Application of the SWAT+gwflow module in water scarce Mediterranean basins to assess water quantity and quality

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International SWAT Conference – 2024 Strasbourg, France

Introduction and objectives

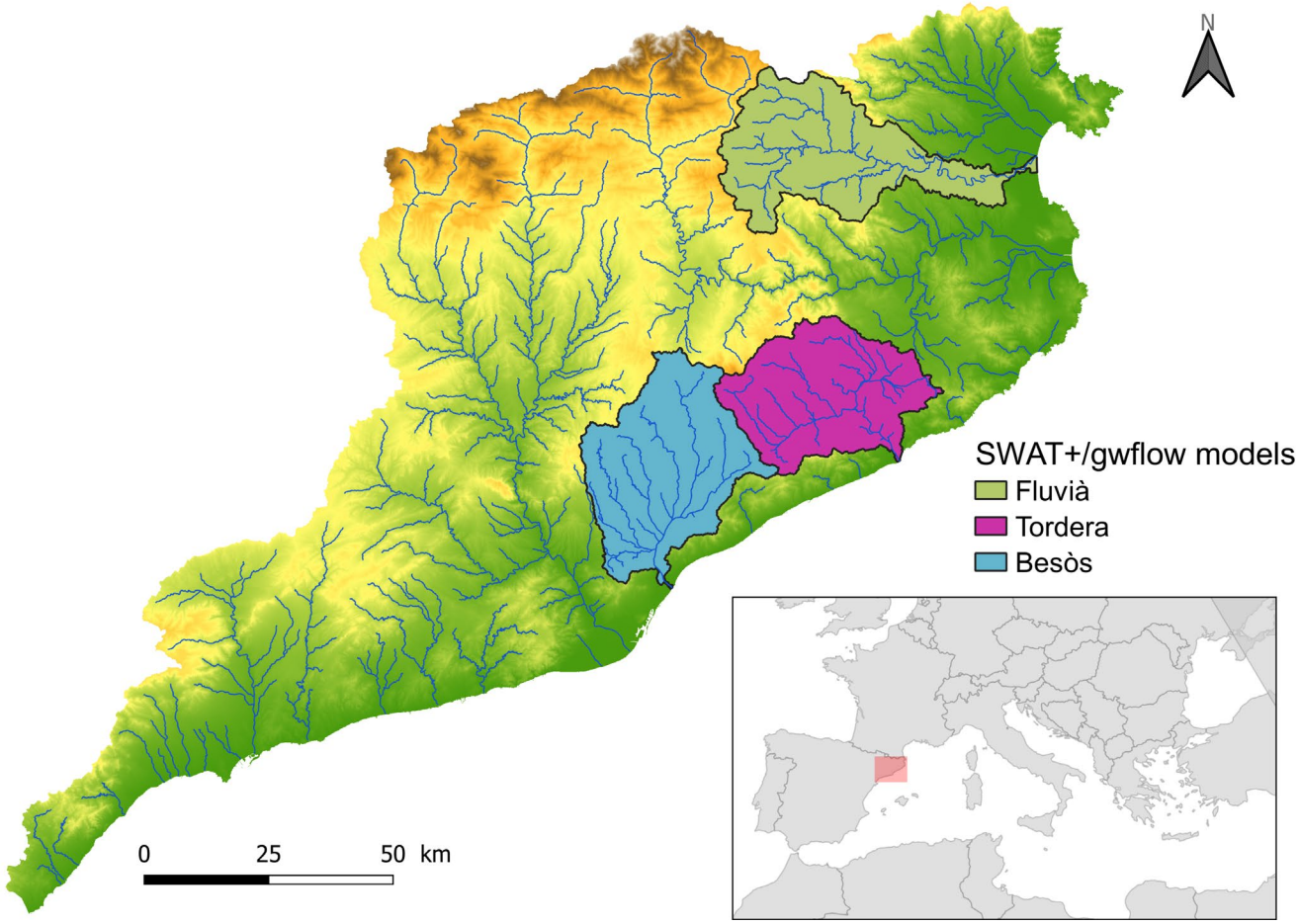
- Climate change: adverse impacts will intensity in the coming decades
- Climate change action is needed to reduce losses to nature and people (co-benefits)
- Mediterranean: already prone to water scarcity due to natural inter-annual rainfall variability, but exacerbated by faster climate change
- Increased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

Introduction and objectives

- We aim to:
  - Apply the SWAT+/gwflow model to several water-scarce Mediterranean basins
  - Incorporate fate and transport of point source pollutants and pesticides into the gwflow module
  - Assess water quantity and quality for future climate and management scenarios
  - Support water resources planning and management

Methods – Study area

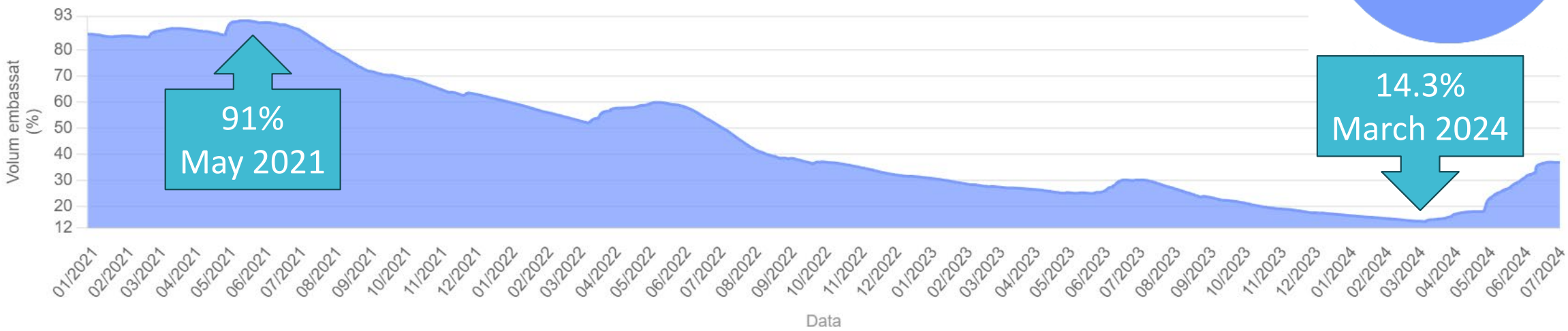
- Catalan River Basin District, NE Iberian Peninsula, W Mediterranean
- 7M inhabitants
- Annual water demand > 1000 hm^3
- Watershed area: 875 – 1016 km^2
- Natural regime



Methods – Study area

- Catalan River Basin District, NE Iberian Peninsula, W Mediterranean
- 7M inhabitants
- Annual water demand > 1000 hm^3
- Vulnerable to water scarcity: 2021-2024 drought

Reservoir reserves

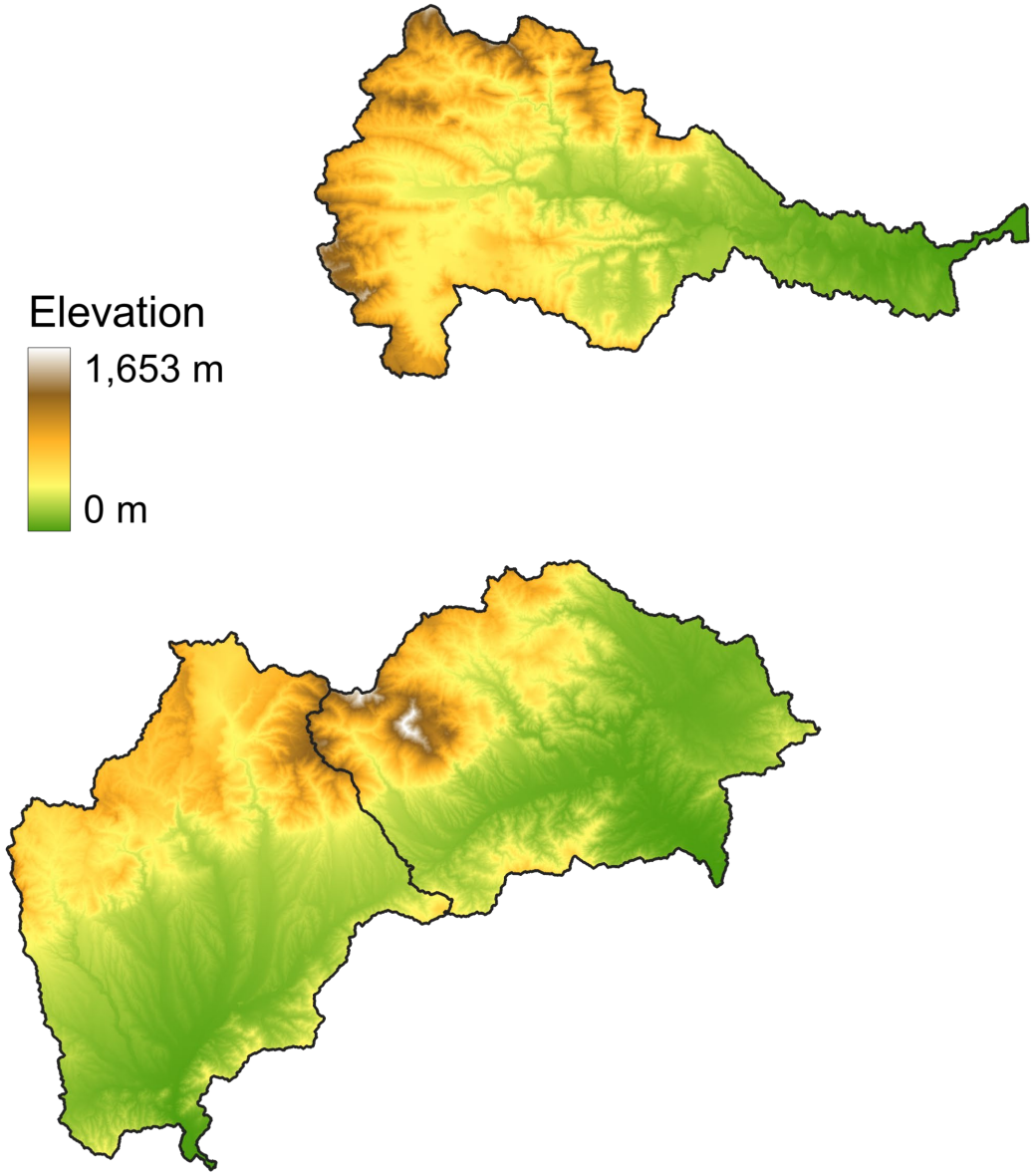


Source: Catalan Water Agency, "El visor de la sequera", https://aplicacions.aca.gencat.cat/visseq/estat-actual

