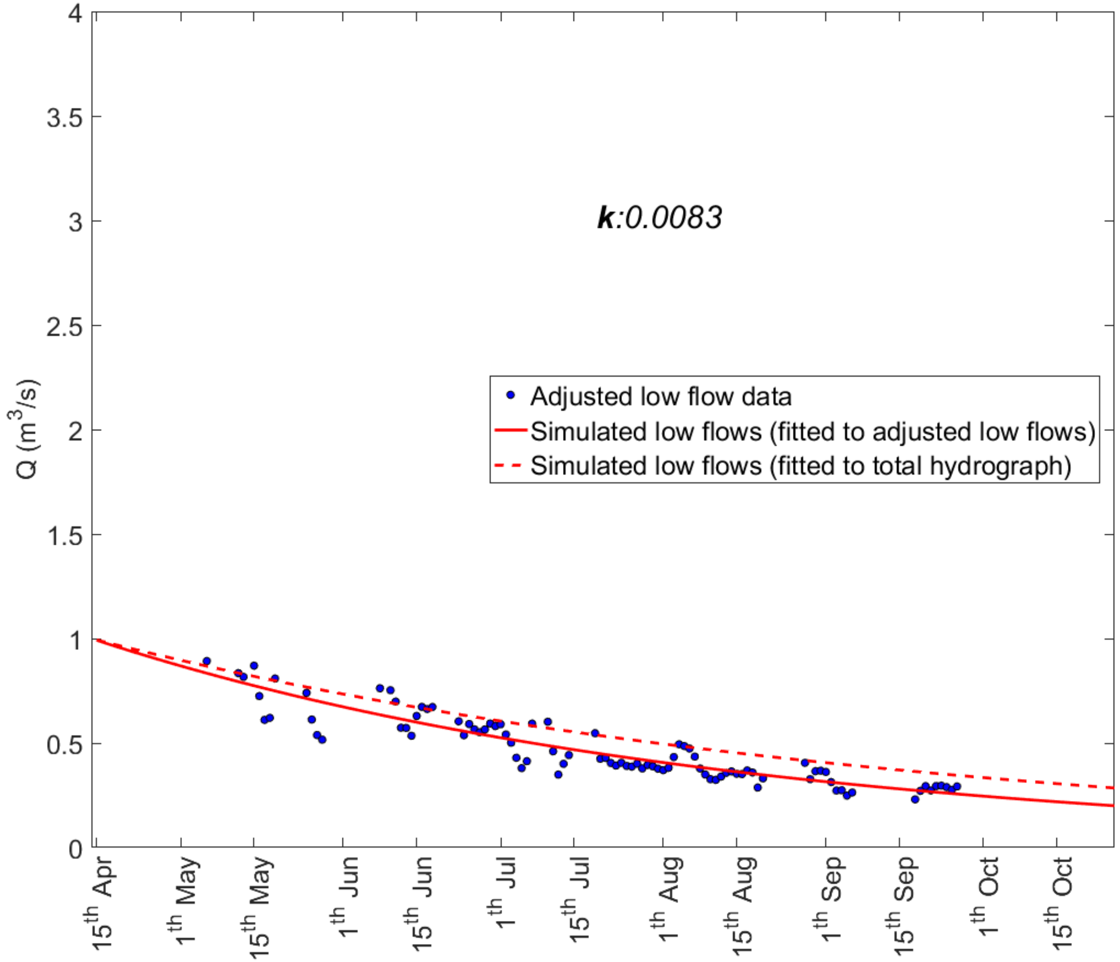
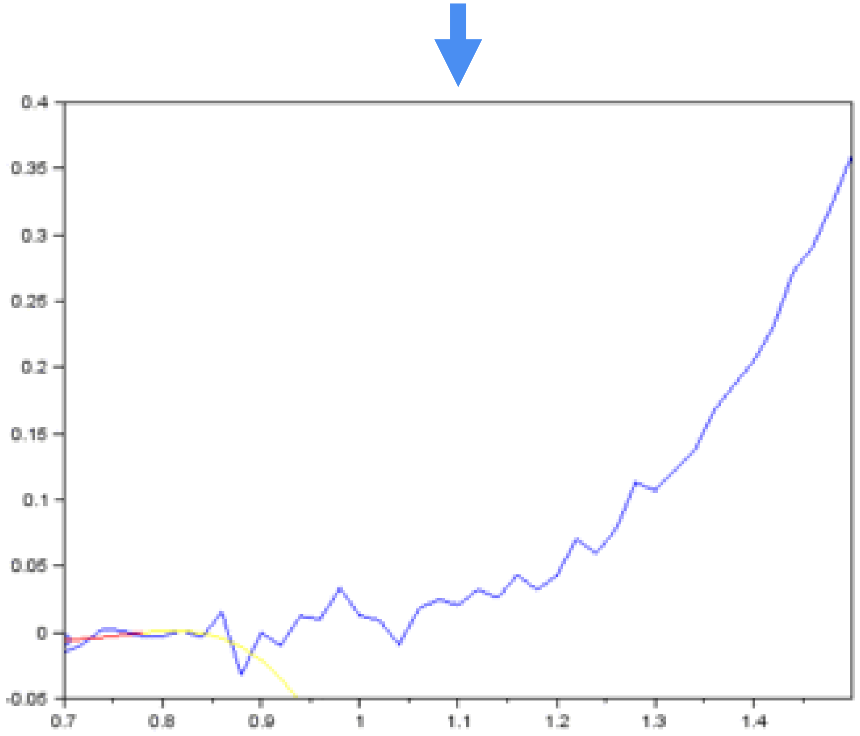
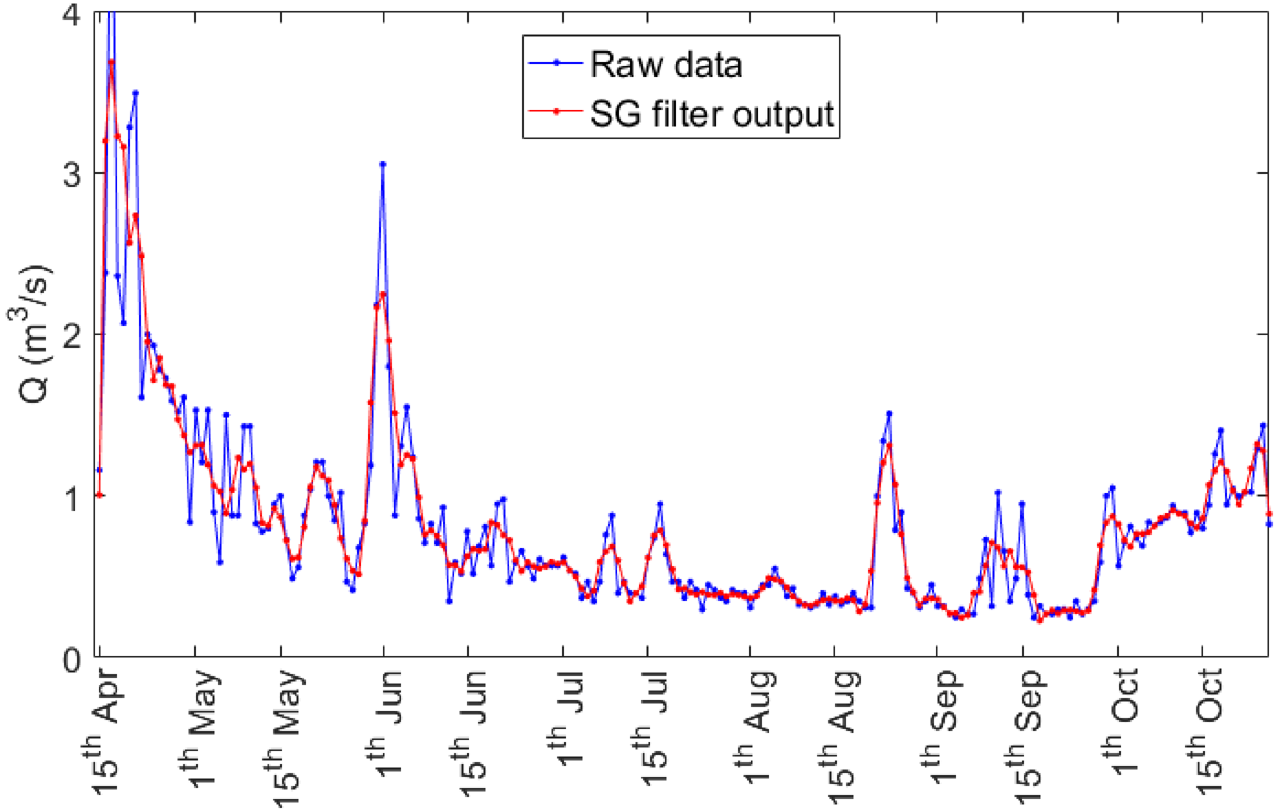
Smoothing of small-scale flow maxima



