SPATIAL AND TEMPORAL PATTERNS OF STREAMFLOW IN MEDITERRANEAN BASINS OVER THE PERIOD 2000-2022 USING SWAT+

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CERCA Centres de Recerca de Catalunya

Agència Catalana de l'Aigua

International SWAT Conference – 2023 Aarhus, Denmark

Introduction and objectives

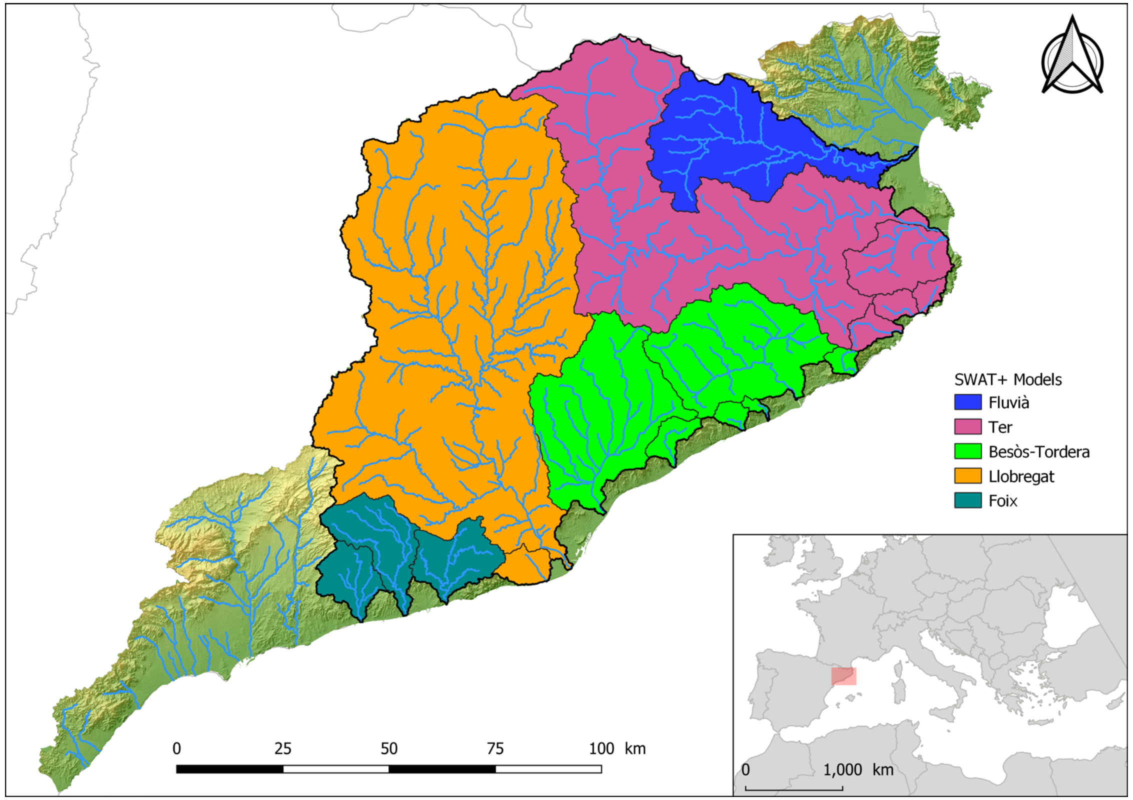
- Climate change: adverse impacts will intensity
- Climate change action: reduce losses to nature and people (co-benefits)
- Mediterranean: already prone to water scarcity due to natural inter-annual rainfall variability, but exacerbated by faster climate change.
- Increased frequency and magnitude of extreme events, both droughts and floods
- Understanding catchment behavior is needed to promote resilient and sustainable management practices
- Inner Catalan Basins (ICB): small-medium sized Western Mediterranean basins

Introduction and objectives

- We aim to:
  - Develop the ICB-SWAT+ model as a support tool for water resources management
  - Develop an innovative calibration/validation strategy considering multiple gauging stations with heterogenous data
  - Identify and characterize spatiotemporal patterns in ICB during the first two decades of the 21st century

Methods – Study site

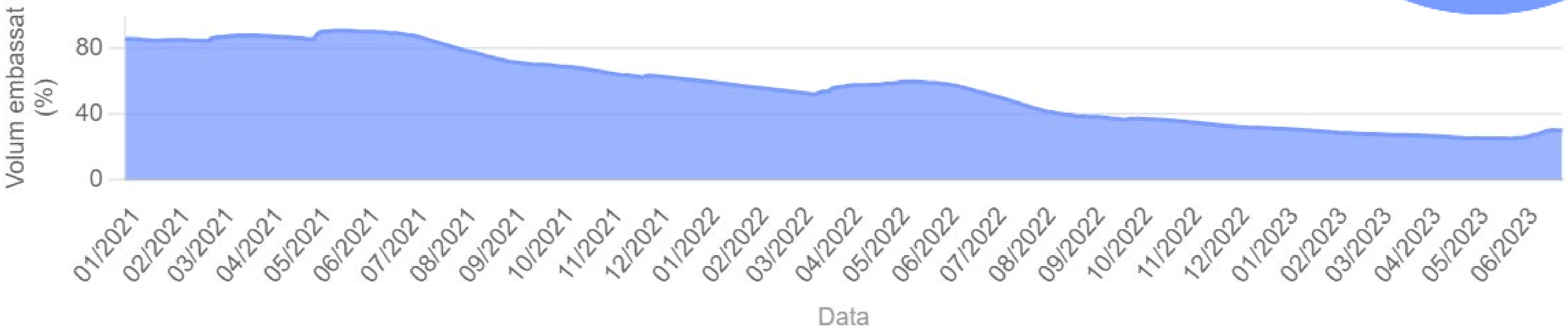
- Inner Catalan Basins, NE Iberian Peninsula, W Mediterranean
- Watershed area: 16 – 5000 km^2, total 12200 km^2
- 7M inhabitants
- Annual water demand > 1000 hm^3



Methods – Study site

- Inner Catalan Basins, NE Iberian Peninsula, W Mediterranean
- Watershed area: 16 – 5000 km^2, total 12200 km^2
- 7M inhabitants
- Annual water demand > 1000 hm^3
- Vulnerable to water scarcity

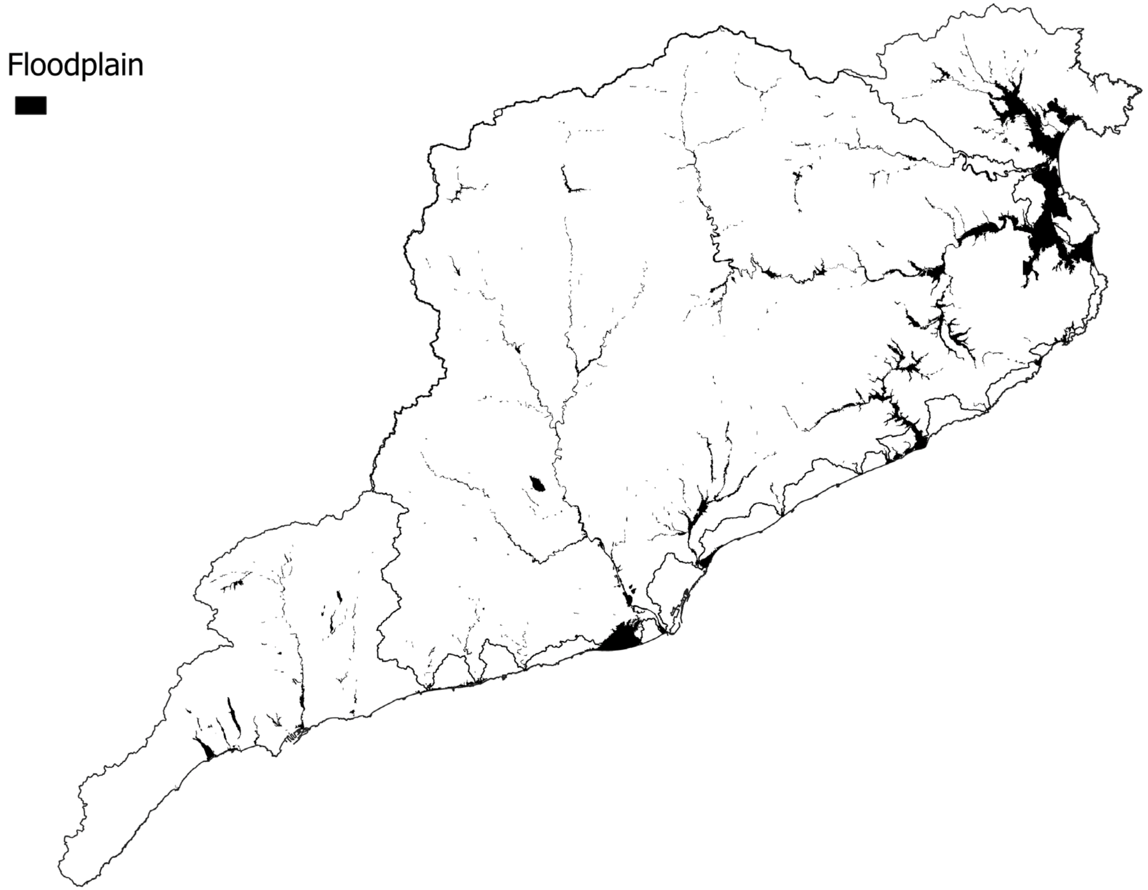
Reservoir reserves
30%
26/06/2023



Source: Catalan Water Agency, “El visor de la sequera”, https://aplicacions.aca.gencat.cat/visseq/estat-actual

Methods – Model configuration

- DEM 70x70m
- Modified CORINE Land Cover 2018
- WIT Openland soil map
- Floodplain map