Methods – SWAT+ gwflow

SWAT+

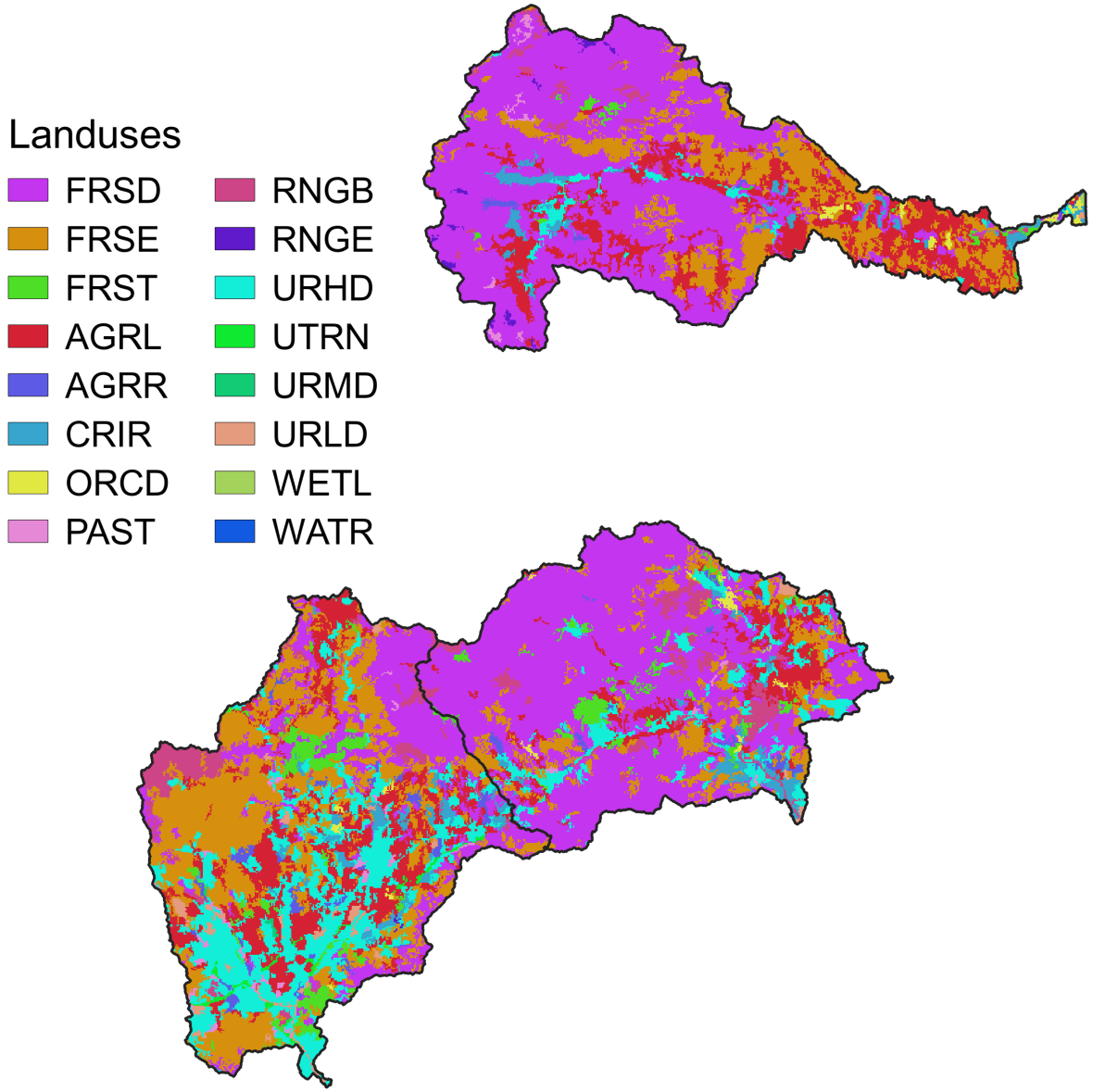
- DEM 25x25m



Methods – SWAT+ gwflow

SWAT+

- DEM 25x25m
- WIT CORINE Land Cover 2018



Methods – SWAT+ gwflow

SWAT+

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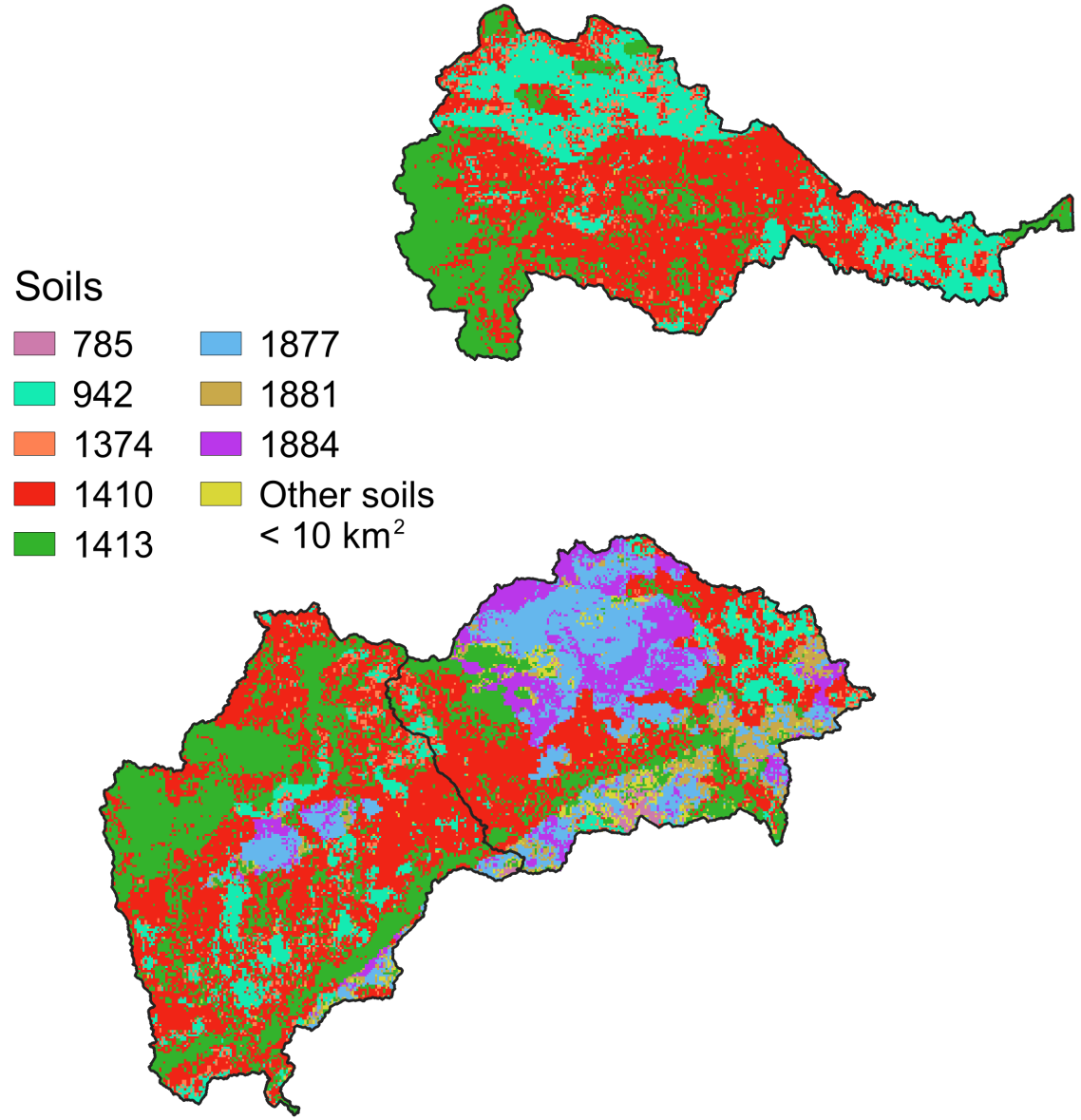
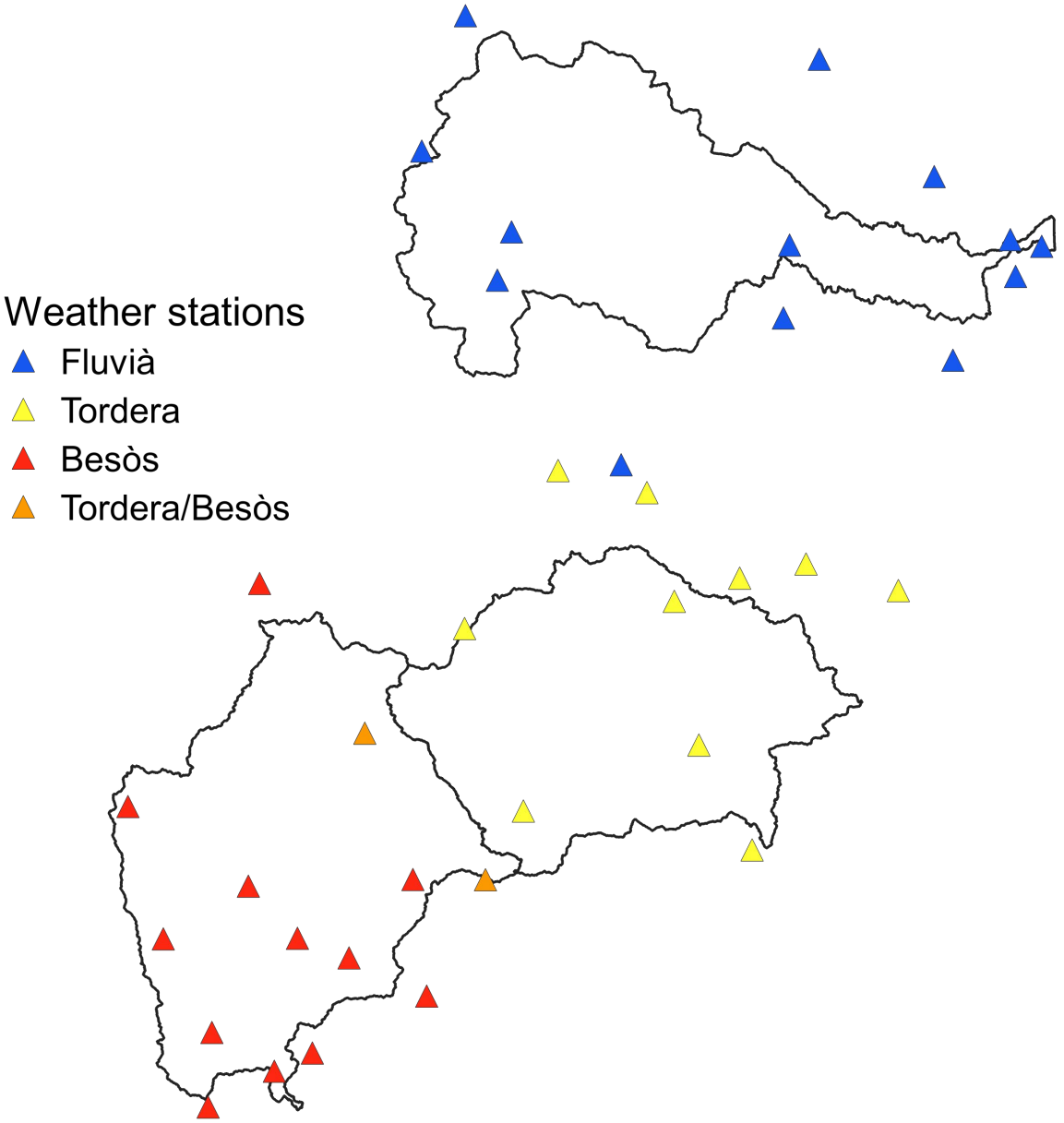
- WIT CORINE Land Cover 2018
- WIT Openland soil map



Methods – SWAT+ gwflow

SWAT+

- DEM 25x25m
- WIT CORINE Land Cover 2018
- WIT Openland soil map
- Weather data: 2000-2022, 1y warm-up
  - Spain Weather Generator
  - 12-14 weather stations



Methods – SWAT+ gwflow

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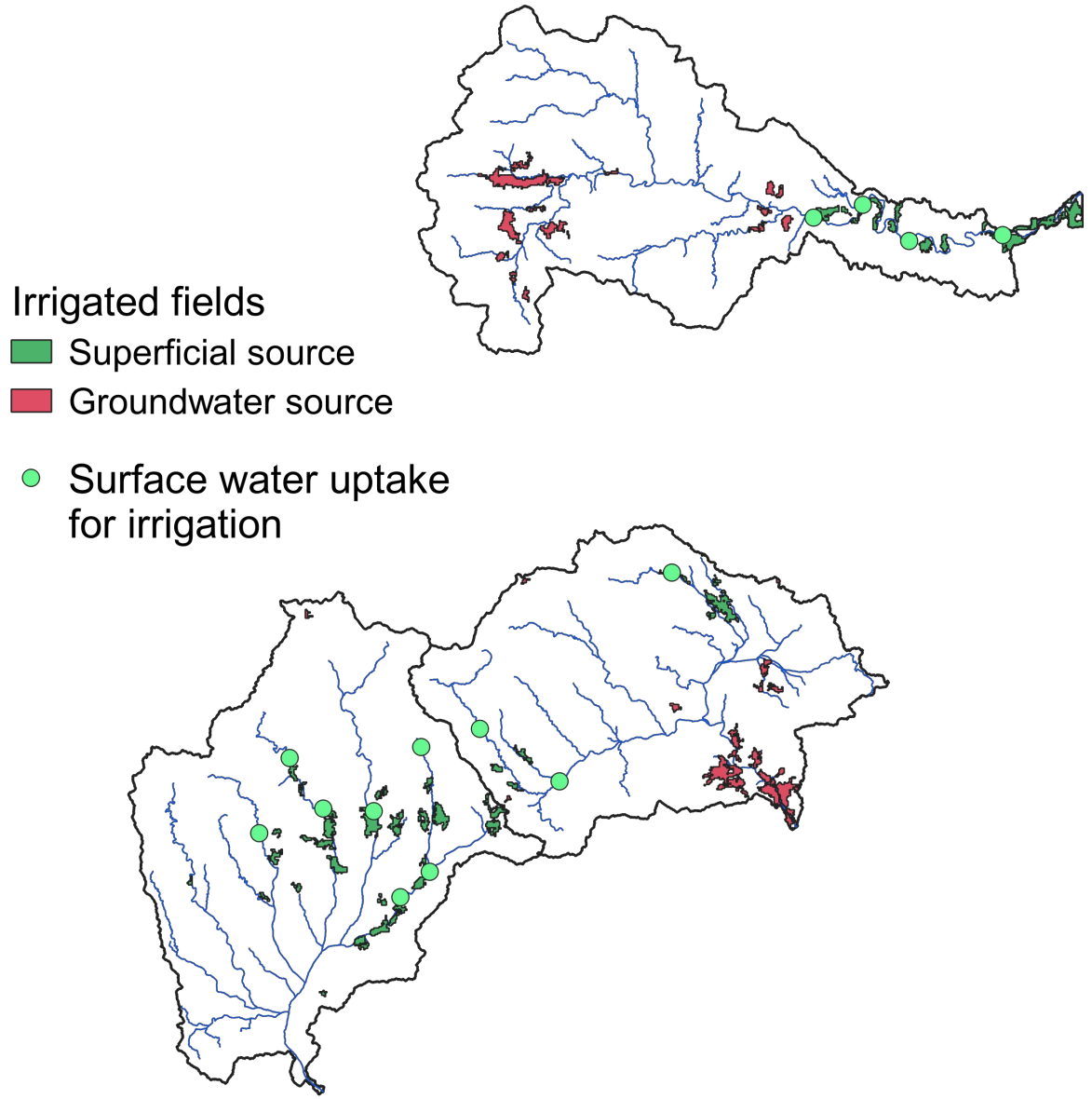
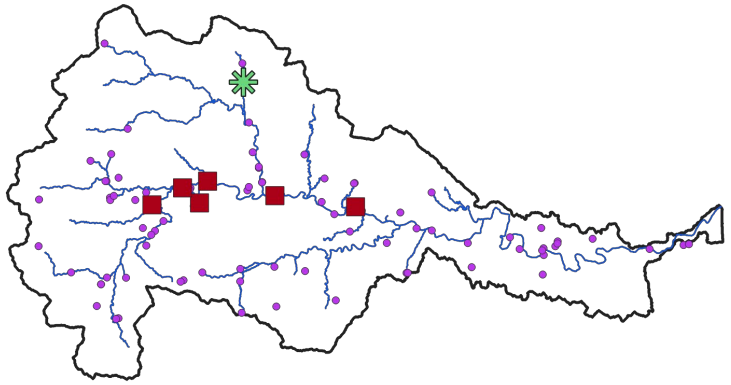
- Crop management



Methods – SWAT+ gwflow

SWAT+

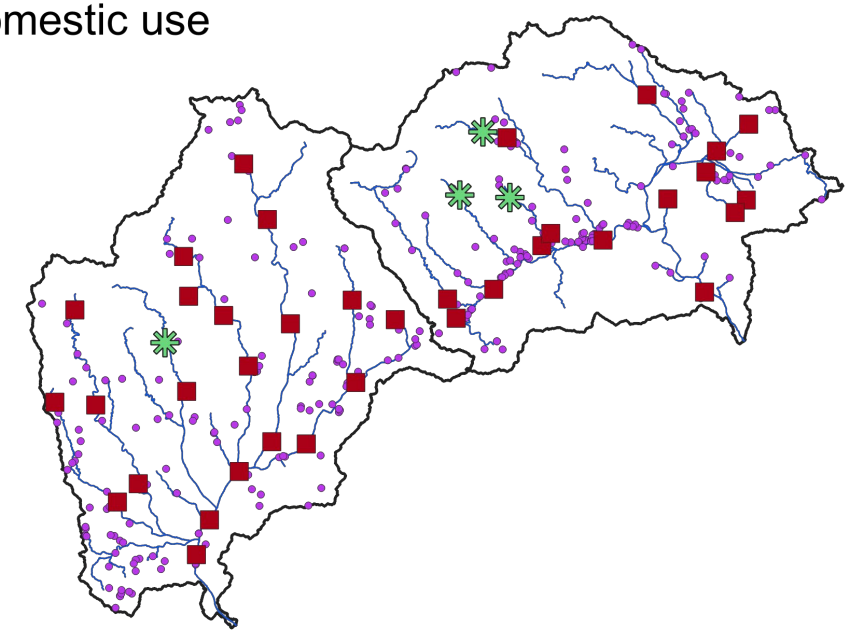
- DEM 25x25m
- WIT CORINE Land Cover 2018
- WIT Openland soil map
- Weather data: 2000-2022, 1y warm-up
  - Spain Weather Generator
  - 12-14 weather stations
- Crop management
- Urban management



