Geomorphological alteration of urban rivers assessed by hydrological modelling

Mohamed Saadi, Anouaar Cheikh Larafa, Frédéric Gob, Ludovic Oudin, Pierre Brigode

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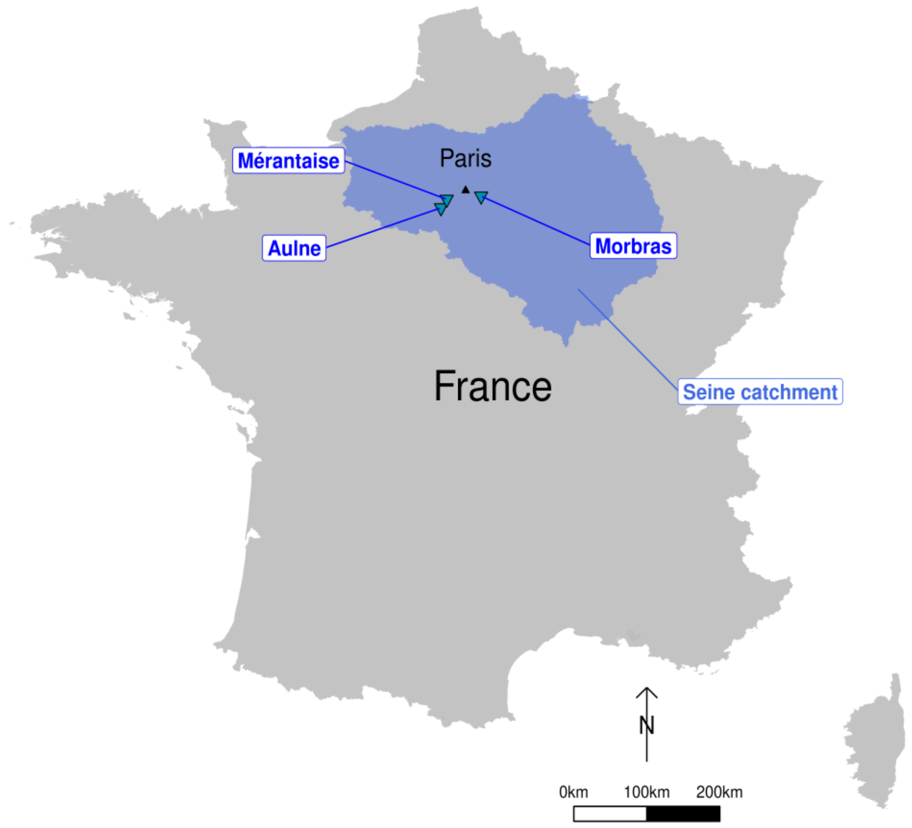
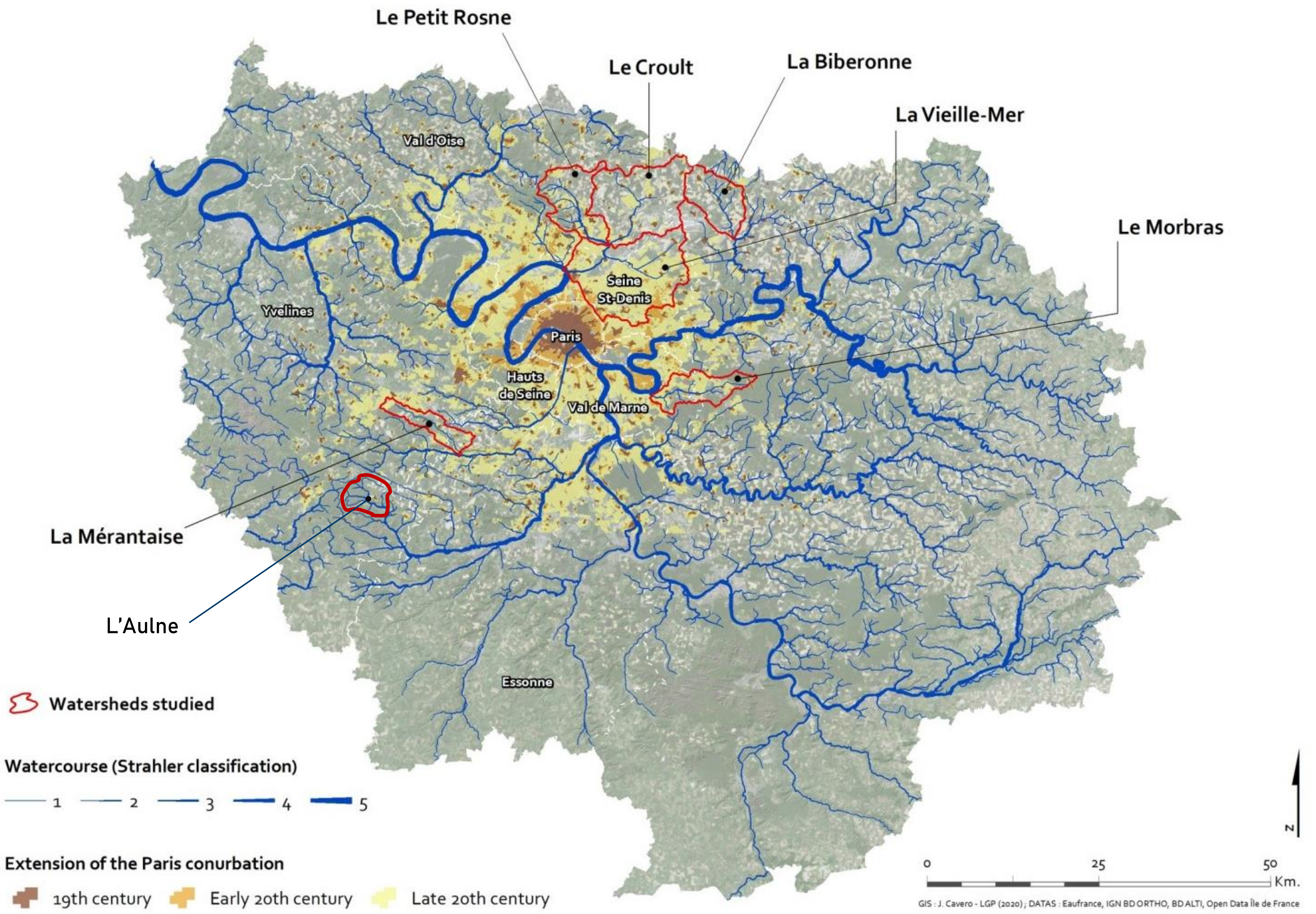
1| Context and objectives



3 catchments located within the Seine river basin

Aulne (34 km^2)
Mérantaise (20 km^2)
Morbras (51 km^2)