Methods – Model configuration

- DEM 70x70m
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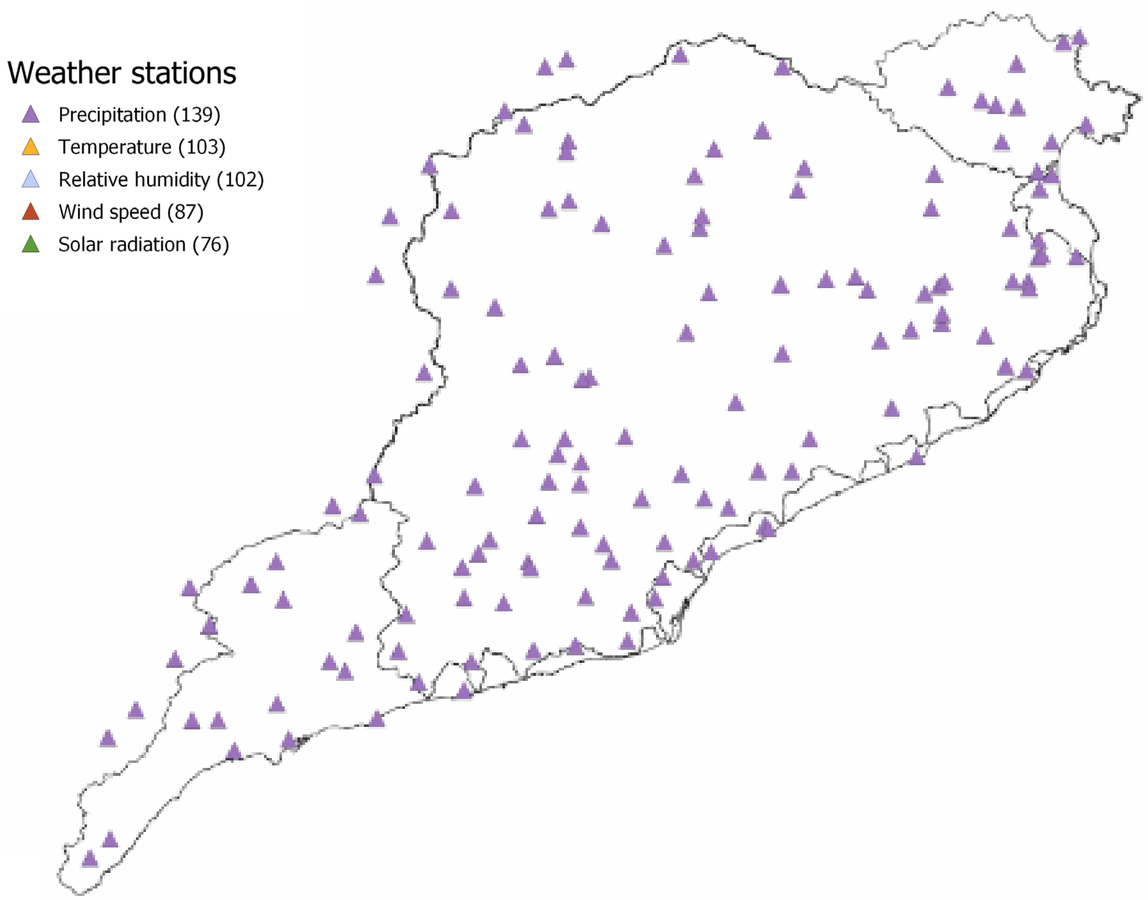
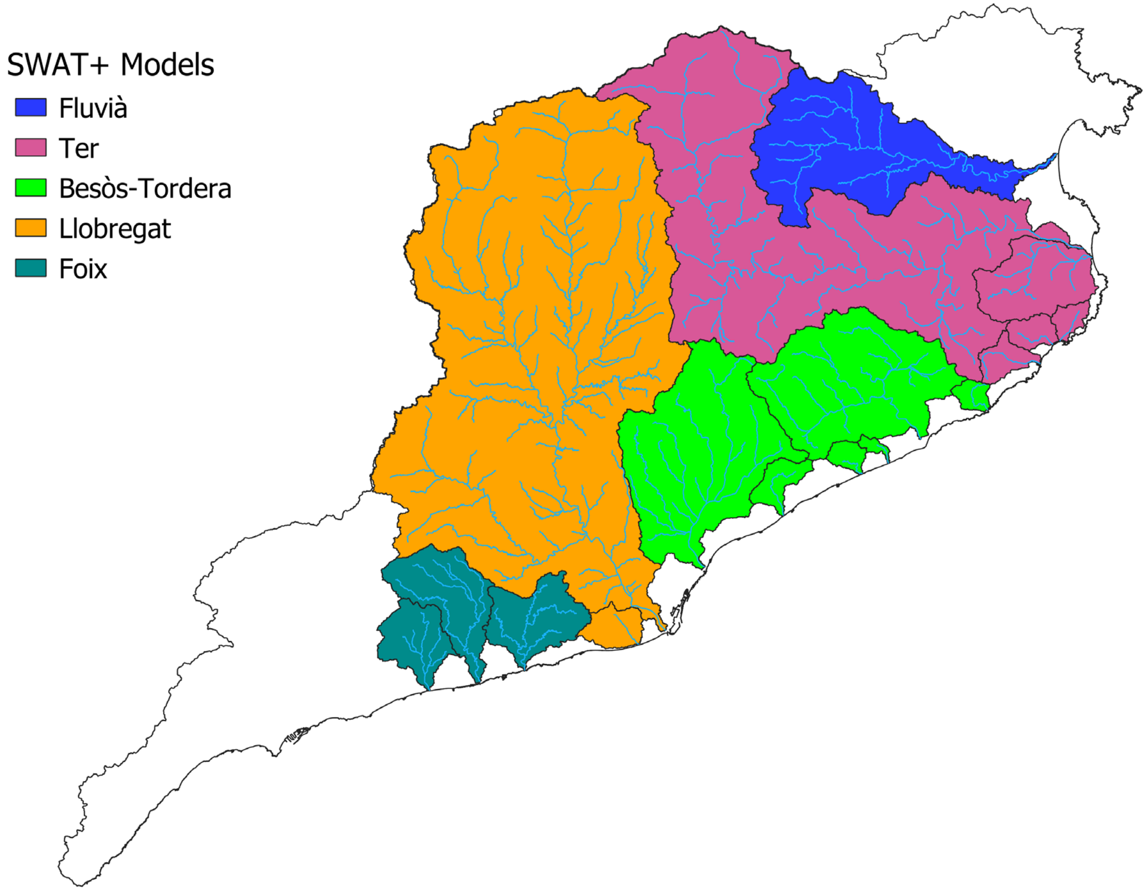
- Floodplain map
- Weather data: 2000-2022, 1y warm-up
  - Spain Weather Generator
  - 141 weather stations