Point source discharges

- WWTP
- Industrial

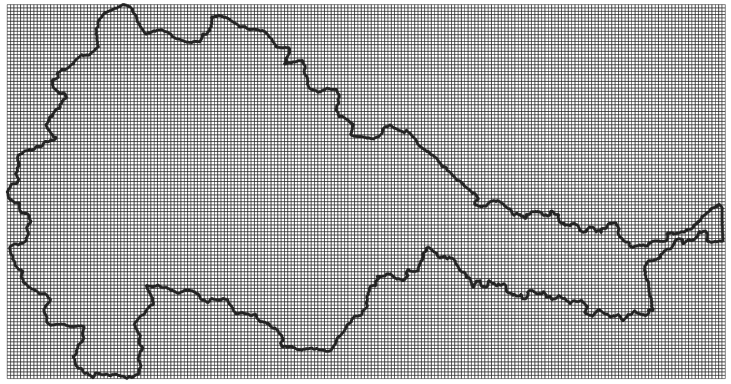
Surface water uptake for domestic use

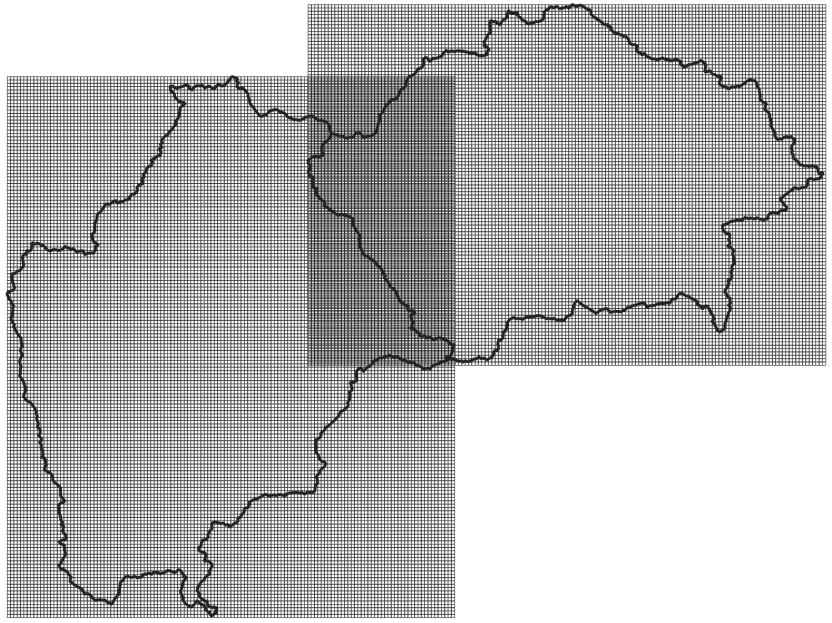


Methods – SWAT+ gwflow

<u>gwflow module</u>

- 200m resolution grid
  - 10,071 – 11,687 active cells

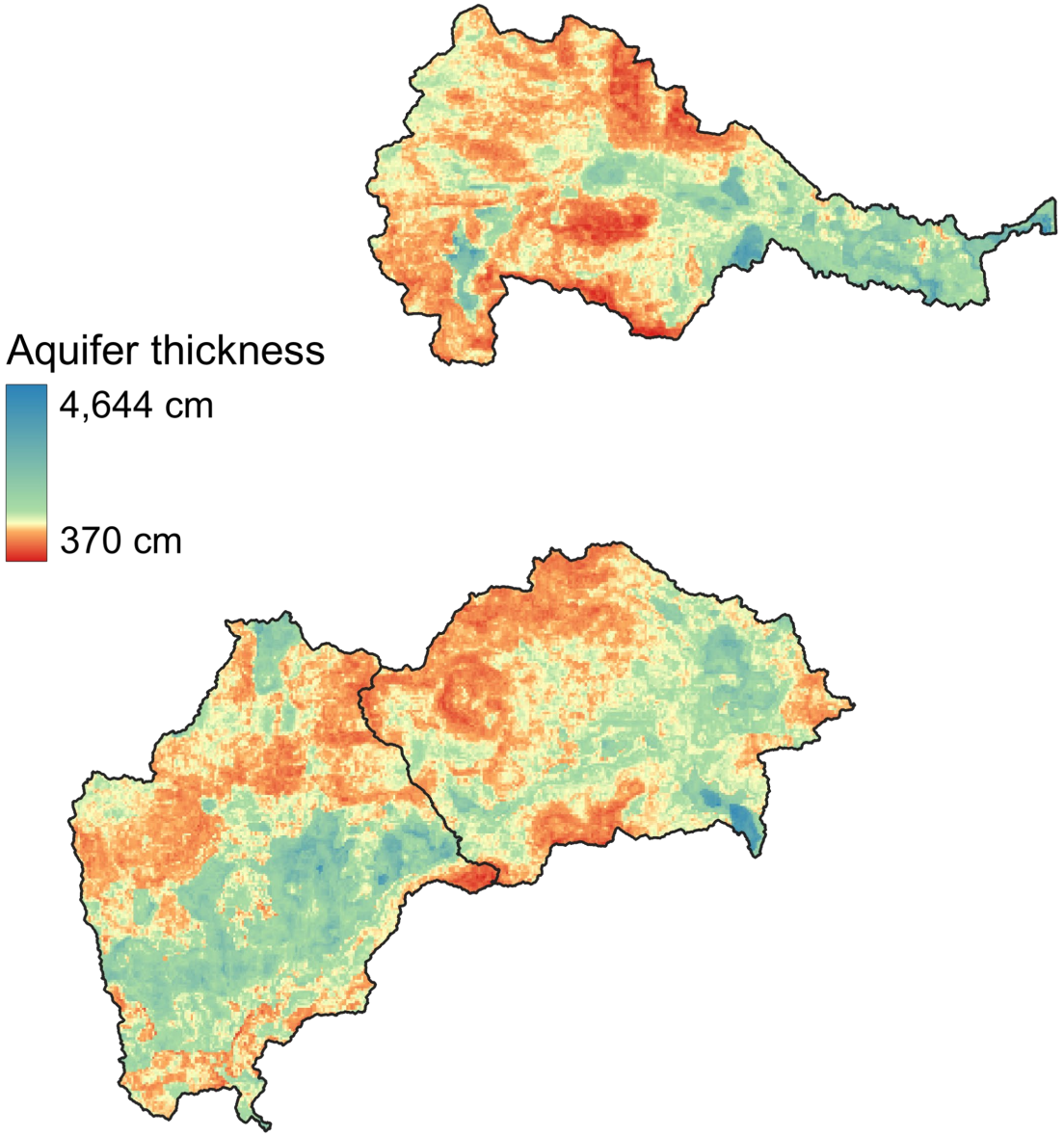




Methods – SWAT+ gwflow

gwflow module

- 200m resolution grid
  - 10,071 – 11,687 active cells
- Aquifer thickness from ISRIC – World Soil Information



Methods – SWAT+ gwflow

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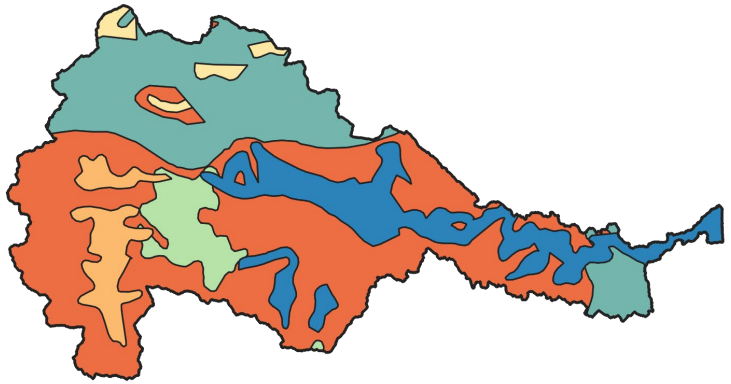
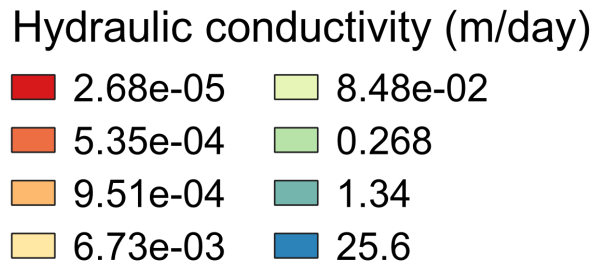
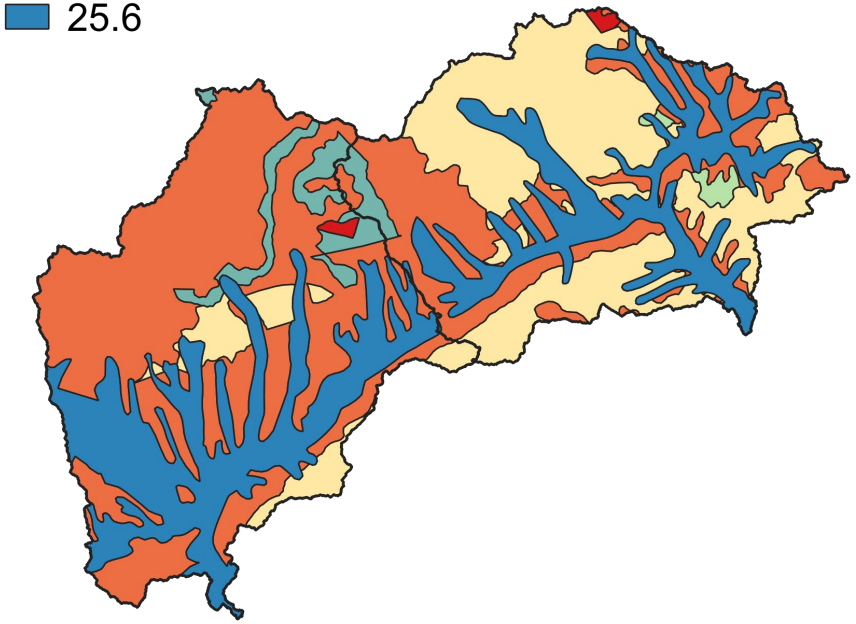
- Aquifer thickness from ISRIC – World Soil Information
- Aquifer permeability zones (GLHYMPS 2.0)



