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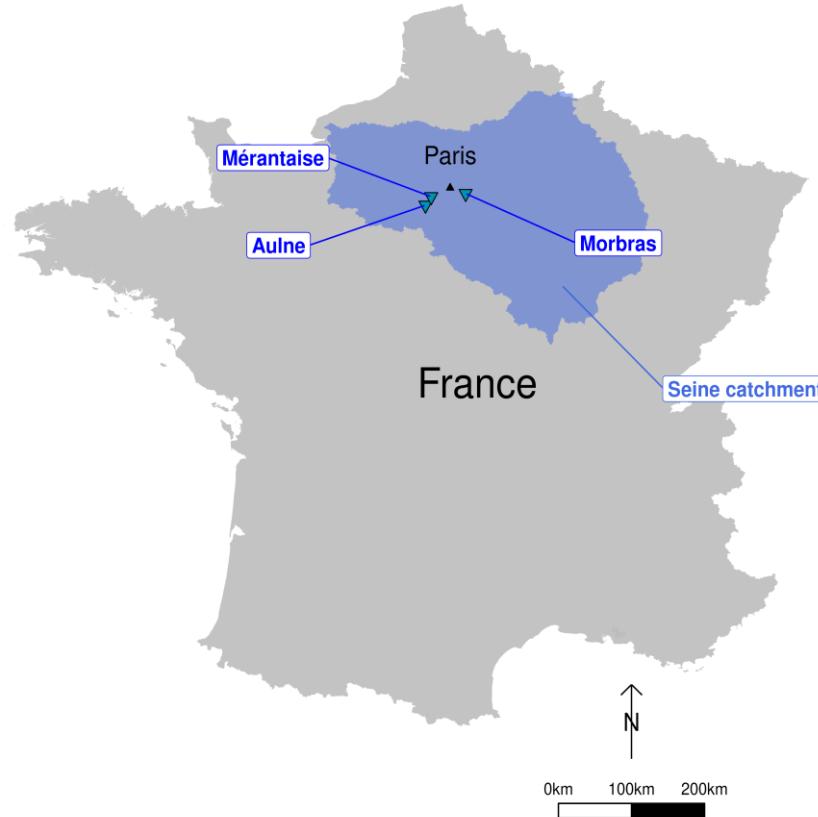
Geomorphological alteration of urban rivers assessed by hydrological modelling

M. Saadi^{1,2}(m.saadi@fz-juelich.de), A. Cheikh Larafa^{2,3}, F. Gob³, L. Oudin², P. Brigode⁴

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2021-12-08 | 4^{es} Rencontres HydroGR 2021

1 | Context and objectives

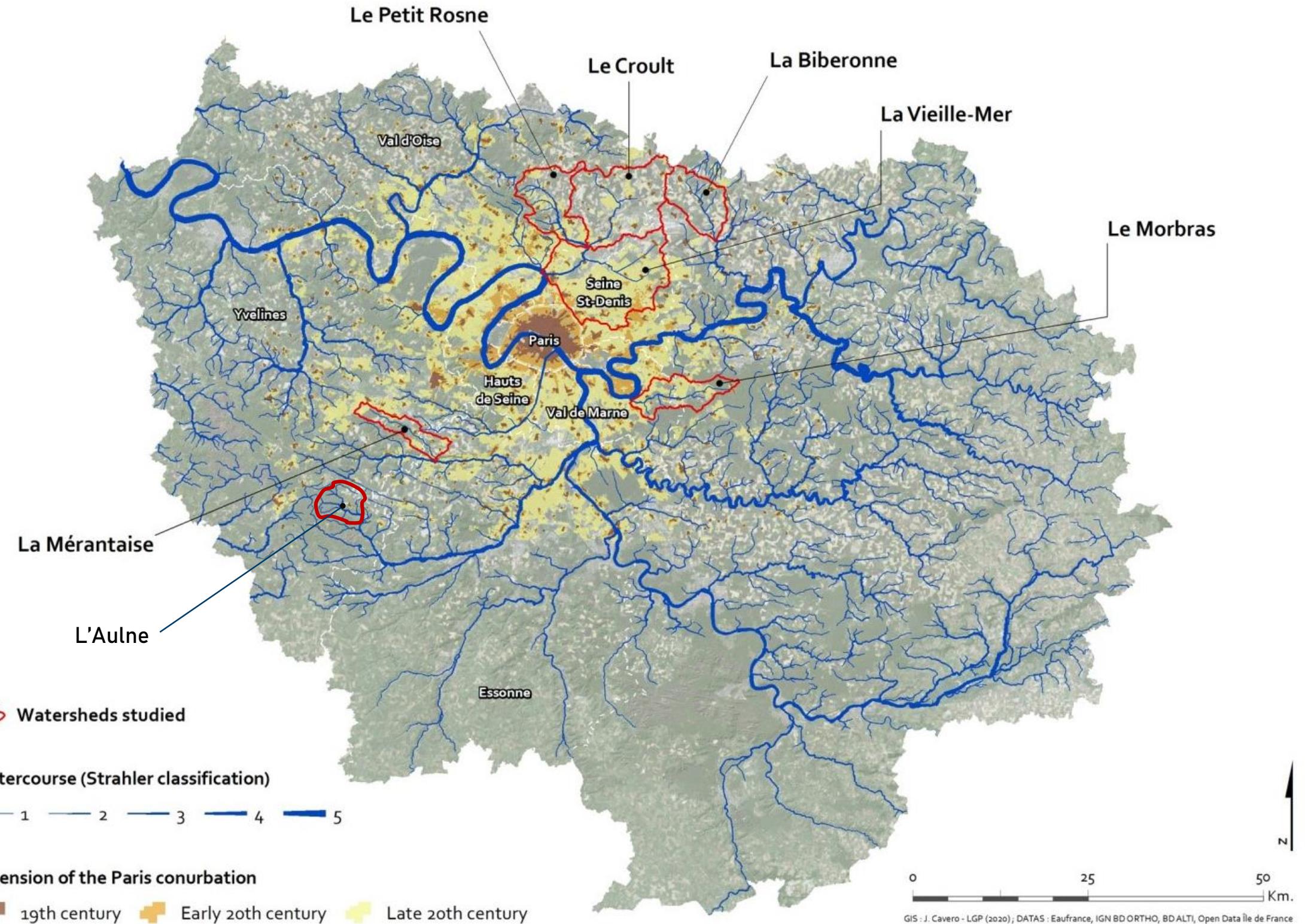


3 catchments located within the Seine river basin

Aulne (34 km^2)

Mérantaise (20 km^2)

Morbras (51 km^2)

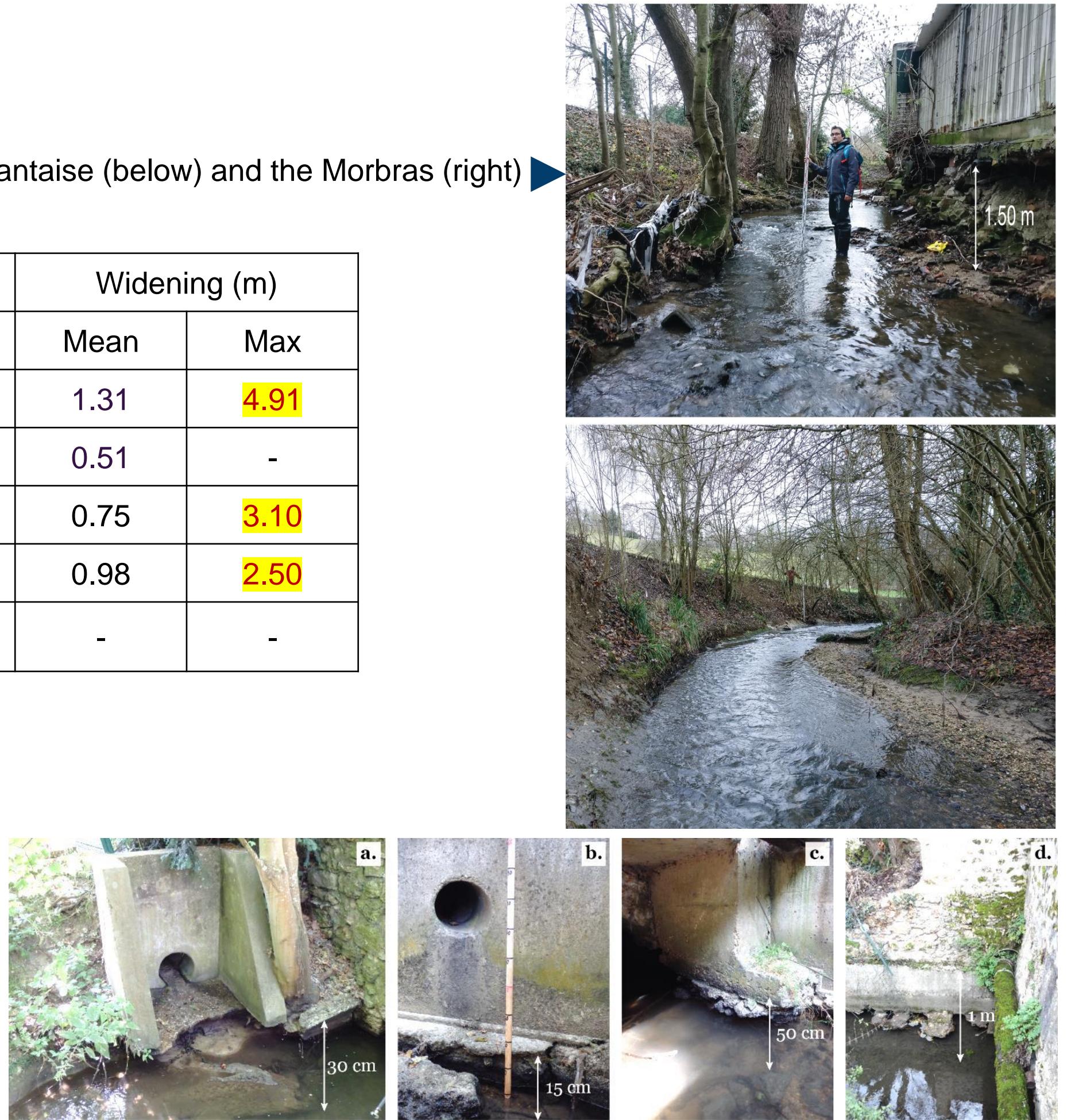
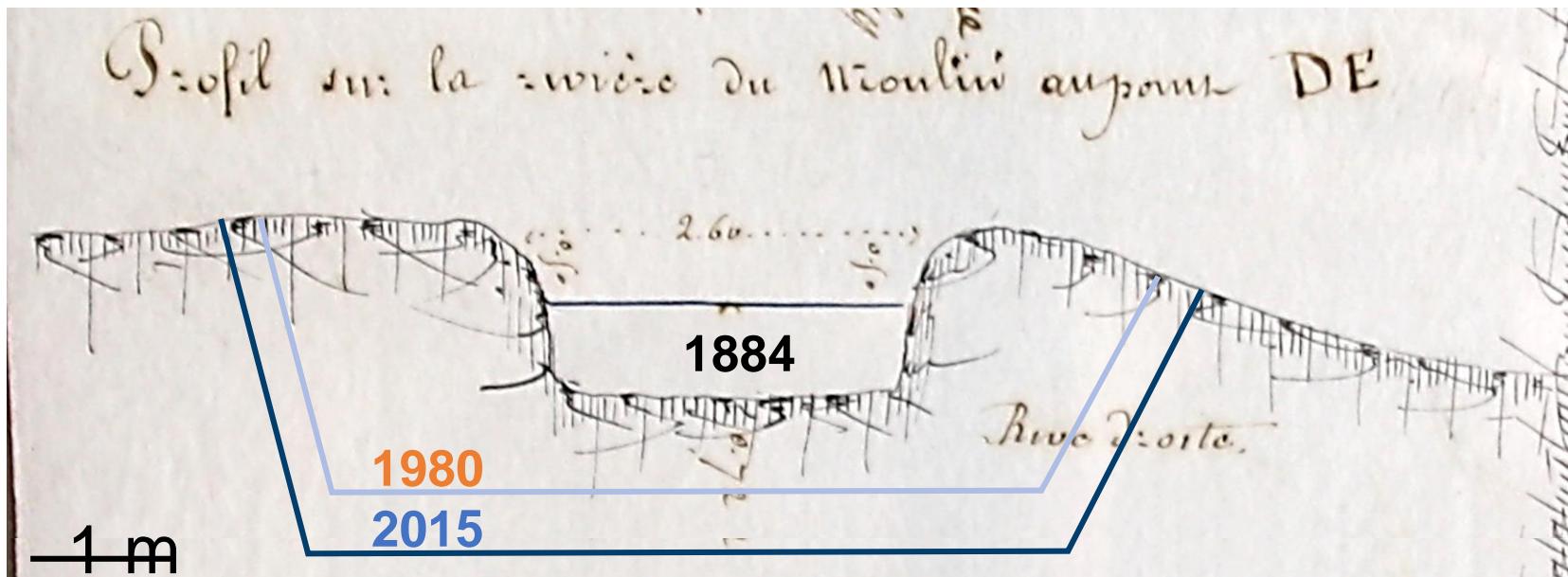