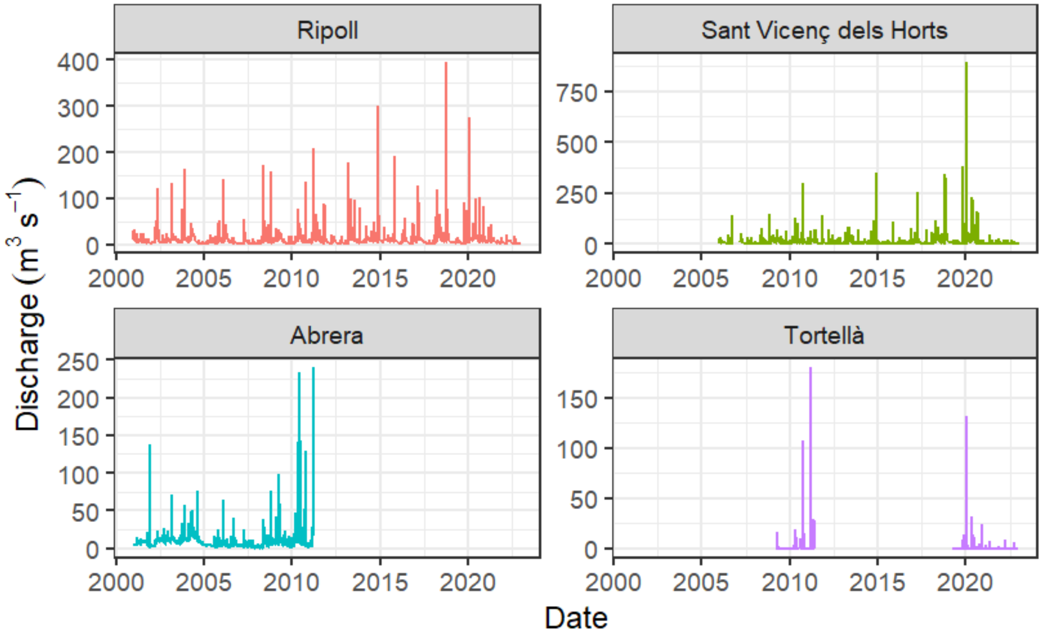
Methods – Model configuration

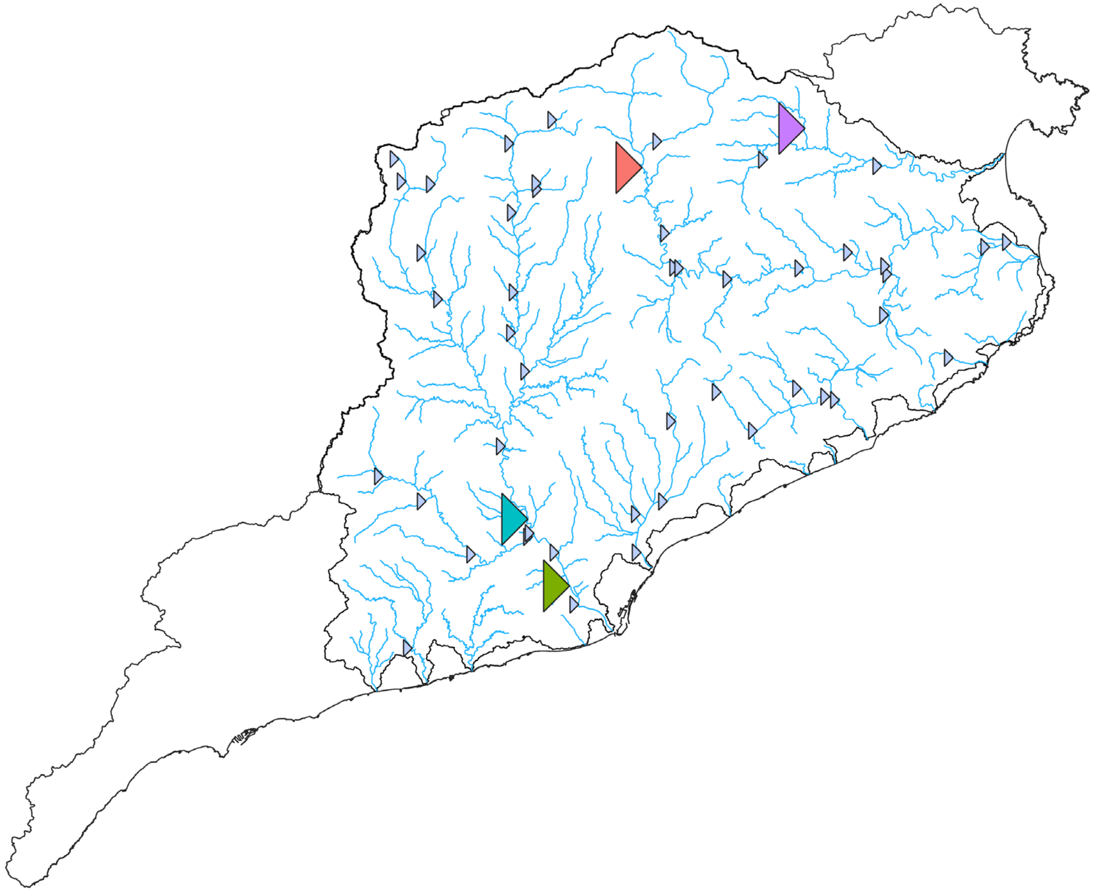
- DEM 70x70m
- Modified CORINE Land Cover 2018
- WIT Openland soil map
- Floodplain map
- Weather data: 2000-2022, 1y warm-up
  - Spain Weather Generator
  - 141 weather stations
- Reservoir and crop operations
- Point source discharges



Methods – Gauging stations

- 50 gauging stations
- Daily streamflow
- 2001 – 2022
- Great spatiotemporal variability





Methods – Sensitivity analysis and calibration

Sensitivity Analysis

- Fourier Amplitude Sensitivity Test (FAST)
- Sensitivity threshold: variance > 1‰
- Kling-Gupta Efficiency (KGE)
- 30 parameters

$$KGE = \sqrt{(r-1)^2 + (\alpha - 1)^2 + (\beta - 1)^2}$$

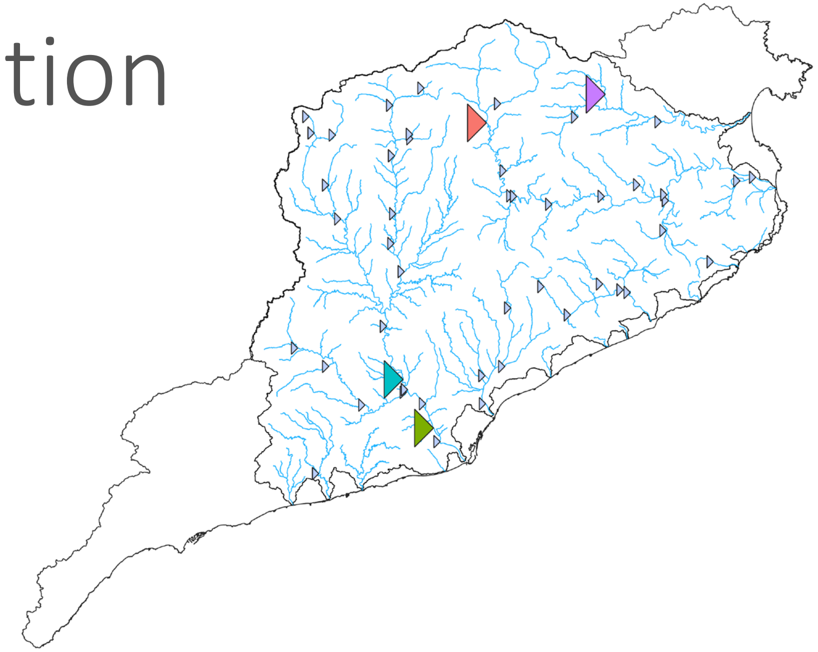
Calibration/validation

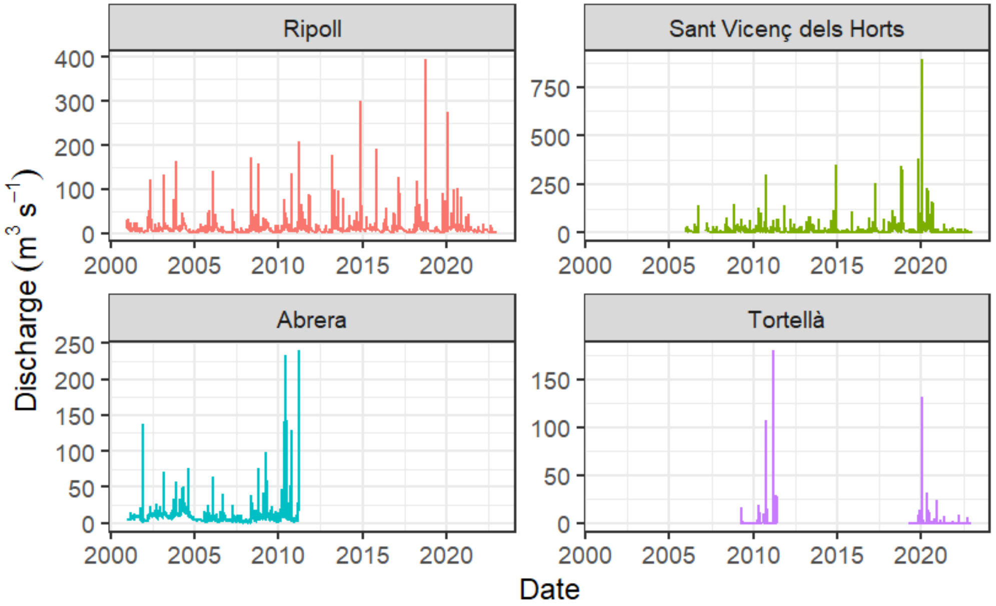
- Latin Hypercube Sampling, N = 2000 simulations
- Evaluating for KGE and PBIAS
- Between 6 and 13 sensitive parameters

$$PBIAS = \frac{\sum_{i=1}^{n} (Q_{obs} - Q_{sim})}{\sum_{i=1}^{n} (Q_{obs})} * 100$$

Methods – Calibration and validation

- 50 gauging stations
- Differences in:
  - Series length
  - Temporal distribution
  - Spatial distribution
- Difficult capturing spatiotemporal climatic variability
- Usual methods to define the calibration and validation periods are not suitable





Methods – Calibration and validation

<u>Usual methods</u>

- Calibration first, then validation
- Validation first, then calibration

← Very different series length

<u>Alternatives</u>

- First 70% calibration, then validation
- Some stations for calibration, others validation
- 70-30% calibration-validation, randomly

Methods – Calibration and validation

Usual methods

- Calibration first, then validation
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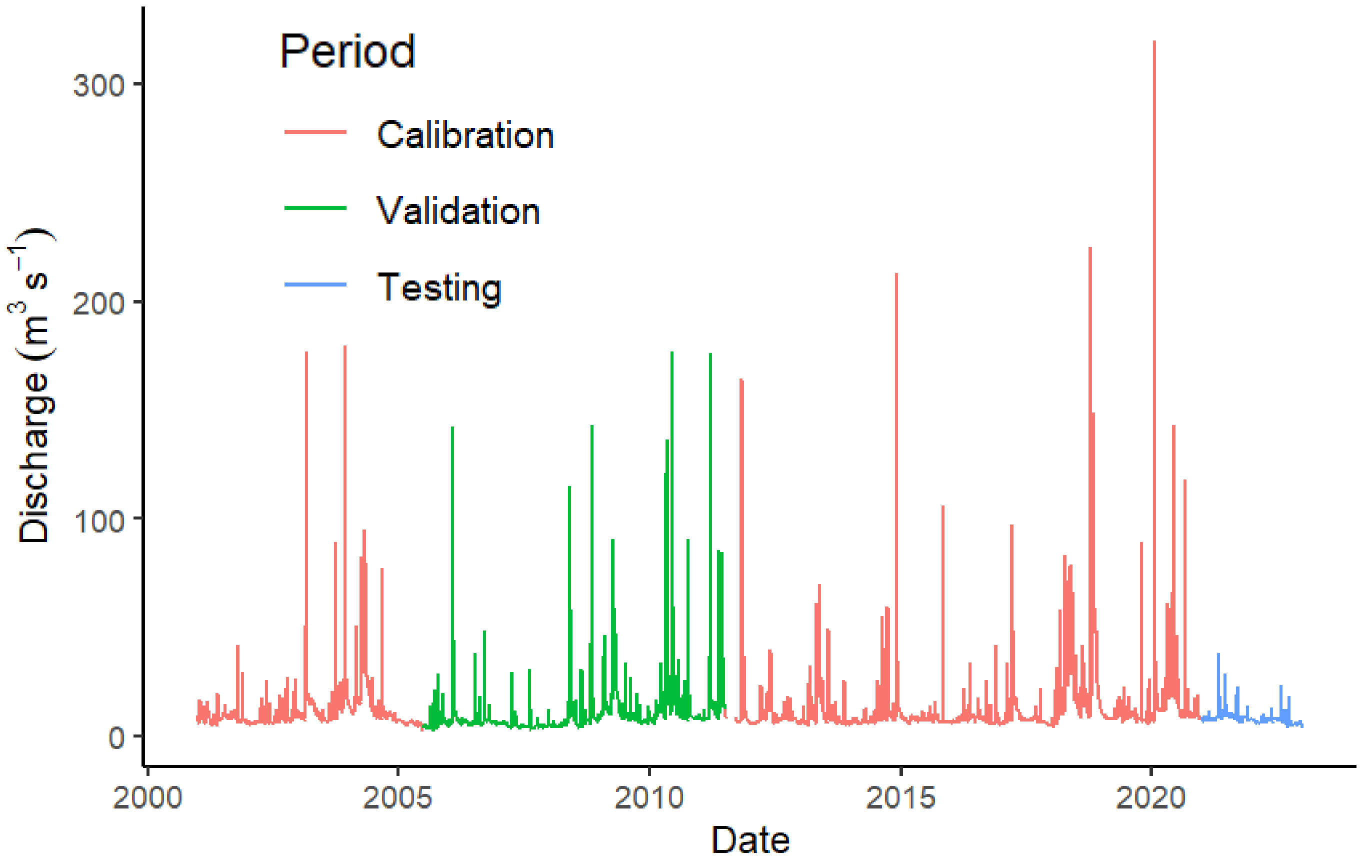
Alternatives