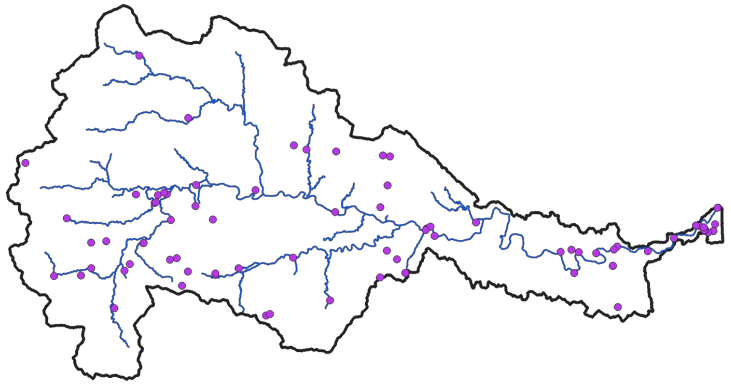




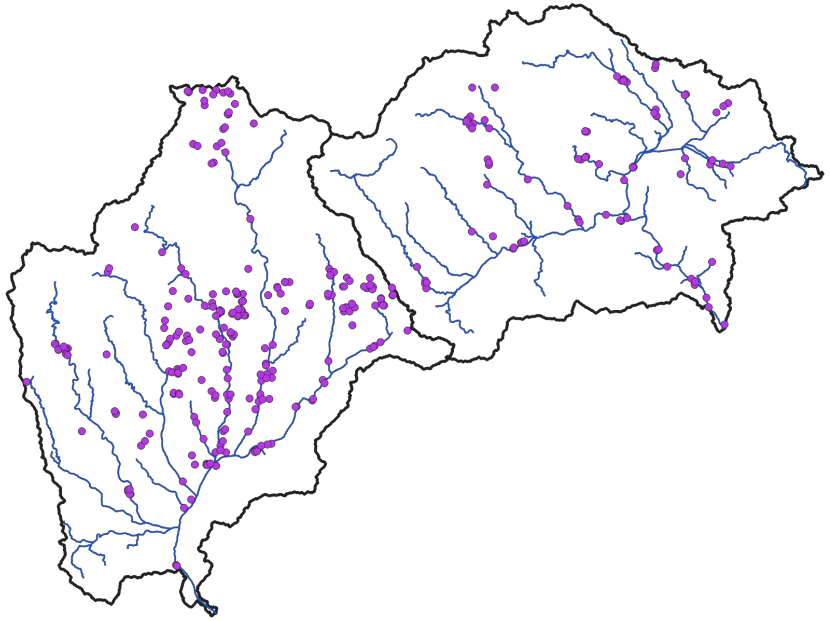
Methods – SWAT+ gwflow

<u>gwflow module</u>

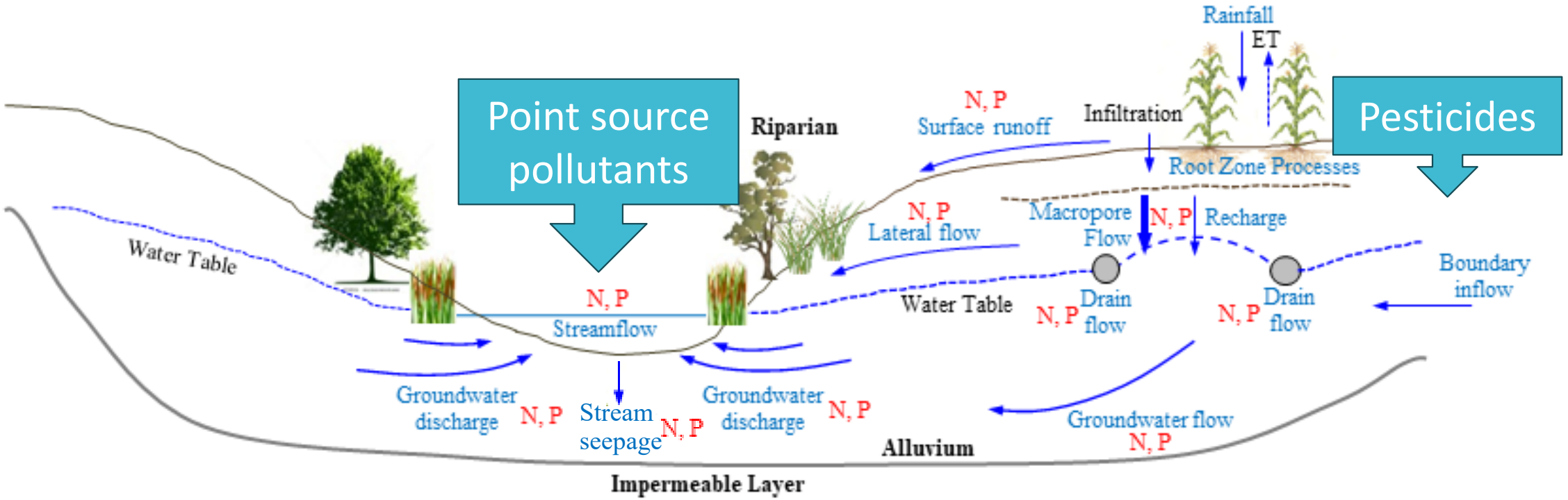
- 200m resolution grid
  - 10,071 – 11,687 active cells
- Aquifer thickness from ISRIC – World Soil Information
- Aquifer permeability zones (GLHYMPS 2.0)
- Groundwater pumping
  - Irrigation: water allocation module
  - Domestic and industrial: rates



- Domestic and industrial pumping wells

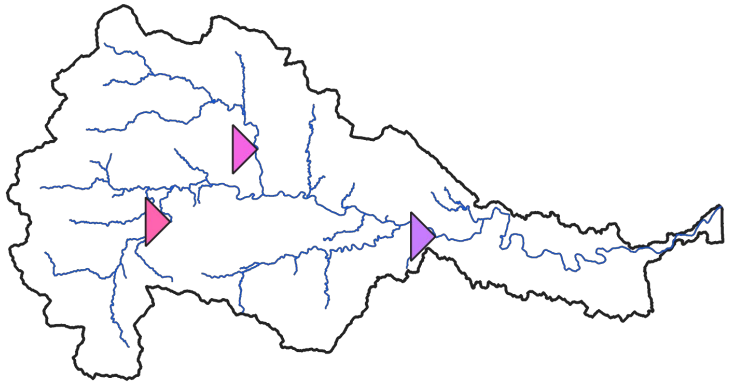


Methods – gwflow water quality

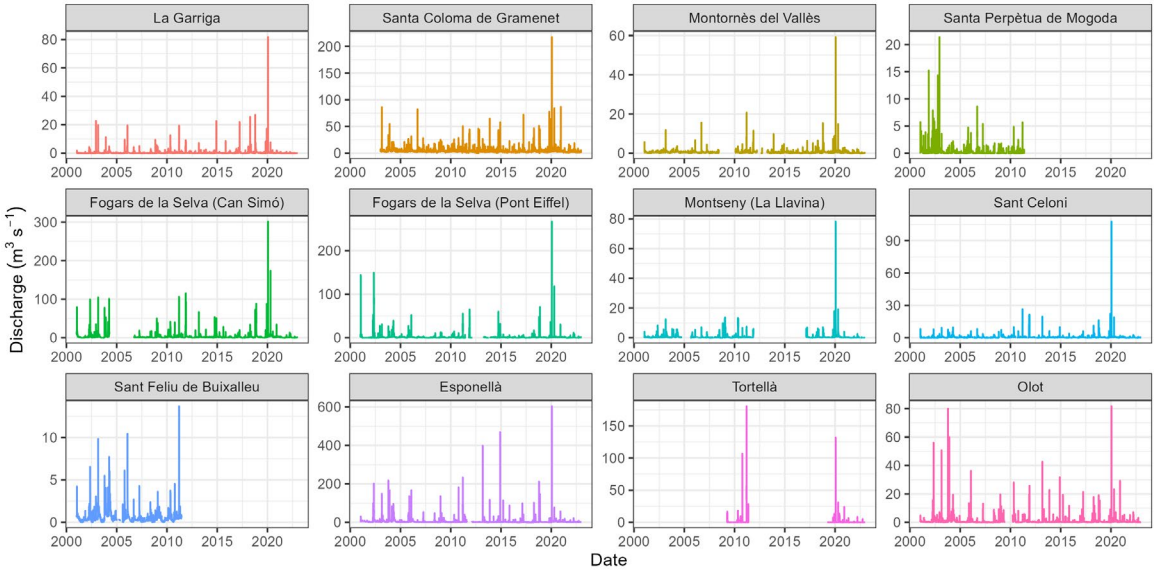


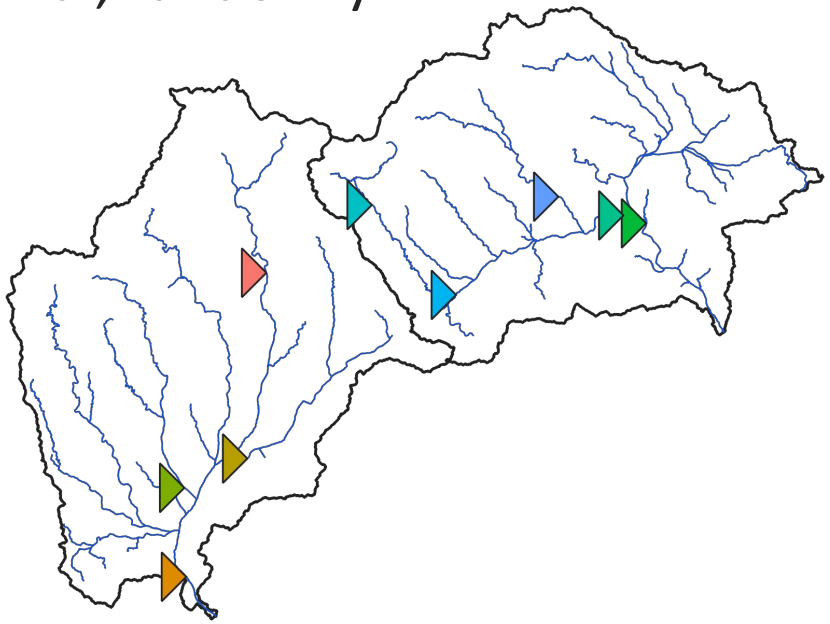
"Modelling instream transport and fate of priority pollutants with SWAT+" by Oliu Llorente today at 15:20

Methods – Observed streamflow



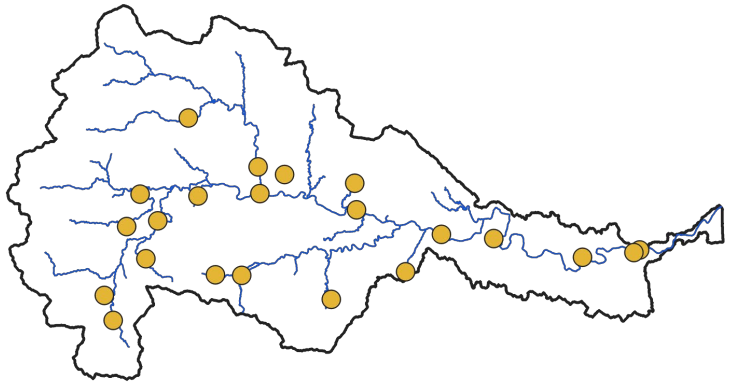
- 3-5 gauging stations per basin
- Daily streamflow
- 2001-2022
- Spatiotemporal variability → 70-30% cal-val, randomly

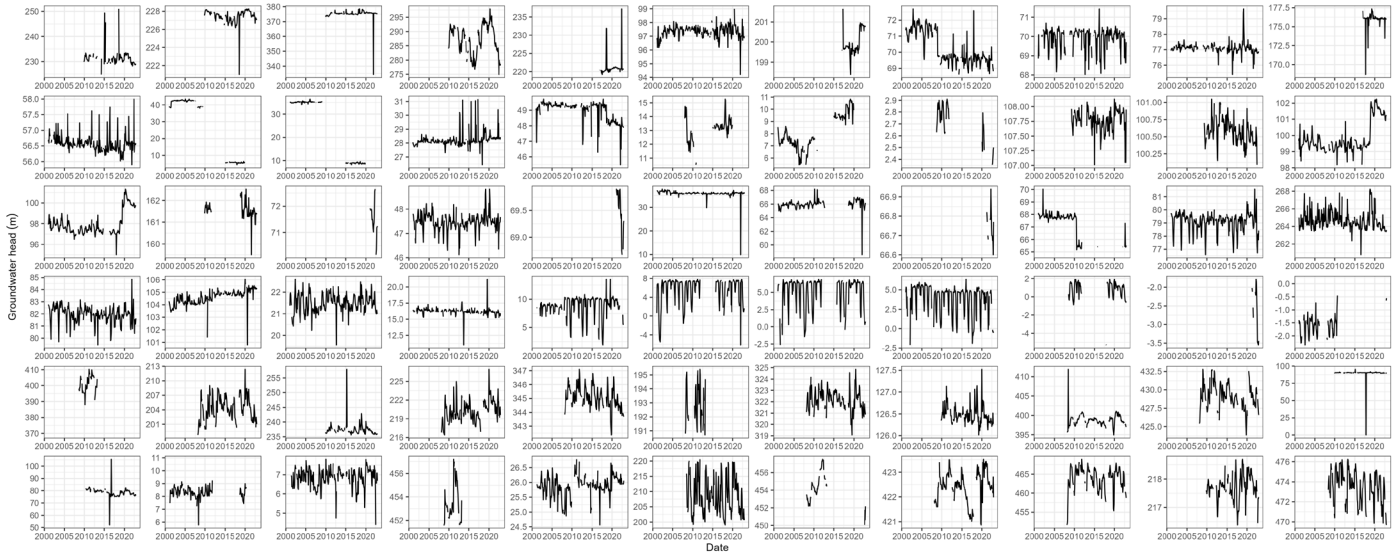


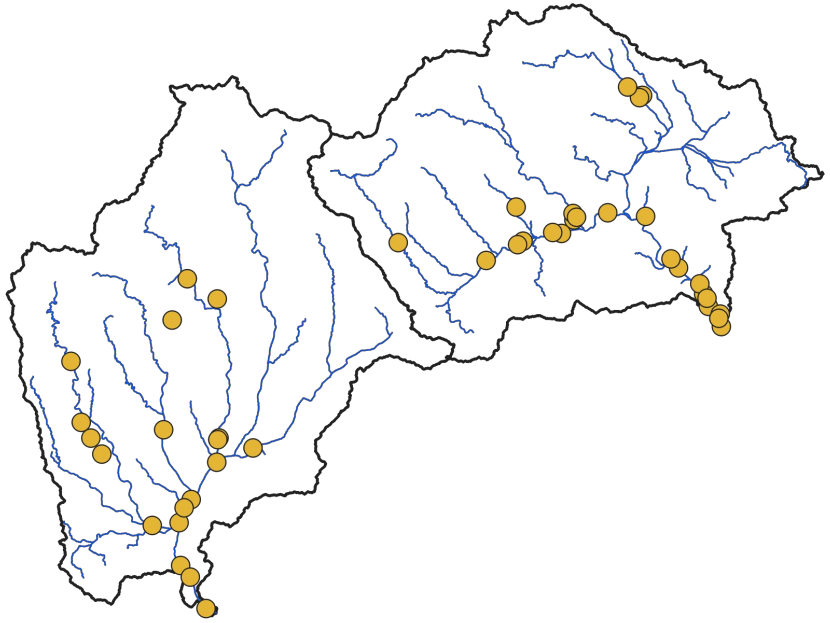


Methods – Observed hydraulic head

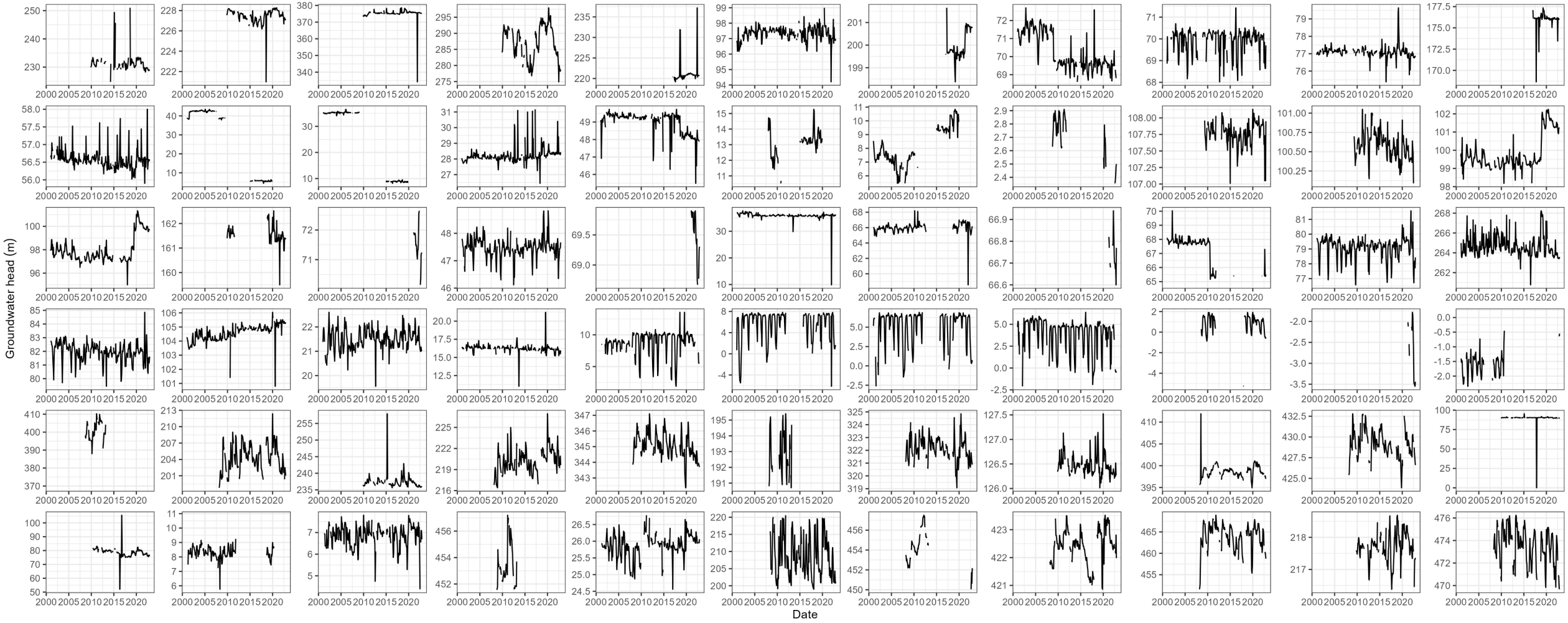
- 19-25 observation wells per basin
- Unconfined alluvial aquifer
- Monthly observation, 2001-2022
- Spatiotemporal variability