1 | Context and objectives

Incision/widening marks on the Mérantaise (below) and the Morbras (right) ➤

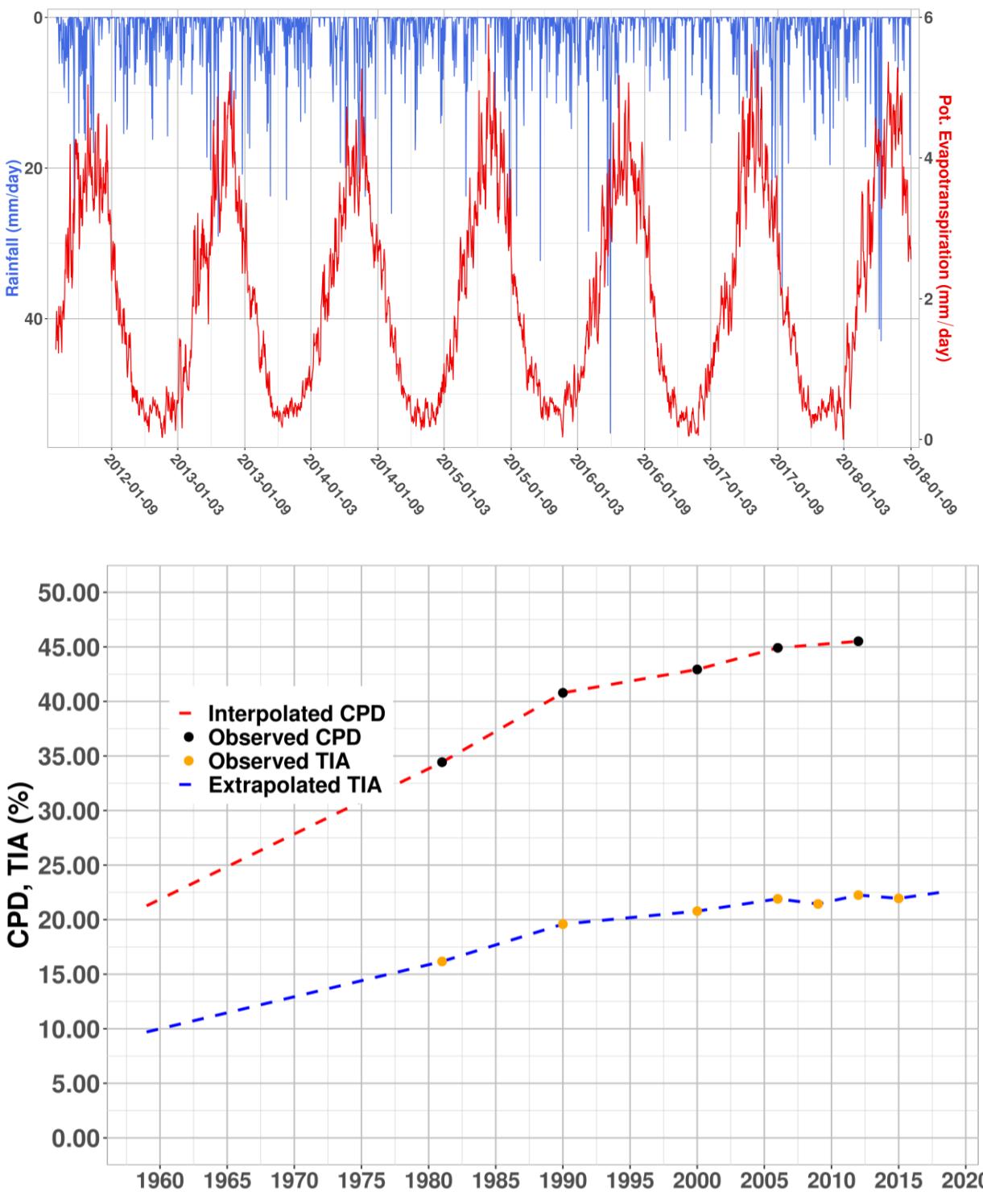
Comparison of 2015 Xsections to...		Incision (m)		Widening (m)	
		Mean	Max	Mean	Max
Mérantaise	1980 Xsections	0.41	1.26	1.31	4.91
	Regional model	0.11	-	0.51	-
Morbras	1964 Xsections	0.39	1.05	0.75	3.10
	Regional model	0.43	0.58	0.98	2.50
Aulne		-	-	-	-

Comparison of the Mérantaise width and depth in 1884/1907, 1980 and 2015 in two close locations

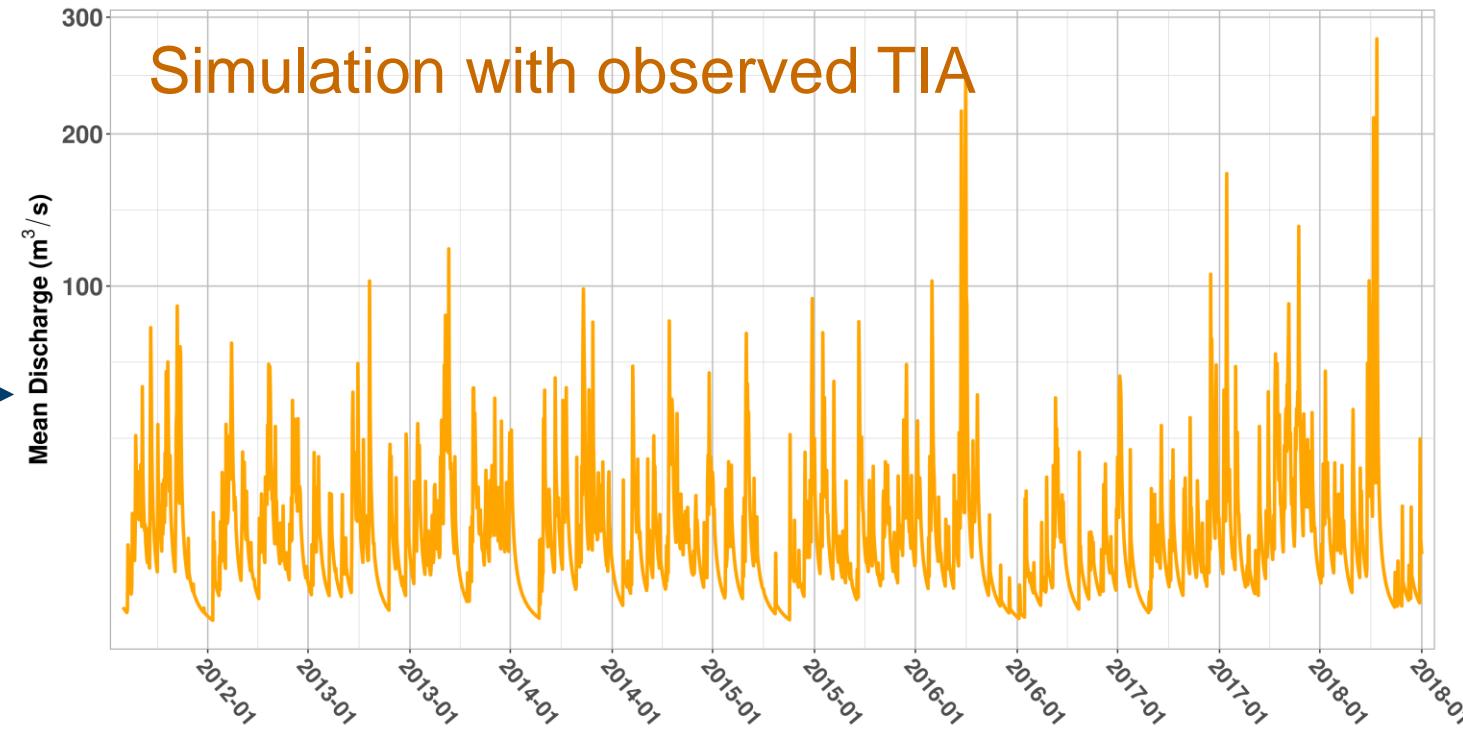


2| Methods

Climate forcing (1959-2018)



Long-term streamflow time series (1959-2018)



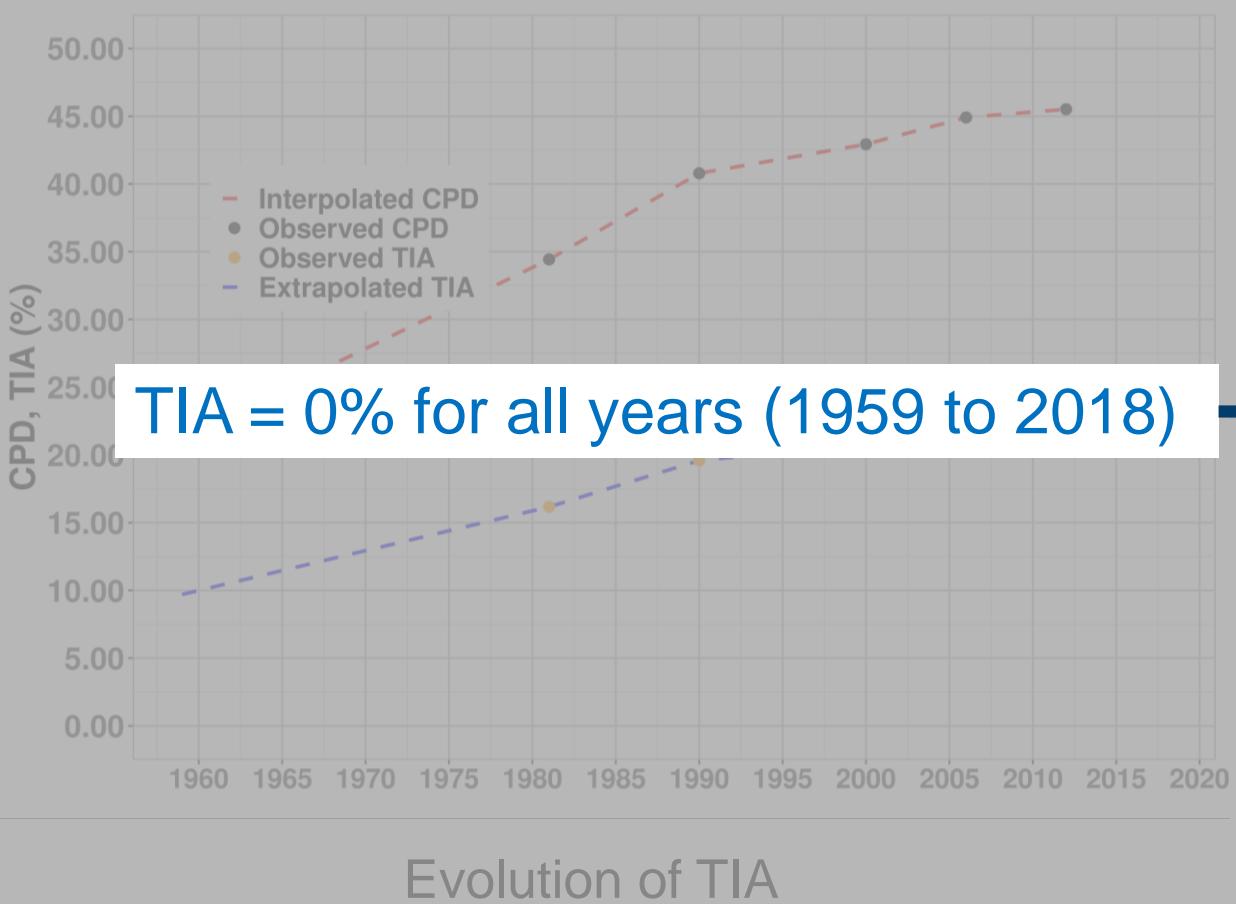
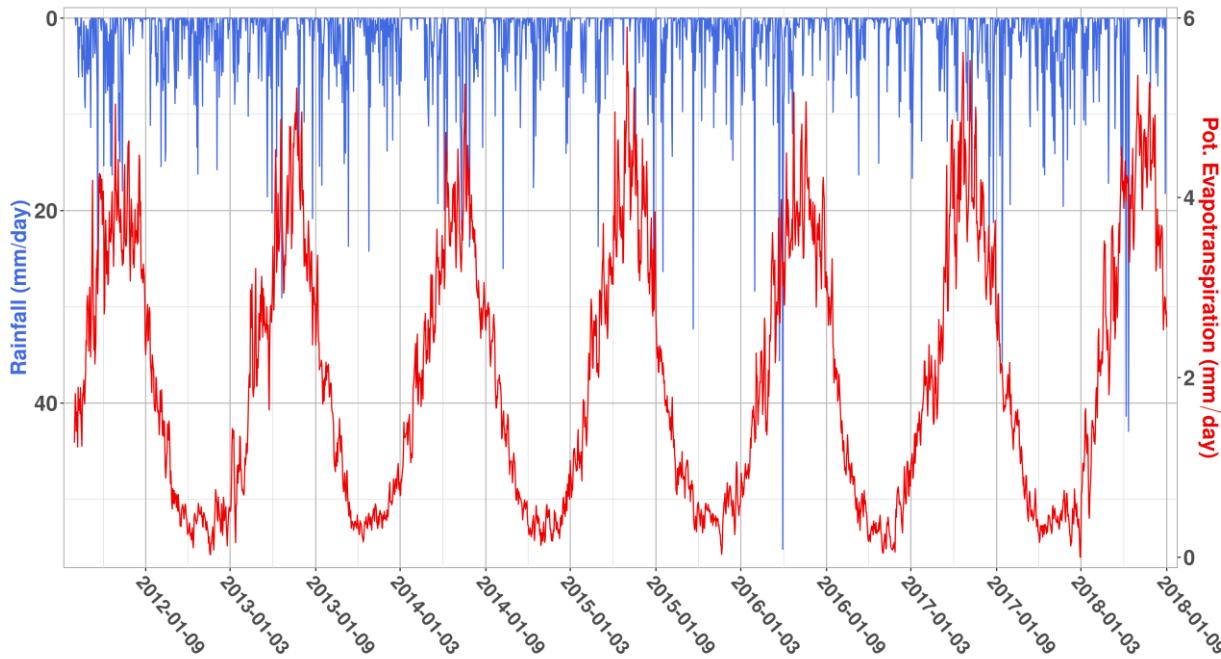
Hydrological model:
MU5H

$$\{\theta\} = \{\theta_{urb}, \theta_{nourb}\}$$

Estimated by calibration using
observed rainfall-runoff time series
(2007-2018)

2 | Methods

Climate forcing (1959-2018)