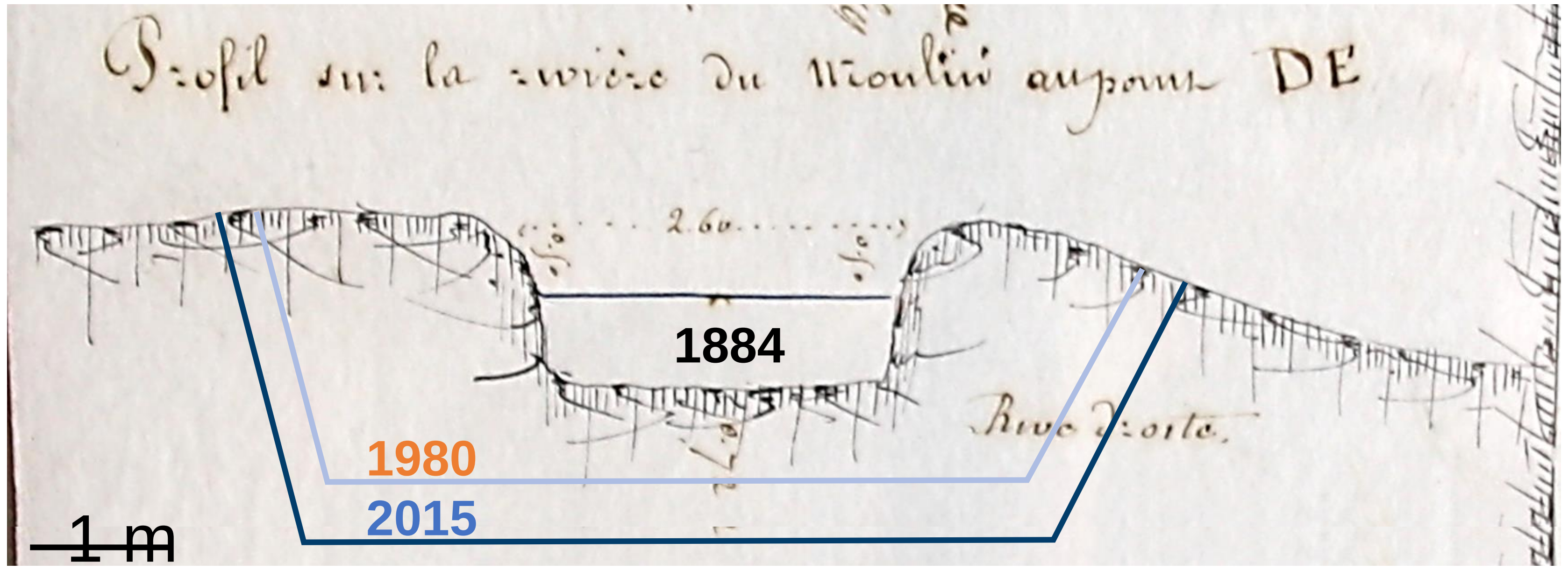


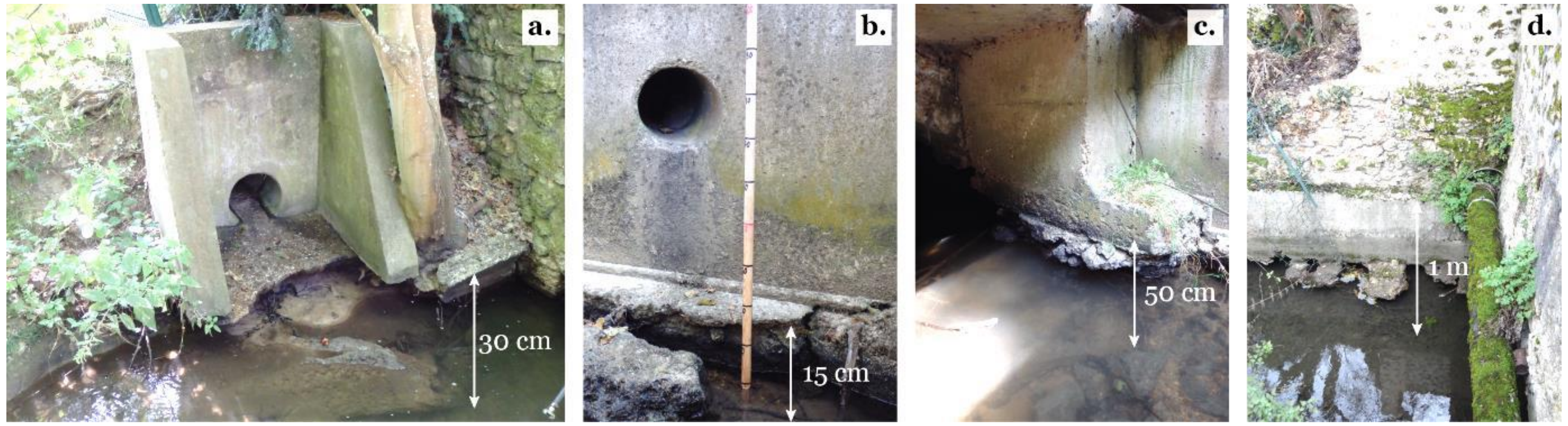
1| Context and objectives

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		-	-	-	-

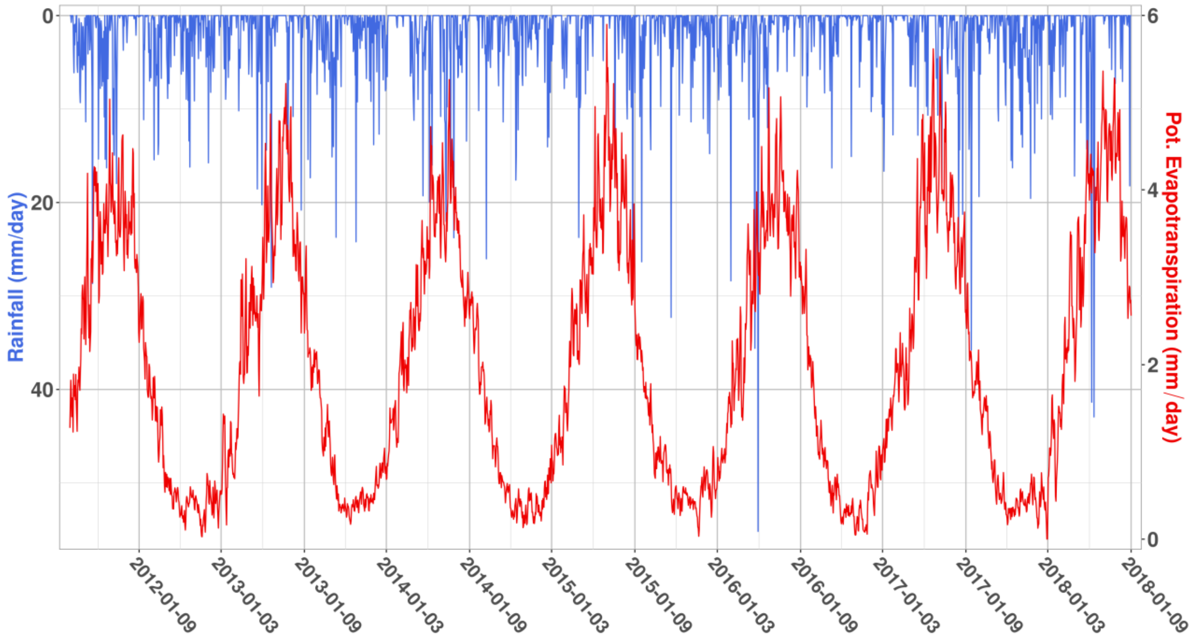
Comparison of the Mérantaise width and depth in 1884/1907, 1980 and 2015 in two close locations

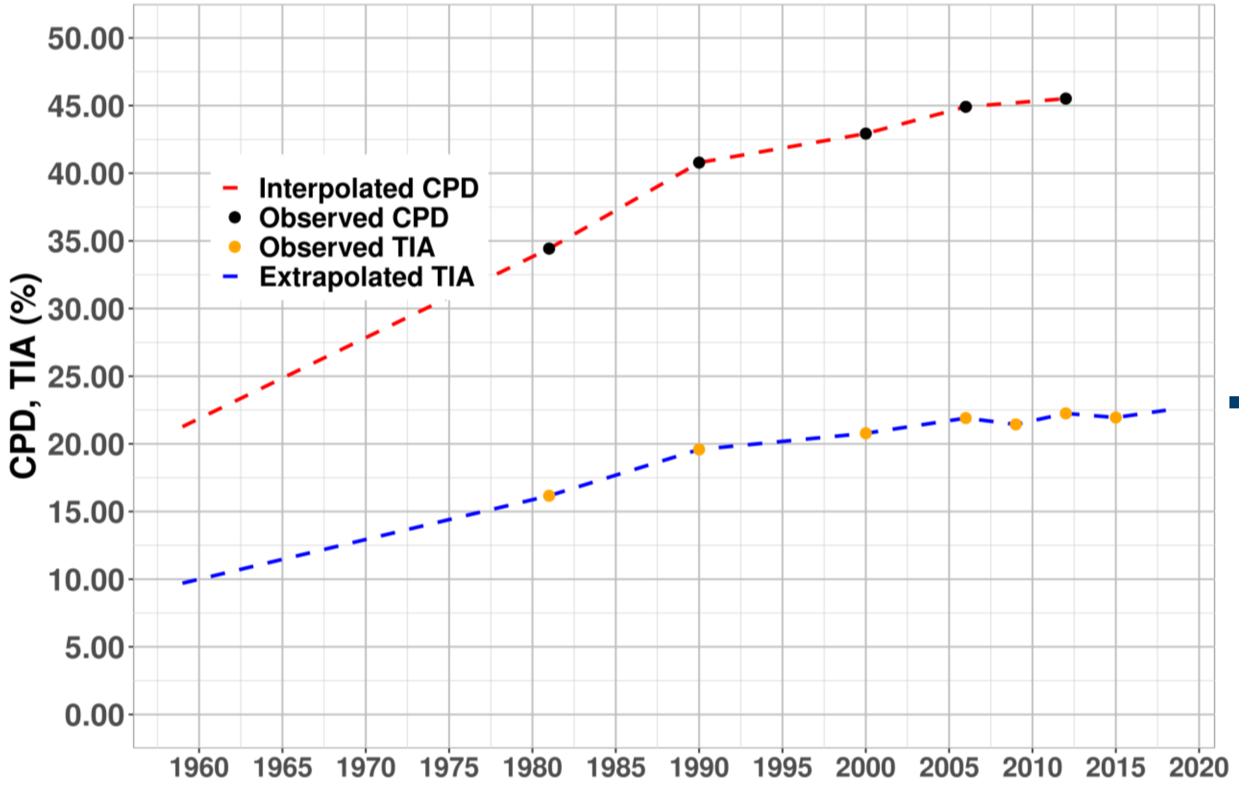




2| Methods

Climate forcing (1959-2018)





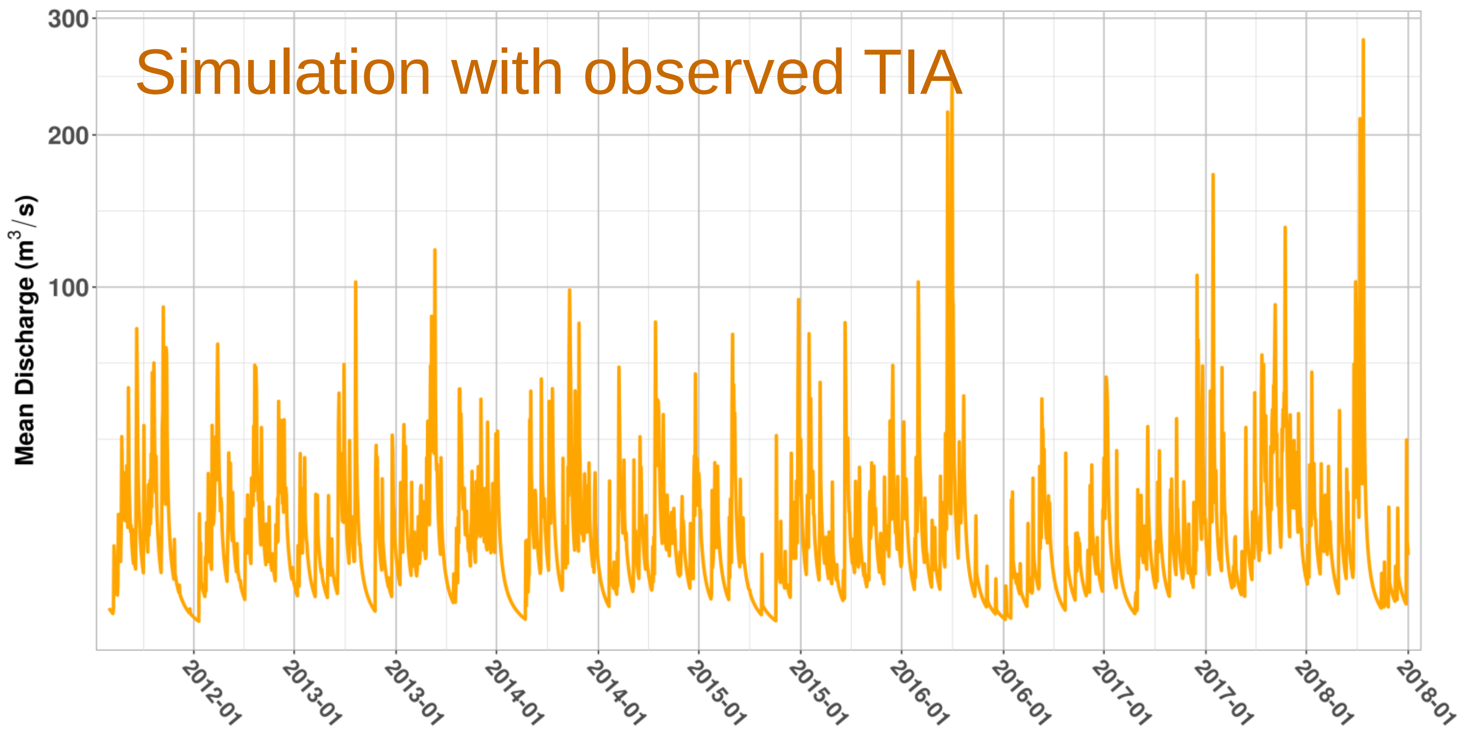
Evolution of TIA

Hydrological model: MU5H

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

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

Long-term streamflow time series (1959-2018)



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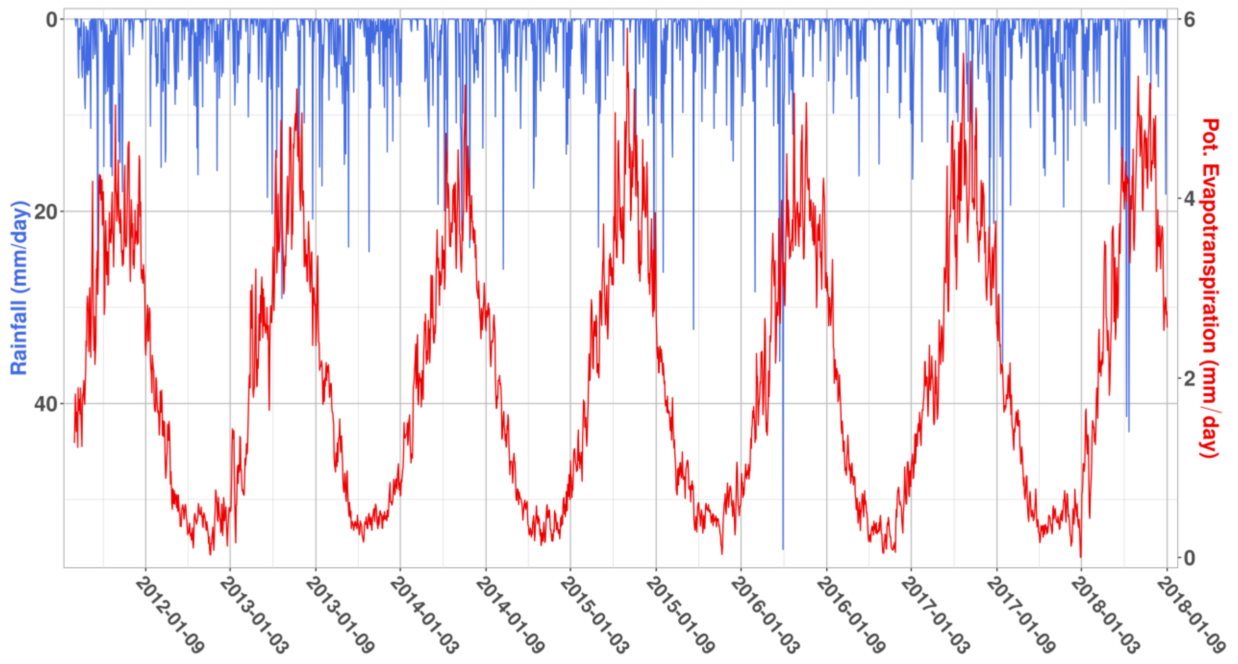