Methods – Observed hydraulic head



Methods – Sensitivity analysis and calibration

PEST++	calibration.cal (SWATrunR)
Sensitivity: Morris	Sensitivity: Morris, FAST
Calibration: Iterative Ensemble Smoother (IES)	Calibration: Latin Hypercube Sampling
Minimization of SSR	Choice of GoF

Results – Hydrology calibration

- Satisfactory: NSE/KGE > 0.5, -25% < PBIAS < 25%
- Very good: NSE/KGE > 0.7, -10% < PBIAS < 10%

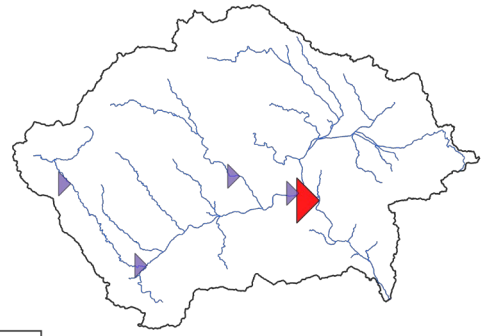
PEST++ IES
2 iterations of 2000 runs

Daily	General			Calibration			Validation		
	NSE	KGE	PBIAS	NSE	KGE	PBIAS	NSE	KGE	PBIAS
Tordera	0.51	0.60	2.4	0.52	0.62	6.3	0.49	0.45	-8.1
Fluvià	0.64	0.52	37	0.63	0.49	40.4	0.69	0.60	27.3
Besòs	0.62	0.65	30.2	0.61	0.61	33.6	0.70	0.69	22.9
Monthly									
Tordera	0.61	0.73	2.3	0.62	0.76	6.4	0.59	0.52	-8.4
Fluvià	0.74	0.61	37.1	0.73	0.58	40.5	0.78	0.66	27.6
Besòs	0.80	0.64	30	0.78	0.61	33.3	0.88	0.72	22.6

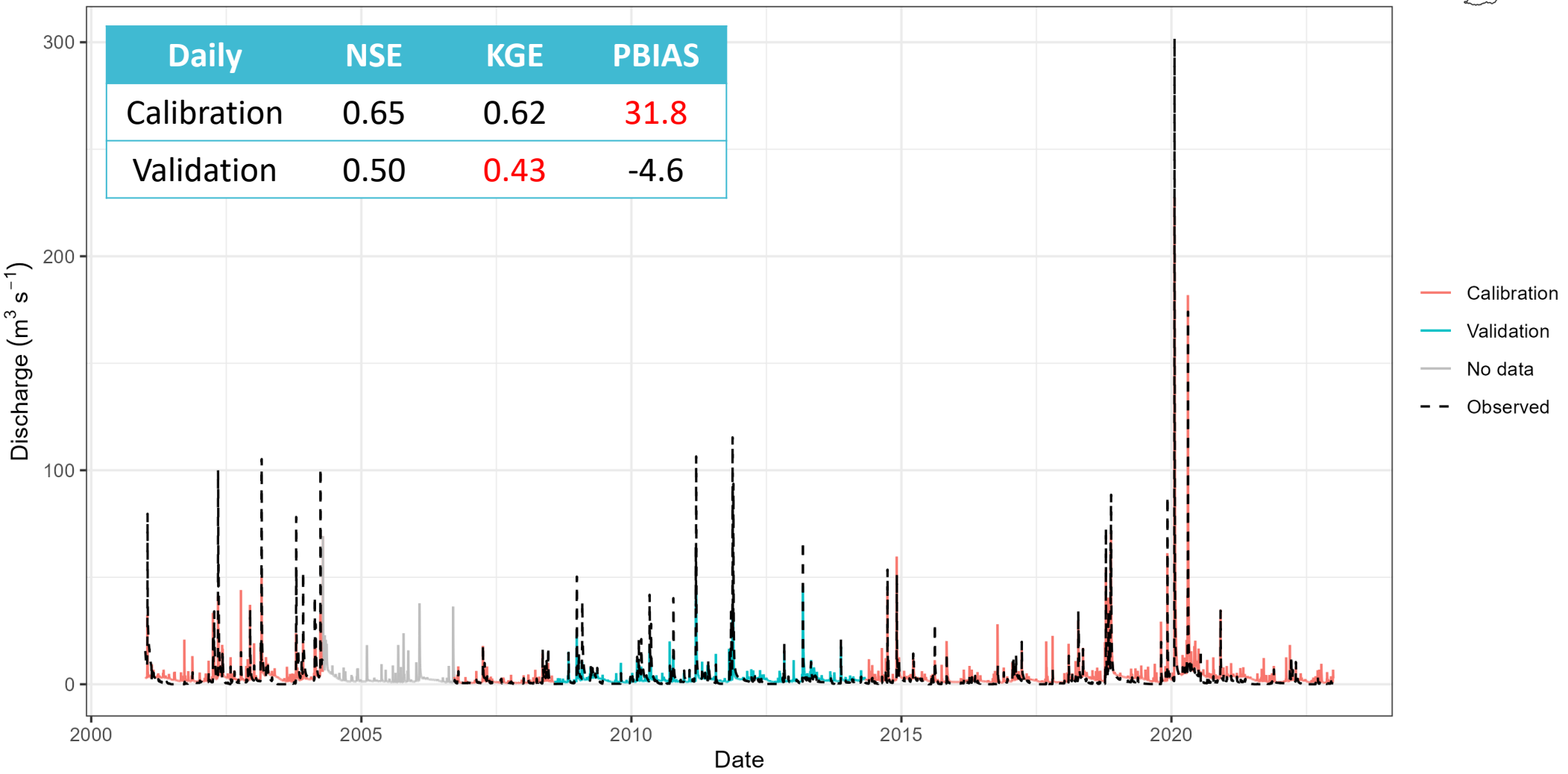
Results – Hydrology calibration

Daily	PEST++ IES (4000 runs)			FAST (4467 – 4796 runs)		
	NSE	KGE	PBIAS	NSE	KGE	PBIAS
Tordera	0.51	0.60	2.4	0.55	0.66	8.1
Fluvià	0.64	0.52	37	0.56	0.55	36.7
Besòs	0.62	0.65	30.2	-0.38	-0.05	4.3
Monthly						
Tordera	0.61	0.73	2.3	0.72	0.82	8.1
Fluvià	0.74	0.61	37.1	0.64	0.59	37.4
Besòs	0.80	0.64	30	-1.09	-0.16	3.8

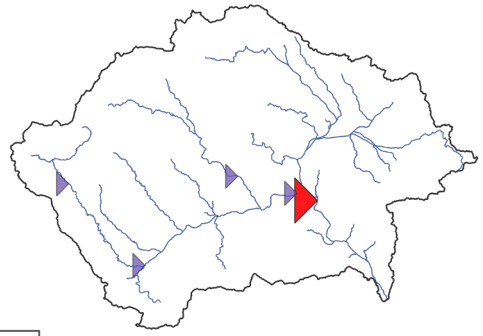
Results – Hydrology calibration



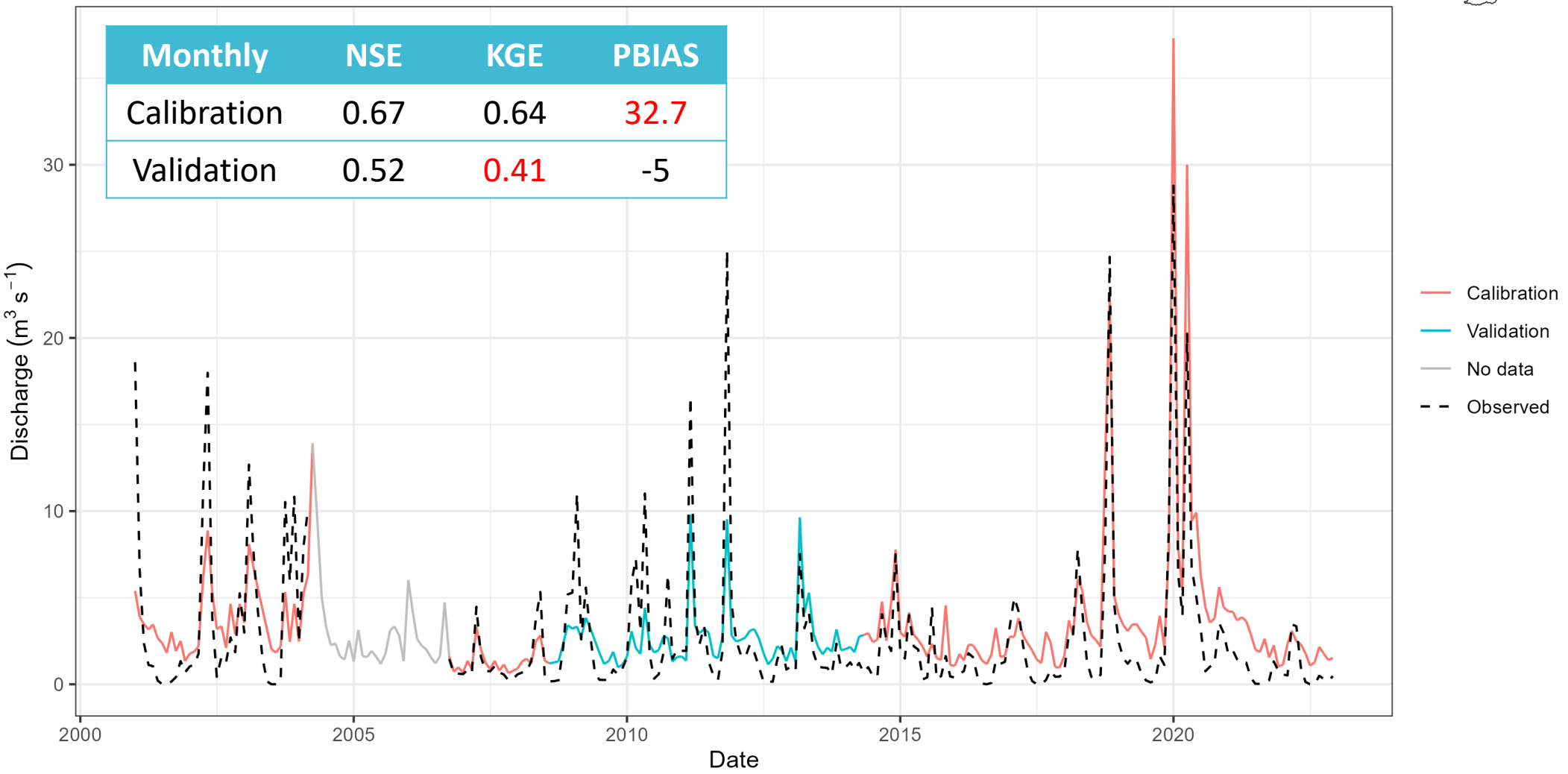
Daily	NSE	KGE	PBIAS
Calibration	0.65	0.62	31.8
Validation	0.50	0.43	-4.6