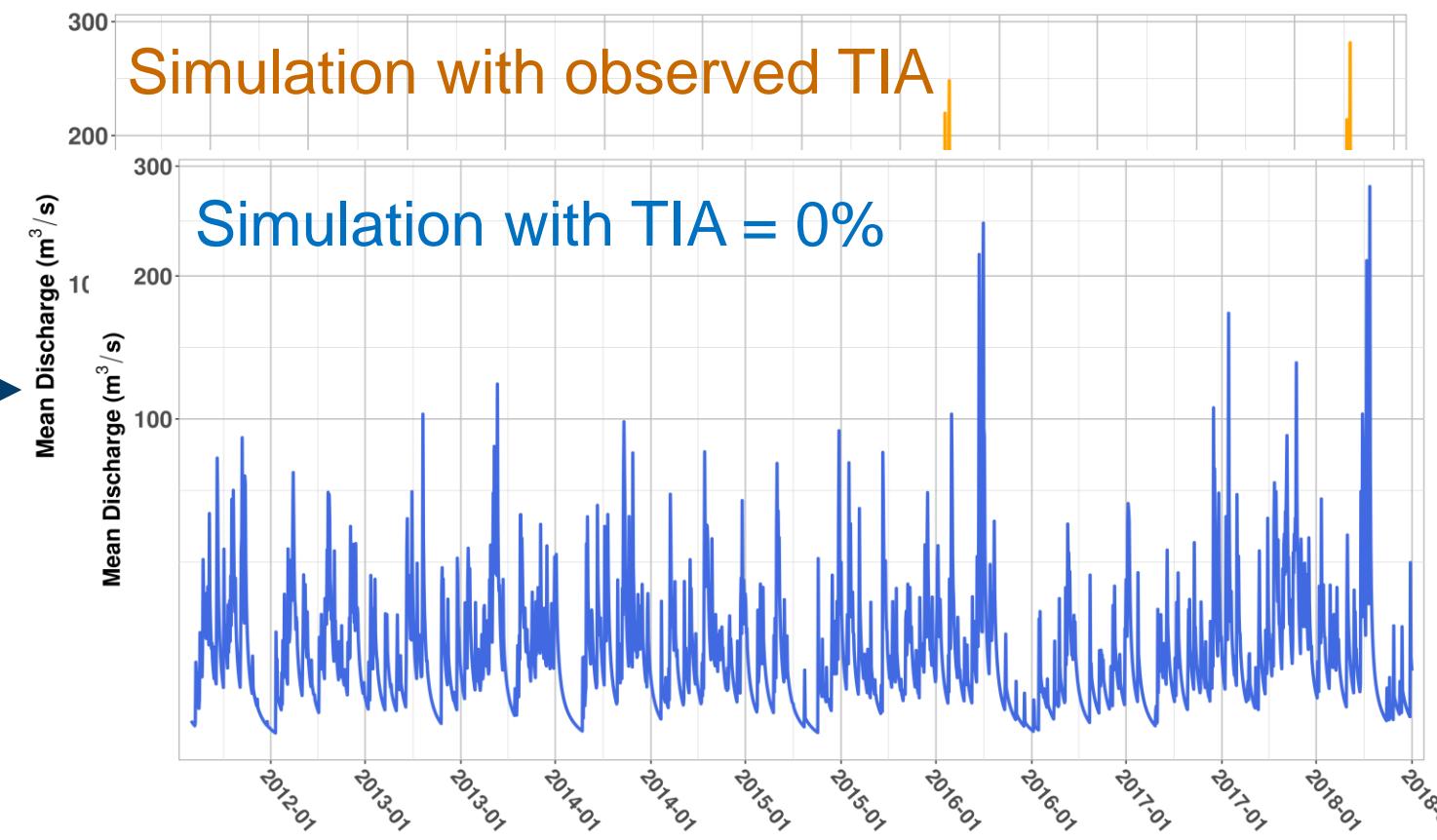


Hydrological model:
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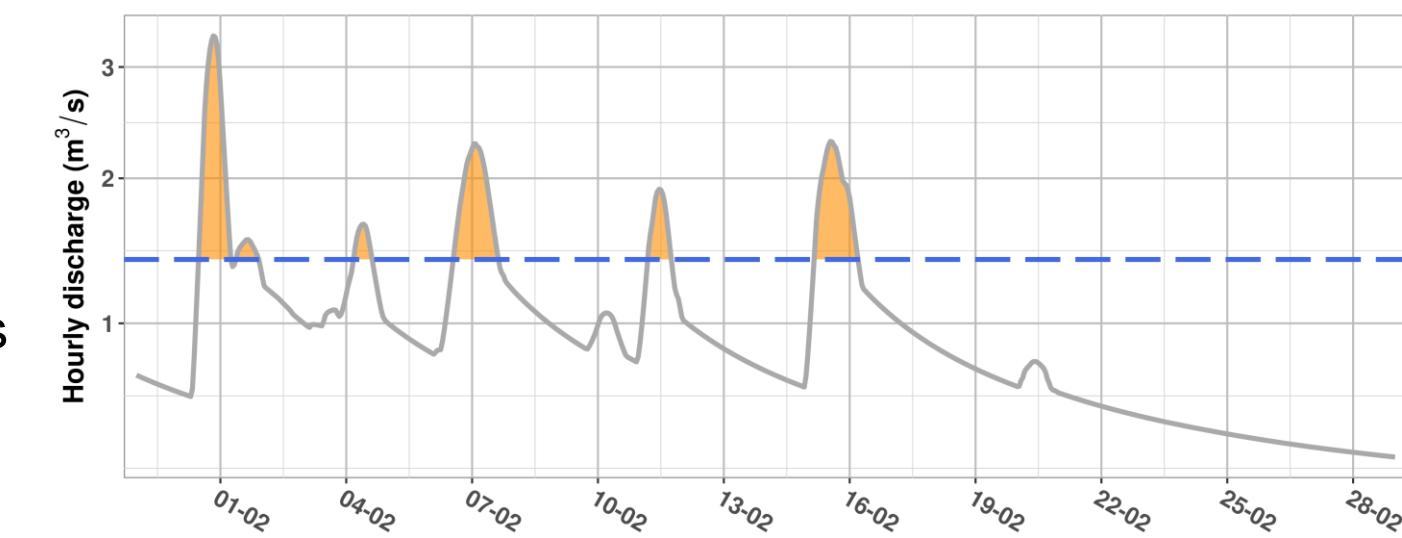
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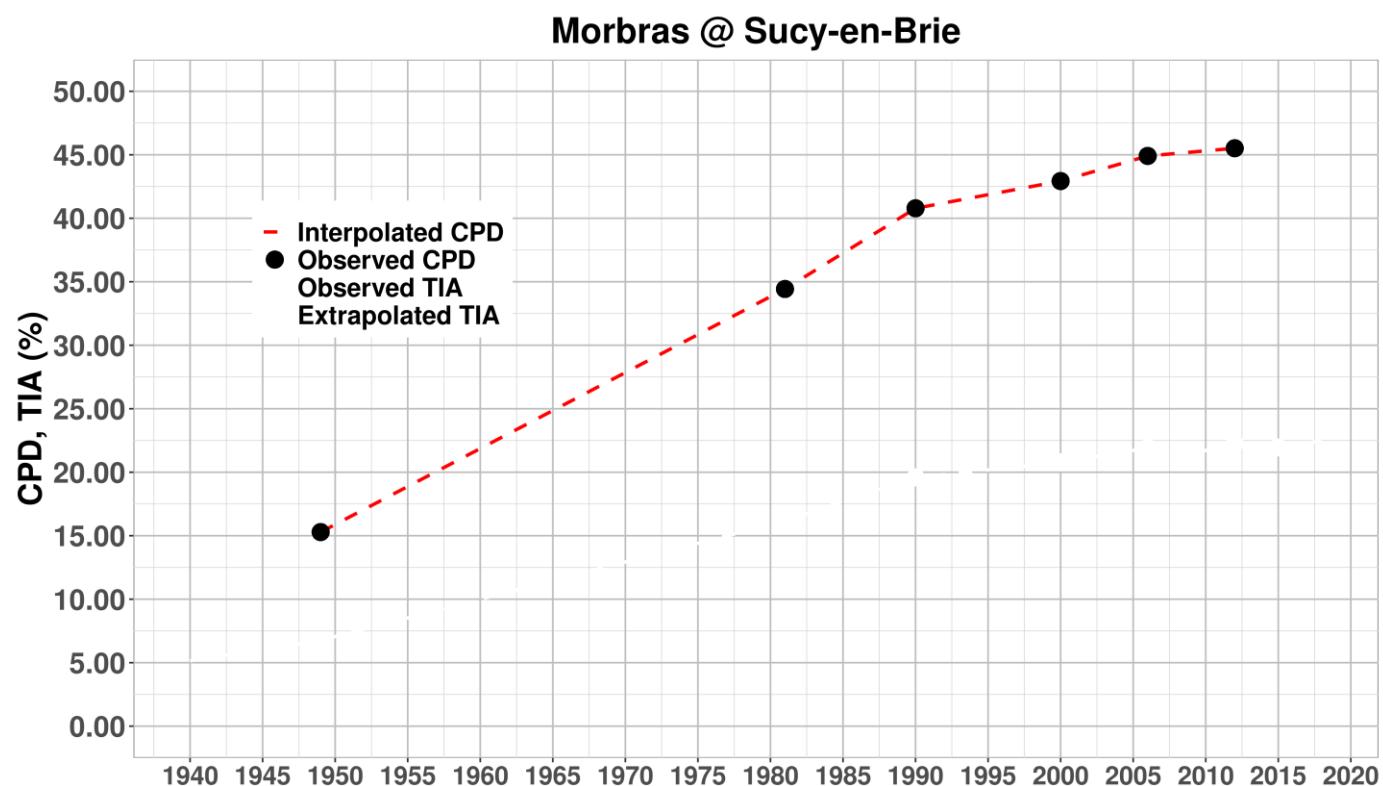
Impact of urbanization on
competent flow



2 | Methods

2.1 | Climate forcing and land cover evolution

Required data	Source	Time period
Precipitation (hourly)		
Potential evapotranspiration (hourly)	SAFRAN (Vidal et al., 2010; 8 km resolution)	1959-2018
Land cover (yearly)	LGP (land cover, polygons) and CORINE database (<u>land cover</u> at 100 m + <u>imperviousness</u> at 20 m)	Mérantaise: 1900-2015 Morbras: 1949-2015 Aulne: 1990-2015
Discharge (hourly)	LGP + INRAE + CD94	Morbras: 2007-2018 Aulne, Mérantaise: 2011-2018



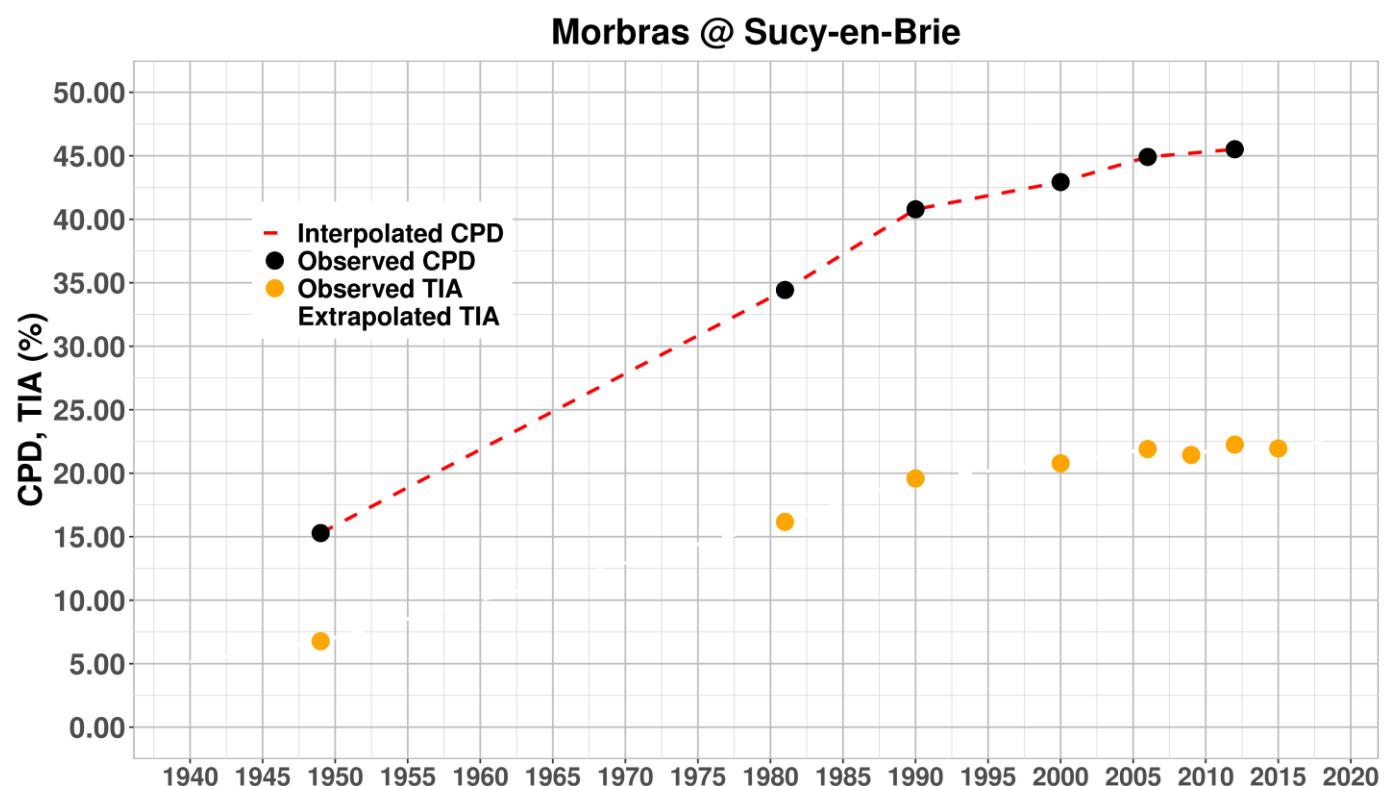
2.2 | TIA time series: Recipe

Step 1: Estimate CPD from CORINE and LGP databases

2 | Methods

2.1 | Climate forcing and land cover evolution

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2.2 | TIA time series: Recipe

Step 1: Estimate CPD from CORINE and LGP databases

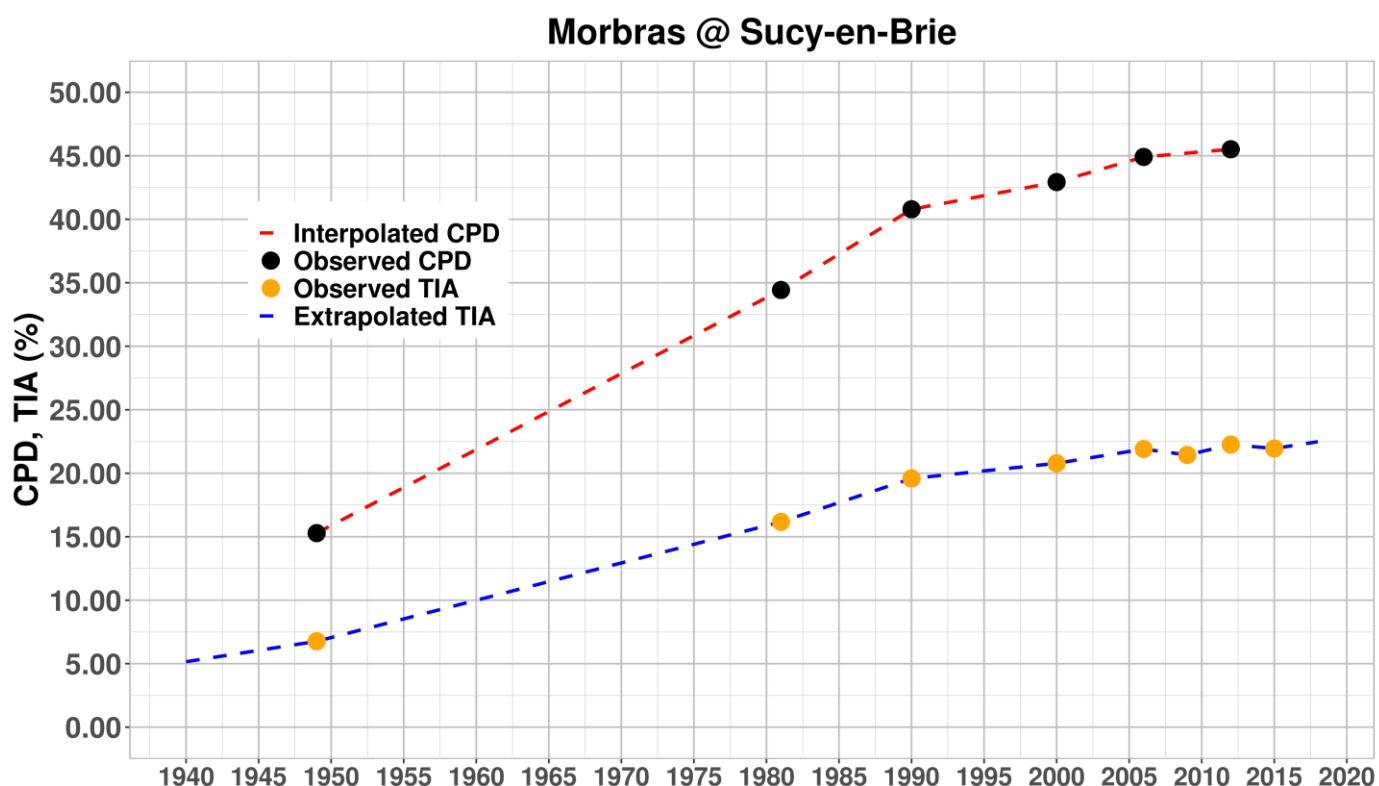
Step 2: Estimate TIA using: $TIA\ (%) = 68.5 \left(1 - \sqrt{1 - \frac{CPD\ (%)}{100}} \right)$