- First 70% calibration, then validation
- Some stations for calibration, others validation
- **70-30% calibration-validation, randomly**

Methods – Calibration and validation + testing

- 70-30% calibration-validation, randomly
  - 70% calibration
  - 30% validation, one window

- + 2 years of testing (2021-2022)
  - True validation



Methods – Analysis of spatial and temporal patterns

Hydrological indicators

- Indicators of Hydrological Alteration (IHA)
- Indicators of zero-flow
  - Annual days
  - Event frequency
  - Event mean duration
  - Onset (jday)
  - Central point (jday)
  - Percentage of dry river network

40 indicators

Trend characterization

- Sen's slope estimator + Modified Mann-Kendall Test
- Clustering techniques

Spatial autocorrelation

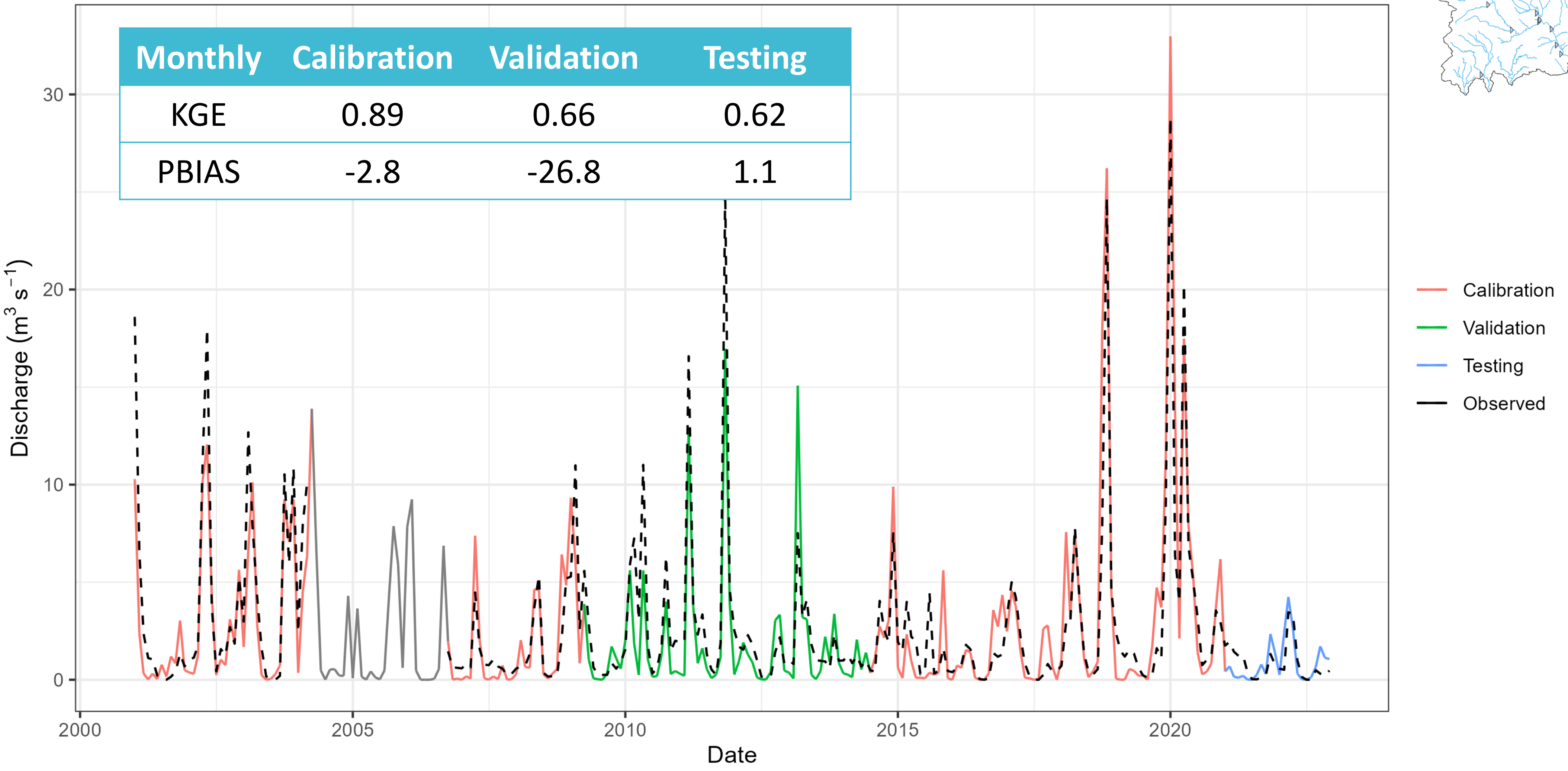
Graph + Spectral clustering

Results – Calibration, validation and testing

- Satisfactory when:
  - KGE > 0.5
  - -25% < PBIAS < 25%

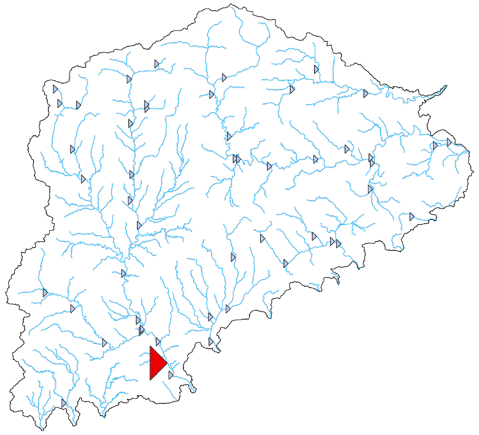
Daily	Calibration		Validation		Testing	
	KGE	PBIAS	KGE	PBIAS	KGE	PBIAS
Besòs-Tordera	0.65	-3.1	0.70	2.9	0.46	5.4
Fluvià	0.50	-16.1	0.71	-14.4	0.36	31.6
Foix	0.54	-10	0.70	-7.1	0.72	11.5
Llobregat	0.49	-4.9	0.48	-19.2	0.42	-11.4
Ter	0.47	-21	0.52	-8.7	0.52	-17.9
Monthly						
Besòs-Tordera	0.86	-3.3	0.85	3	0.81	5.4
Fluvià	0.57	-16.1	0.65	-13.9	0.62	31.5
Foix	0.75	-9	0.59	-6.6	0.70	11.3
Llobregat	0.80	-5.4	0.72	-19.2	0.72	-11.4
Ter	0.64	-21.3	0.60	-8.6	0.66	-17.9