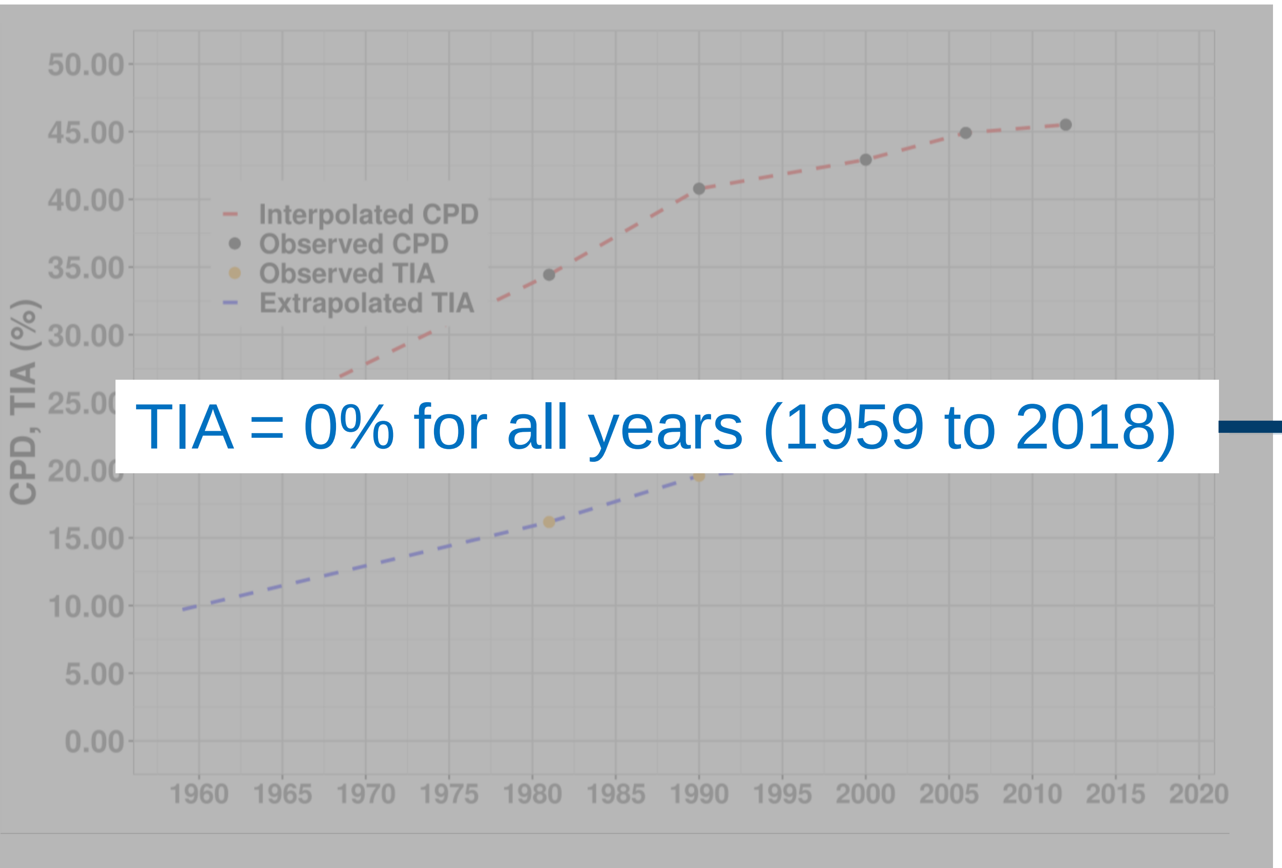

TIA = 0% for all years (1959 to 2018)

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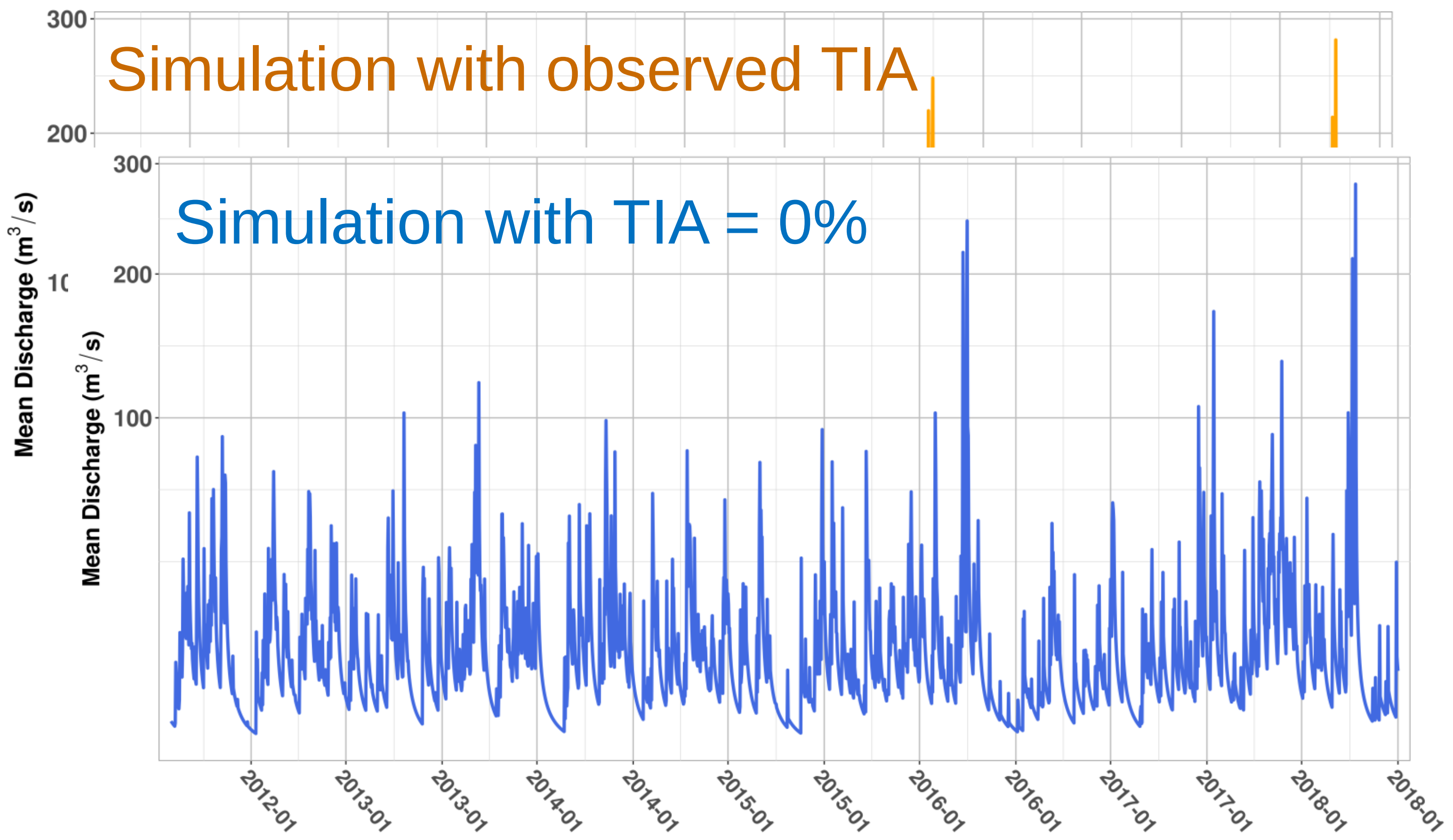
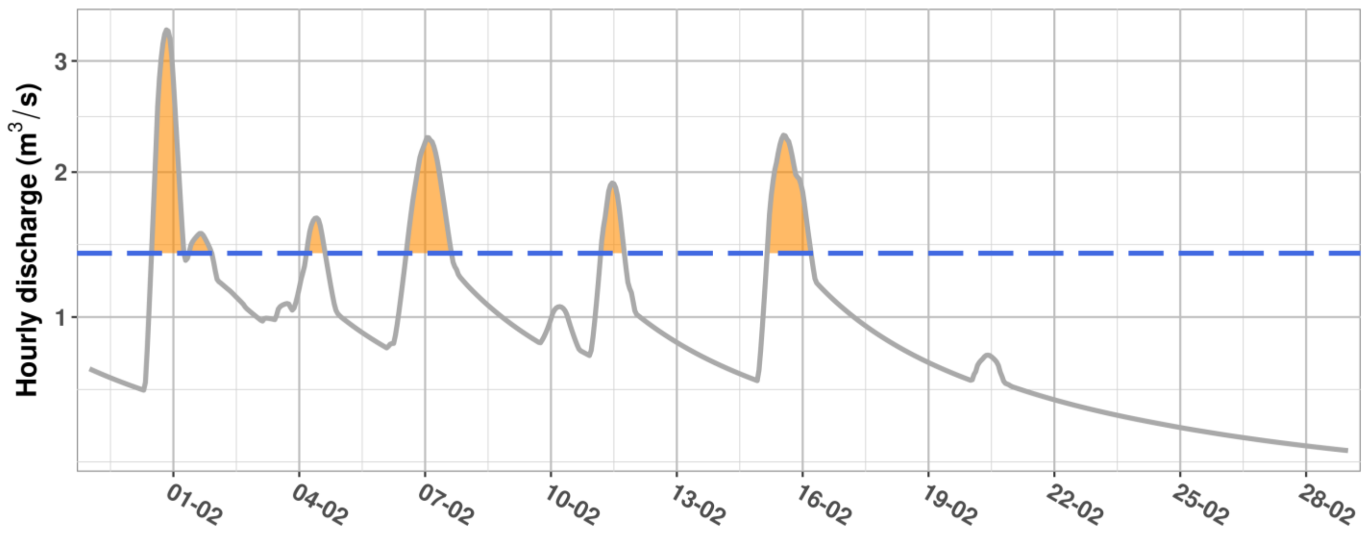


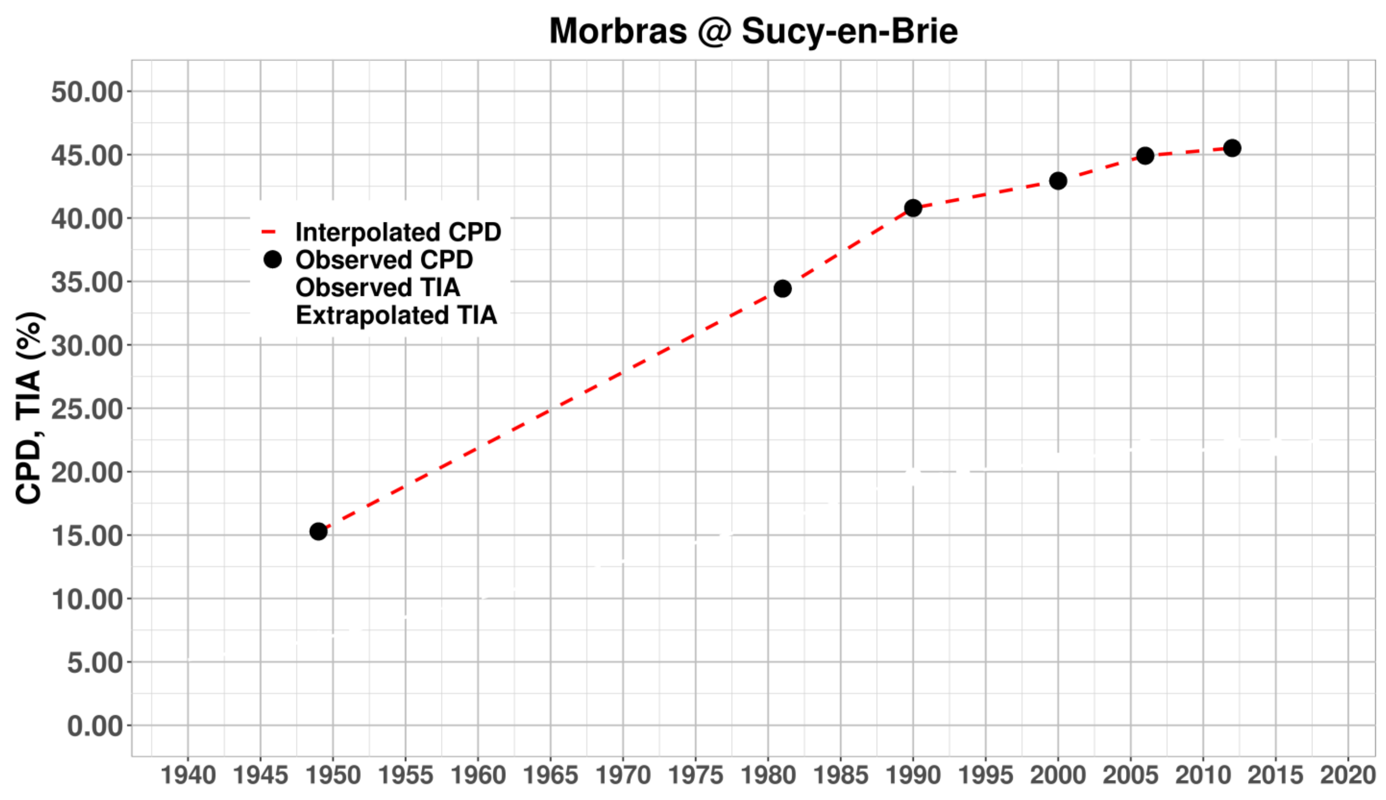
Impact of urbanization on competent flow