Step A: Smoothing of total hydrograph

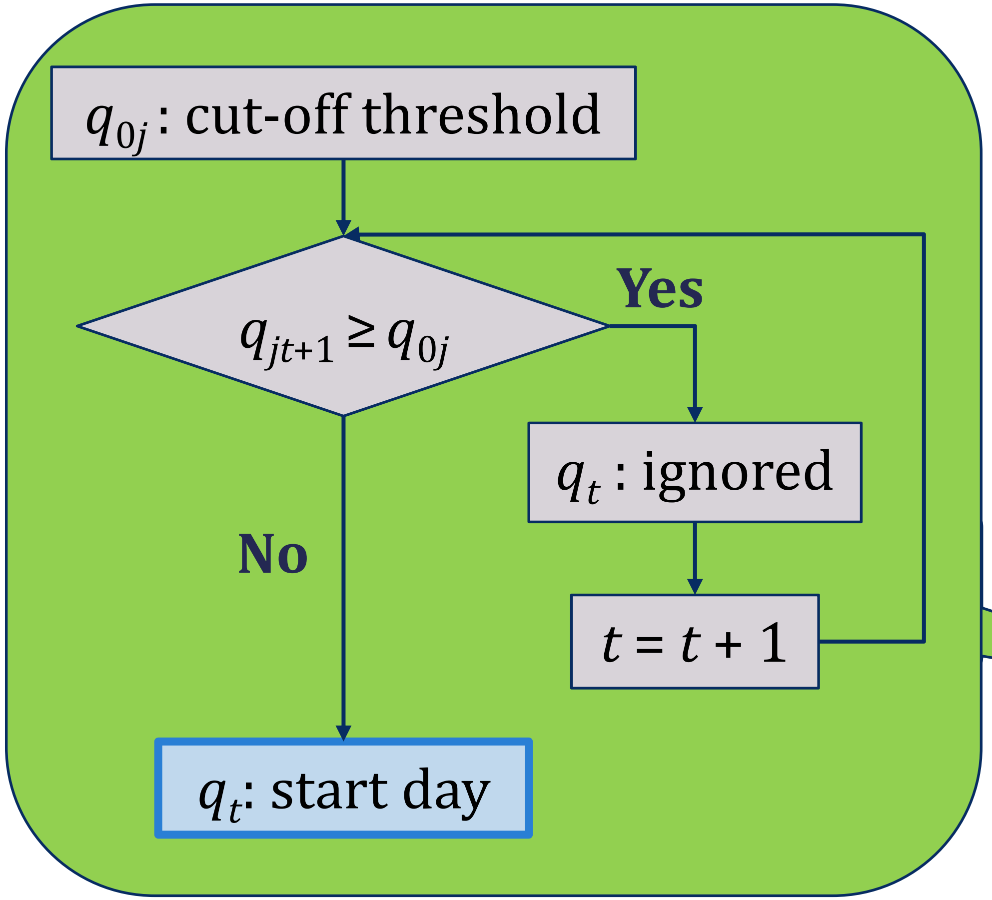
- Savitzky & Golay (1964) numerical filter
- 3rd order polynomial
- Fitting period n = 59 days
- Moving polynomial fit to $2n$+1 neighboring points