Results – Calibration, validation and testing

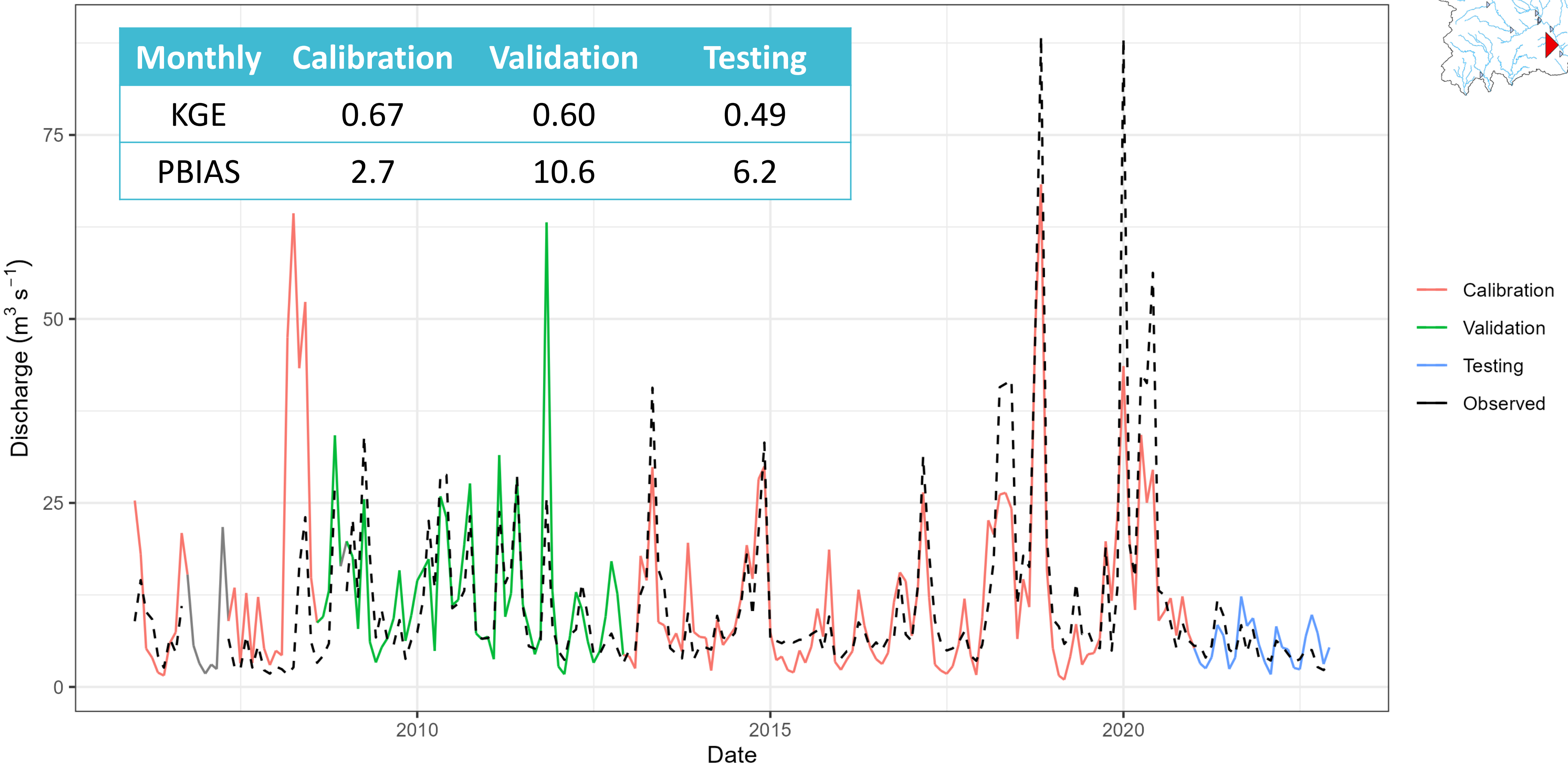


Monthly	Calibration	Validation	Testing
KGE	0.89	0.66	0.62
PBIAS	-2.8	-26.8	1.1

Results – Calibration, validation and testing



Monthly	Calibration	Validation	Testing
KGE	0.67	0.60	0.49
PBIAS	2.7	10.6	6.2



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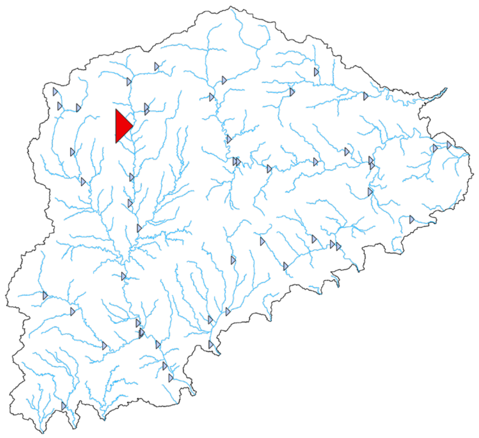
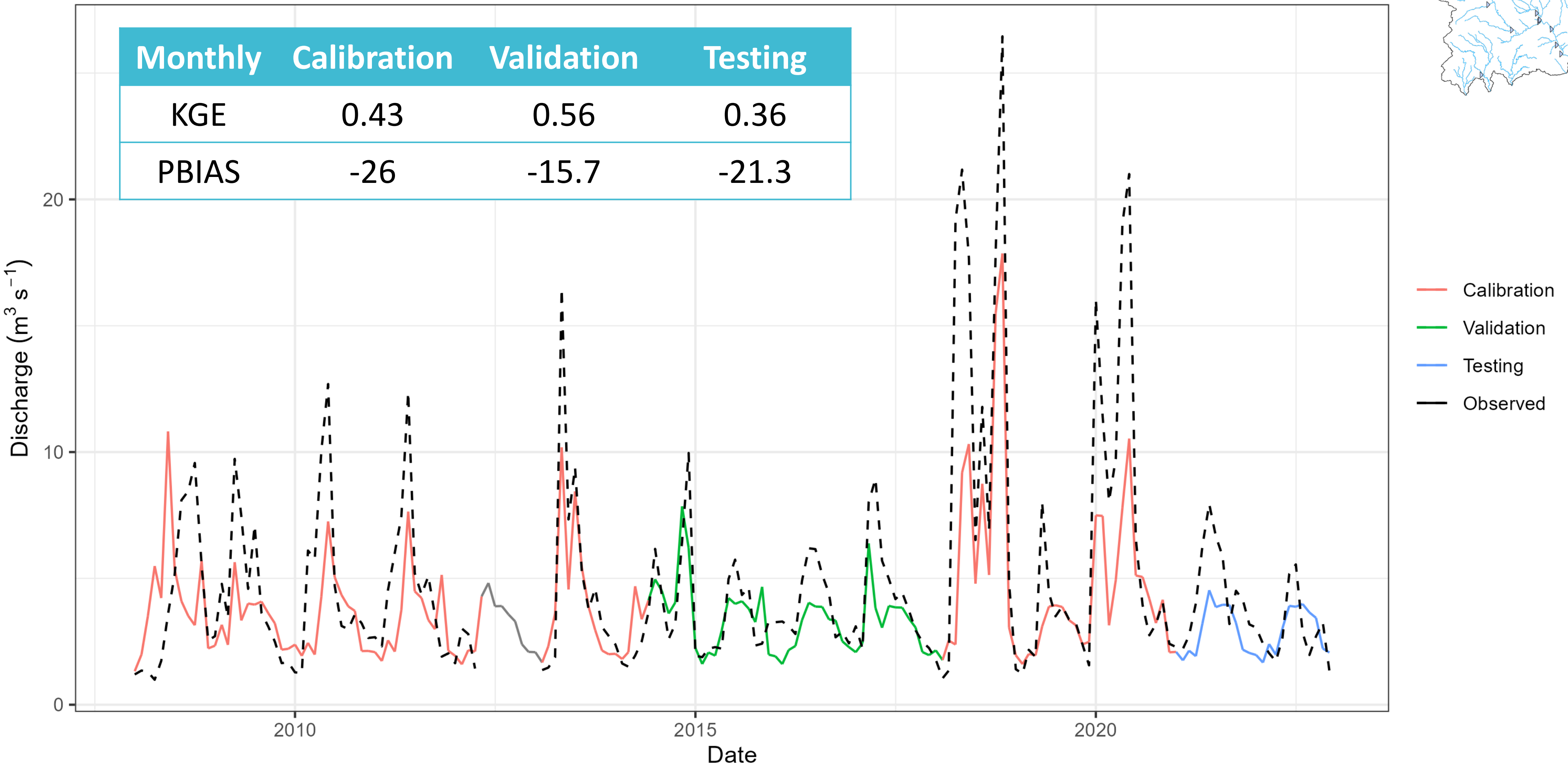