2| Methods

2.1 | Climate forcing and land cover evolution

Required data	Source	Time period
Precipitation (hourly)	SAFRAN (Vidal et al., 2010; 8 km resolution)	1959-2018
Potential evapotranspiration (hourly)		
Land cover (yearly)	LGP (land cover, polygons) and CORINE database (land cover at 100 m + imperviousness 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

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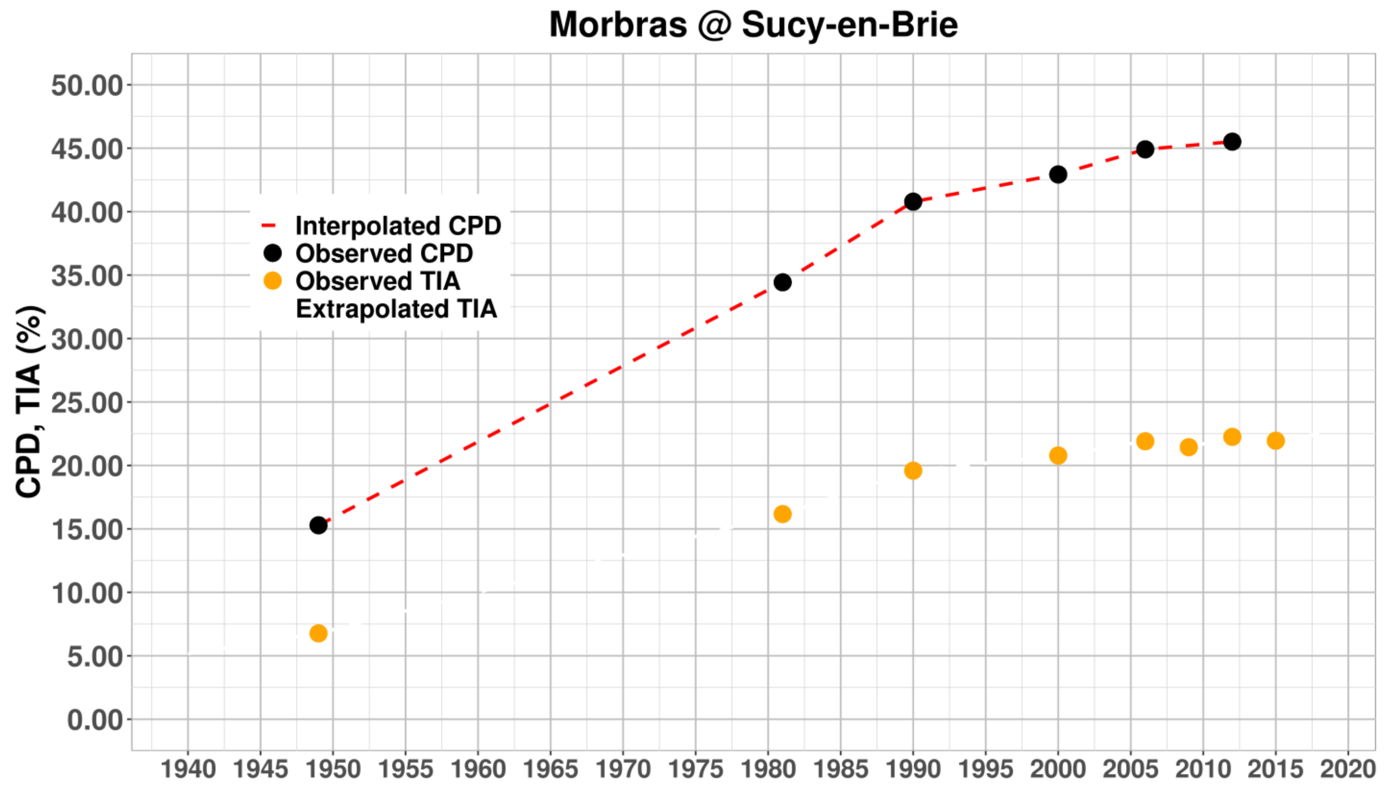

2.2 | TIA time series: Recipe

Step 1: Estimate CPD from CORINE and LGP databases

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

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

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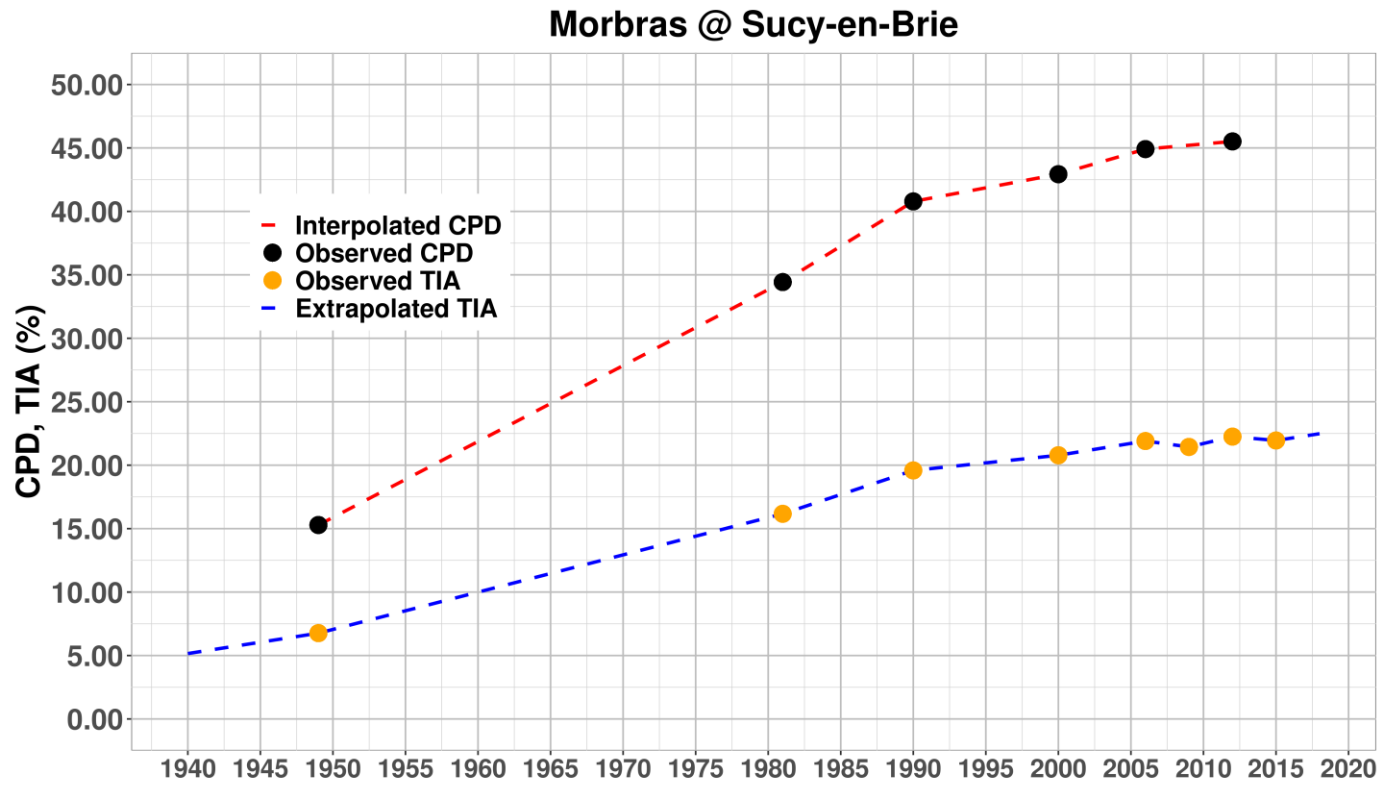

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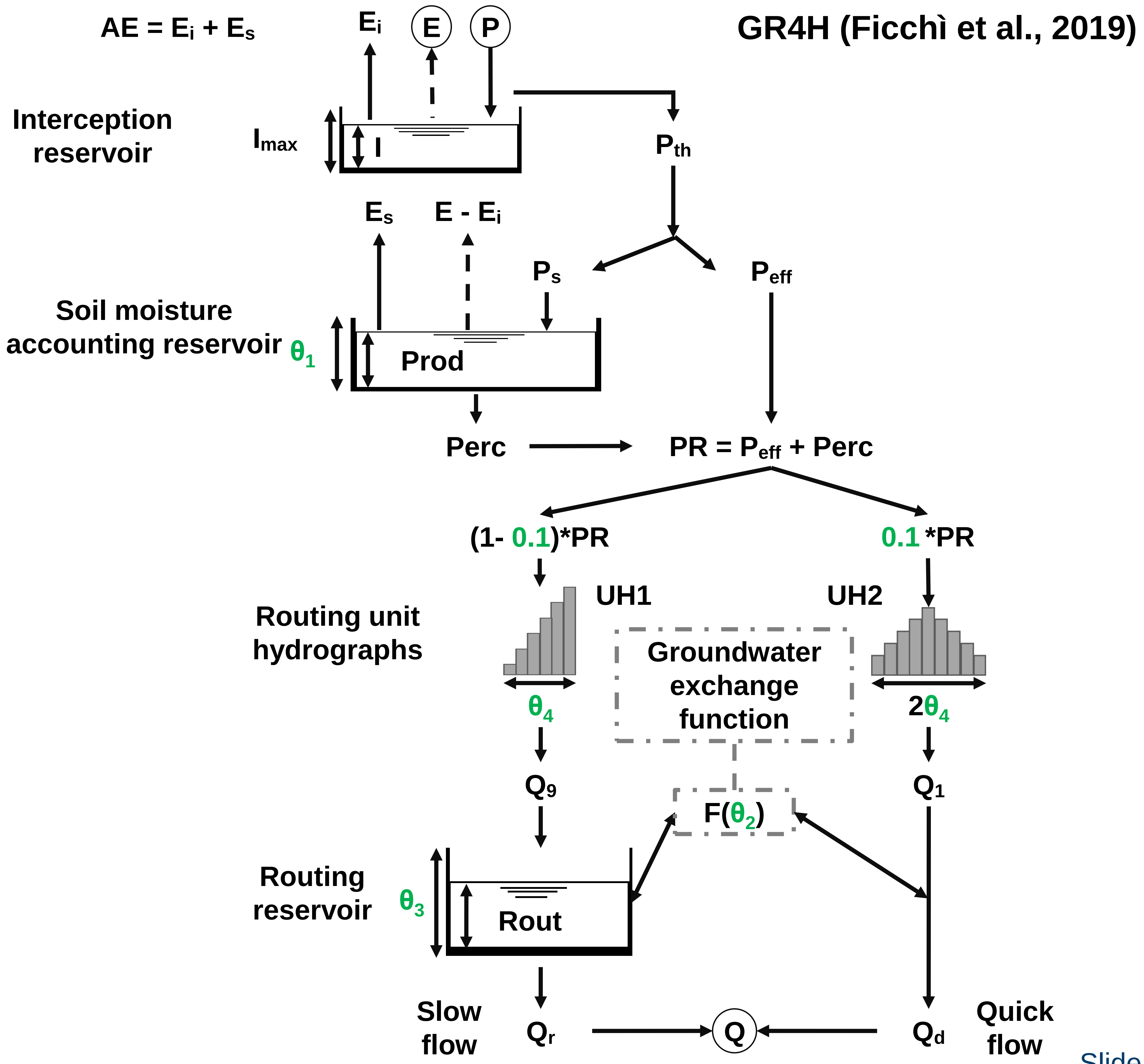
Step 4: Interpolation and extrapolation

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)