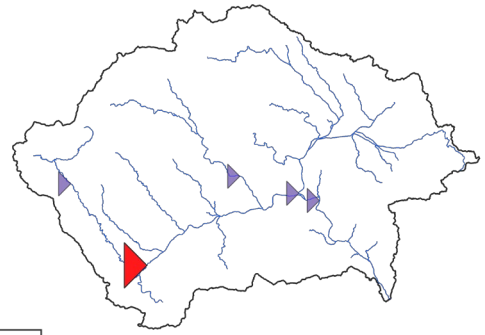
Results – Hydrology calibration



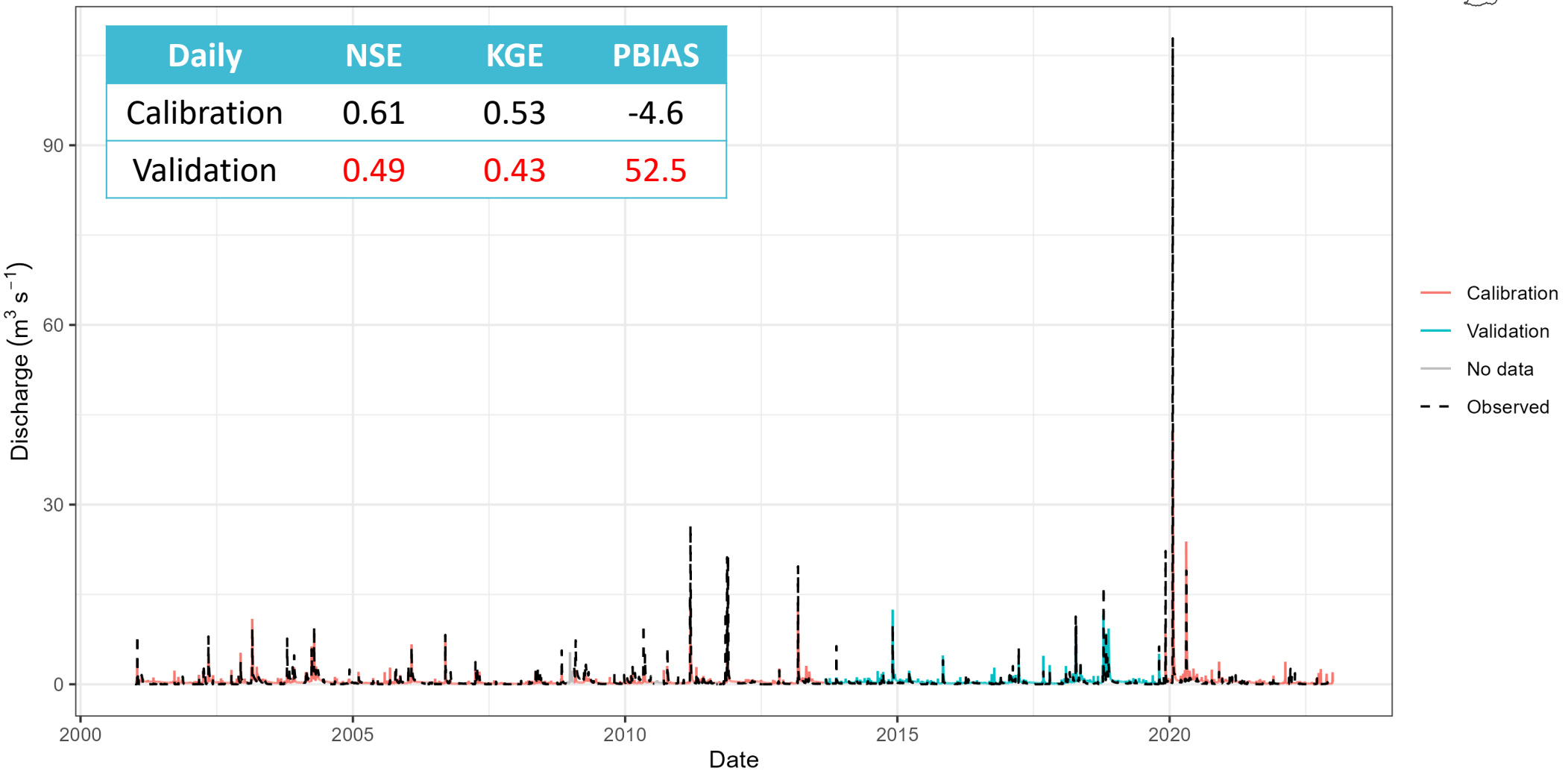
Monthly	NSE	KGE	PBIAS
Calibration	0.67	0.64	32.7
Validation	0.52	0.41	-5



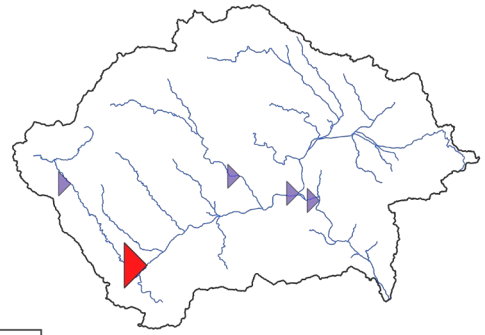
Results – Hydrology calibration



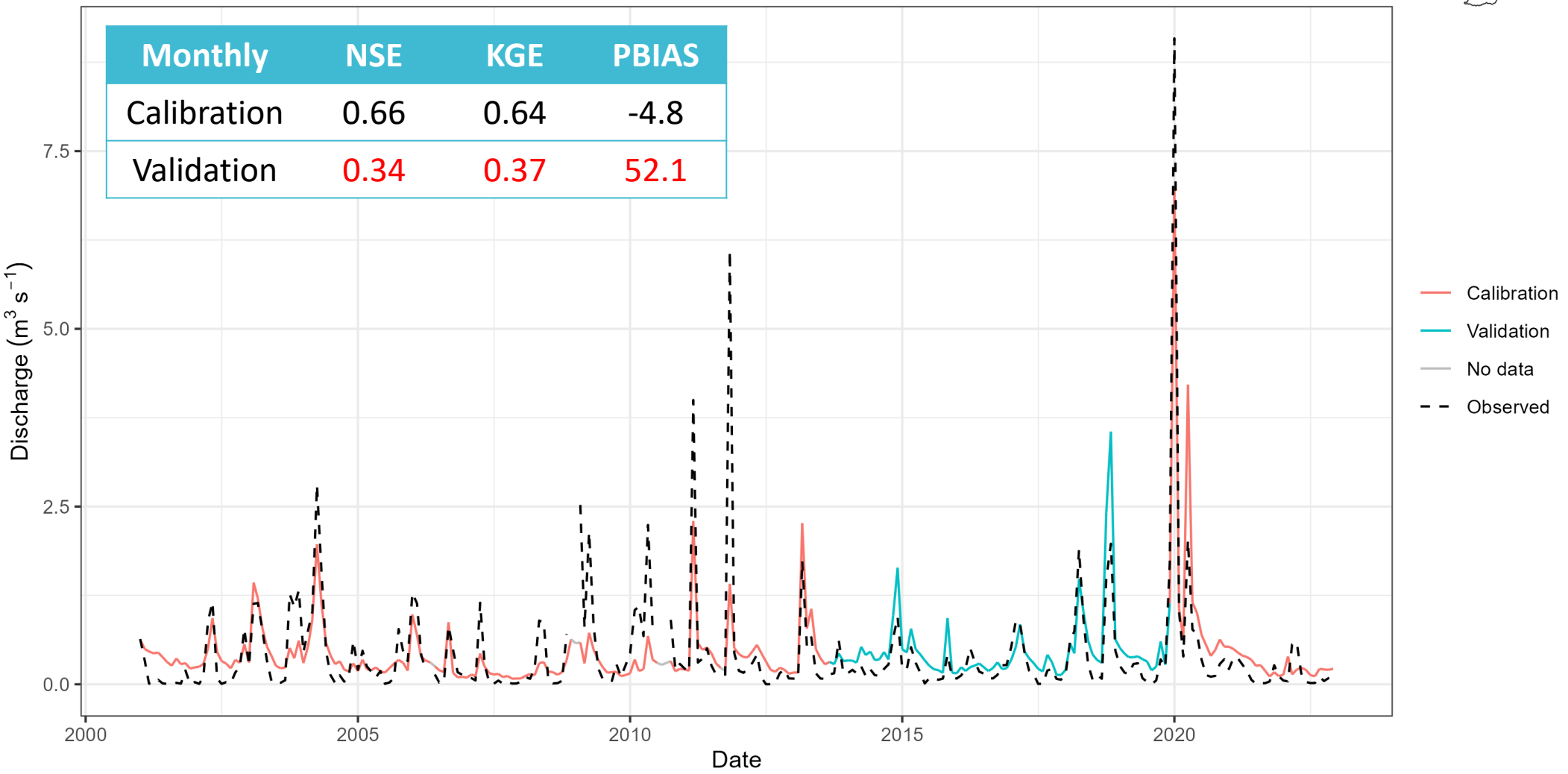
Daily	NSE	KGE	PBIAS
Calibration	0.61	0.53	-4.6
Validation	0.49	0.43	52.5



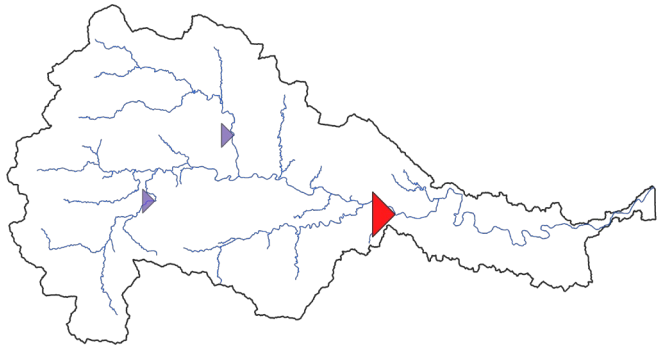
Results – Hydrology calibration



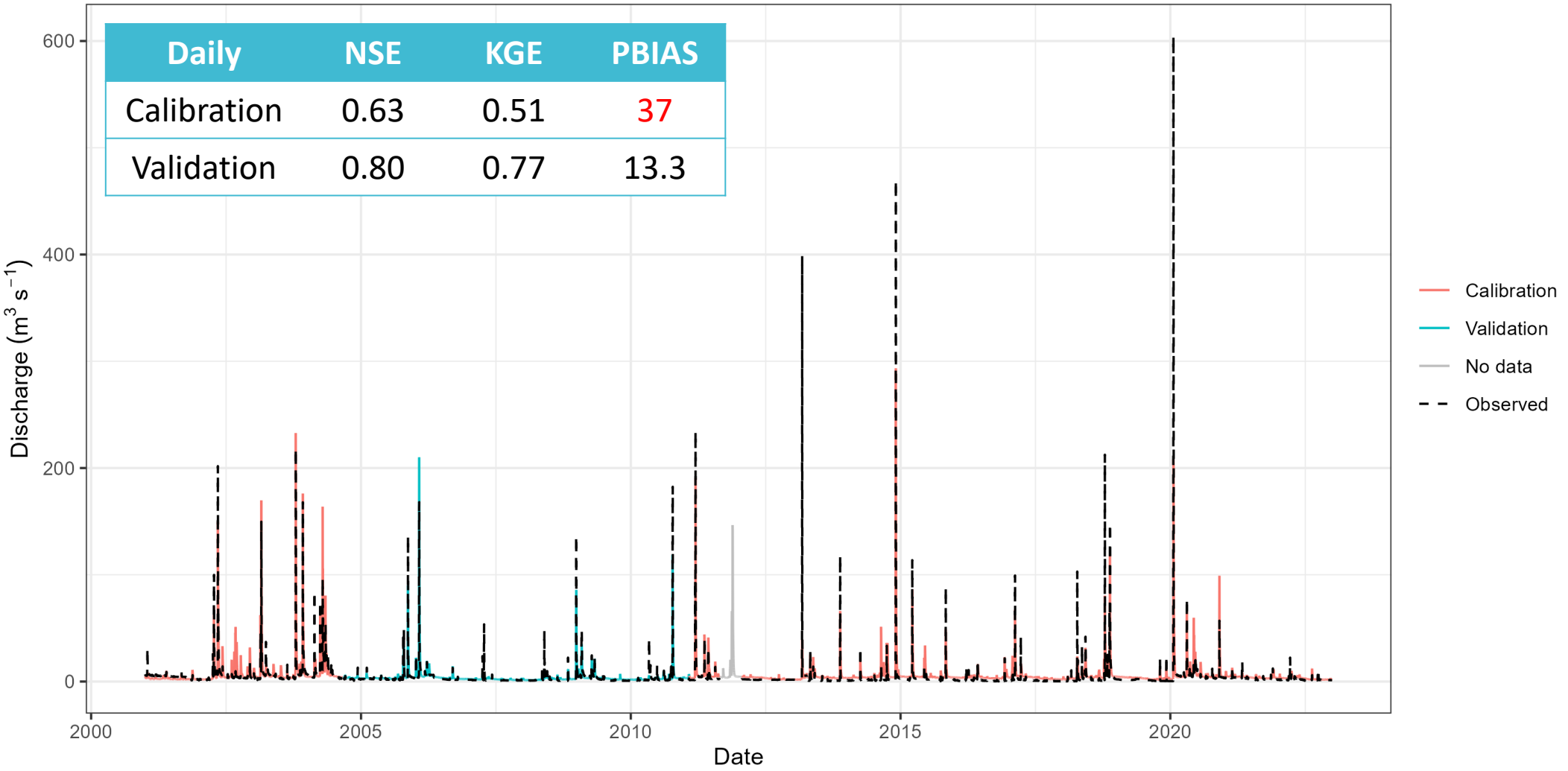
Monthly	NSE	KGE	PBIAS
Calibration	0.66	0.64	-4.8
Validation	0.34	0.37	52.1