Step 3: Correct the estimations of TIA using the observed TIA for the year 2006

2 | Methods

2.1 | Climate forcing and land cover evolution

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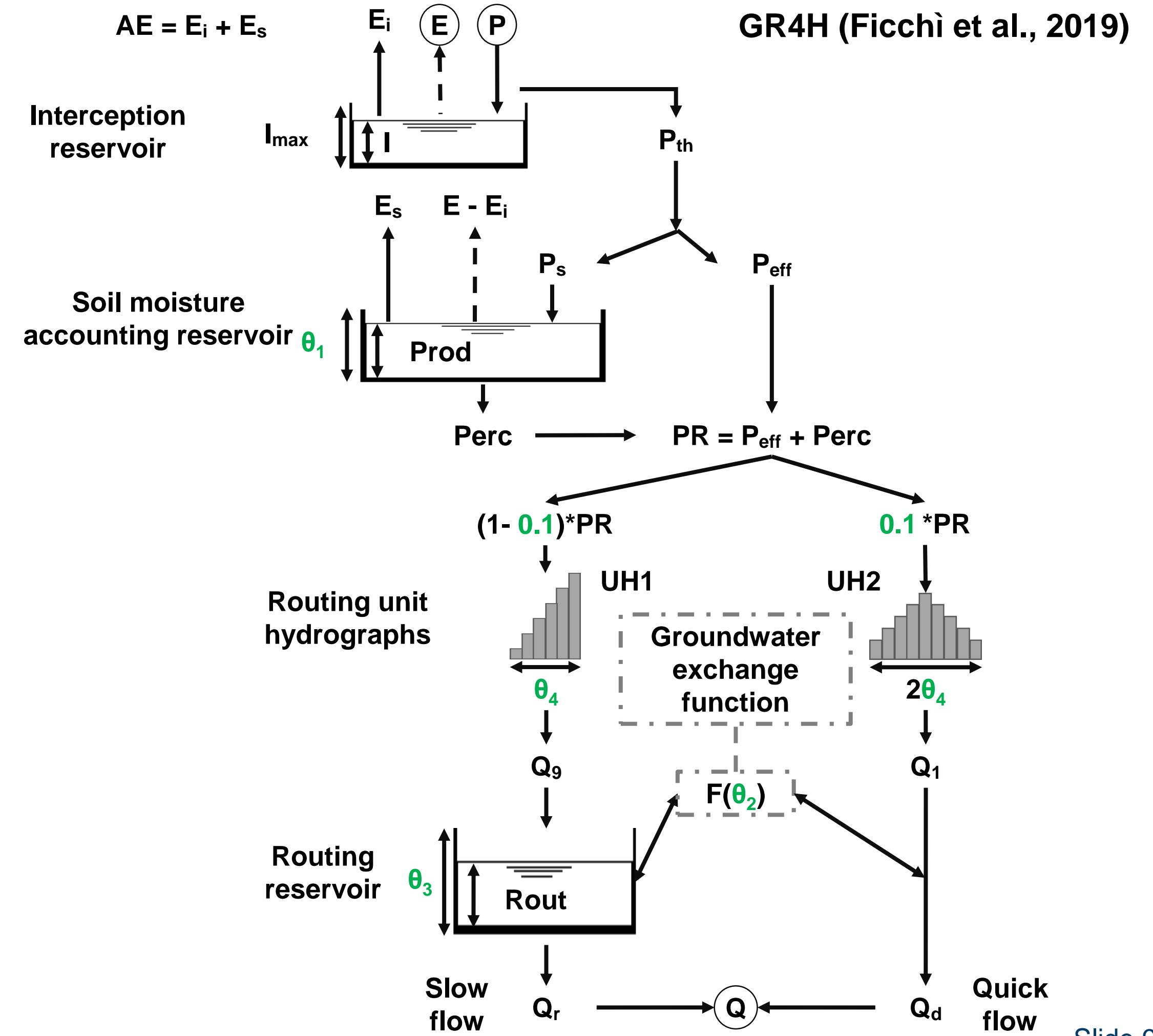
Step 4: Interpolation and extrapolation

2 | Methods

2.3 | Hydrological model MU5H

Parameters

- I_{max} , θ_1 , θ_3 : Reservoir capacities (mm)
- θ_2 : Potential exchange parameter (mm)
- θ_4 : Base time of unit hydrographs (h)

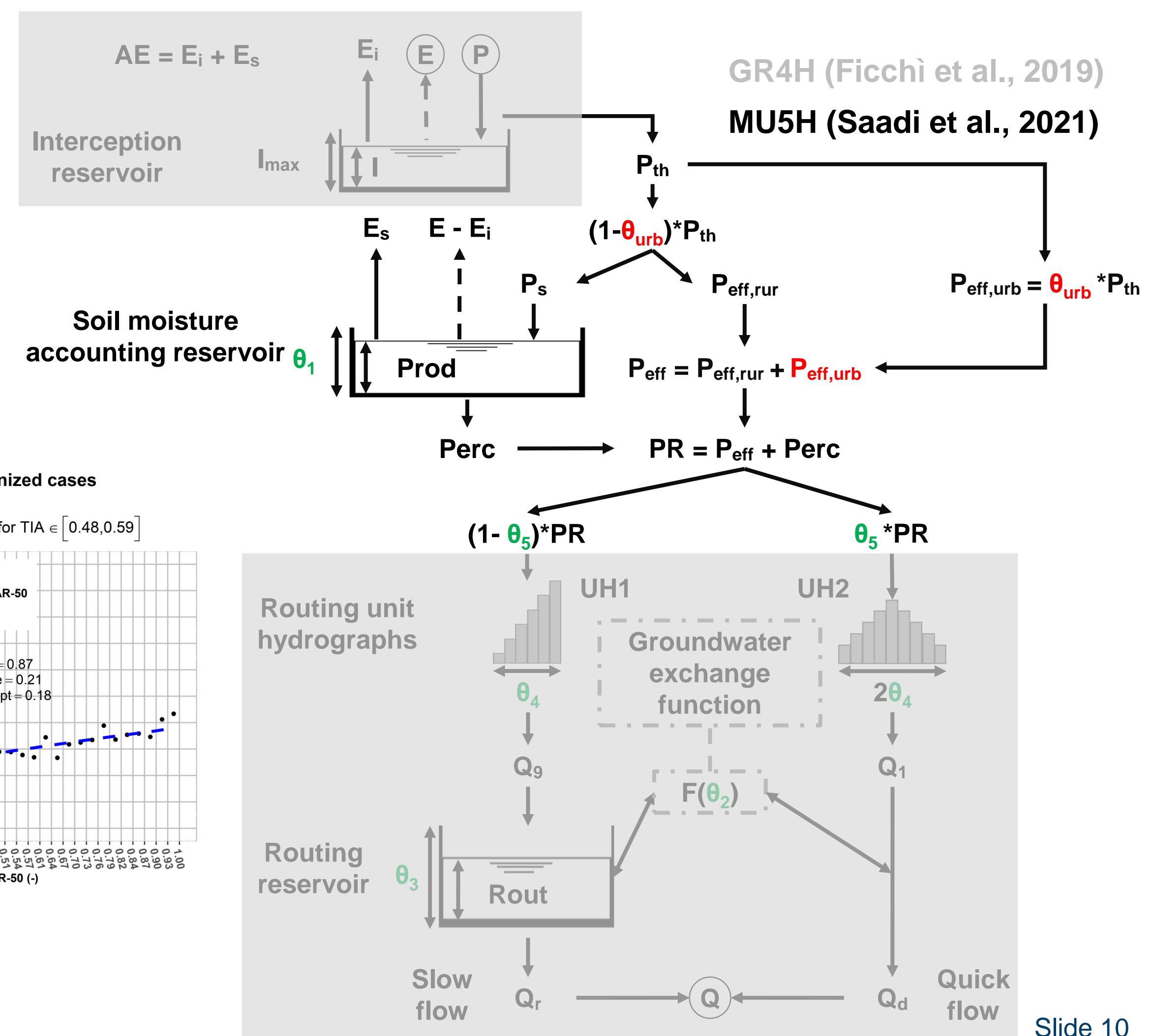
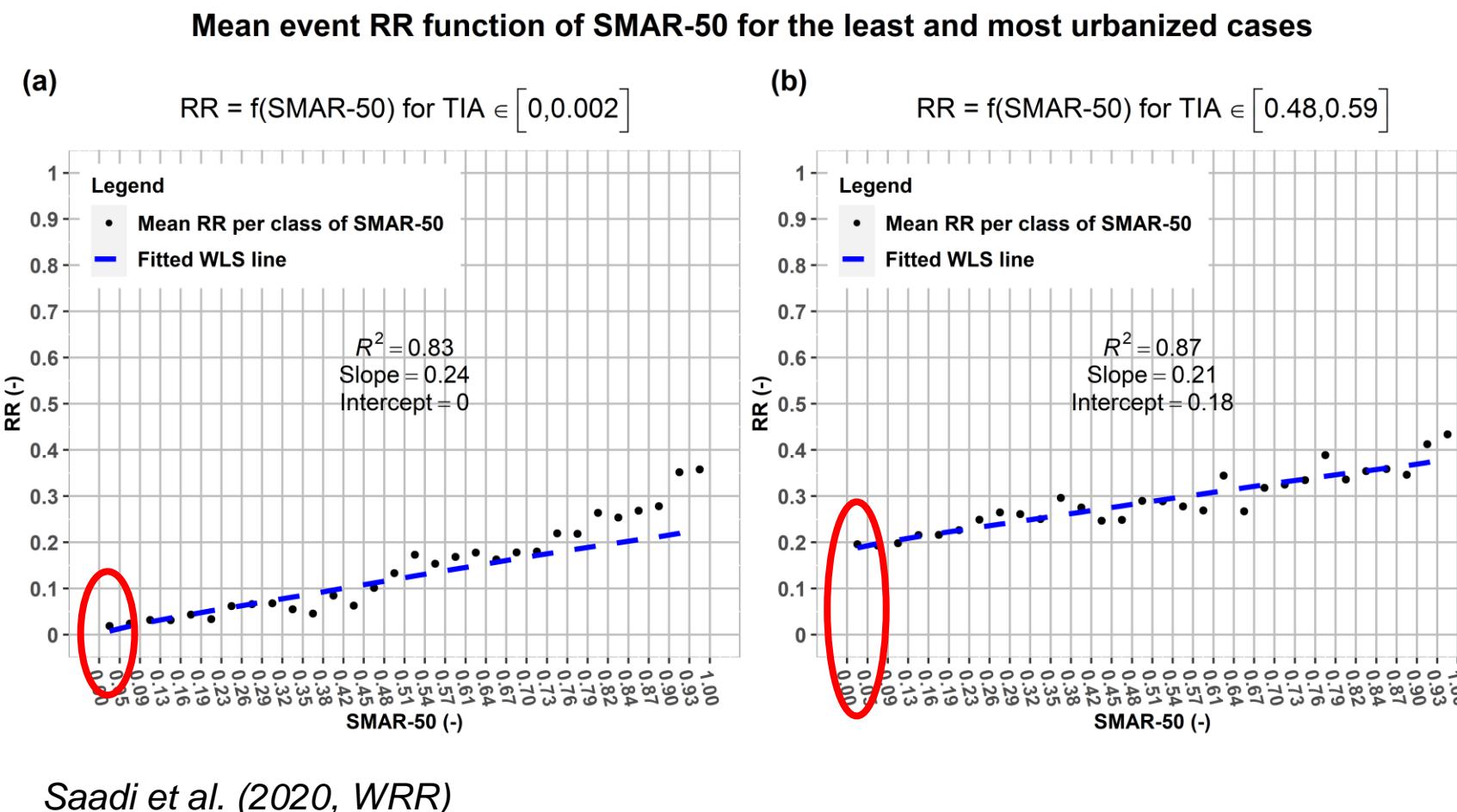


2 | Methods

2.3 | Hydrological model MU5H

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- θ_5 : Quick-flow/slow-flow split parameter (-)



2 | Methods

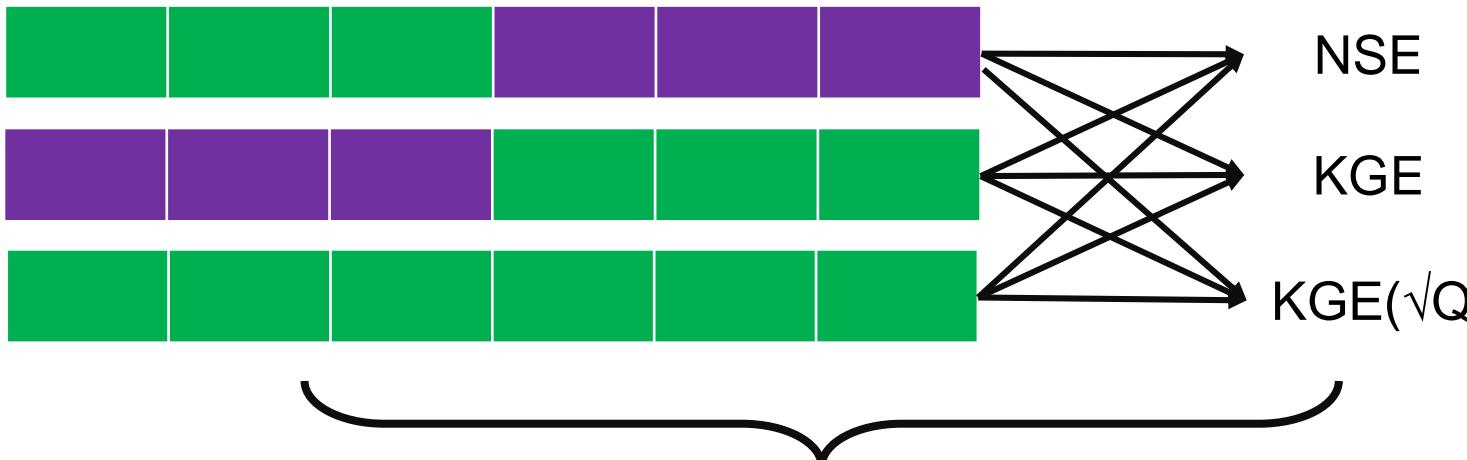
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3 periods of calibration