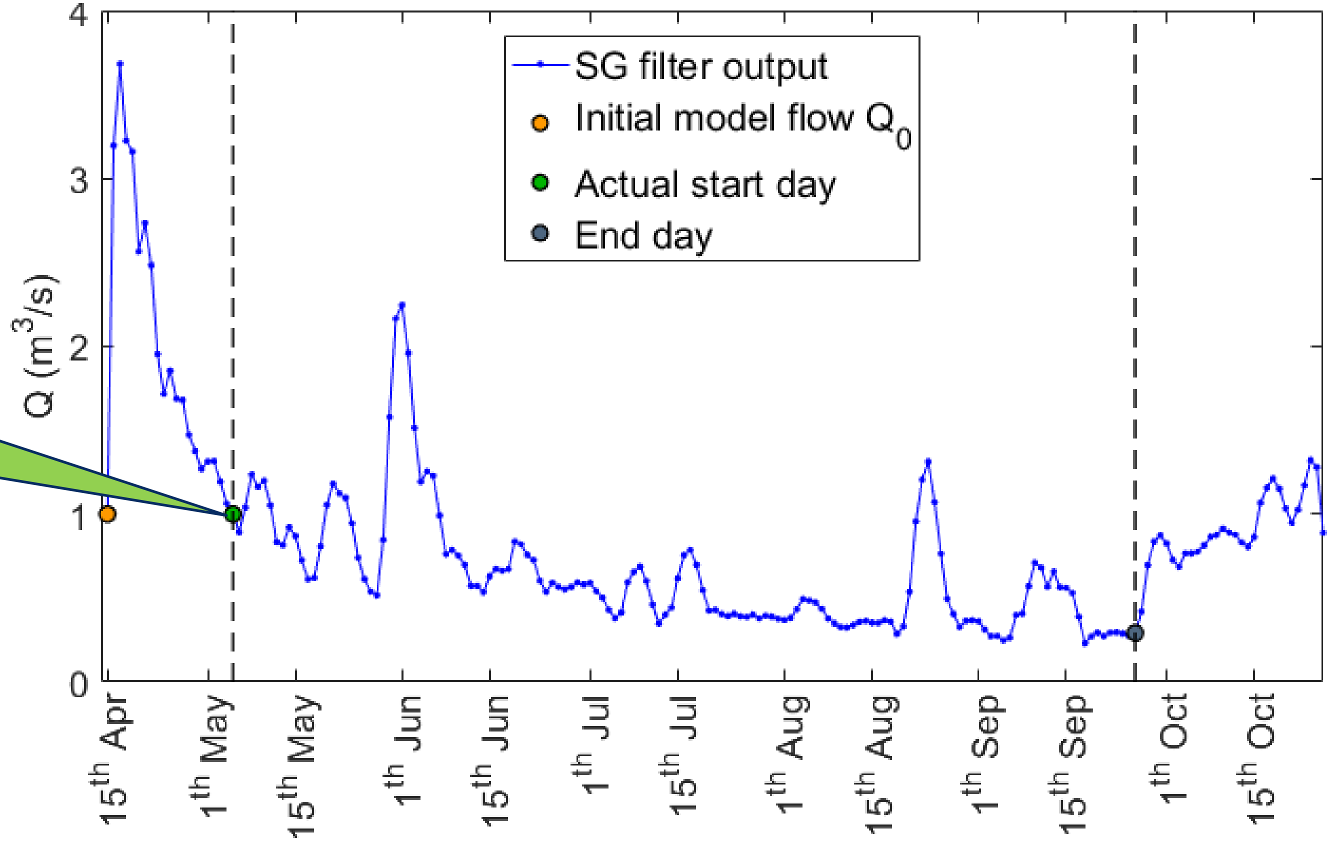




- Increase of the signal-to-noise ratio without significant signal distortion.
- Filters both large and small-scale fluctuations.
- Resemblance to weighted MA schemes