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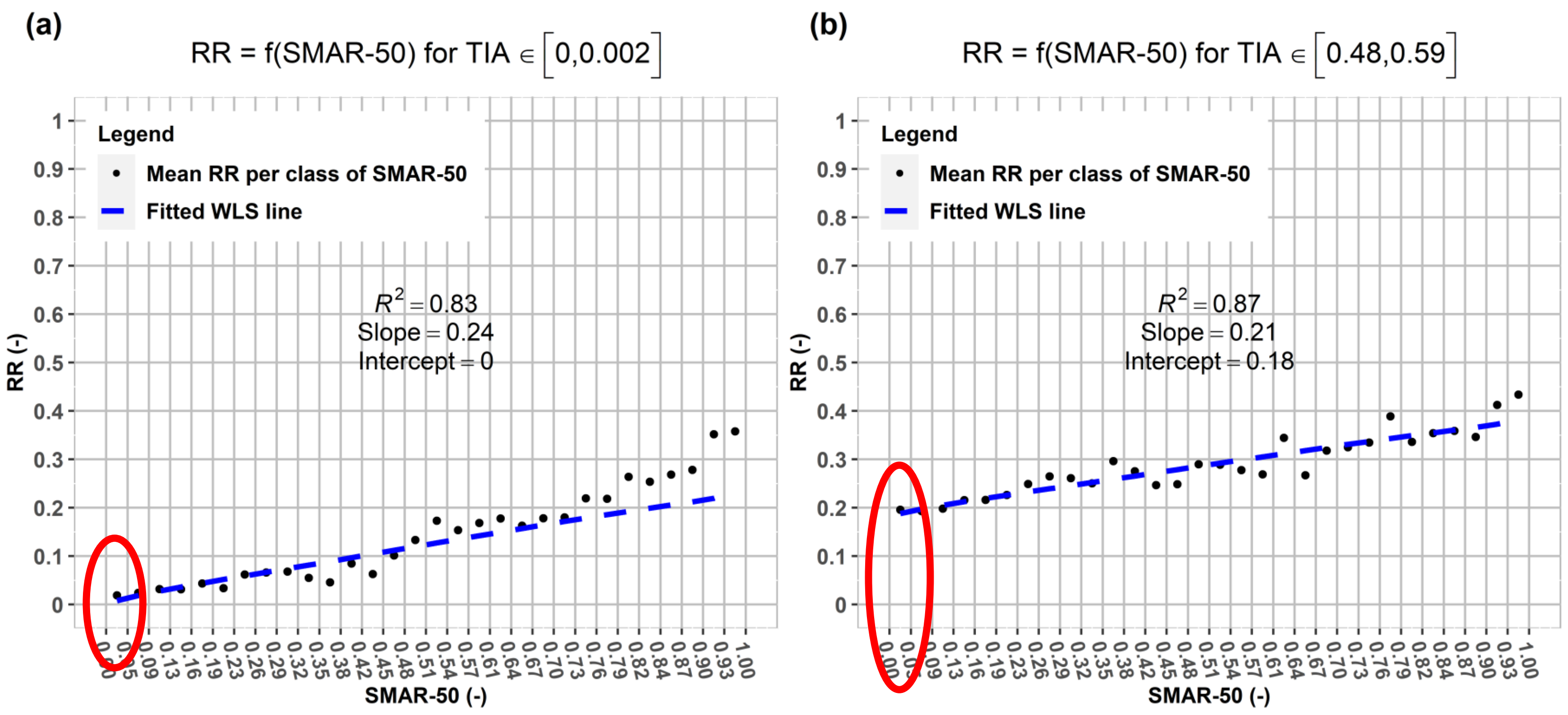
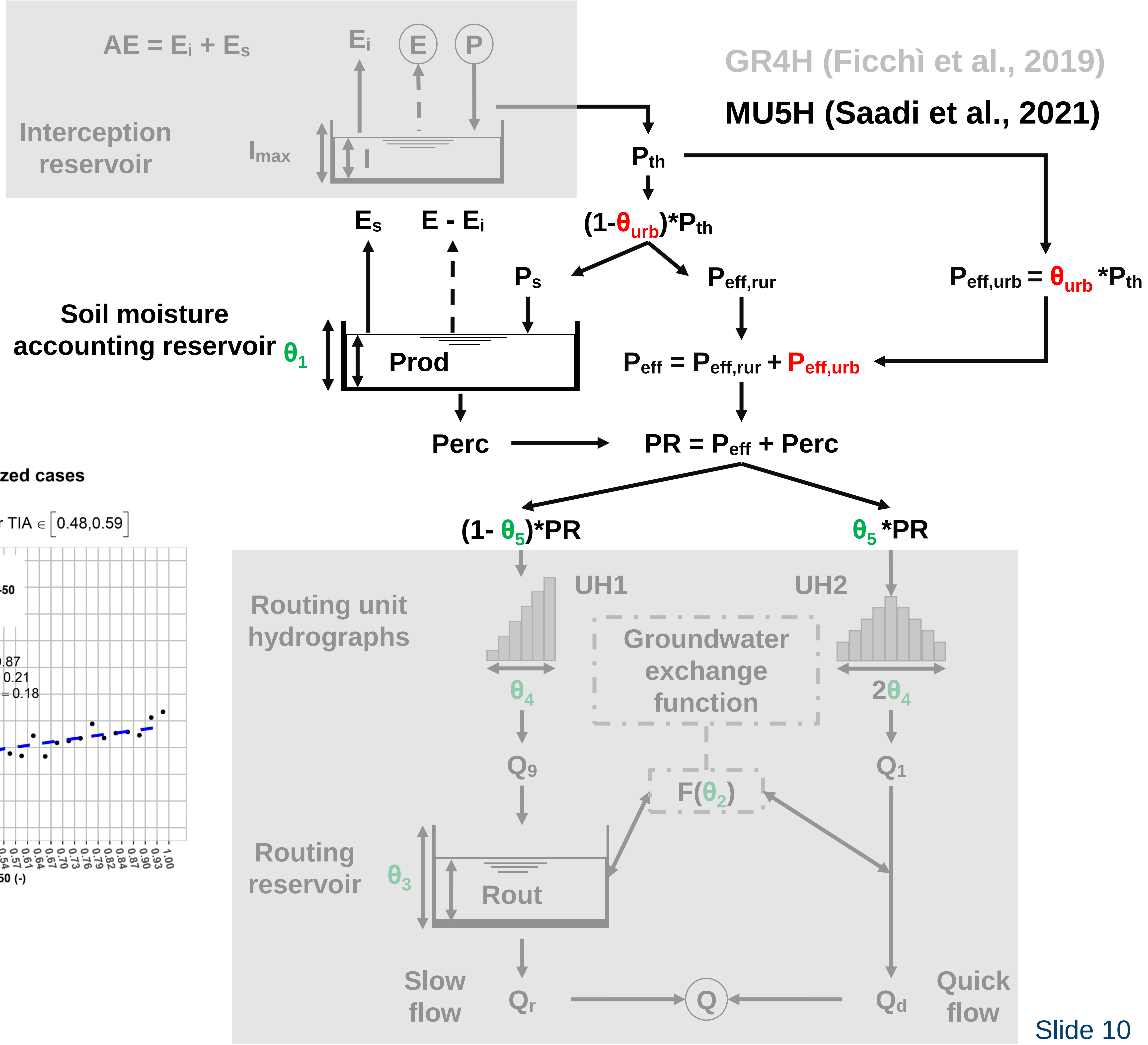
θ_5 : Quick-flow/slow-flow split parameter (-)

Mean event RR function of SMAR-50 for the least and most urbanized cases



Saadi et al. (2020, WRR)



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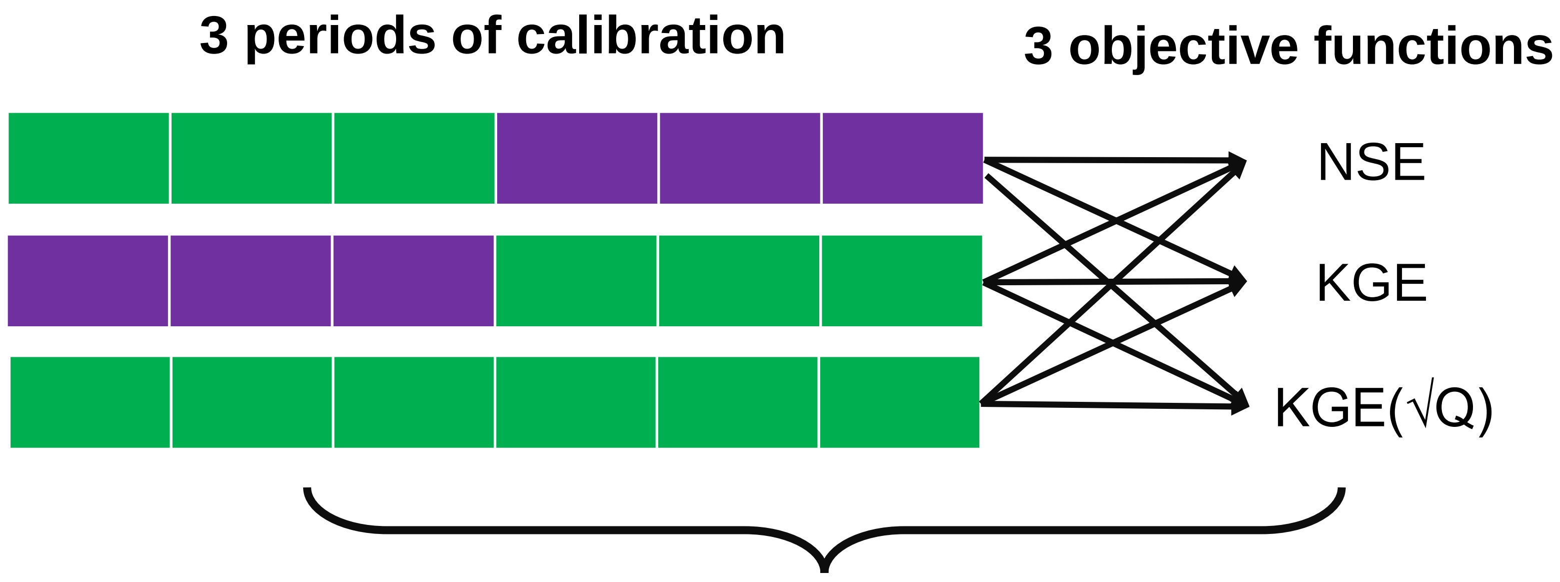
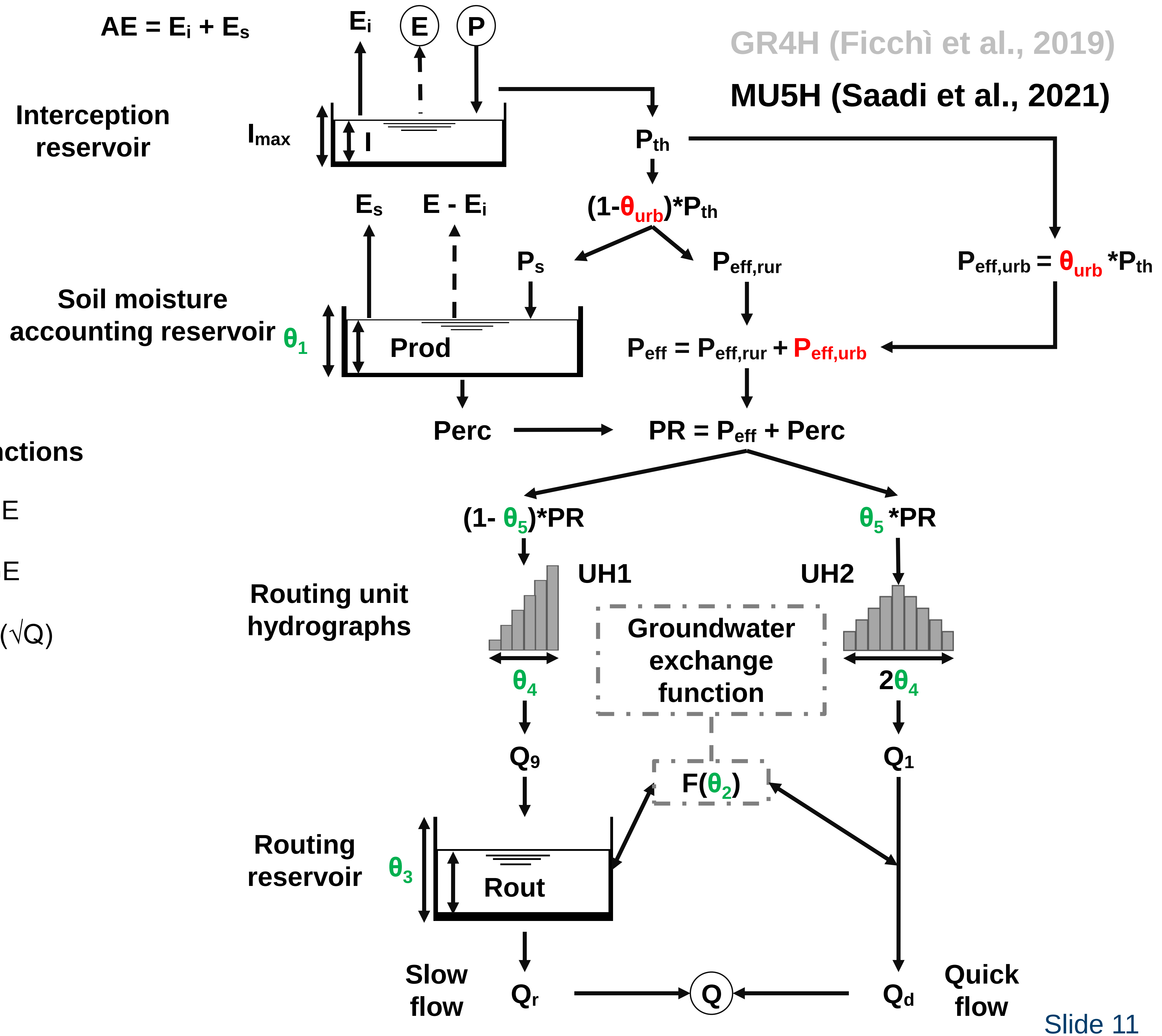