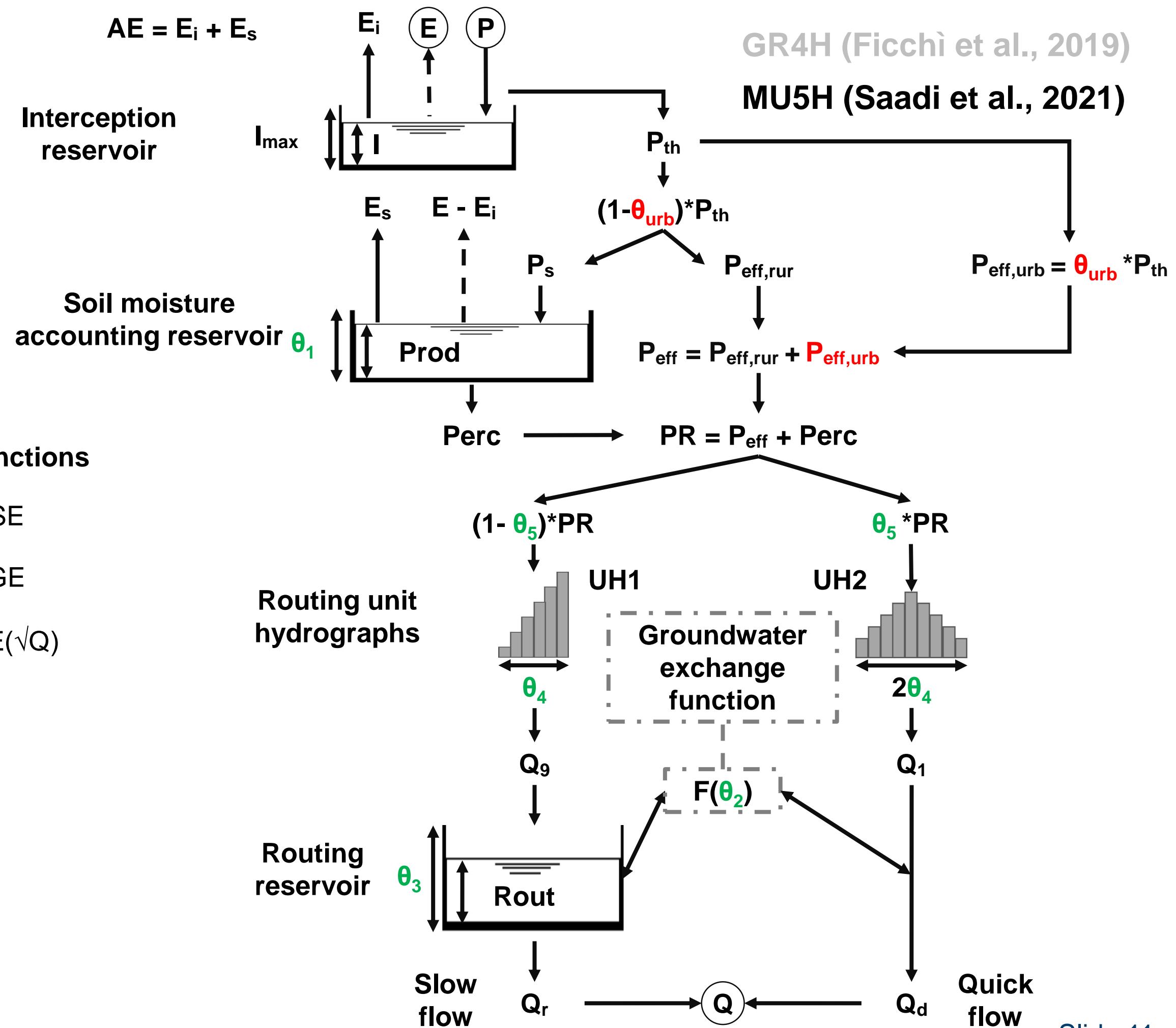
3 objective functions



= 9 optimal parameter sets
 $\{\theta_1, \theta_2, \theta_3, \theta_4, \theta_5\}$

θ_{urb} is fixed as the observed TIA
(changes every year)

Coron et al. (2017); Edijatno et al. (1999);
Nash et Sutcliffe (1970); Gupta et al. (2009)



2 | Methods

2.4 | Change in flow competence due to urbanization

3 periods of calibration

3 objective functions

= 9 optimal parameter sets
 $\{\theta_1, \theta_2, \theta_3, \theta_4, \theta_5\}$

Actual evolution of the catchment

$\theta_{urb} = \text{Observed yearly TIA}$

$\theta_{urb} = 0\%$

Catchment response if there were no urbanization (nonurbanized)

1. Q_{cr} is estimated from the nonurbanized simulation using

$$Q_{cr} = 0.6 \cdot \frac{1}{N} \cdot \sum_y Q_{d,max,y} (\theta_{urb} = 0) \quad \text{Pfaundler et al. (2011)}$$

2. Total competent flow (TCF) for the observed and simulated discharge

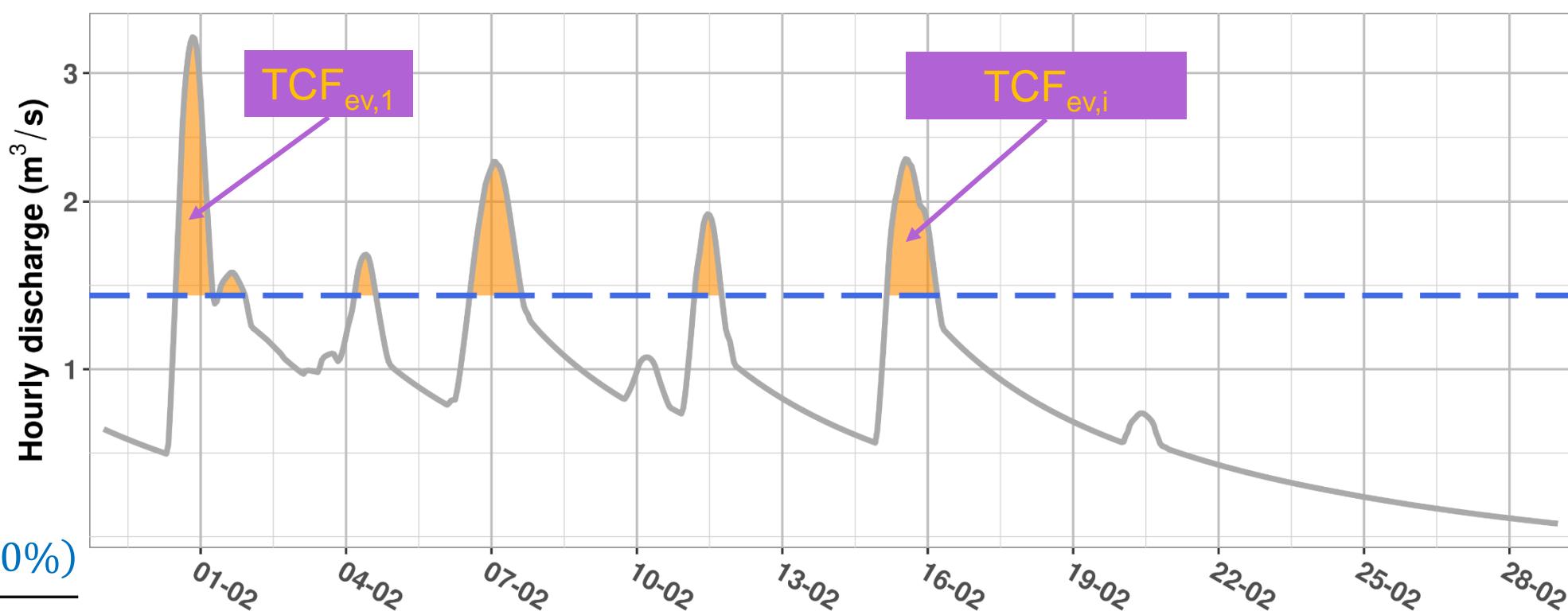
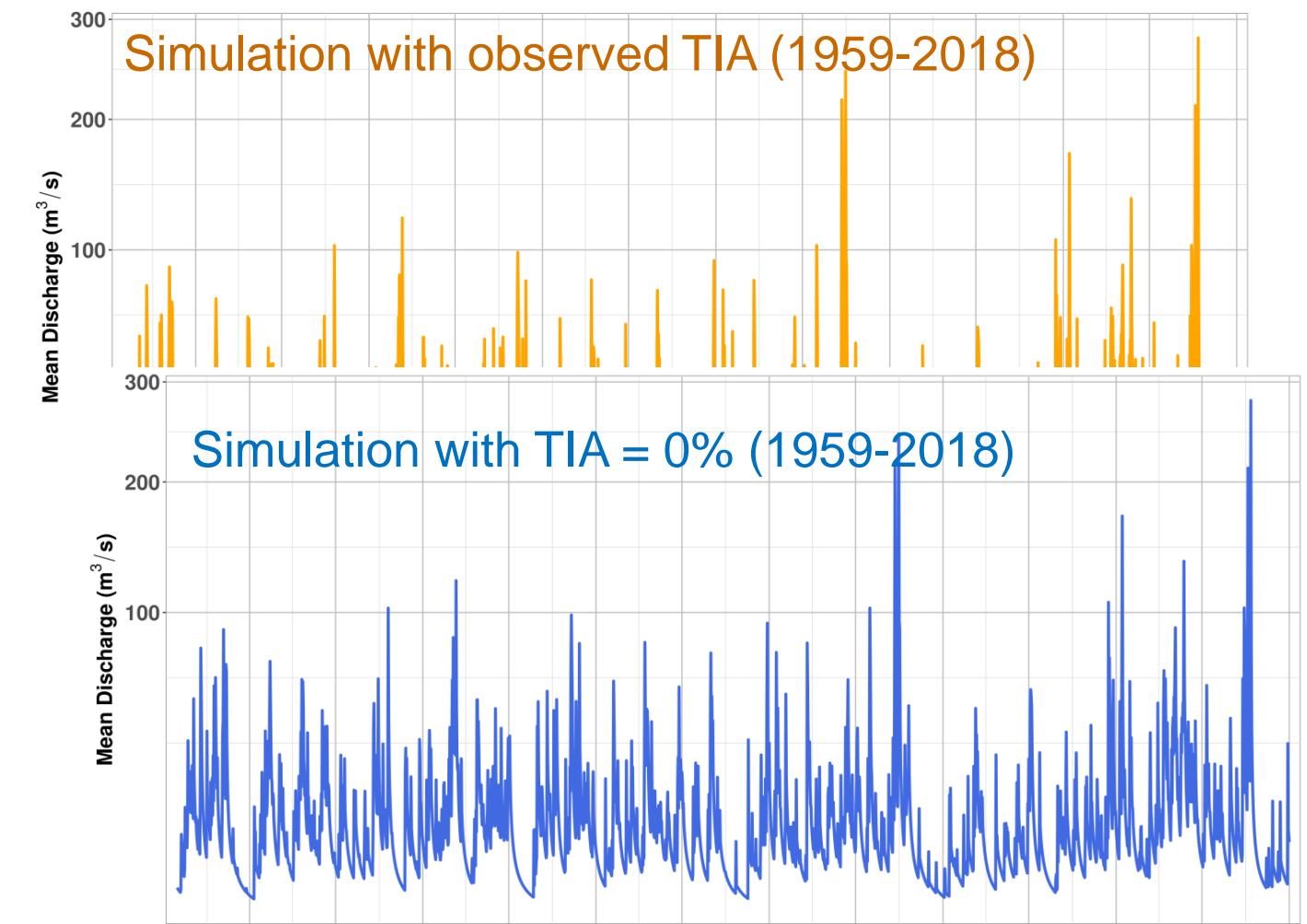
$$TCF_{ev} = \sum_{h \in ev} \max(Q_h - Q_{cr}, 0) \cdot \Delta t$$