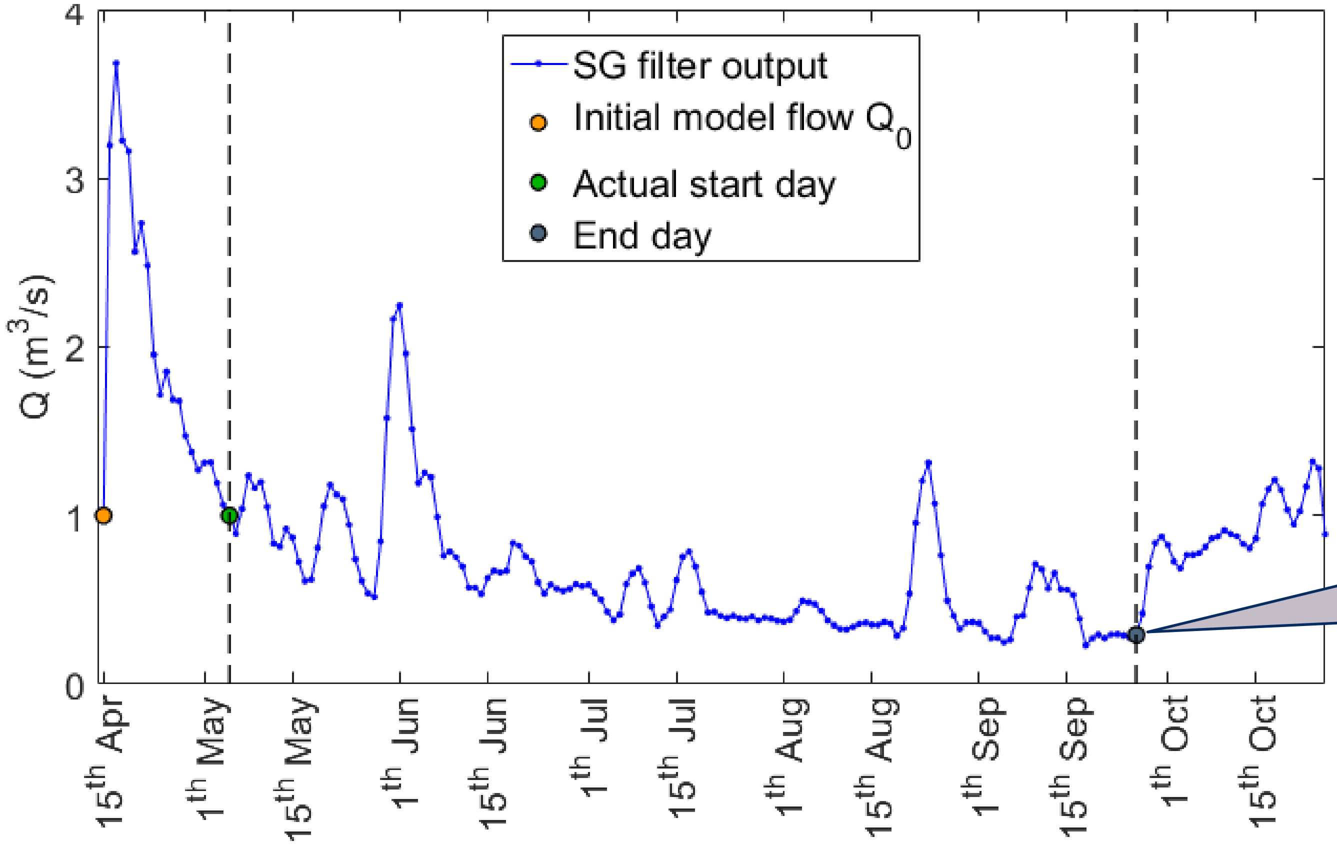
Step B1: Identification of start day

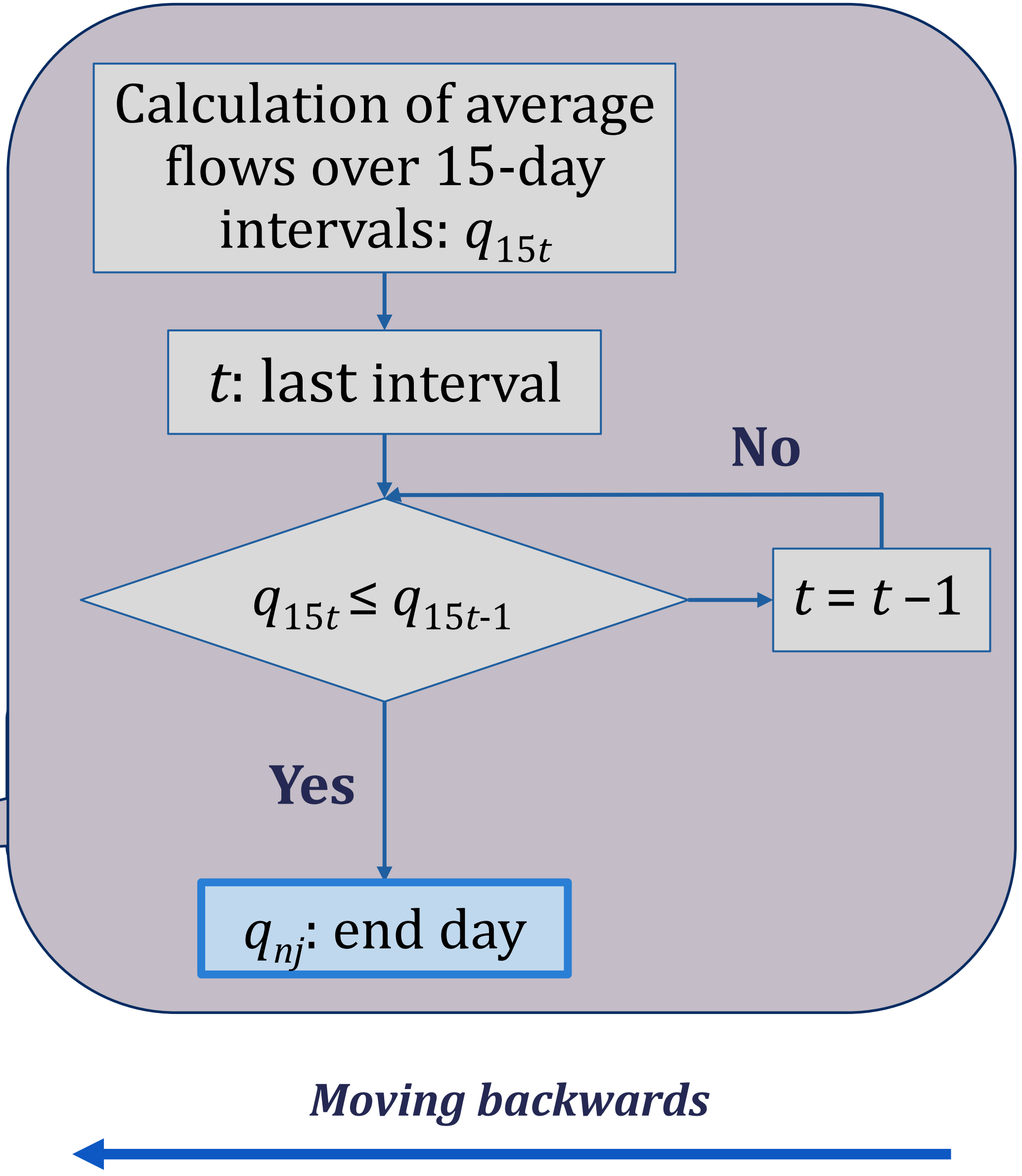




Moving forwards

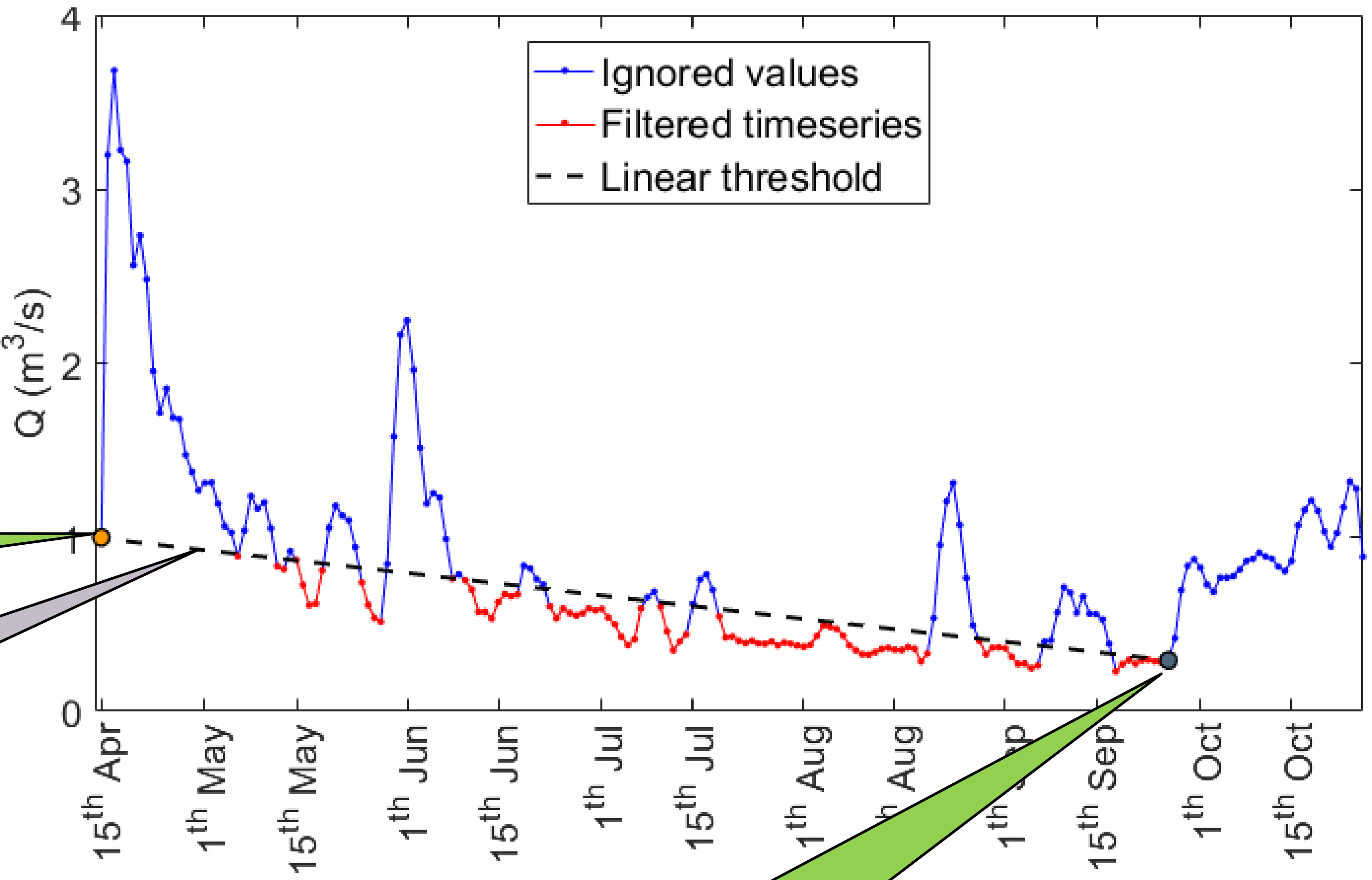
Step B2: Identification of end day





Step C: Removal of flows above theoretical upper threshold

- Theoretical upper bound of low flow model ⟶ linear decrease between initial and end flow of each year *j*.
- Removal of flow values above the line joining q_{0j} with q_{nj}.