= 9 optimal parameter sets
$\{\theta_1, \theta_2, \theta_3, \theta_4, \theta_5\}$

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



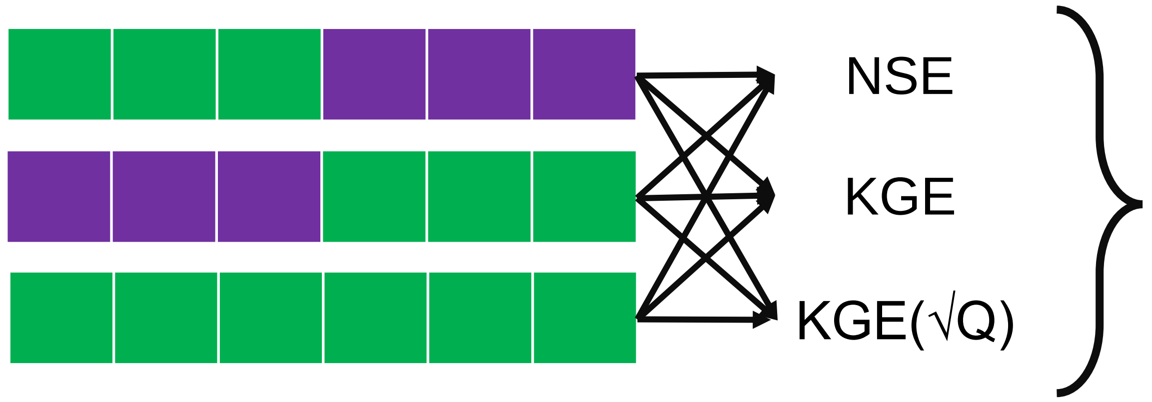
Coron et al. (2017); Edijatno et al. (1999); Nash et Sutcliffe (1970); Gupta et al. (2009)

2| Methods

2.4 | Change in flow competence due to urbanization

3 periods of calibration

3 objective functions



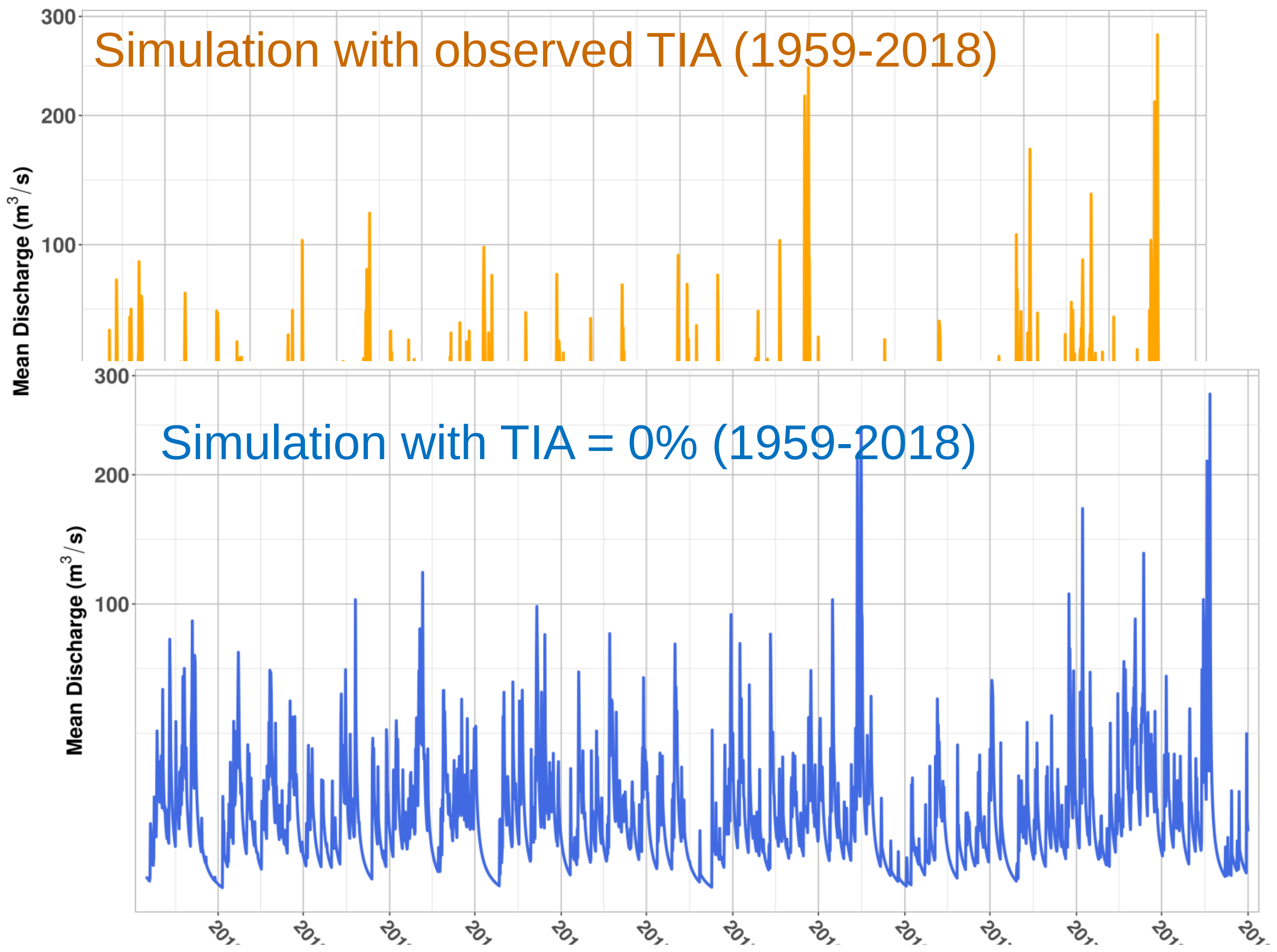
= 9 optimal parameter sets
$\{\theta_1, \theta_2, \theta_3, \theta_4, \theta_5\}$

Actual evolution of the catchment

θ_{urb} = Observed yearly TIA

θ_{urb} = 0%

Catchment response if there were no urbanization (nonurbanized)



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

$$Q_{cr} = 0.6 \cdot \frac{1}{N} \cdot \sum_{y} Q_{d,max,y}\,(\theta_{urb} = 0)$$

Pfaundler et al. (2011)

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

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

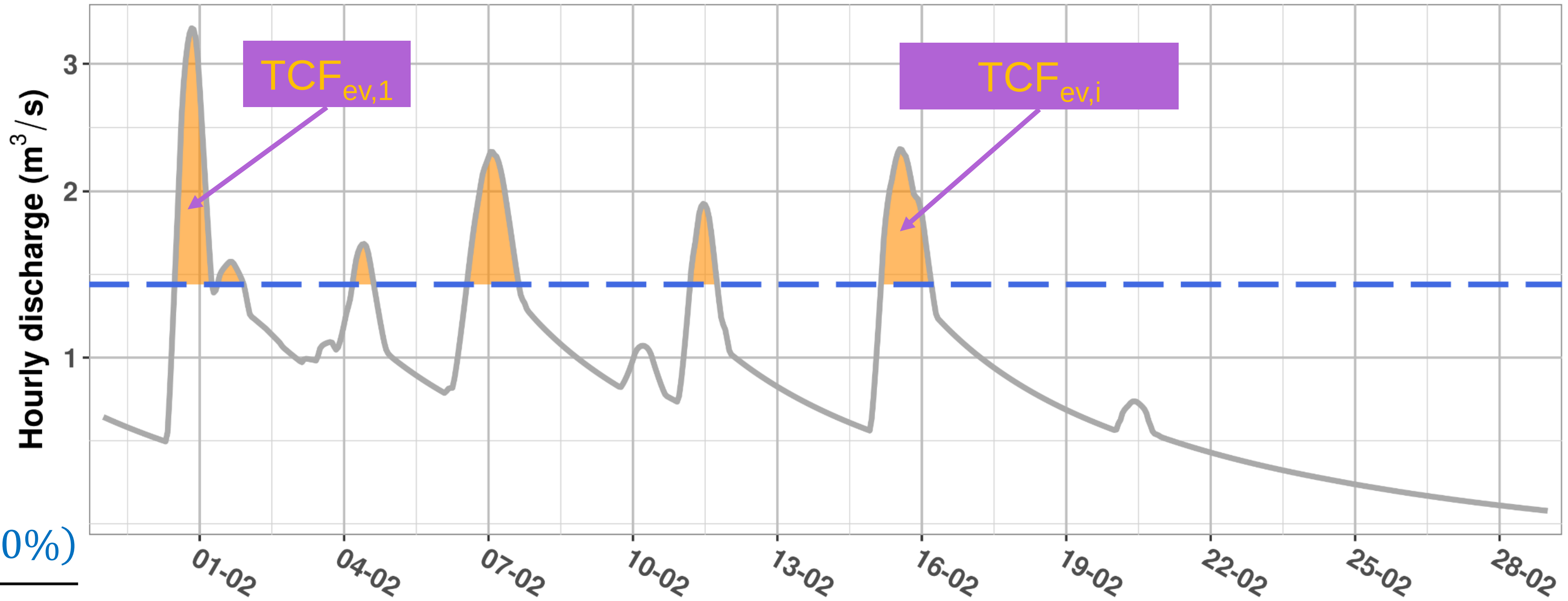
Q_{sim} **θ_{urb} = Obs. TIA**

Q_{sim} **θ_{urb} = 0%**

Q_{obs}

3. Relative change in TCF due to urbanization

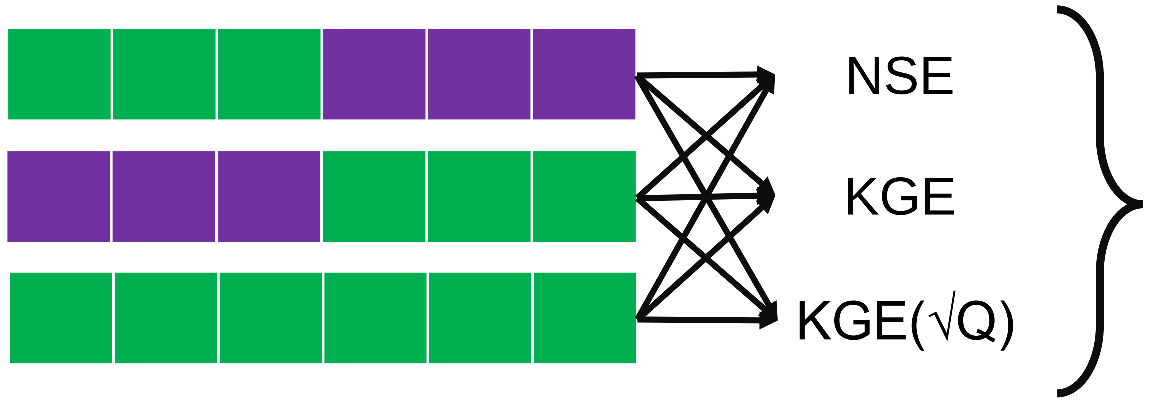
$$\Delta_{rel}TCF_{ev,y}\,(\%) = 100\,\frac{\sum_{y-2}^{y+2} TCF_{ev,y}(\theta_{urb} = \text{Obs. TIA}) - \sum_{y-2}^{y+2} TCF_{ev,y}(\theta_{urb} = 0\%)}{\sum_{y-2}^{y+2} TCF_{ev,y}(\theta_{urb} = 0\%)}$$