Q_{sim} $Q_{sim} = \text{Obs. TIA}$

Q_{obs}

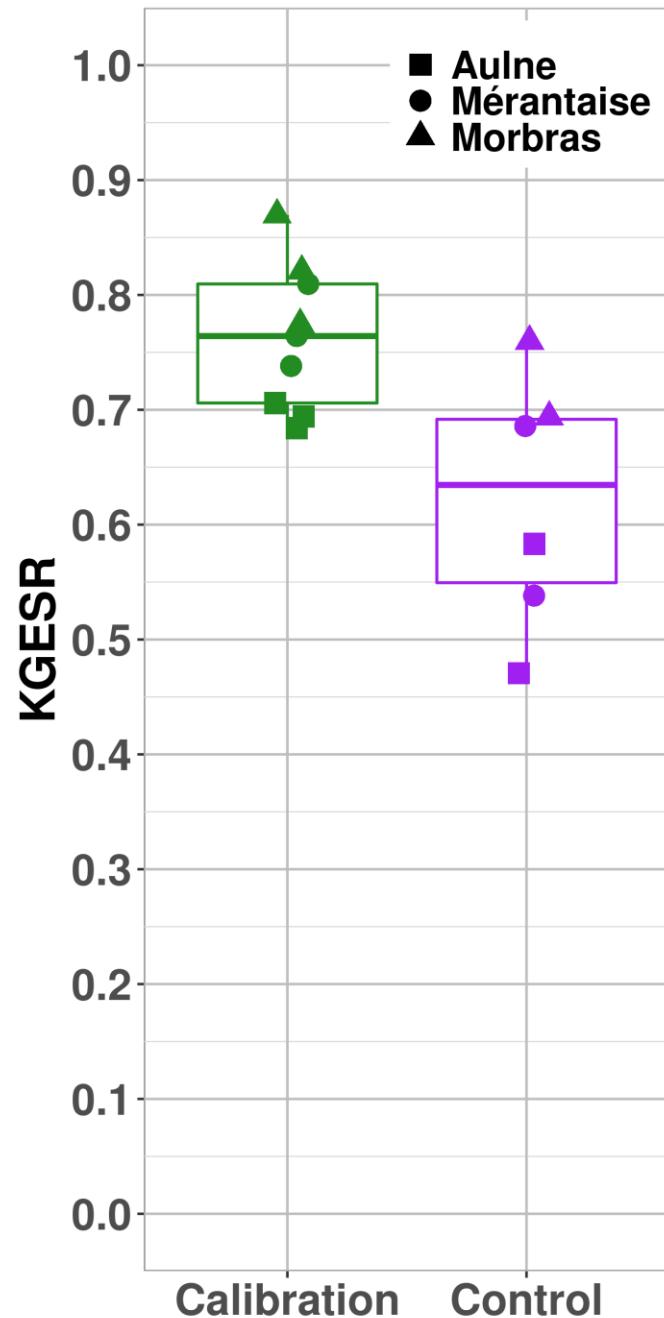
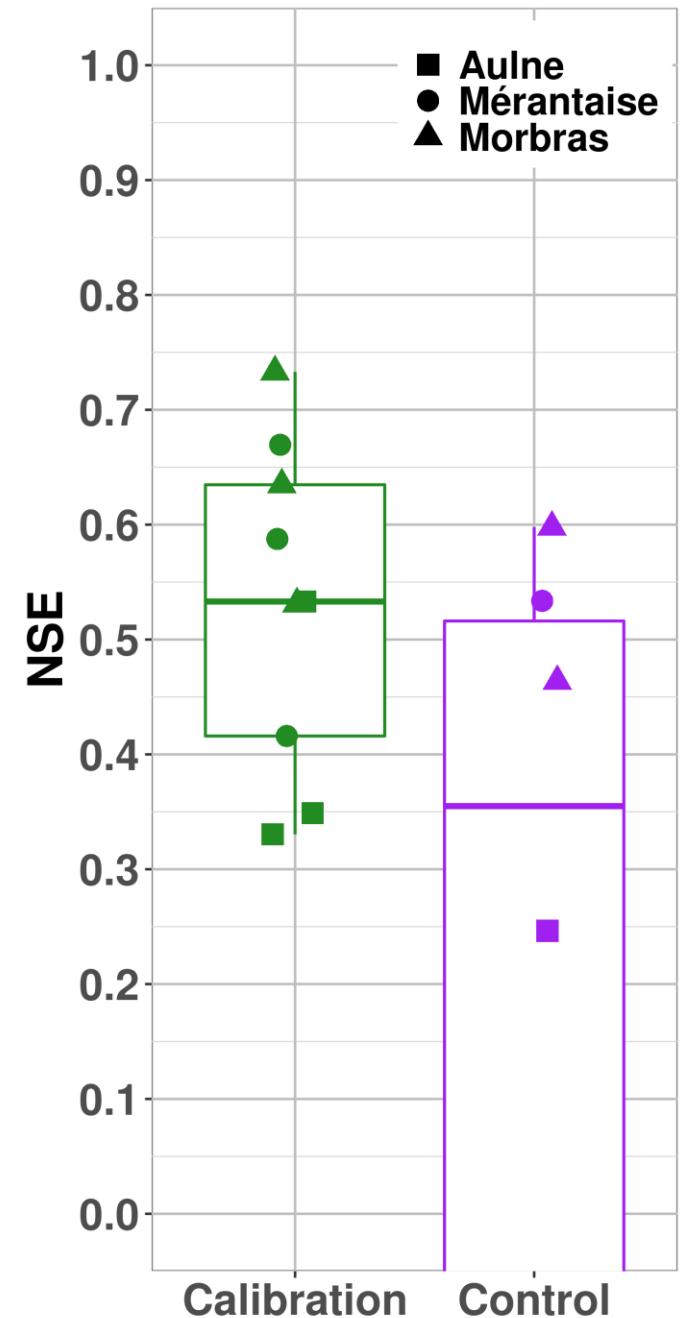
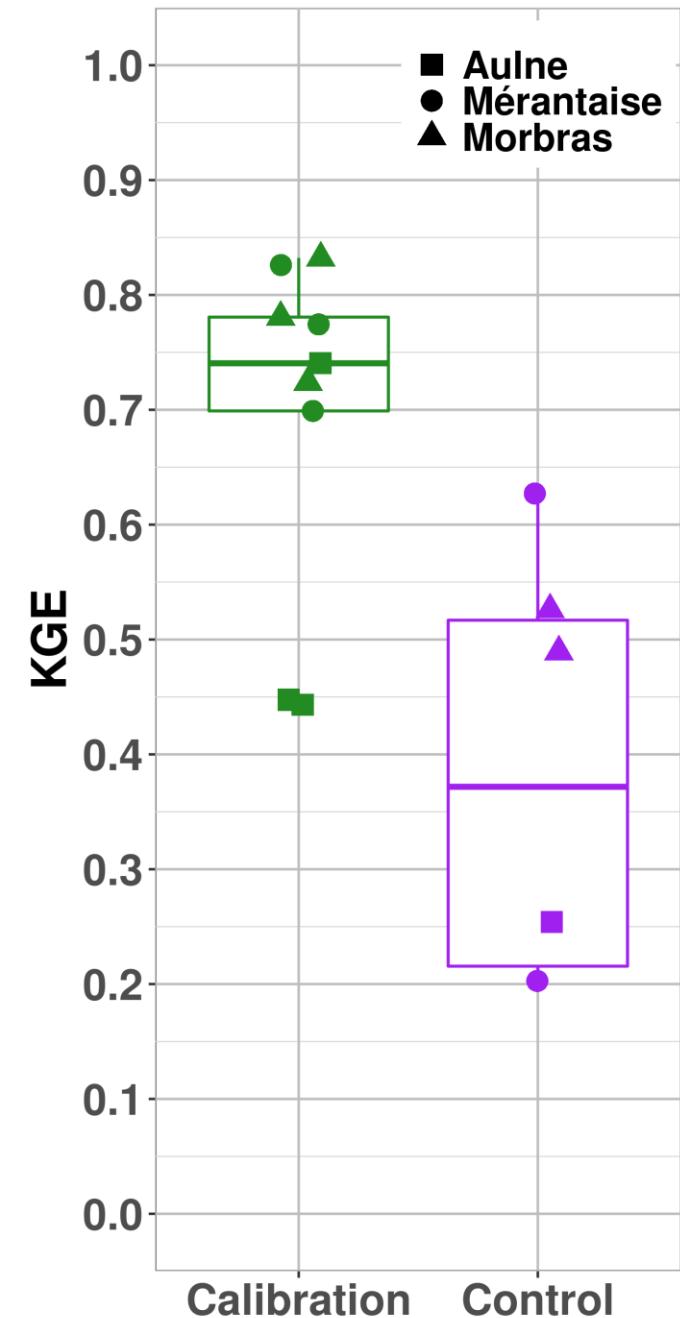
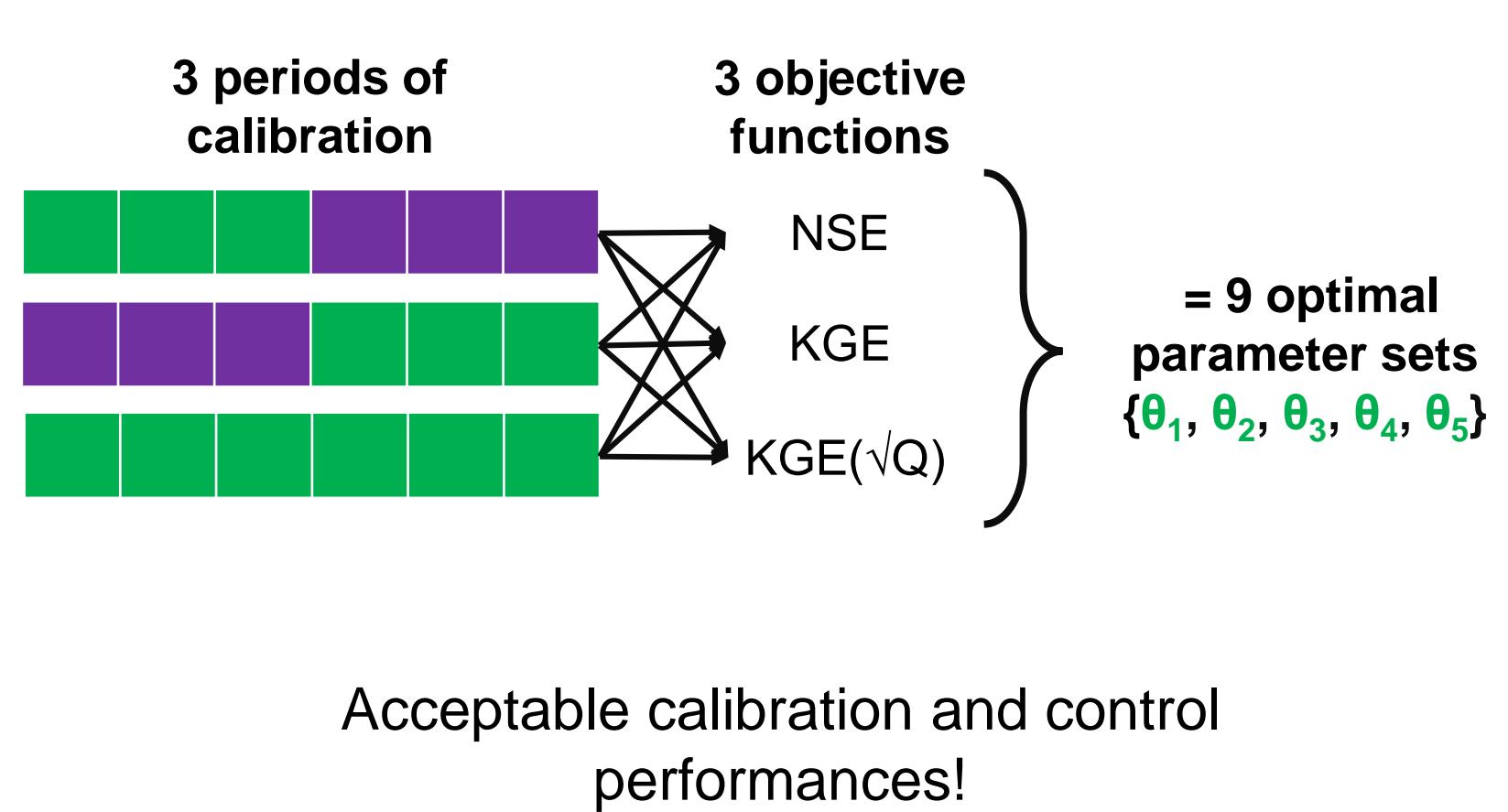
3. Relative change in TCF due to urbanization

$$\Delta_{rel} TCF_{ev,y} (\%) = 100 \frac{\sum_{y=2}^{y+2} TCF_{ev,y} (\theta_{urb} = \text{Obs. TIA}) - \sum_{y=2}^{y+2} TCF_{ev,y} (\theta_{urb} = 0\%)}{\sum_{y=2}^{y+2} TCF_{ev,y} (\theta_{urb} = 0\%)}$$