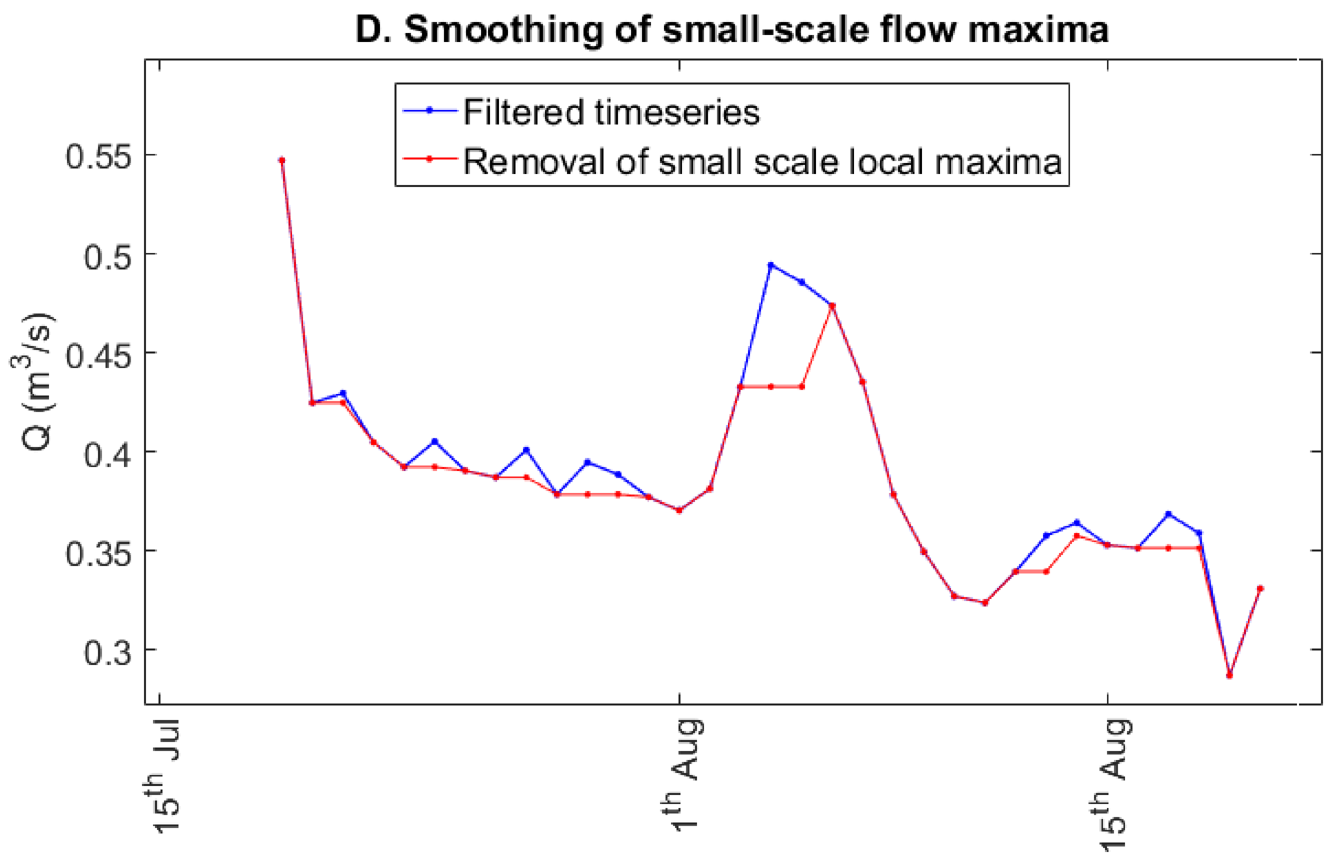
15 April

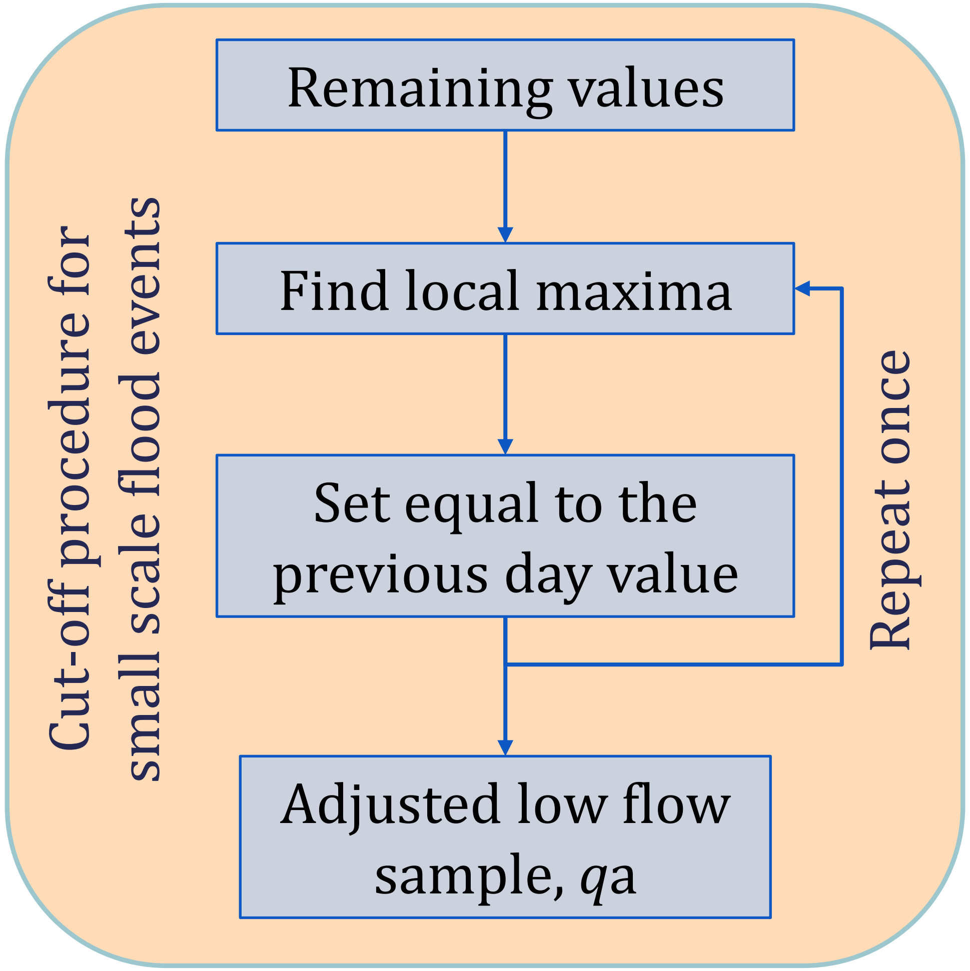
Linear decrease formula:
$q_{jt} = q_{0j} - (q_{0j} - q_{nj})\, t \,/\, n_j$

End of dry period, as determined in step B2

Step D: Smoothing of small-scale flow maxima

- Remaining local flow maxima are reduced
- Adjusted sample *qa*: non-continuous, much less values than the full dry-period sample of length n_j





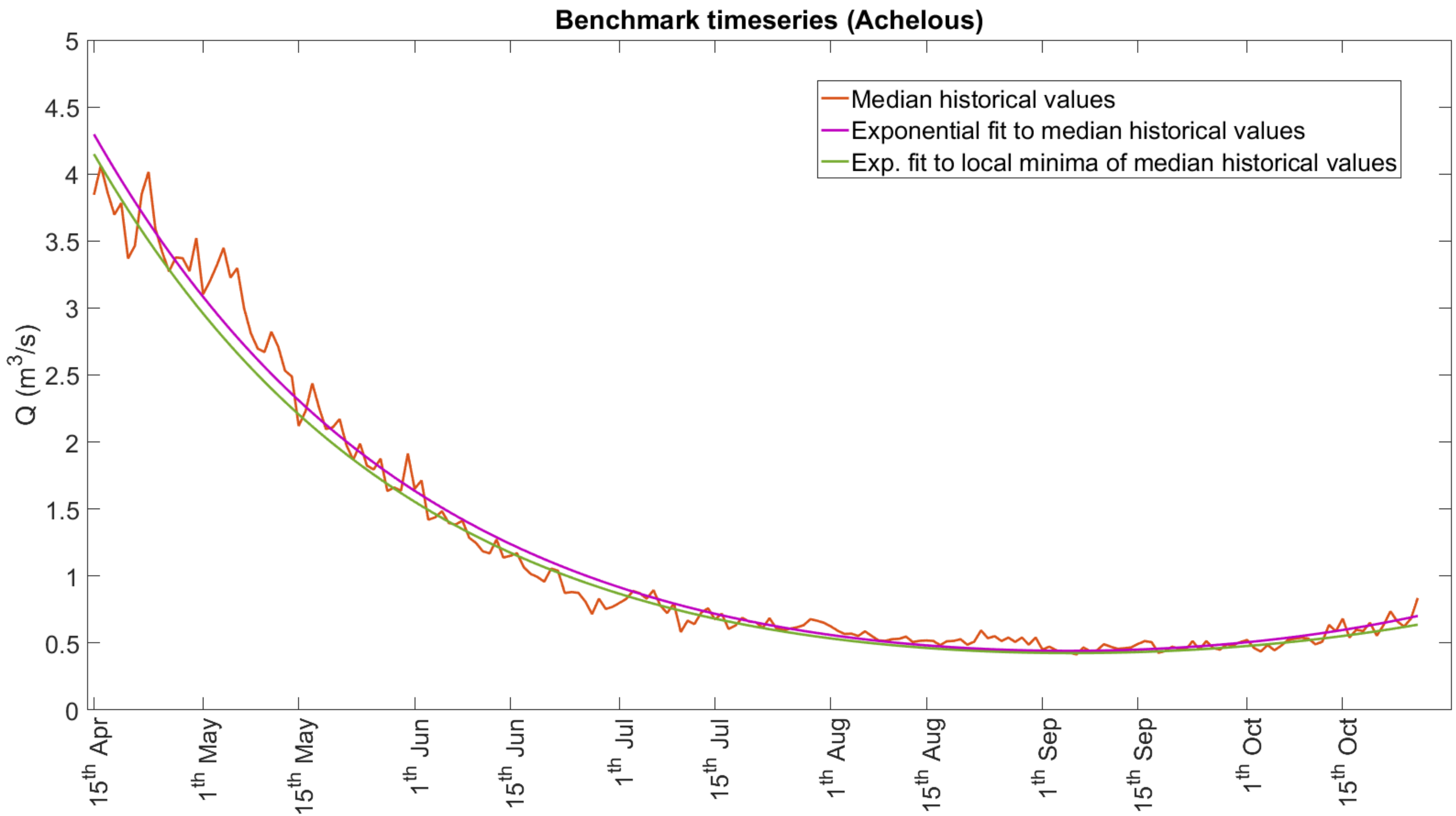
Model calibration

- Shortcomings of traditional NSE metric:
  - Comparison of simulated flows against the average flow provides unrealistically high model performance.
  - The systematic flow decrease is non – stationary.
- Objective function: **modified expression of efficiency (MEF)**

$$\text{MEF} = 1 - \frac{\sum\{qa_{jt} - q_{0j}\, exp(-k_j t)\}^2}{\sum\{qa_{jt} - Benchmarck_t\}^2}$$