Monthly	Calibration	Validation	Testing
KGE	0.43	0.56	0.36
PBIAS	-26	-15.7	-21.3



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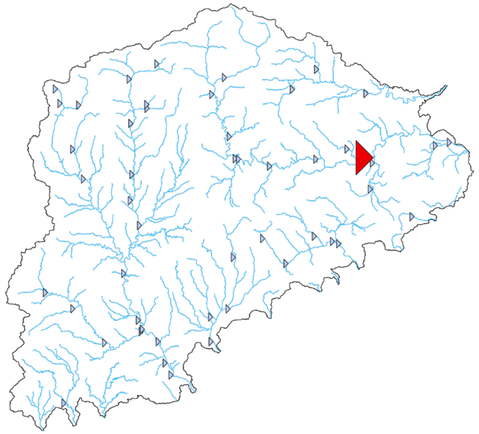
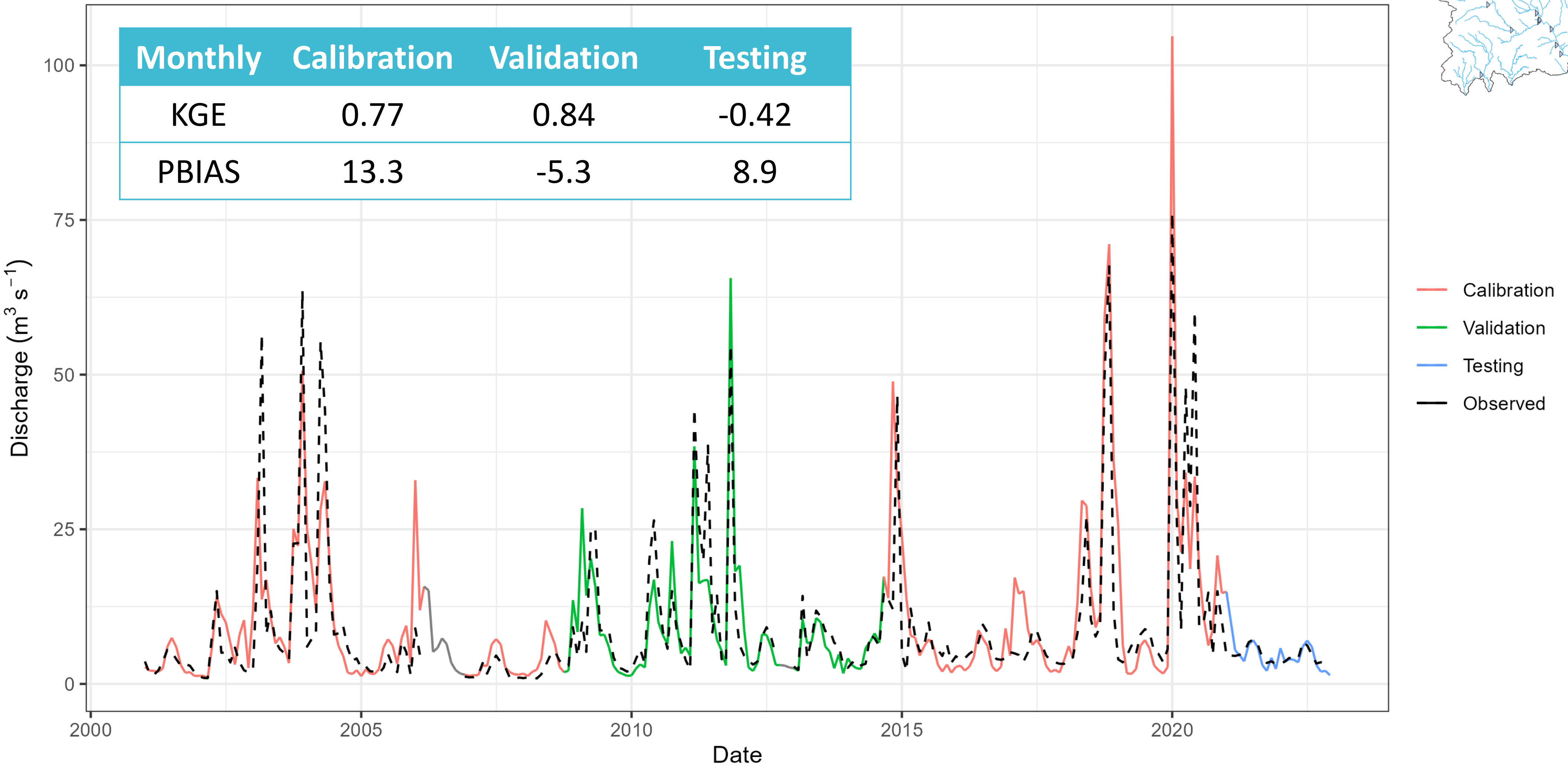
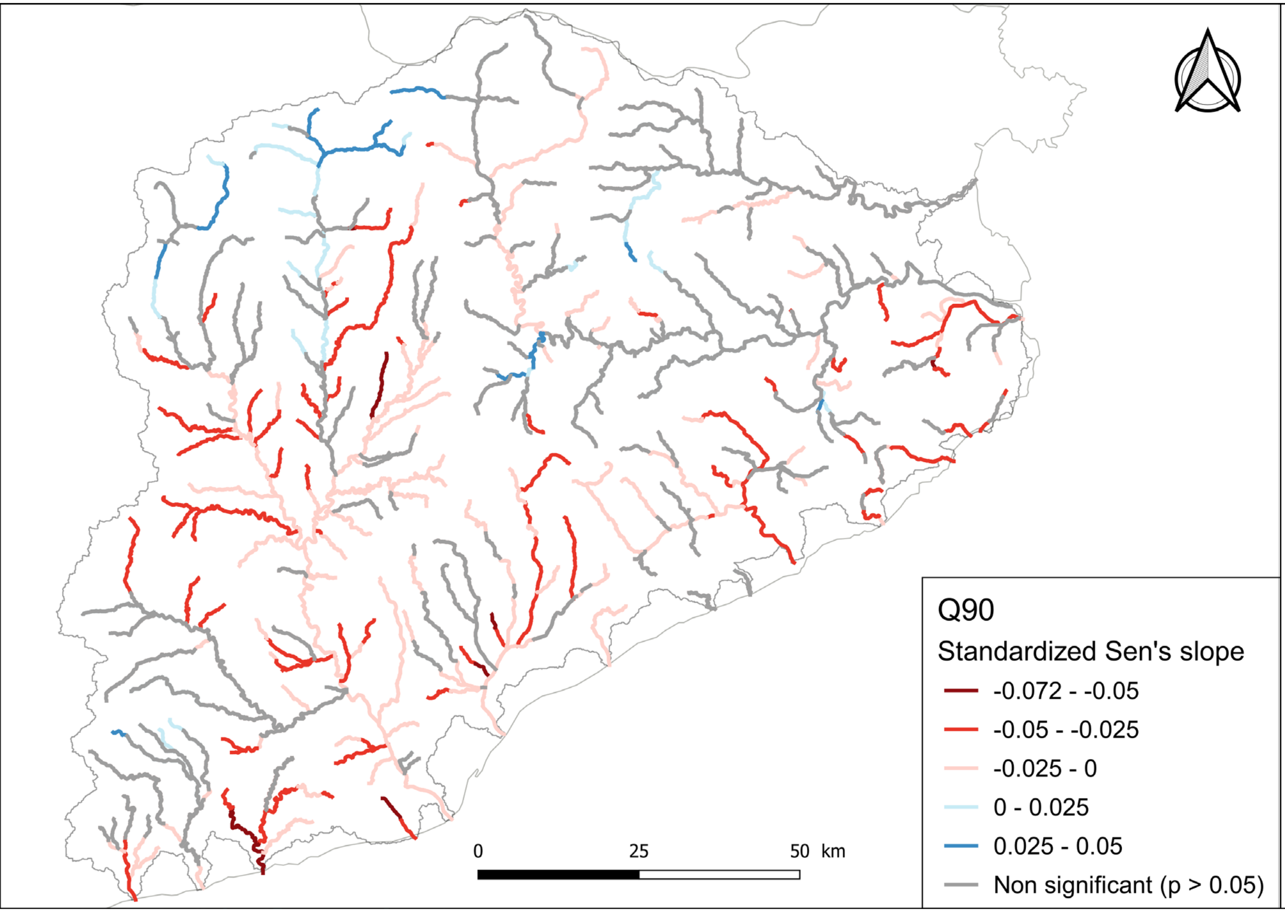


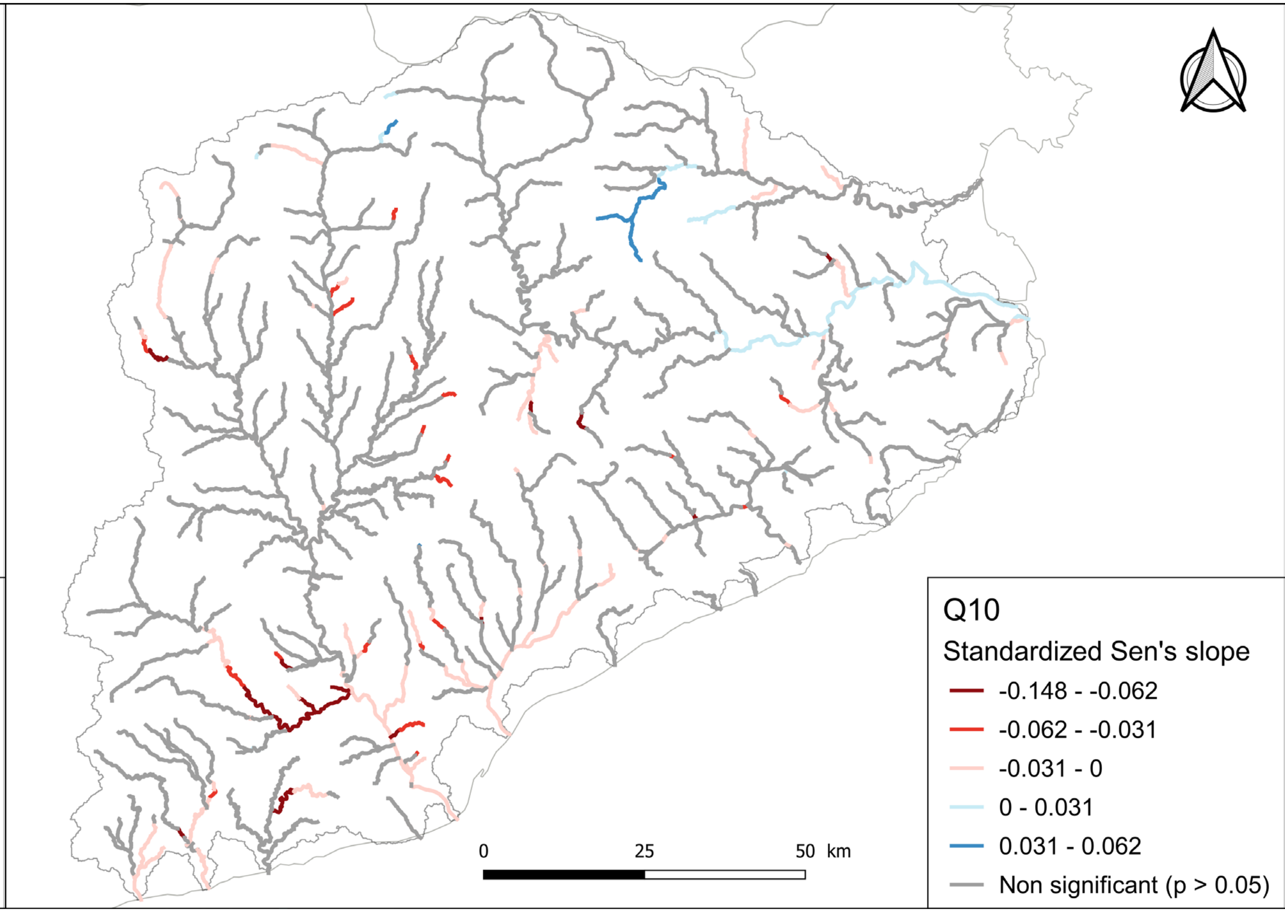
Monthly	Calibration	Validation	Testing
KGE	0.77	0.84	-0.42
PBIAS	13.3	-5.3	8.9