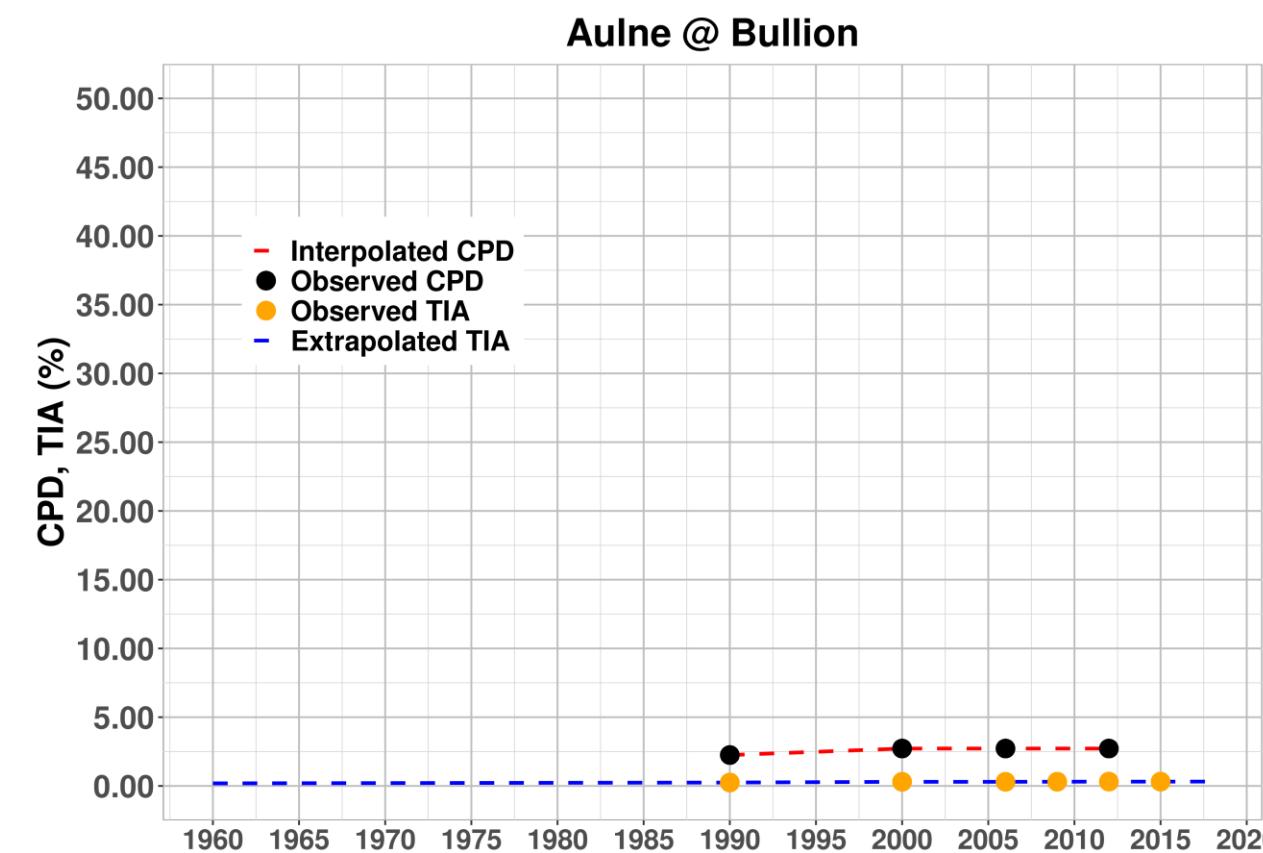
3 | Results

3.1 | Model calibration

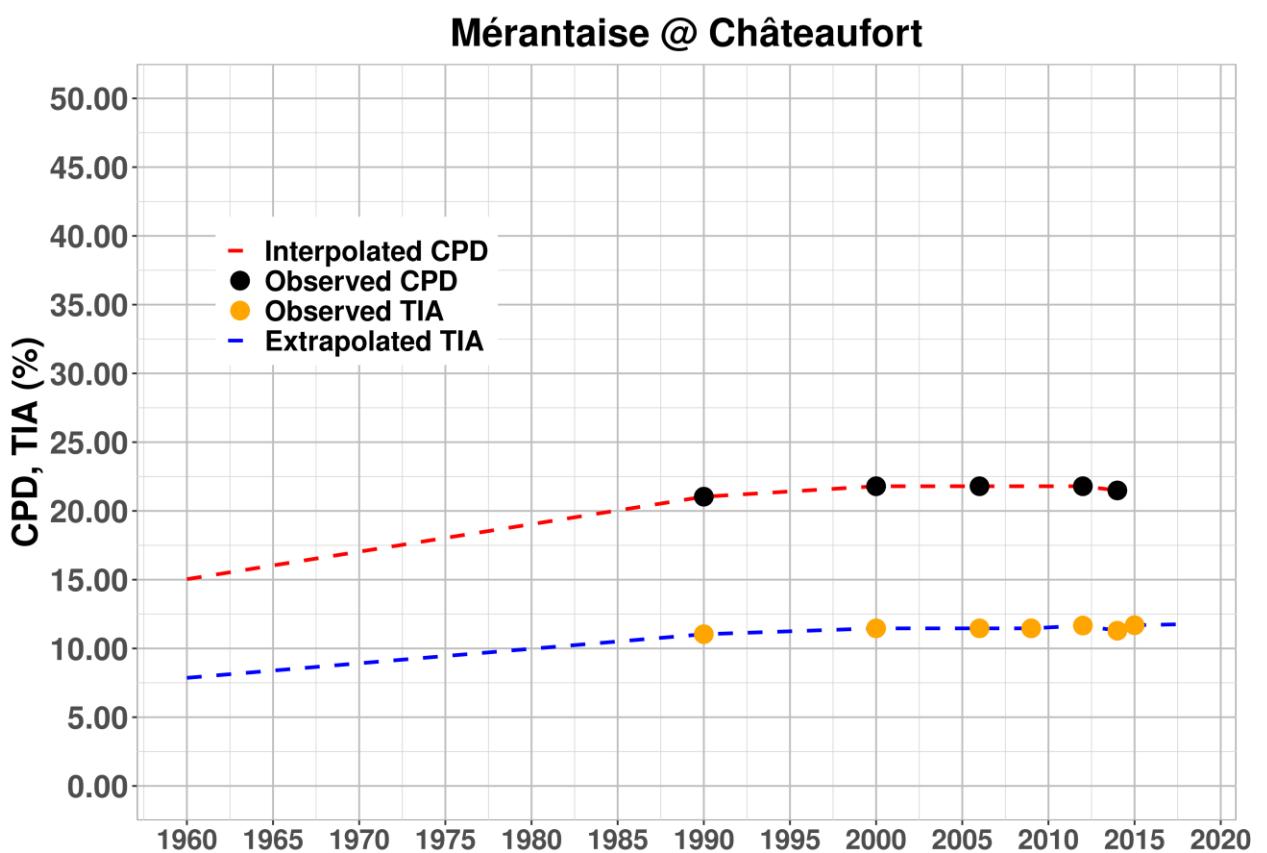


3| Results

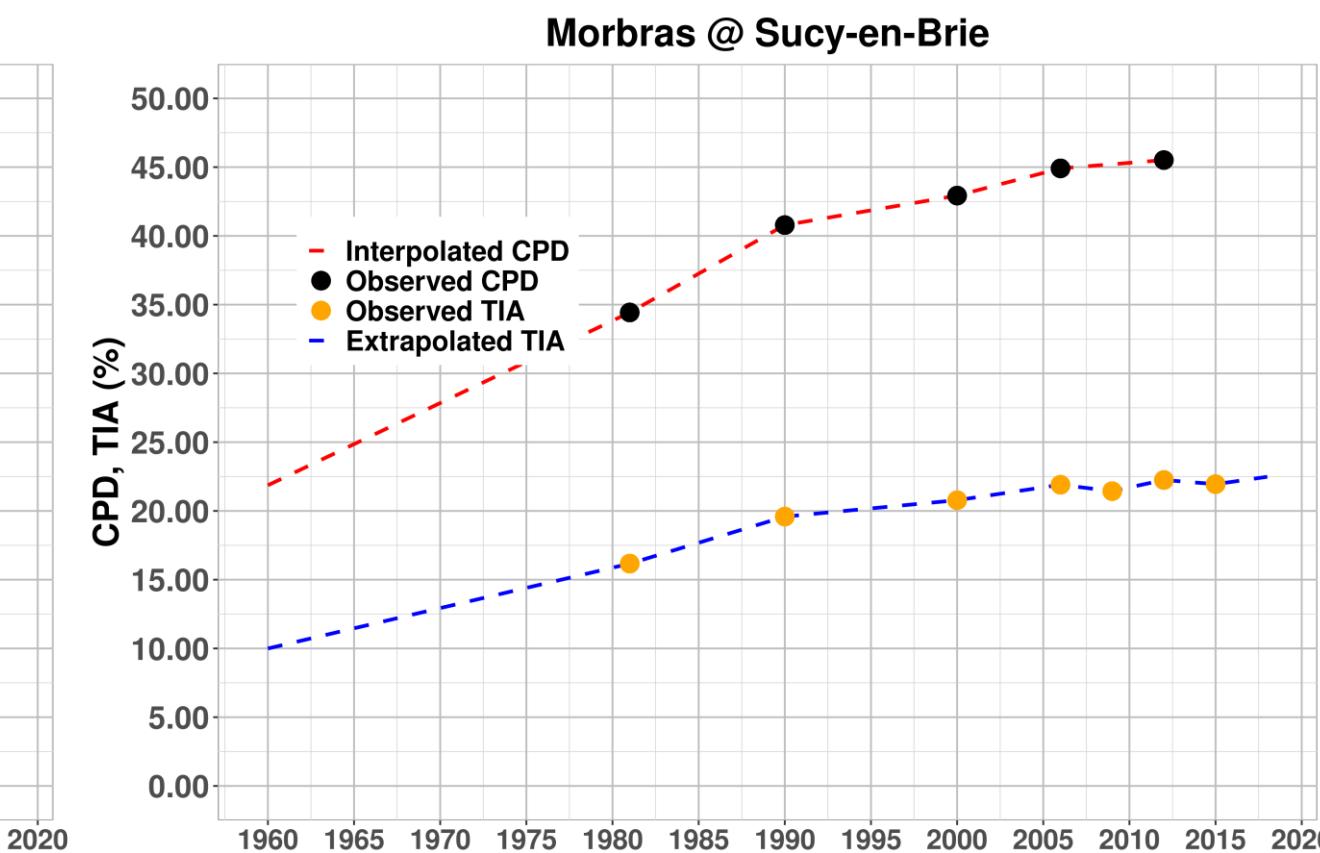
3.2 | Yearly evolution of catchment urbanization



The Aulne illustrates the case of near-nonurbanized situation



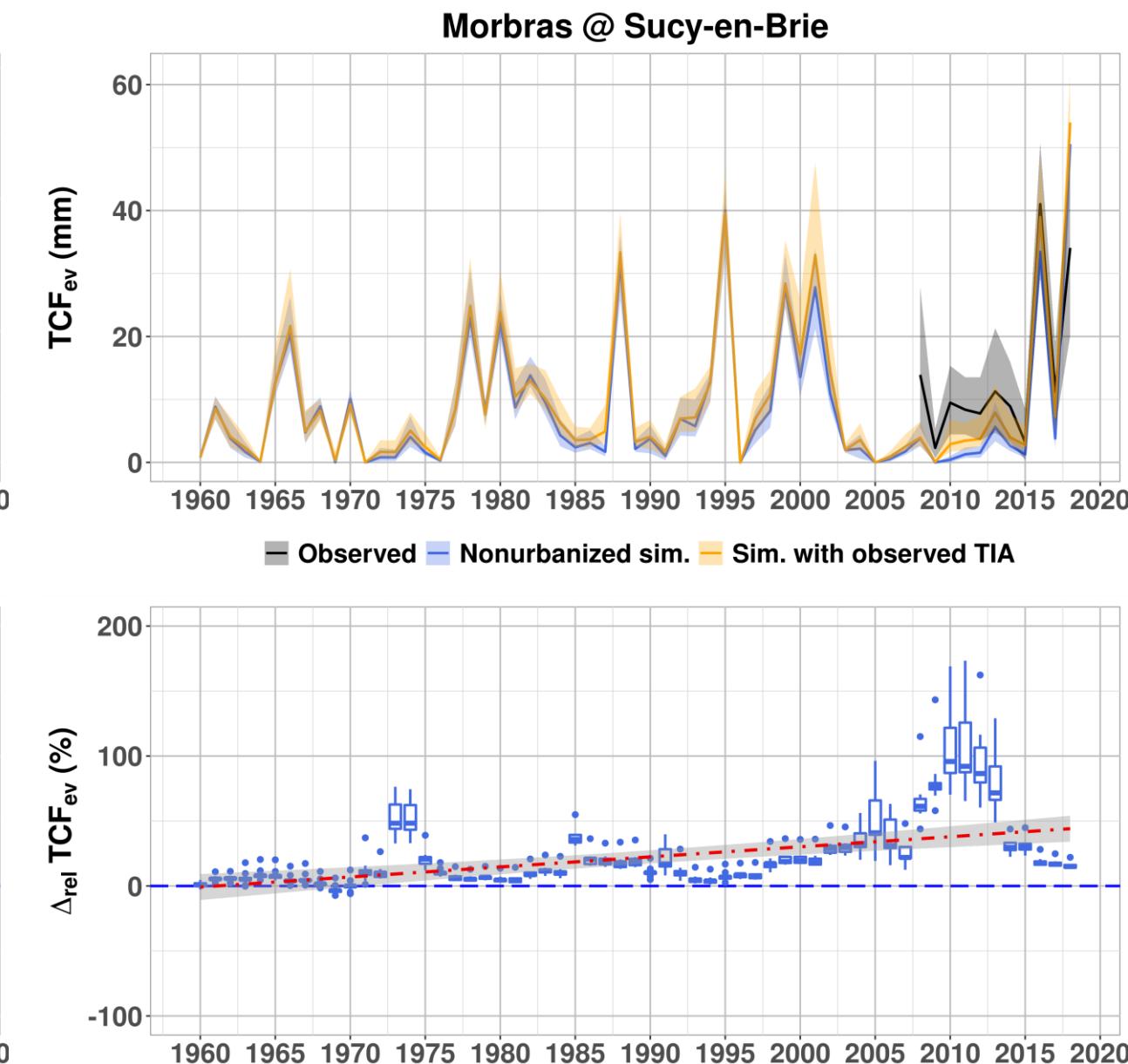
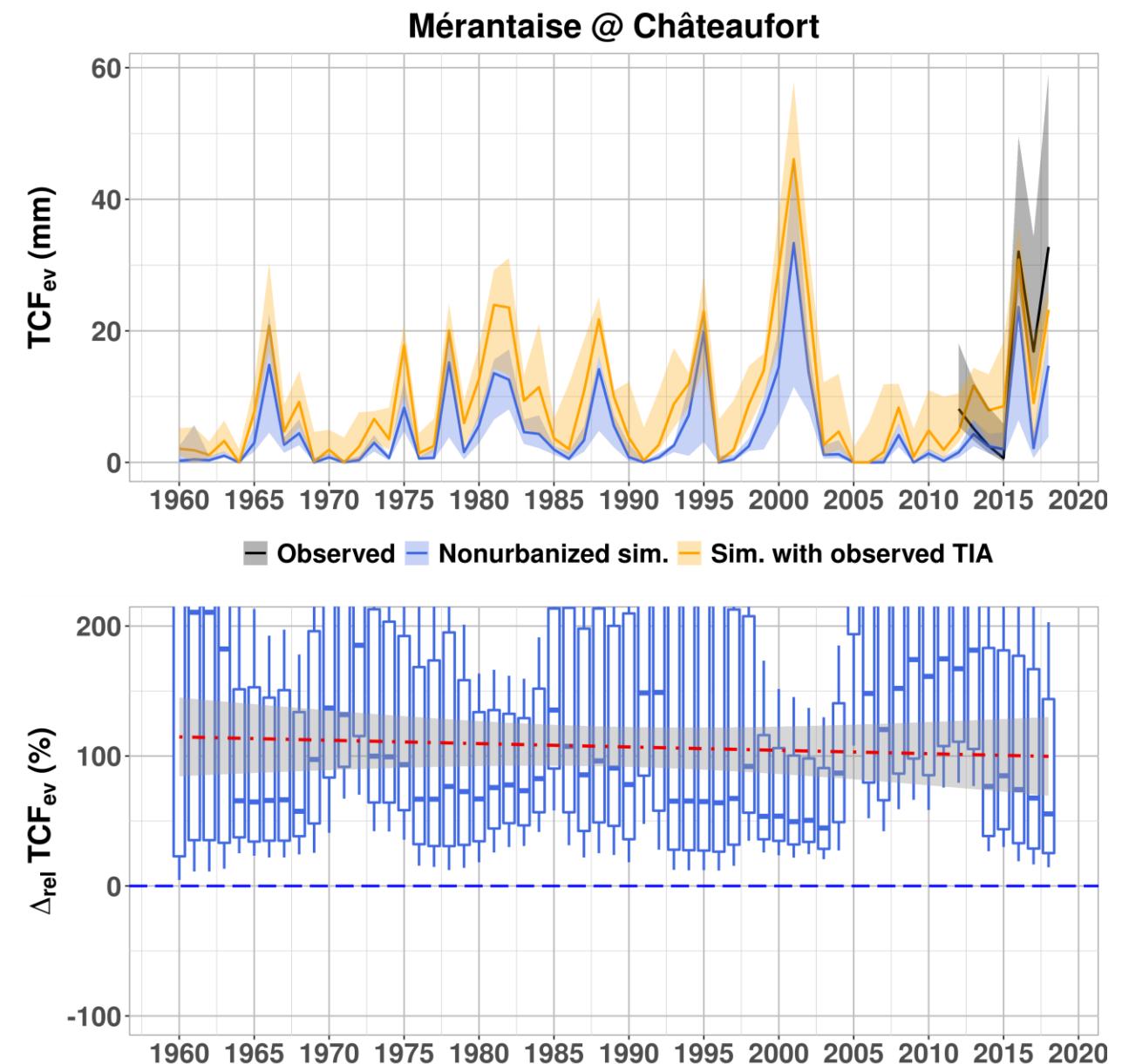
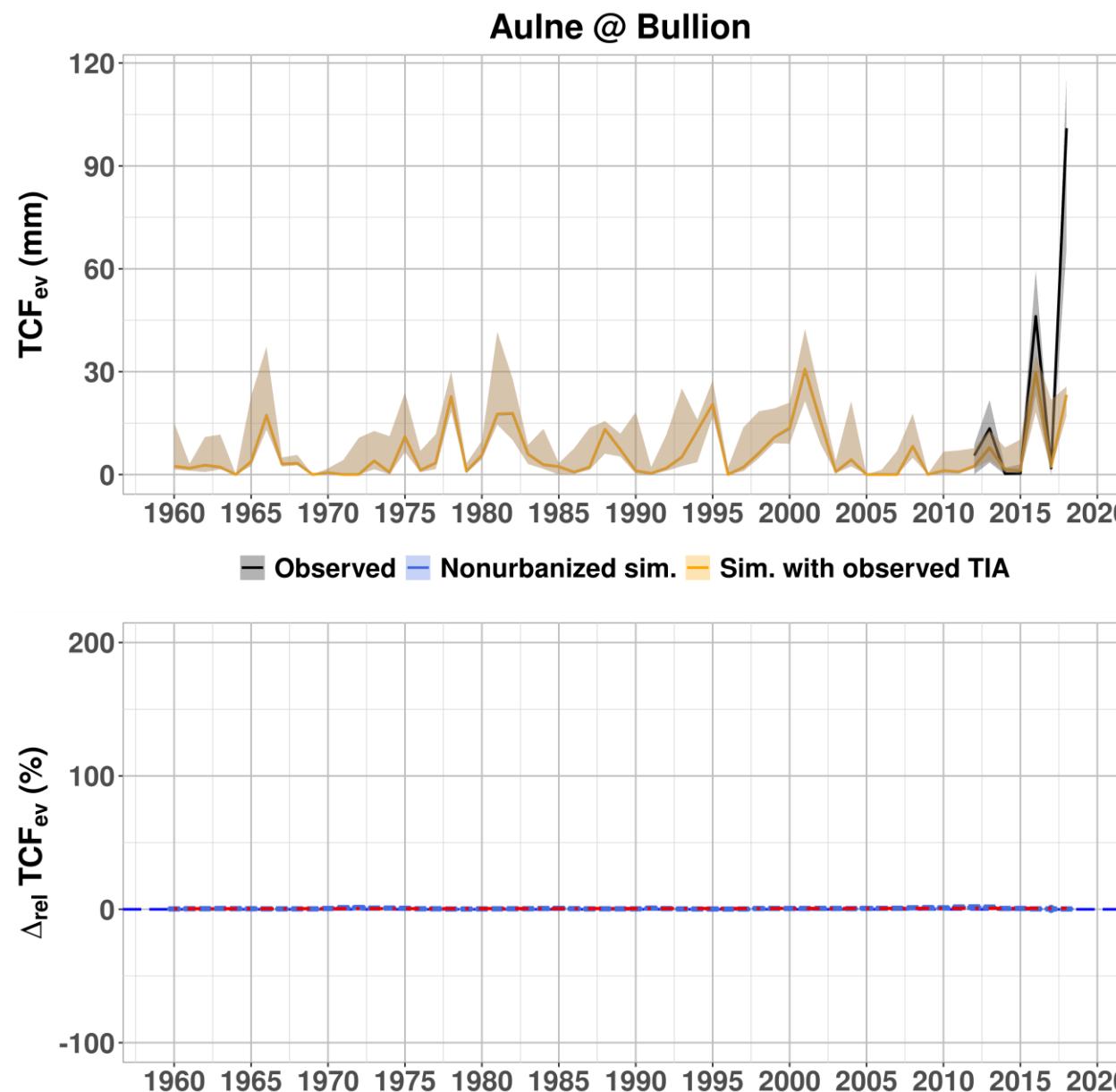
The Mérantaise shows a “smooth” gradient of urbanization that reaches a significant level by the 1980s