3| Results

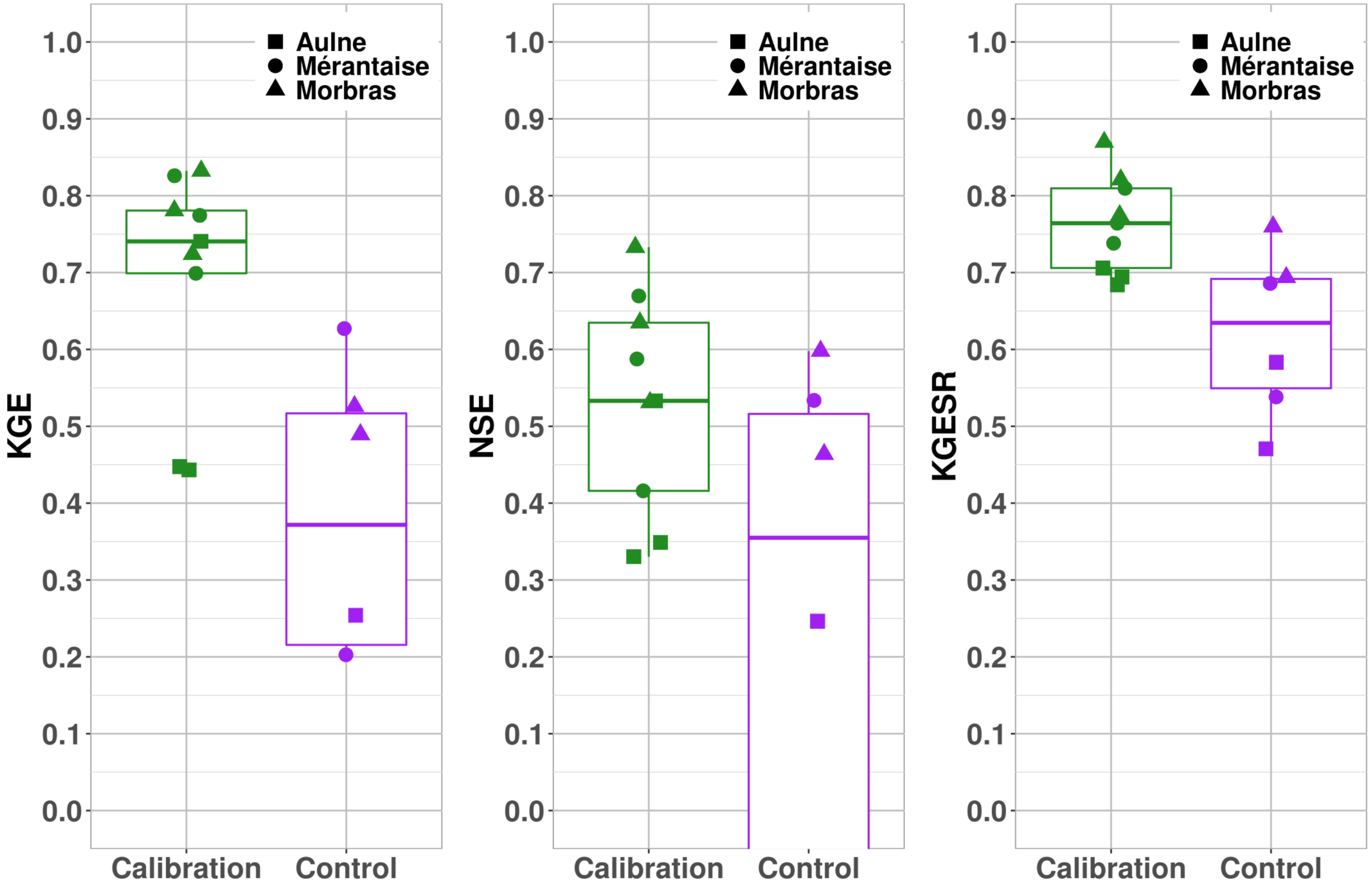
3.1 | Model calibration

3 periods of calibration **3 objective functions**



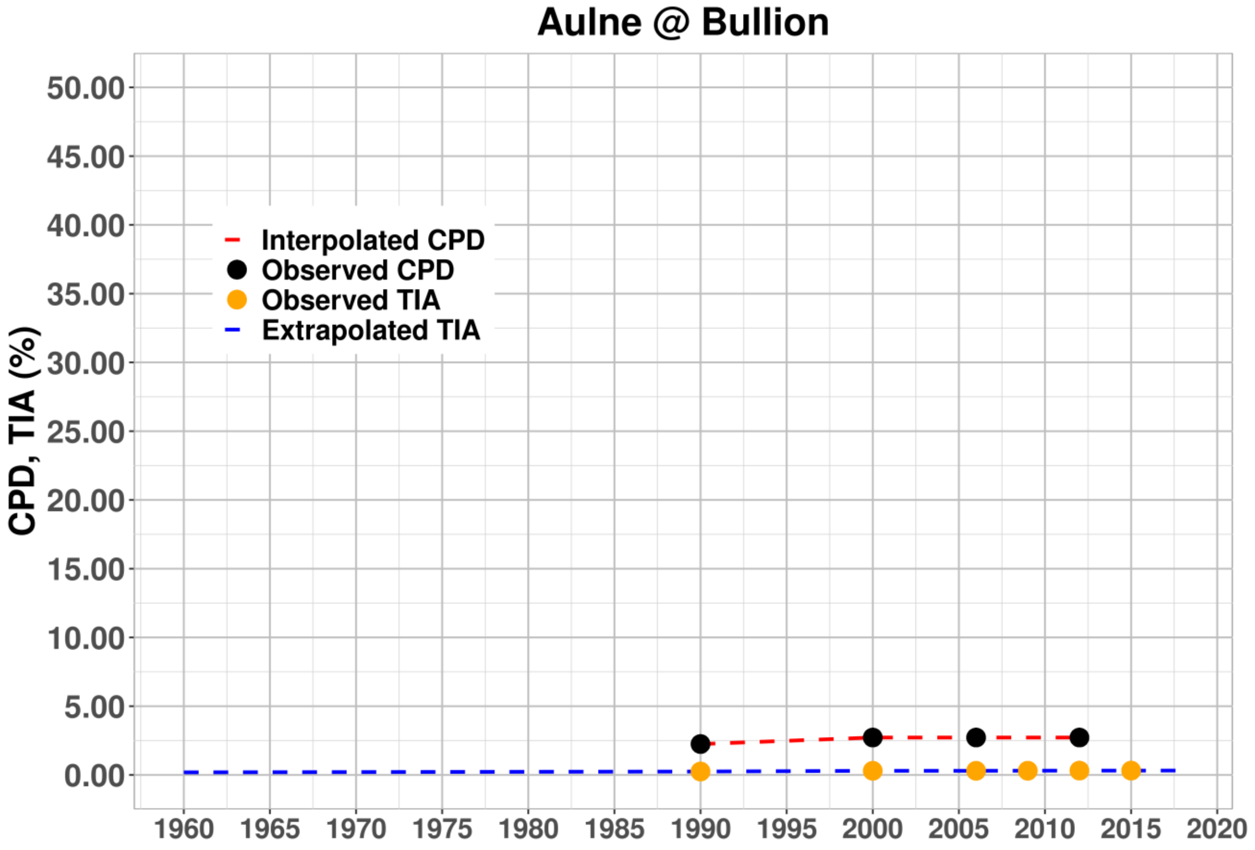
= 9 optimal parameter sets
{θ1, θ2, θ3, θ4, θ5}

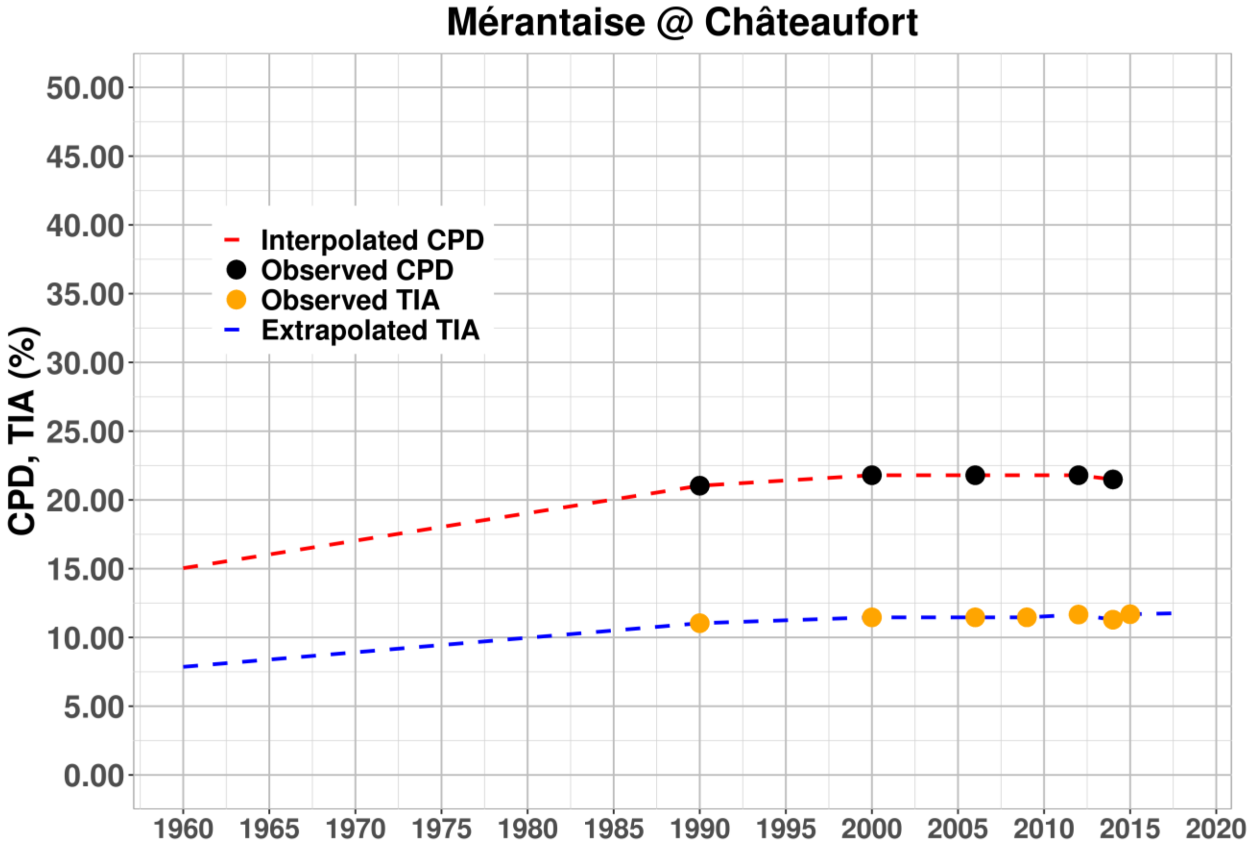
Acceptable calibration and control performances!