Results – Analysis of temporal flow patterns

- Sen's slope estimator + Modified Mann-Kendall Test ± Standardization





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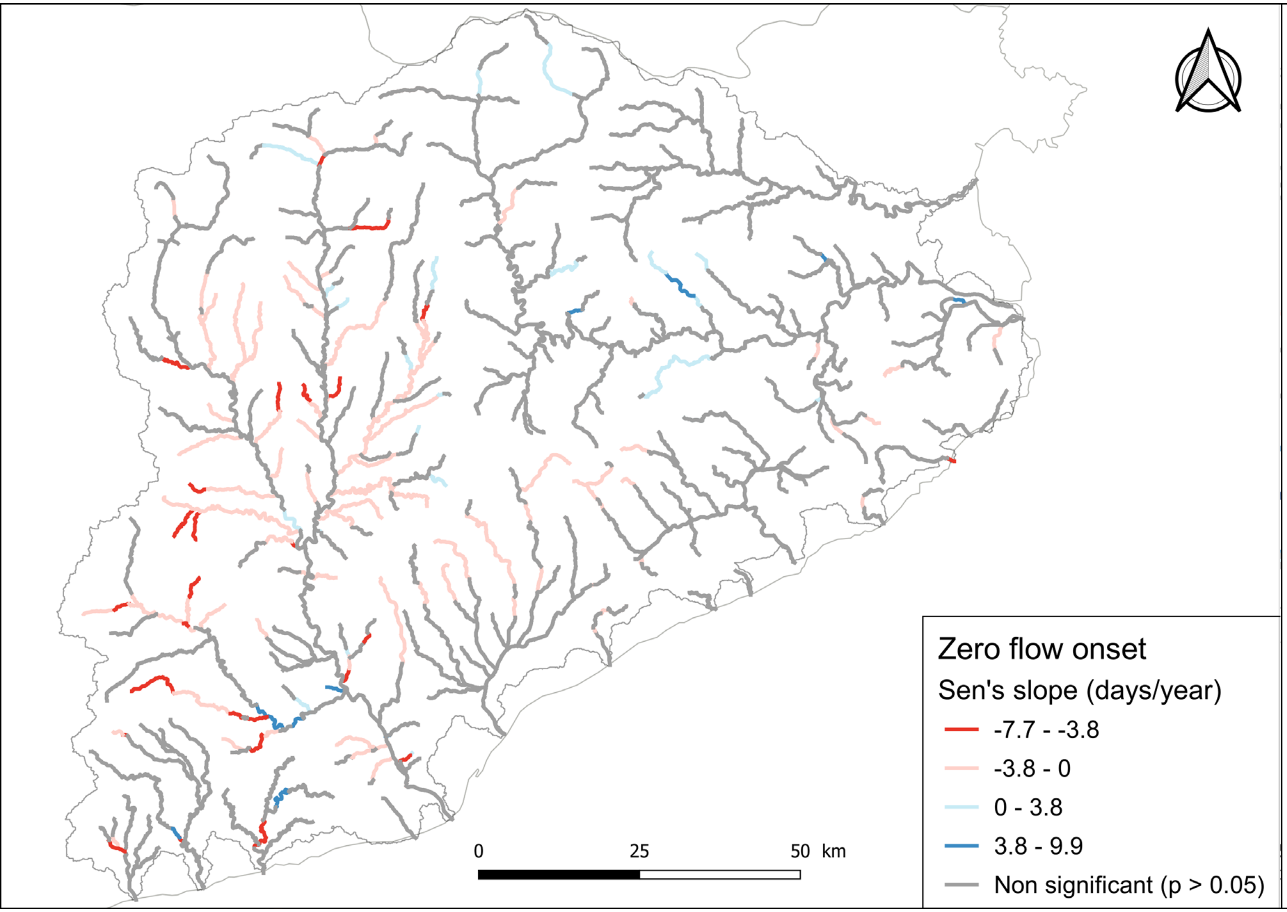

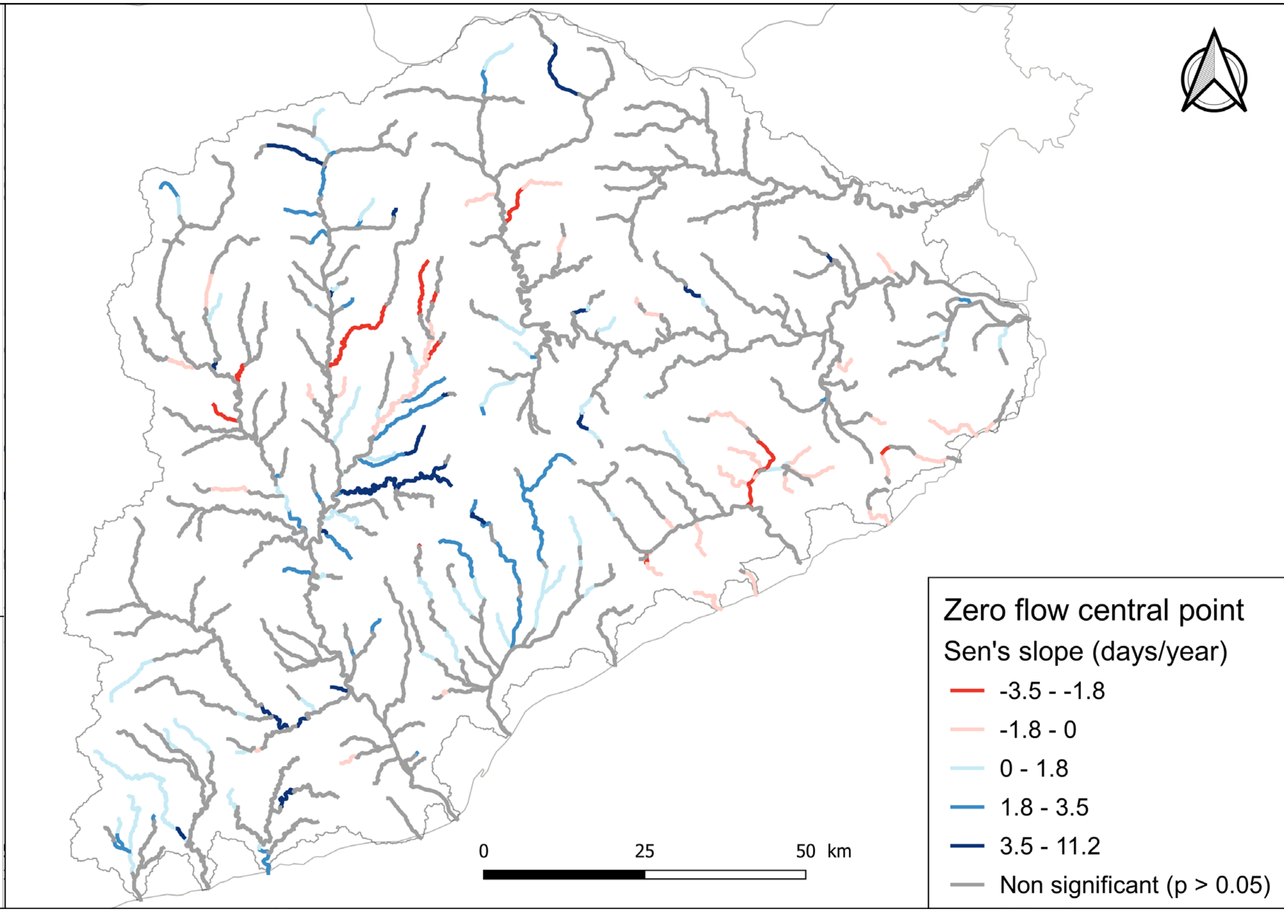

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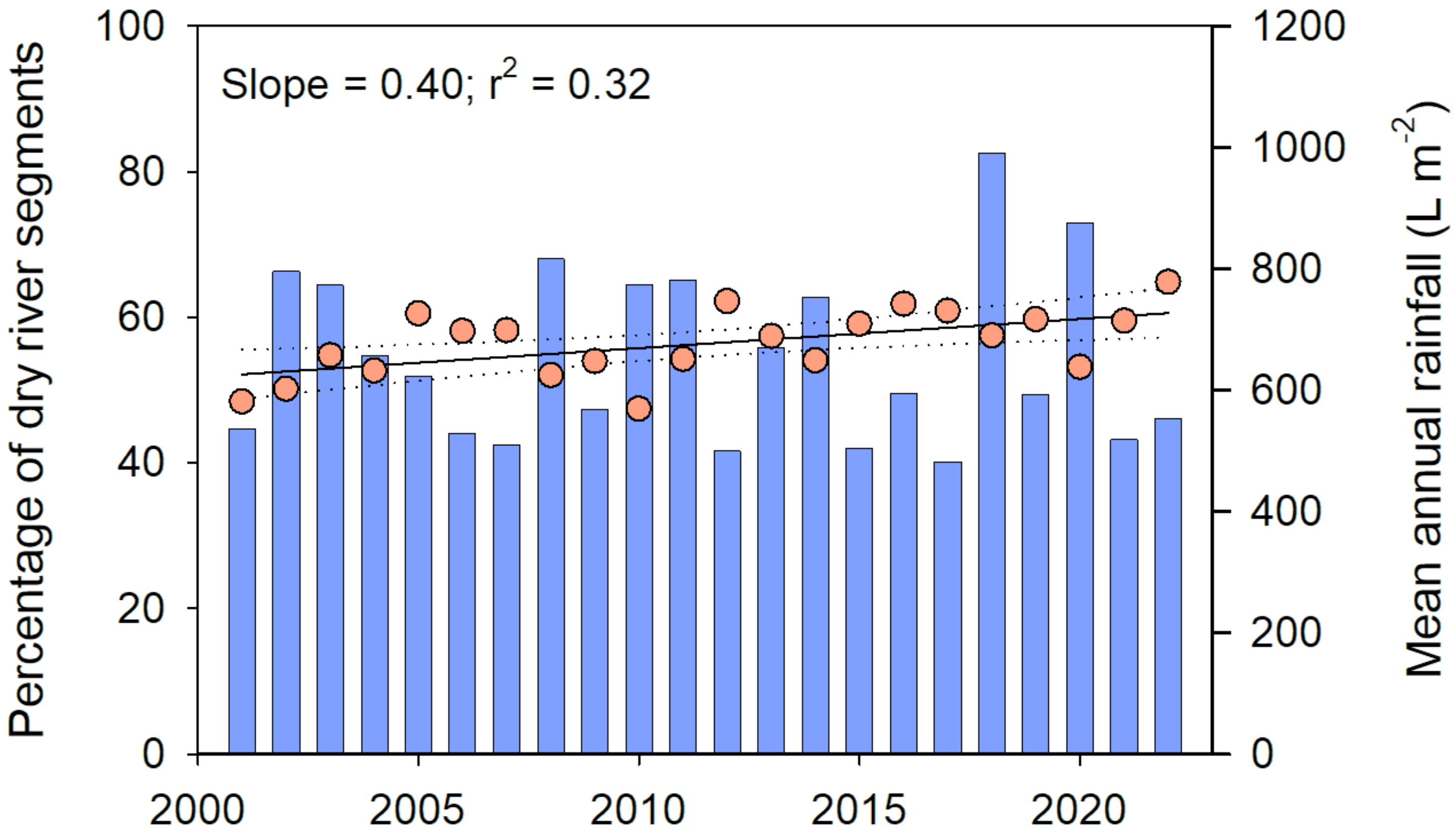