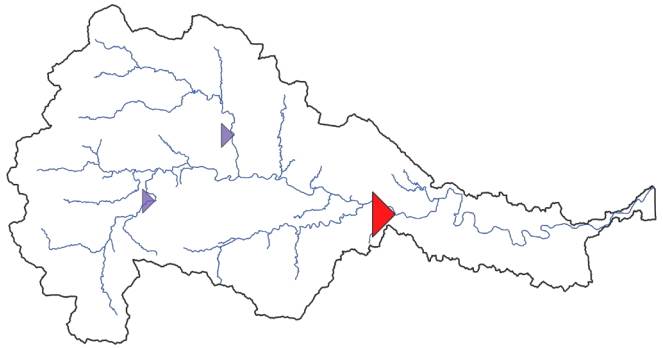
Results – Hydrology calibration



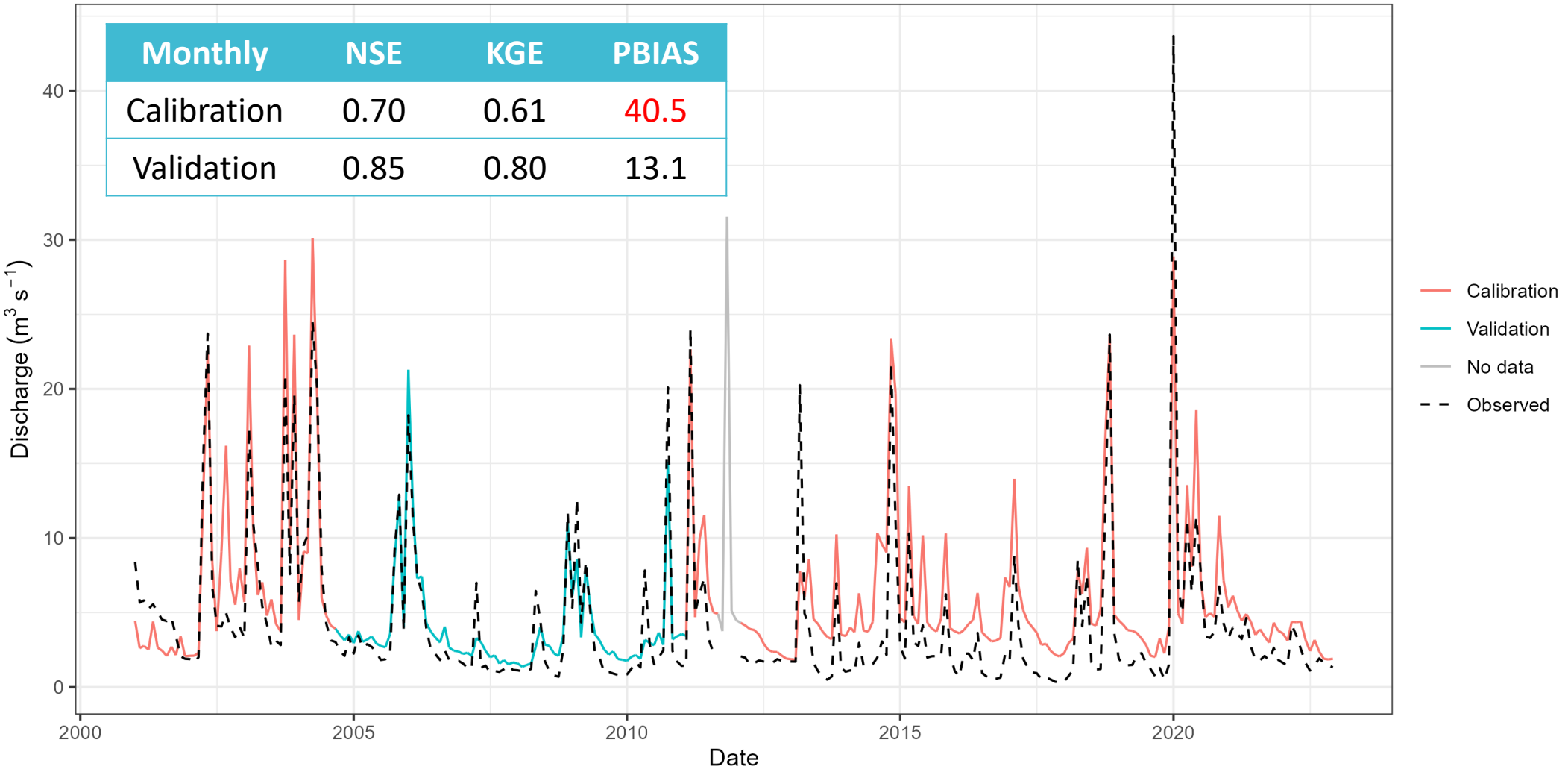
Daily	NSE	KGE	PBIAS
Calibration	0.63	0.51	37
Validation	0.80	0.77	13.3



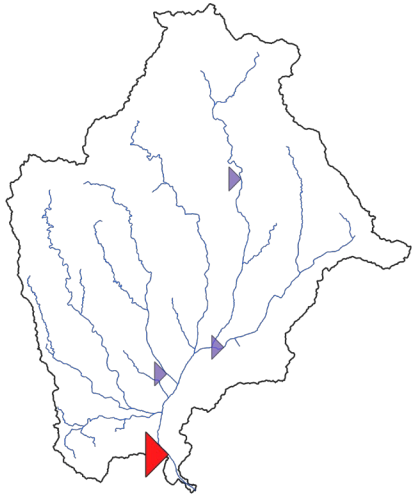
Results – Hydrology calibration



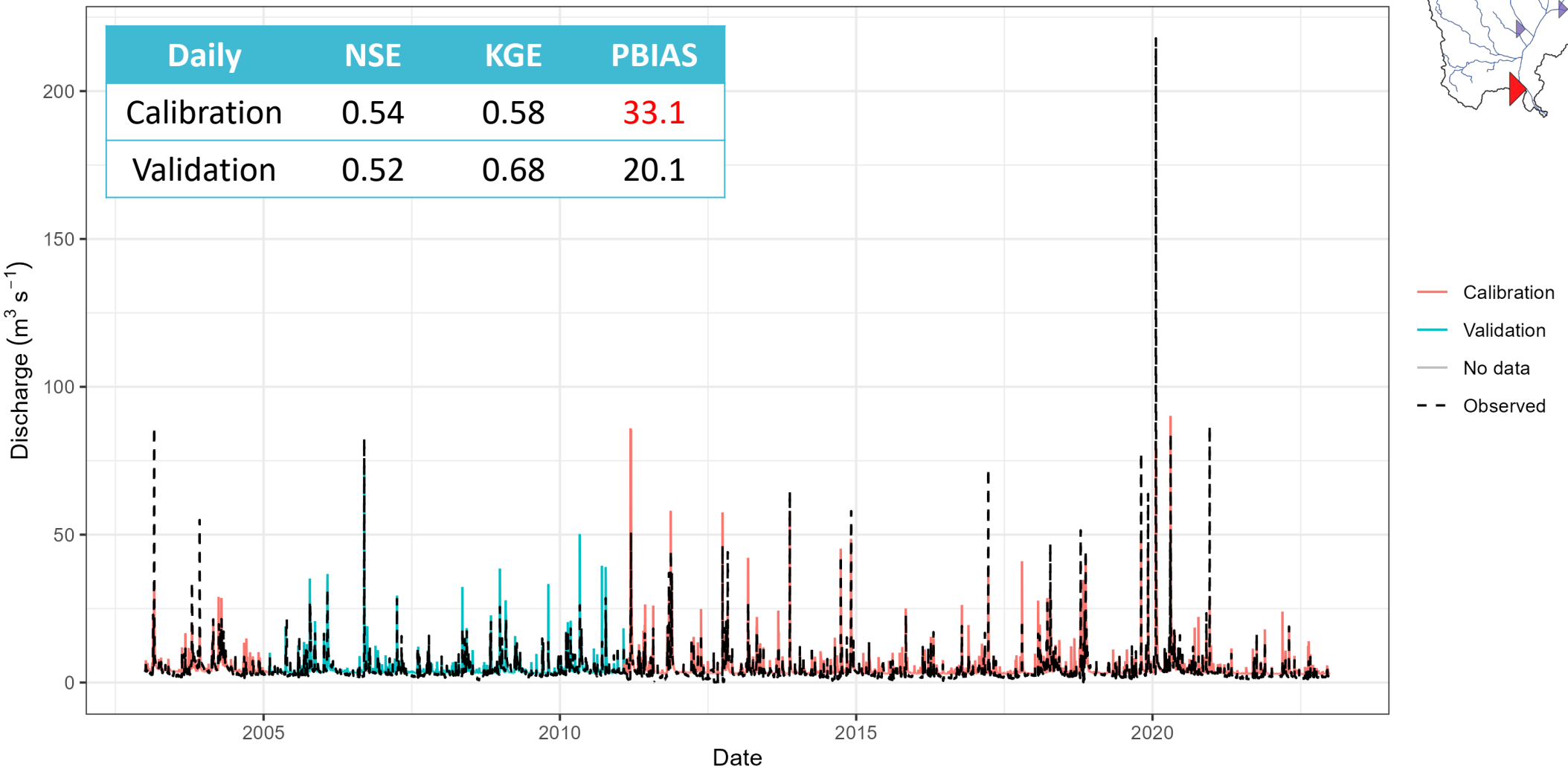
Monthly	NSE	KGE	PBIAS
Calibration	0.70	0.61	40.5
Validation	0.85	0.80	13.1



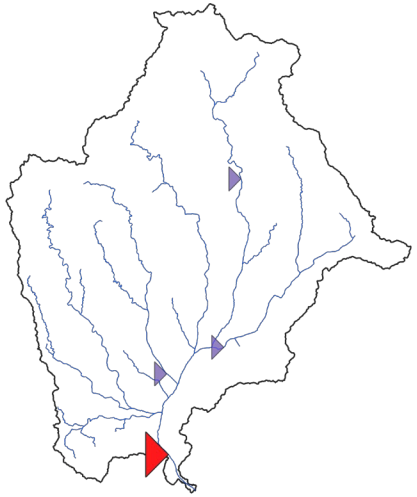
Results – Hydrology calibration



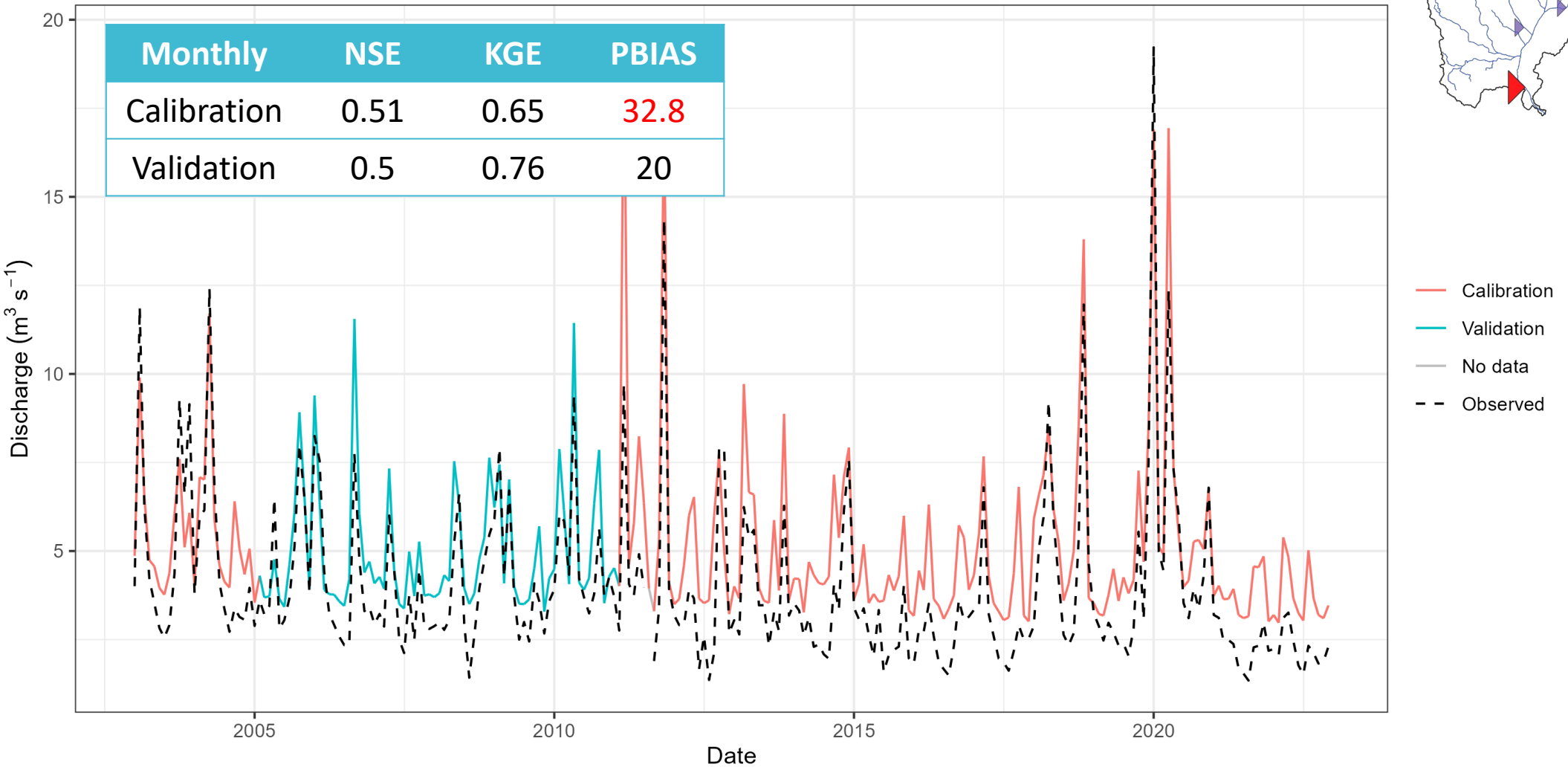
Daily	NSE	KGE	PBIAS
Calibration	0.54	0.58	33.1
Validation	0.52	0.68	20.1