- **Benchmark**: mean flow value or median of each individual day
- Stepwise exponential functions fitted to:
  - daily means
  - daily medians
  - **lower envelope of medians** ⟶ most representative of the river regime

Benchmark timeseries example



Model formulation in forecast mode

Calibration samples

Calibrate k_j independetly for every sample

Set $k_j = a q_{0j} + b$

Linear regression model:
$k_j = a q_{0j} + b$

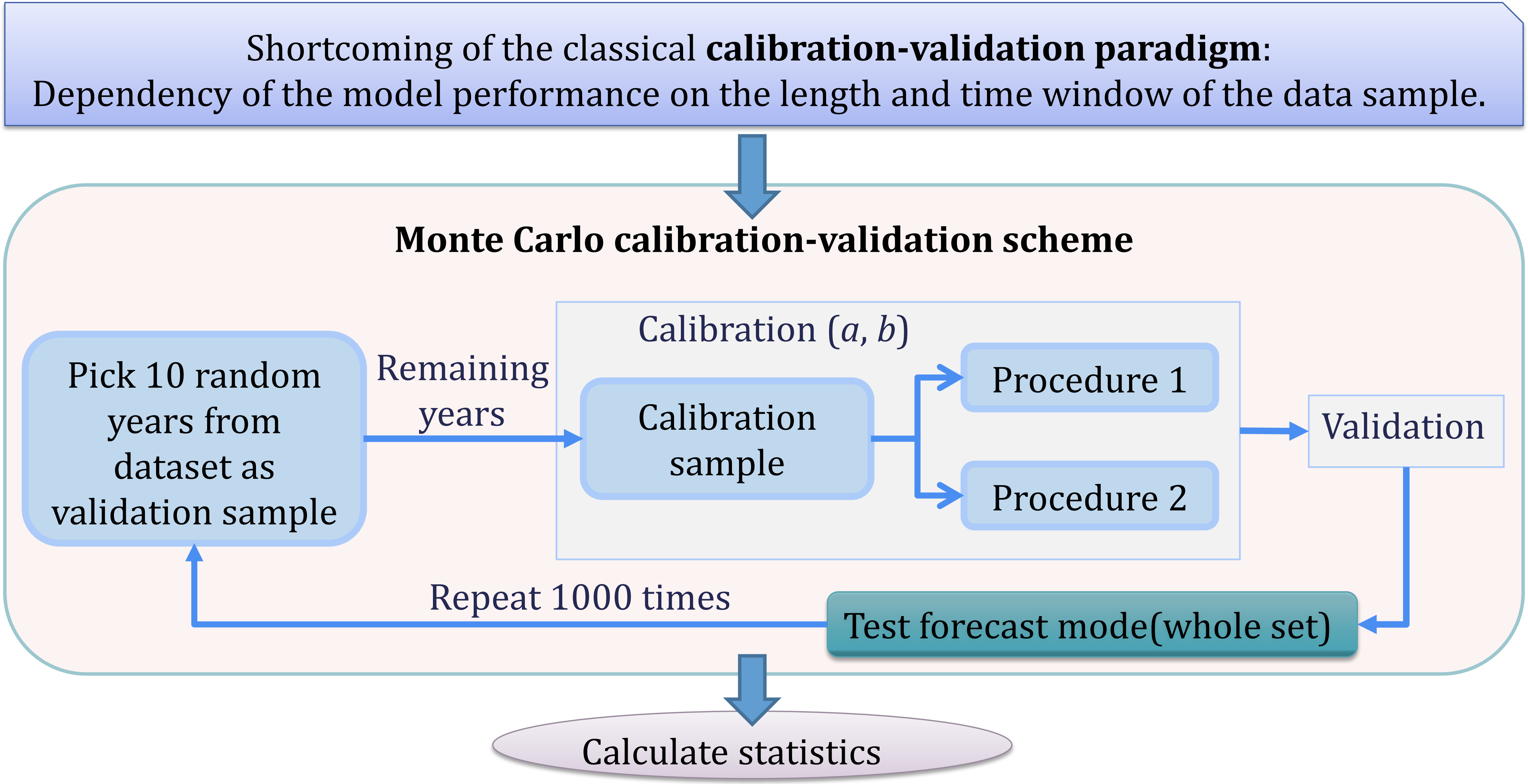
Global optimization problem
against the whole dataset