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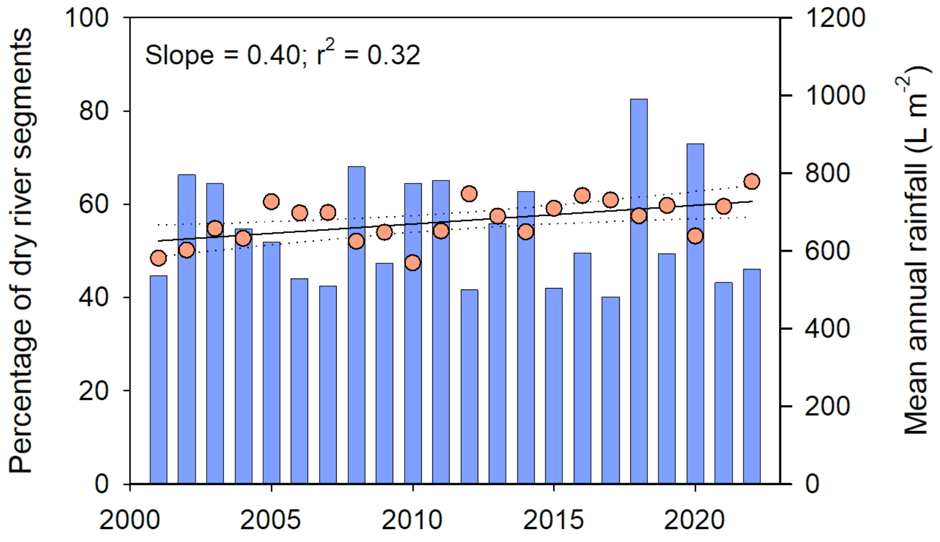
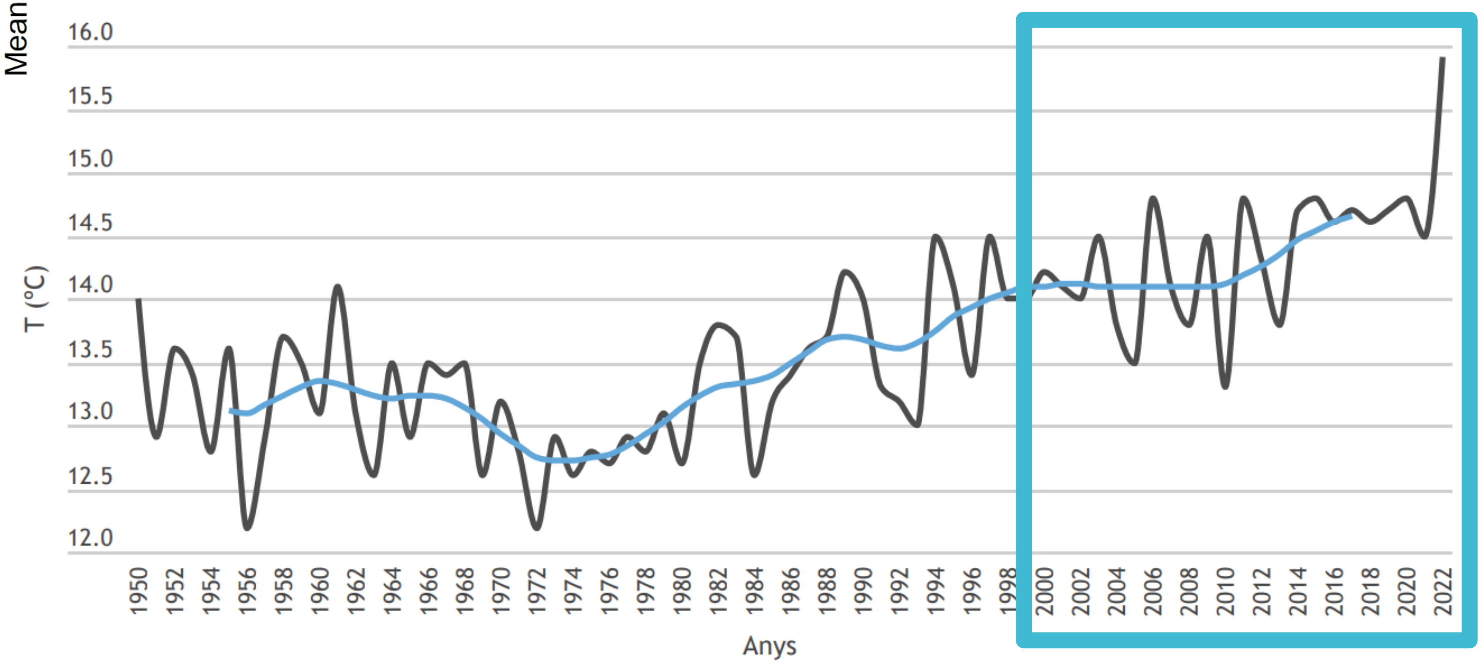


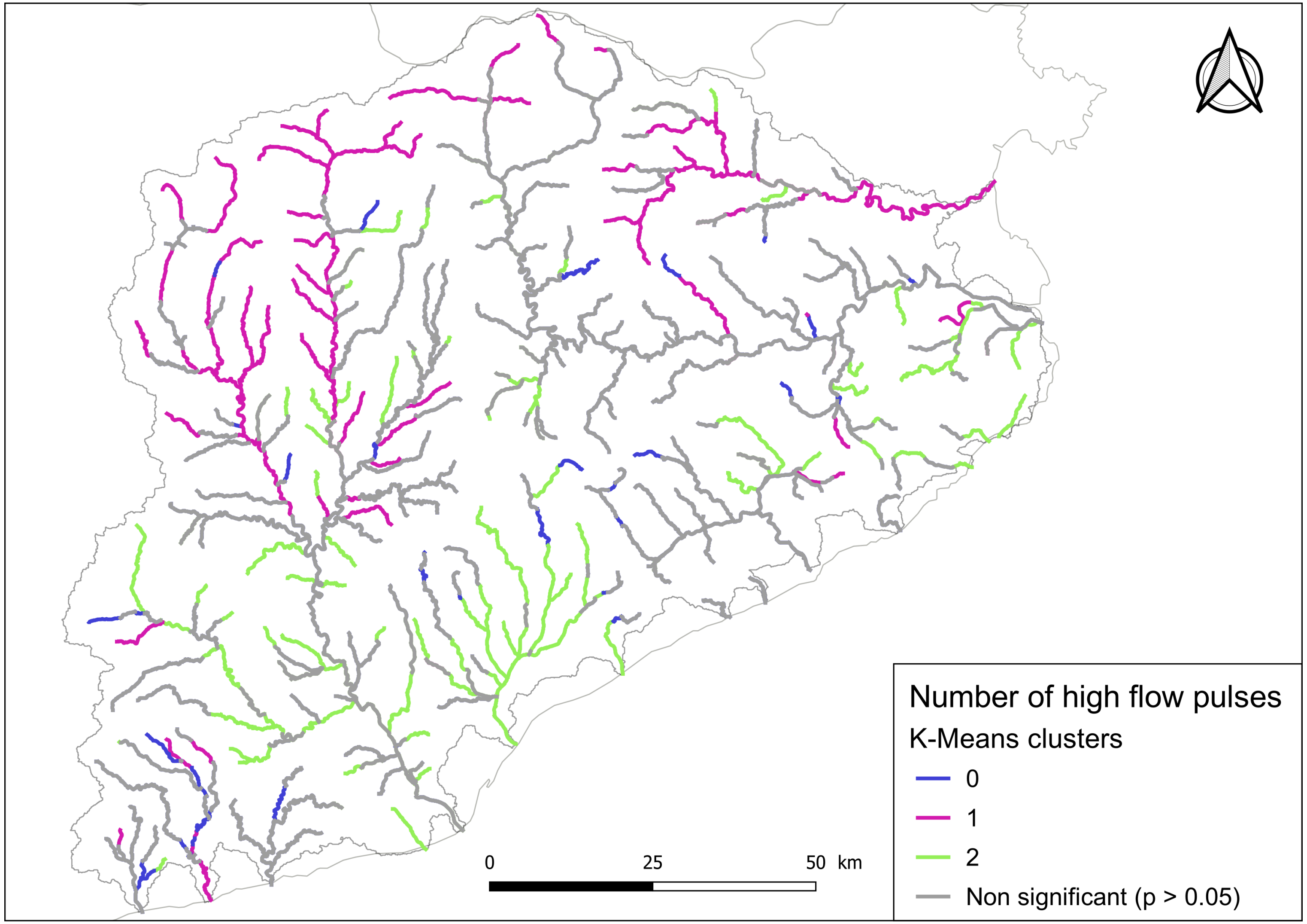
Source: Meteorological Service of Catalonia, “Butlletí Annual d’Indicadors Climàtics 2022”



Results – Analysis of spatial flow patterns

- Visual interpretation
- Clustering techniques

Spatial autocorrelation
Graph + Spectral clustering



Summary and conclusions

- We have successfully implemented SWAT+ in the Inner Catalan Basins
- We have developed a calibration strategy which considers multiple gauging stations with highly variable temporal data
- We have extracted 40 hydrological indicators from simulated streamflow and identified significant spatiotemporal trends for the period 2001-2022
- We are developing a graph + clustering technique to screen out spatial autocorrelation between connected river segments

Summary and conclusions

<u>Significant trends over the 21st century in ICB</u>

- Q50 and Q90 have generally decreased
- The number of low flow episodes has increased
- The number of high flow episodes shows a marked spatial pattern:
  - Increase in the headwaters/Pyrenees
  - Decrease in the lower basin/Mediterranean
- Days with zero flow have increased, and the first occurs earlier in the year
- While no significant trend in annual precipitation has been identified, drying river segments in ICB has increased by 15%

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Thank you!

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