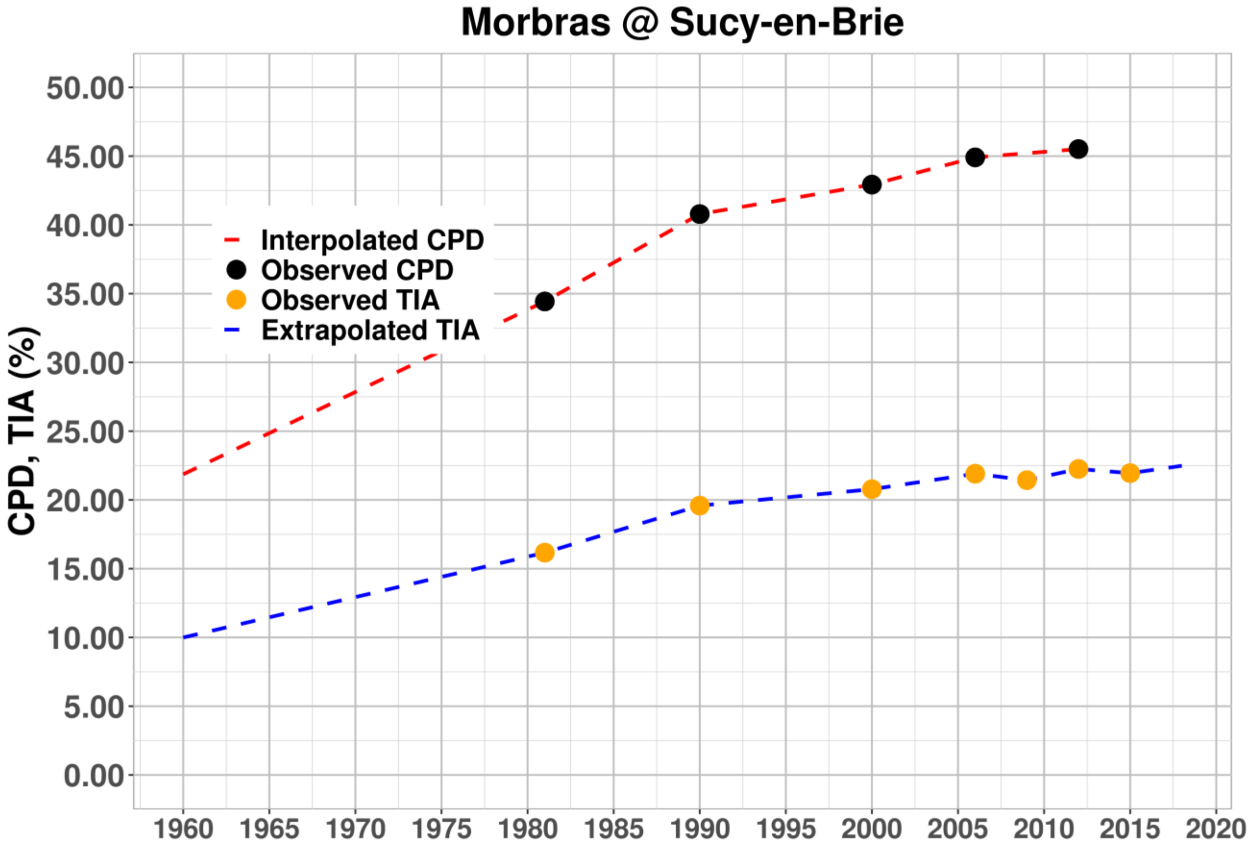


3| Results

3.2 | Yearly evolution of catchment urbanization







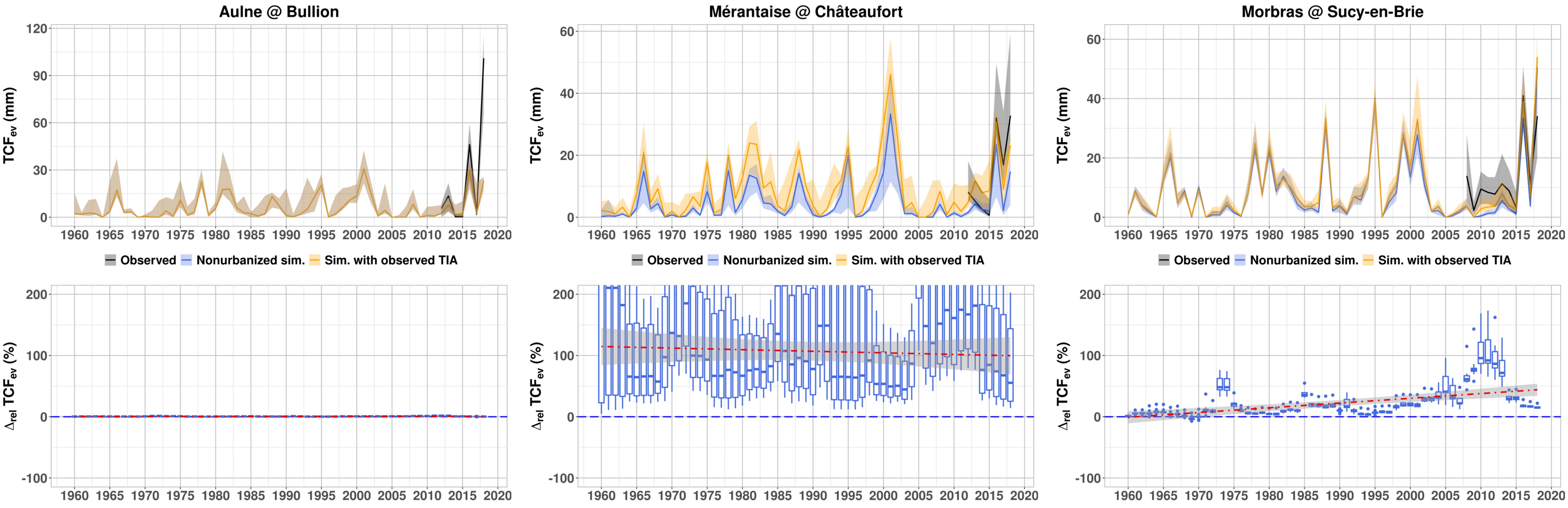
The Aulne illustrates the case of near-nonurbanized situation

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



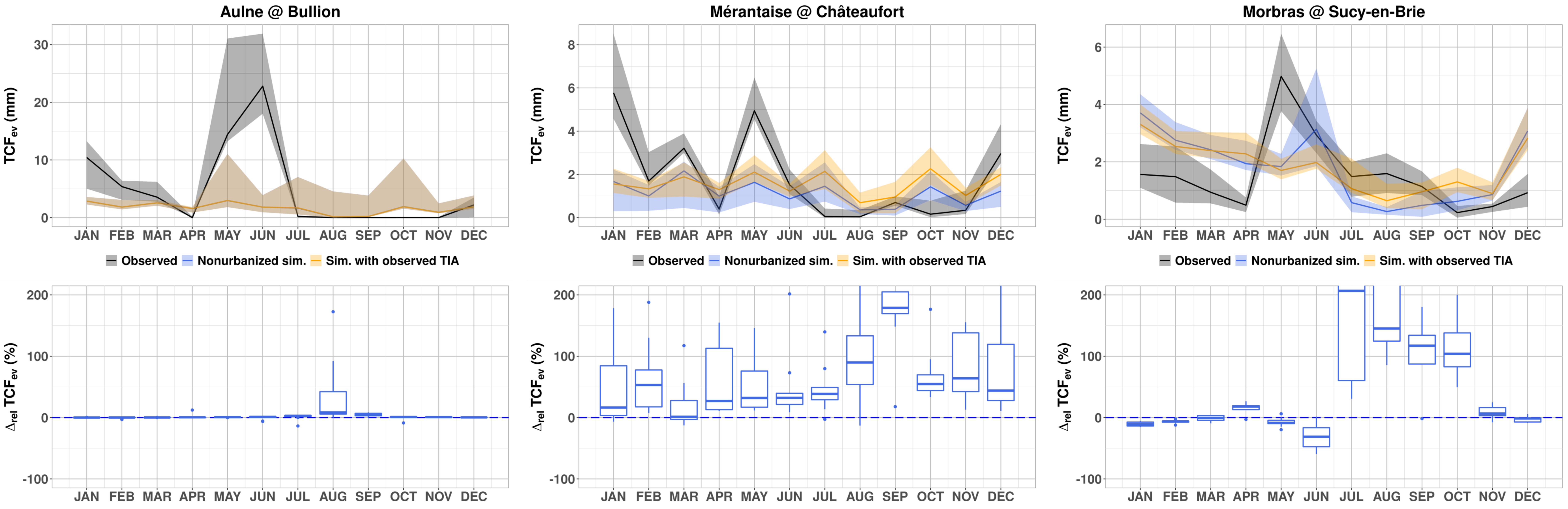
No substantial urbanization, no change in TCF_{ev}

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}



No substantial urbanization, no change in TCF_{ev}

No clear seasonality of the effect of urbanization on TCF_{ev}

A substantial effect of urbanization from late spring to fall

4| Conclusion

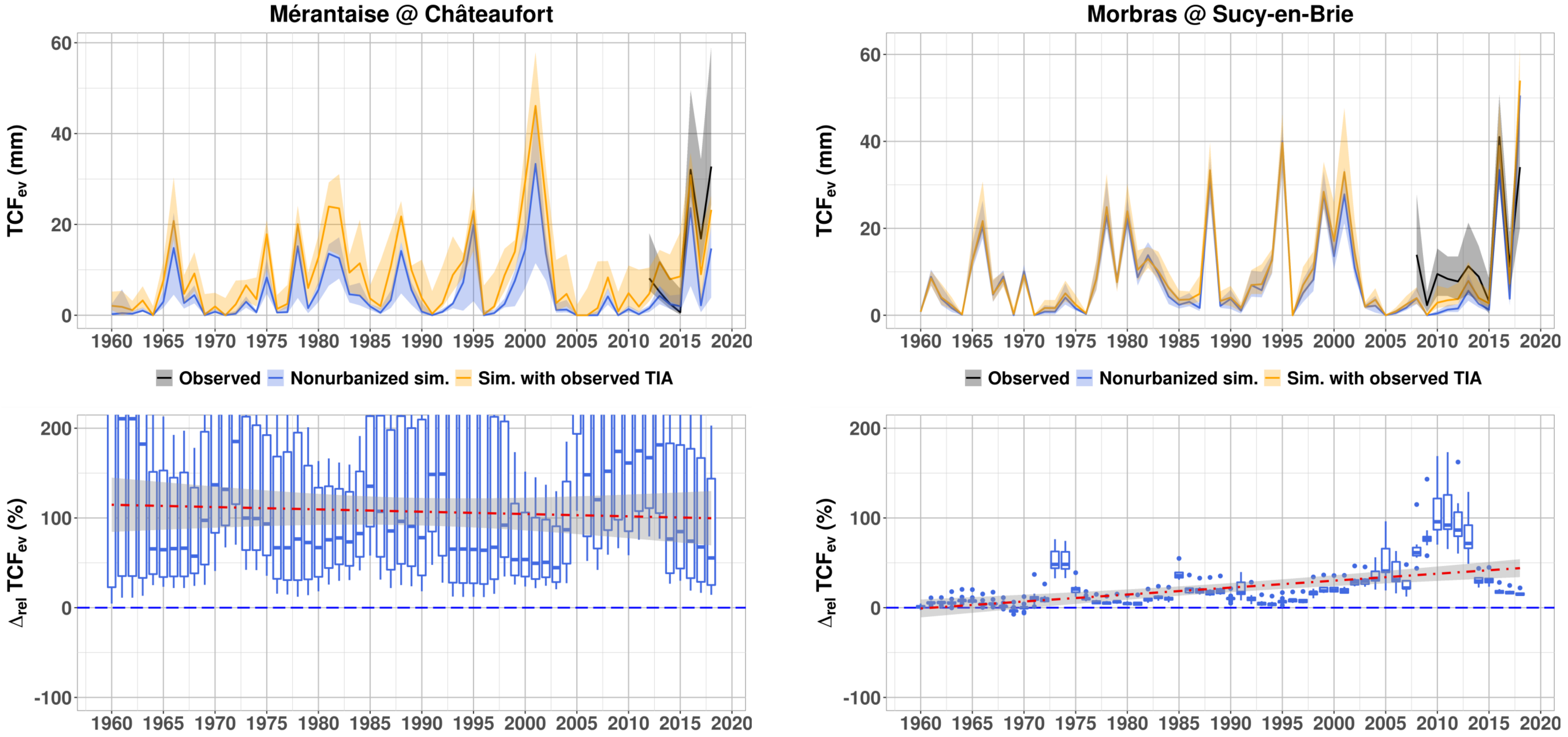
River	2015 X-sections compared to…	Incision (m)		Widening (m)	
		Mean	Max	Mean	Max
Mérantaise	1980 X-sections	0.41	1.26	1.31	4.91
Morbras	1964 X-sections	0.39	1.05	0.75	3.10

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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