Validation samples

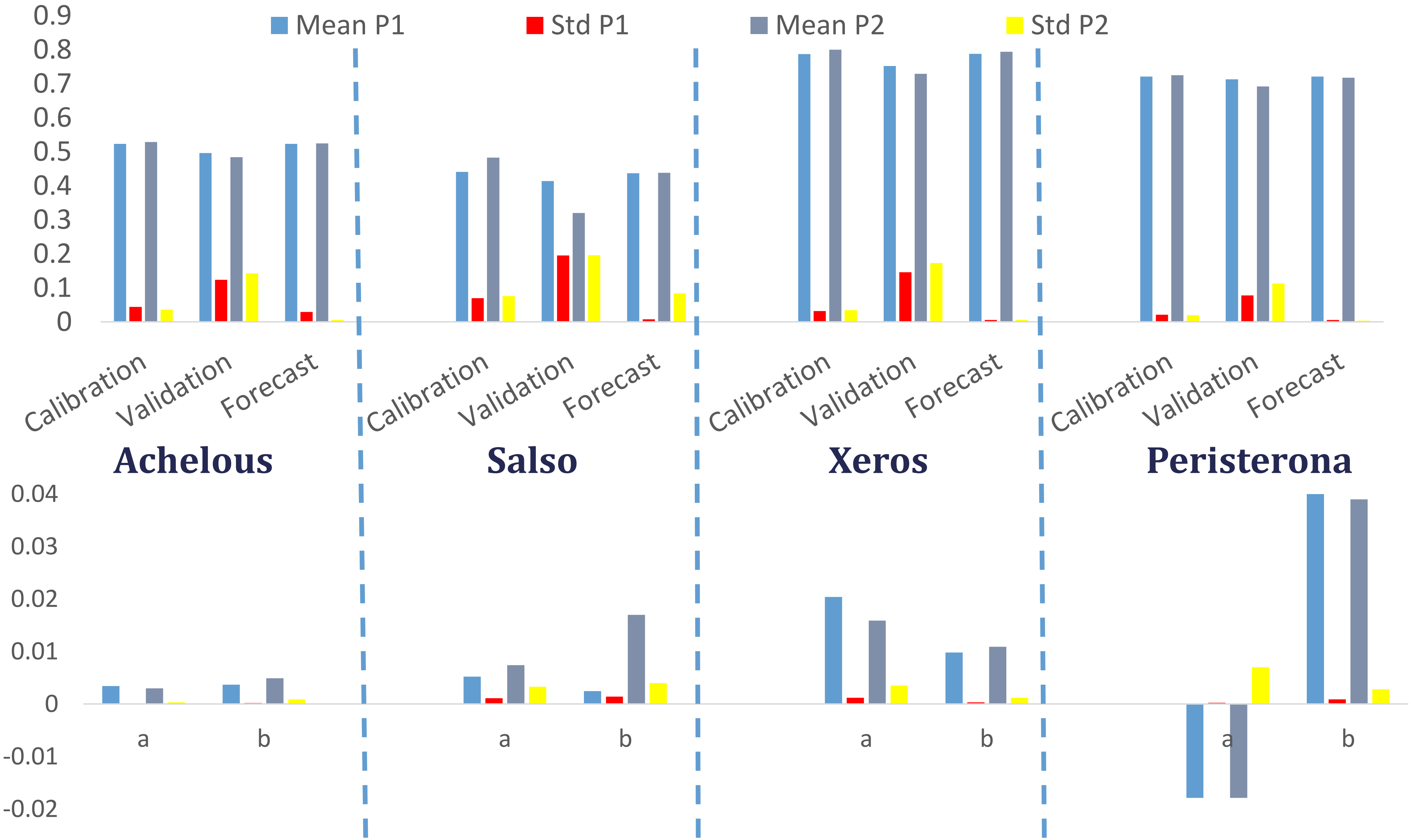
Forecast mode: $q_{jt} = q_{0j} \exp[-(a q_{0j} + b) t]$

Problem setting:
Identification of regional parameters
a (s m^{-3} d^{-1}) and b (d^{-1})

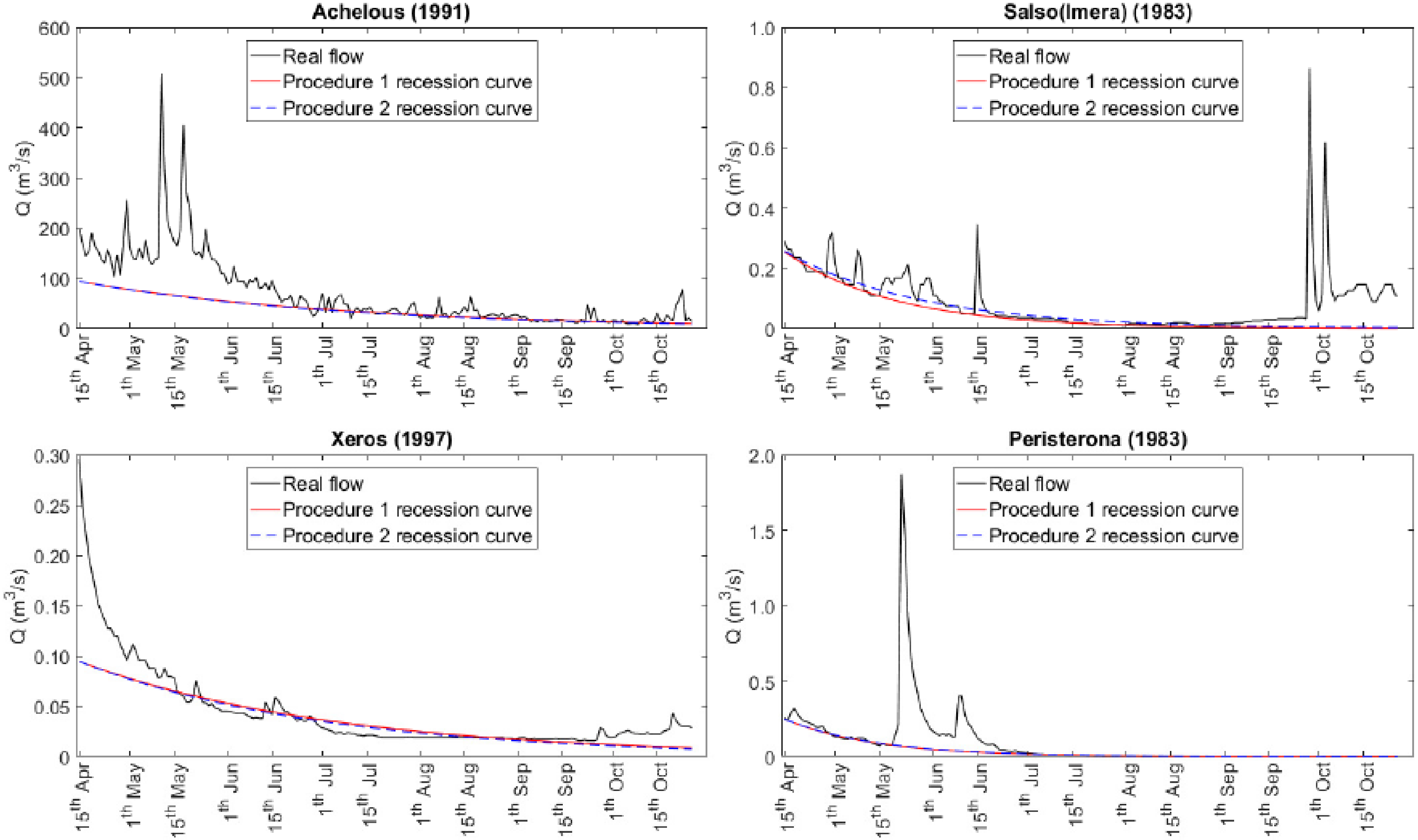
Uncertainty analysis



Results procedure 1 (P1) and 2 (P2)



Forecast examples



Conclusions

- Low flow dynamics in Mediterranean rivers can be well approximated using the linear reservoir concept.
- The proposed methodology is suitable for river basins of a wide range of spatial extent, producing both permanent and intermittent runoff during the dry period.
- The strong advantage of the model is its parsimony, in terms of
  - data requirements
  - parameters
- The model is easy to apply in an operational context, since after calibration the sole input is the starting flow q_0, which is easily observable.

Low flows on the Lower Darling River