Results – Hydrology calibration

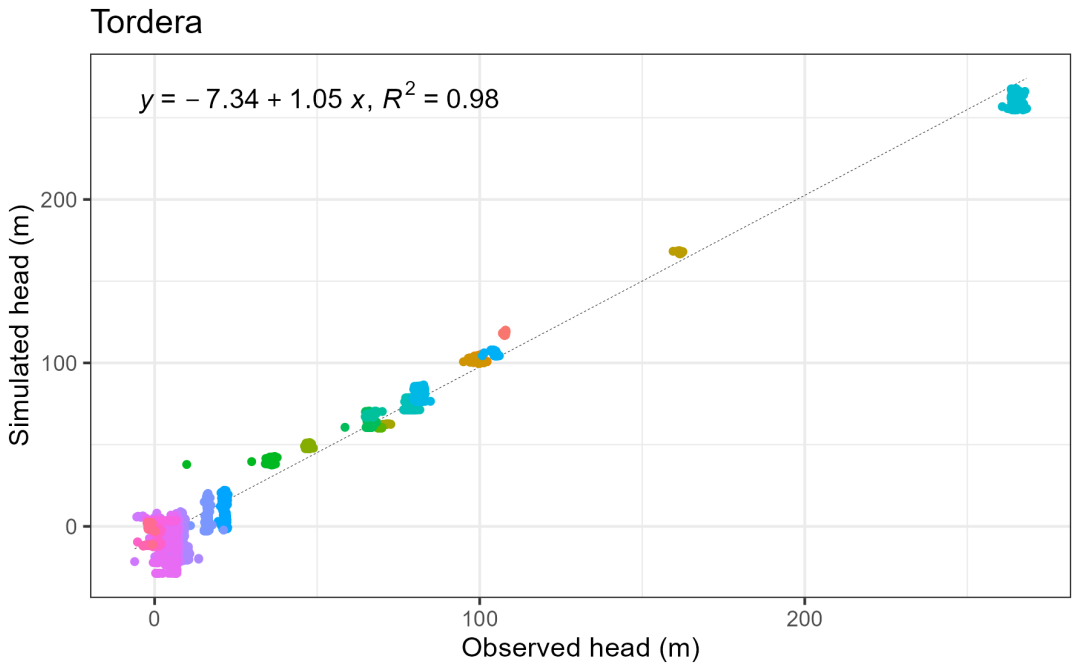


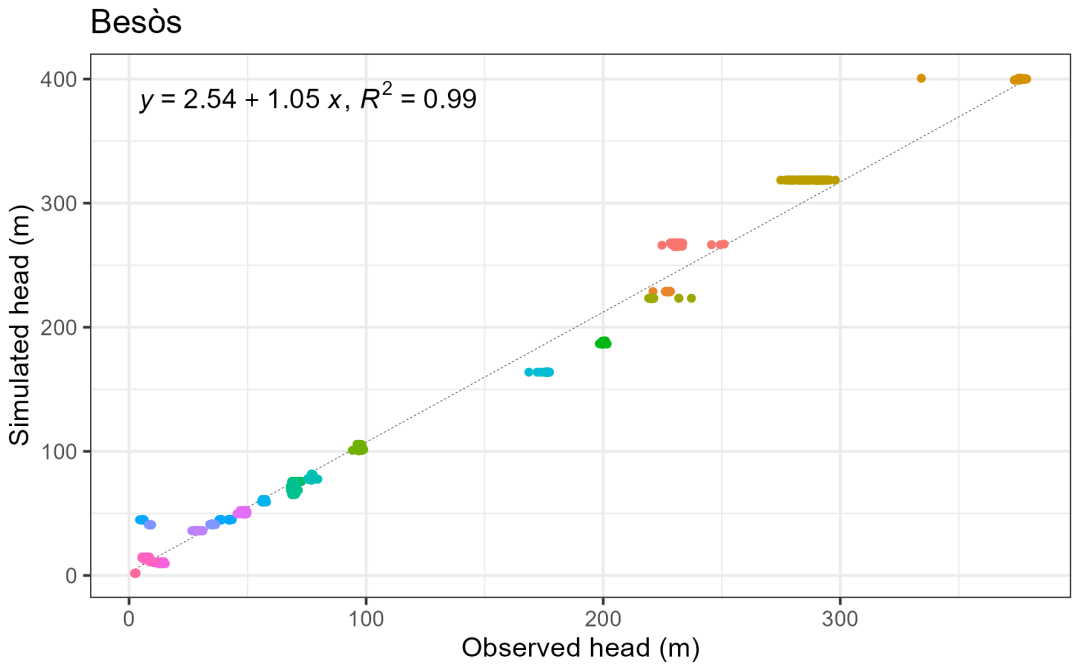
Monthly	NSE	KGE	PBIAS
Calibration	0.51	0.65	32.8
Validation	0.5	0.76	20



Results – gwflow module

Monthy	PEST++ IES (4000 runs)		FAST (4467 – 4796 runs)	
	MAE	PBIAS	MAE	PBIAS
Tordera	7.40	-6.2	5.64	-2.4
Fluvià	14.26	5.6	13.14	5.2
Besòs	9.12	7.3	10.02	8.5
Yearly				
Tordera	7.39	-6.6	5.60	-2.5
Fluvià	14.52	5.7	13.50	5.3
Besòs	9.37	7.3	10.58	8.7

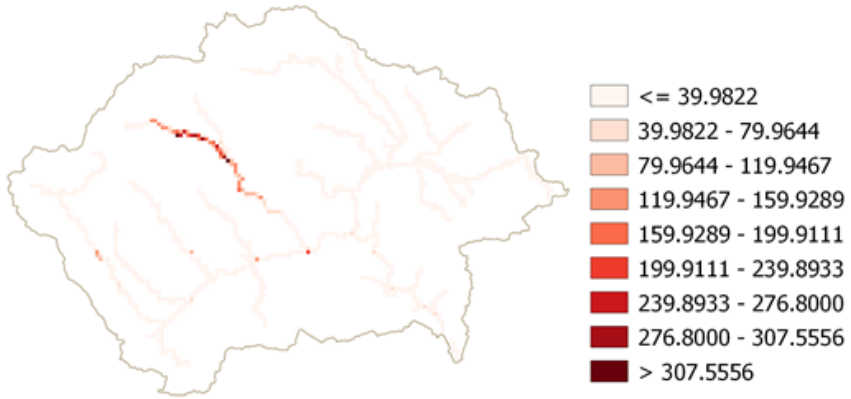




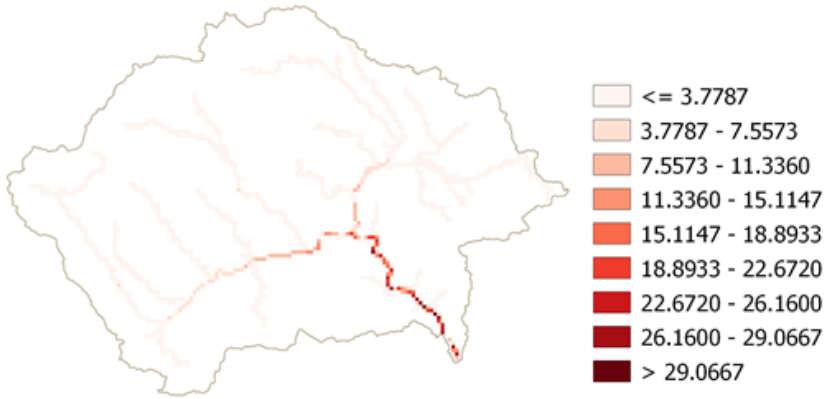
Results – gwflow module

Groundwater to surface water excharge (m^3/day)

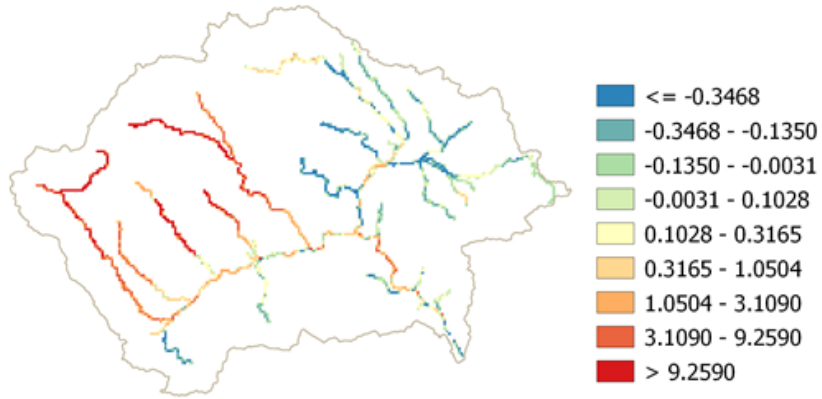
Default model



Calibrated model

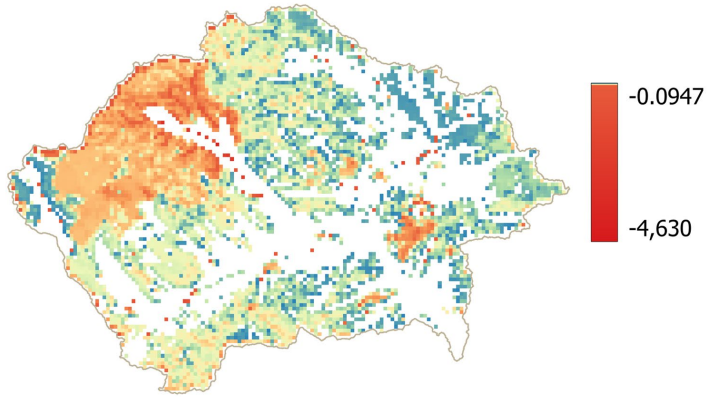


New default model

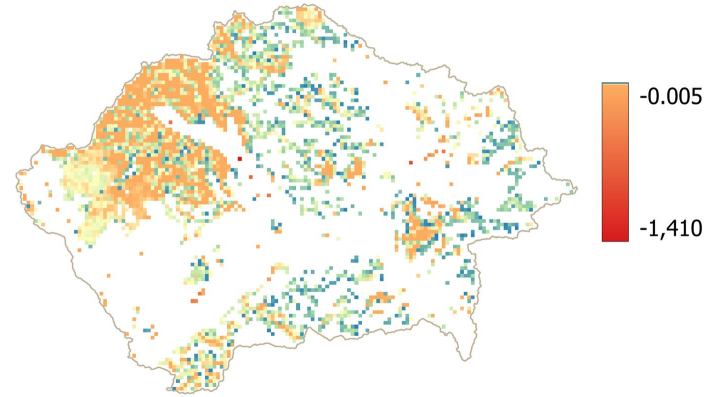


Saturation excess flow (m^3/day)

Default model

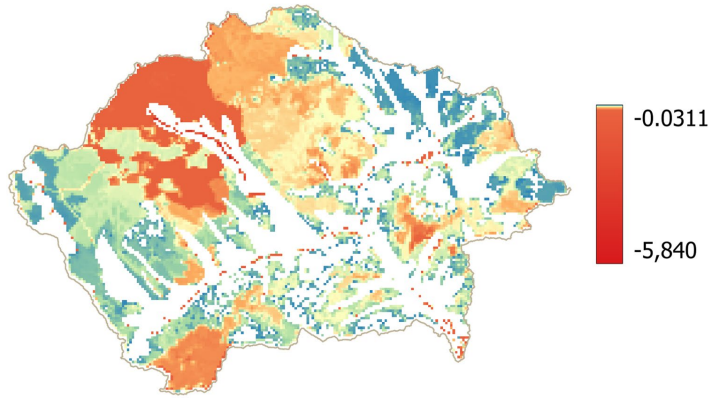


Calibrated model

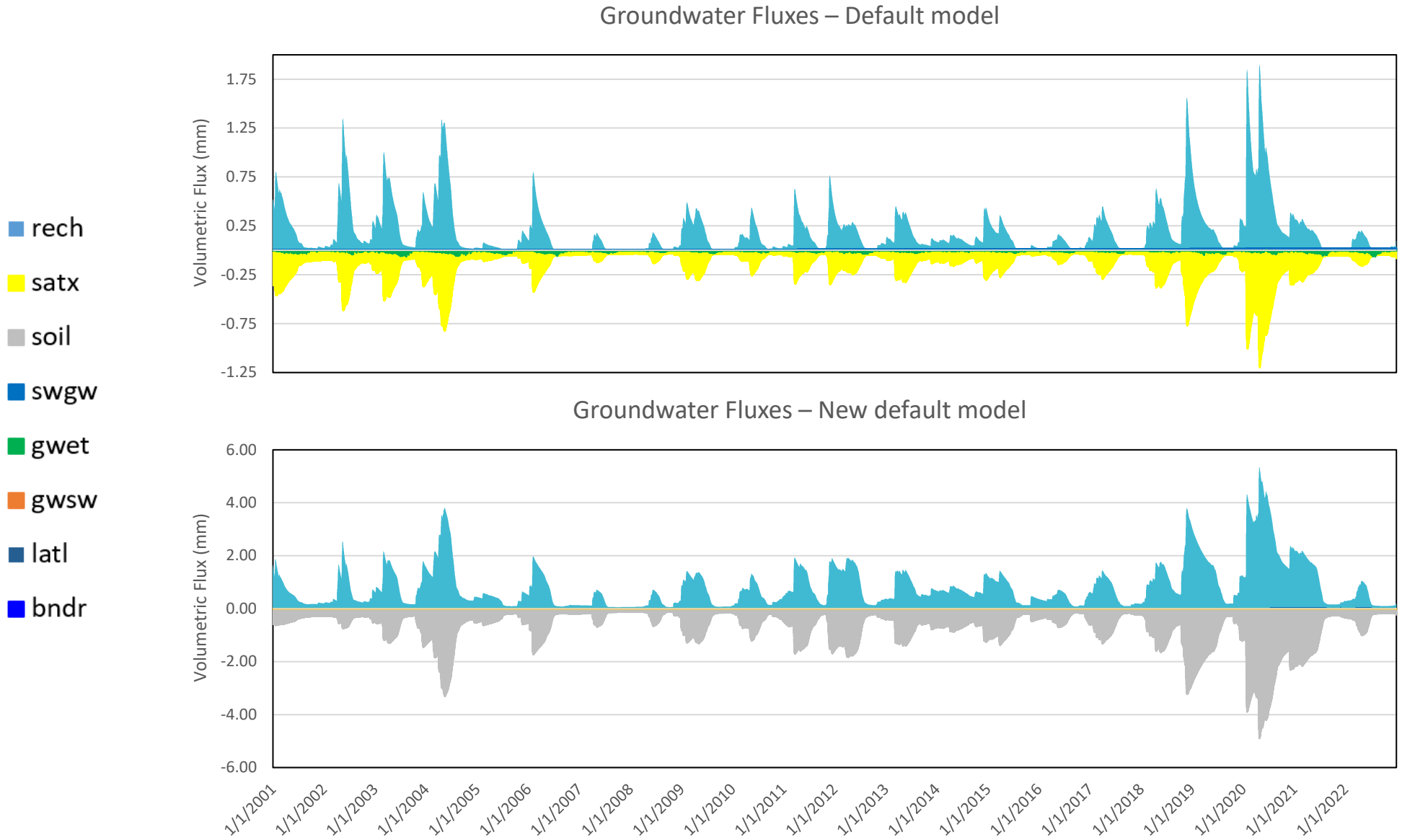


Groundwater to soil transfer (m^3/day)

New default model



Results – gwflow module



Summary and future developments

- Rebuild SWAT+/gwflow models
  - Recalibrate surface hydrology
  - Calibrate groundwater head

  } Multi-objective calibration

- Water quality assessment
  - Add pesticides and point source pollutants routines
  - Calibrate concentrations/loads

- Potential use as to support decision-making in the water management sector

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Thank you!

Acknowledgements:

Research that led to this presentation has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101036337 (project MERLIN). Authors also acknowledge the support from the Economy and Knowledge Department of the Catalan Government through Consolidated Research Group ICRA-ENV (2021 SGR 01282), as well as from the CERCA program. LEstrada acknowledges funding from the Secretariat of Universities and Research of Generalitat de Catalunya and the European Social Fund for her FI fellowship (2024 FI-3 00168).