The Morbras catchment shows a strong gradient of urbanization with TIA doubling in ~30 yrs (1960-1990)

3 | Results

3.3 | Yearly evolution of TCF_{ev} vs. of urbanization



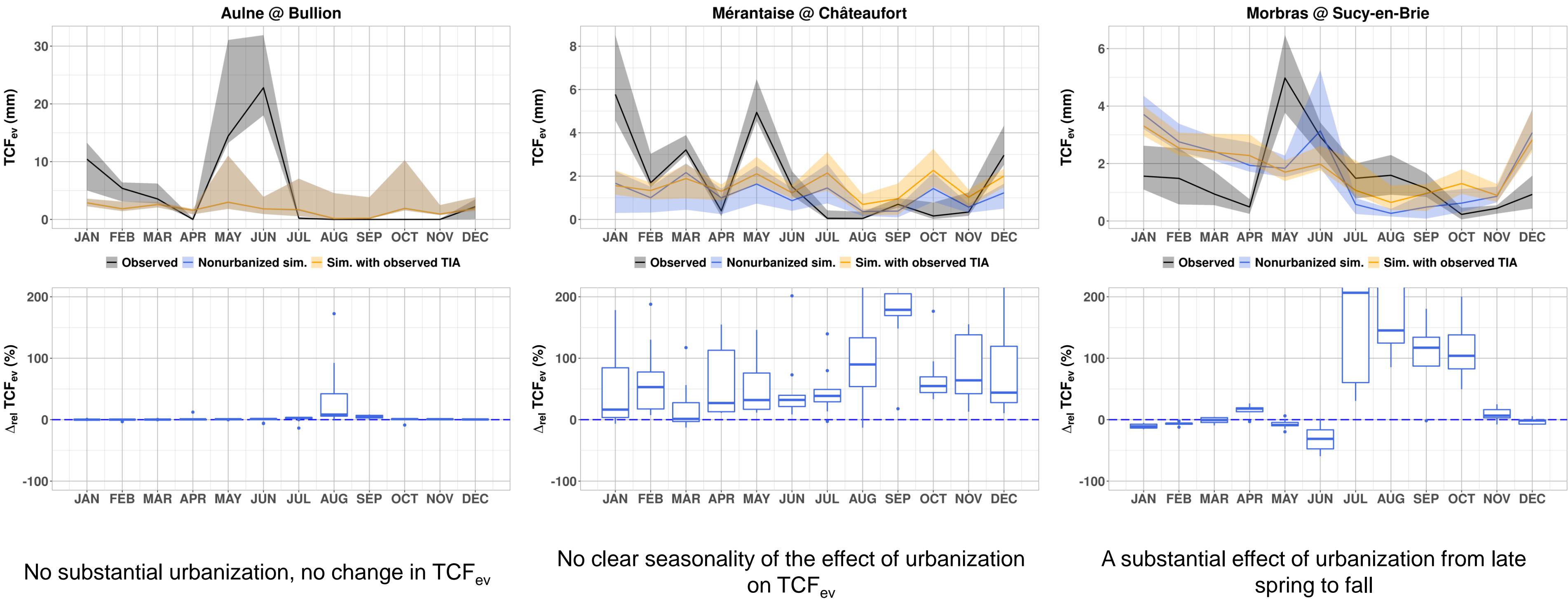
No substantial urbanization, no change in TCF_{ev}

Increased TCF_{ev} due to urbanization (44%-320%), but without a significant trend

Increase in TCF_{ev} for the Morbras catchment (-4%-96%), with a significant trend ($p < 0.001$)

3 | Results

3.4 | Monthly evolution of TCF_{ev}



4 | Conclusion

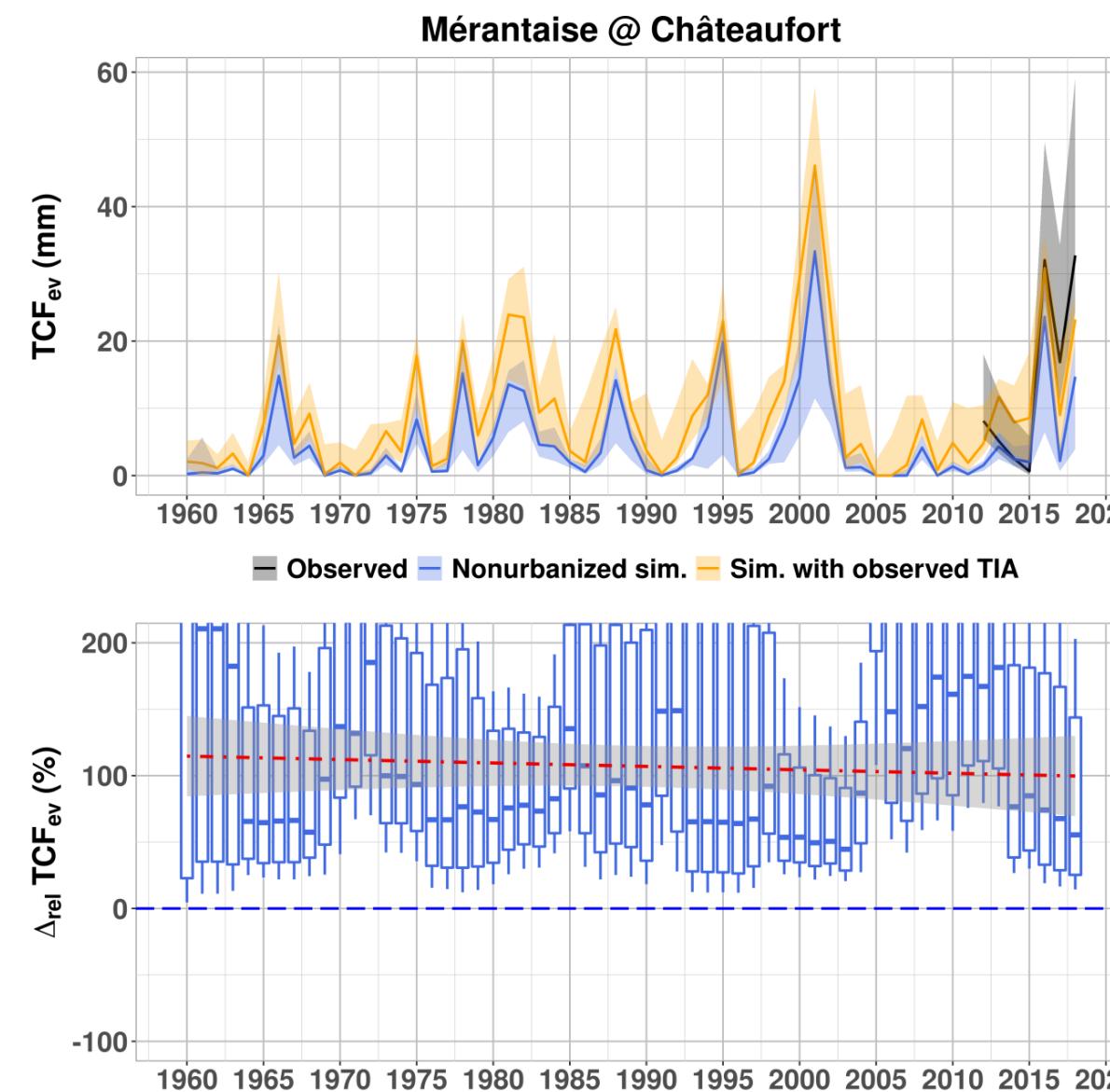
River	2015 X-sections compared to...	Incision (m)		Widening (m)	
		Mean	Max	Mean	Max
Mérantaise	1980 X-sections	0.41	1.26	1.31	4.91
Morbras	1964 X-sections	0.39	1.05	0.75	3.10

Mérantaise

Good model performances

Evidence for the effect of urbanization

But no clear trend!

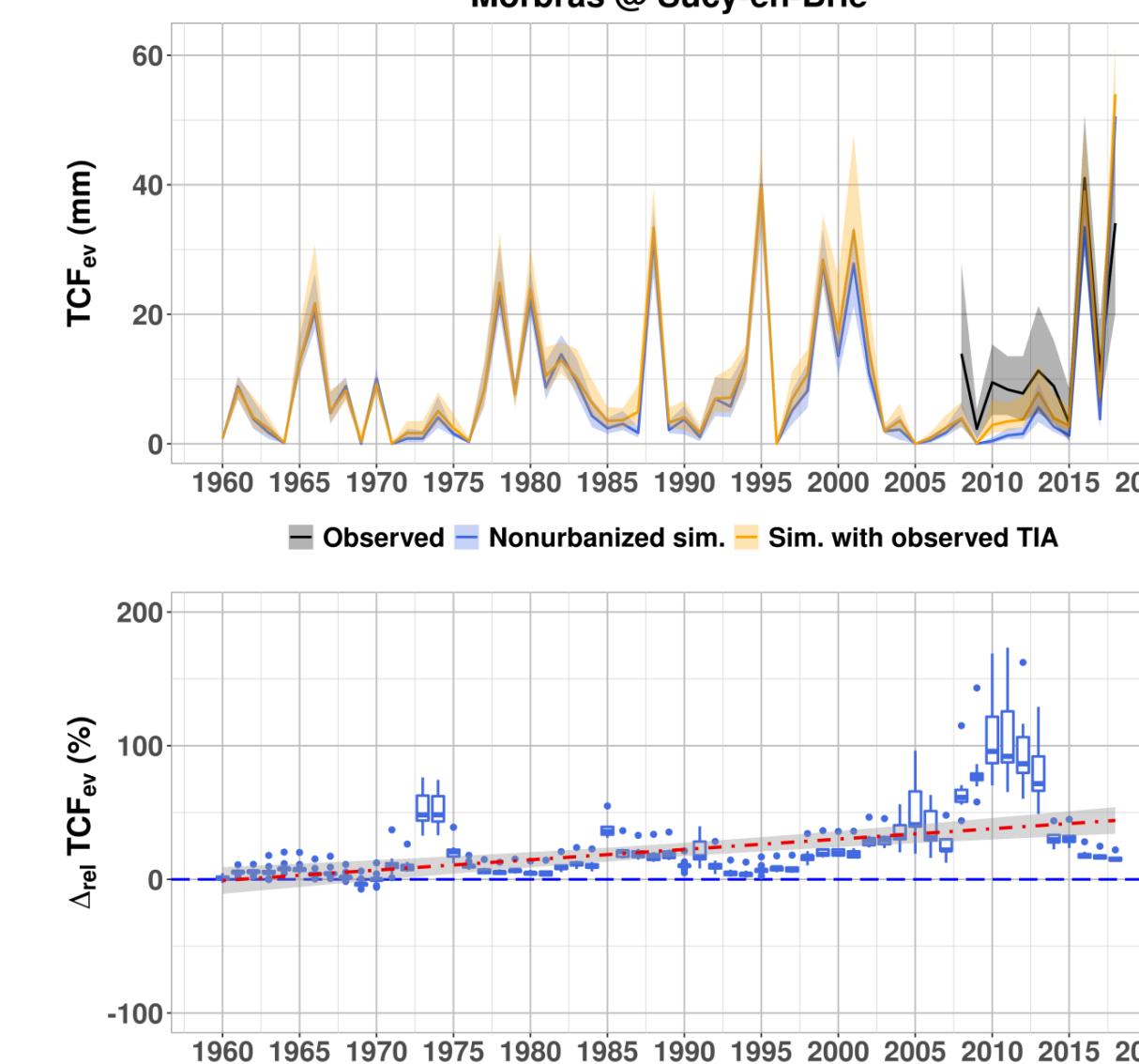


Morbras

Model underestimates the competent flow

Evidence for the effect of urbanization

With a significant trend!



Thank you for your attention!

Questions?

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