A sequential calibration strategy for an operational semi-distributed river flow model

Implementation all over France

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28th Sept 2016

Irstea (HBAN), Antony, France

Introduction

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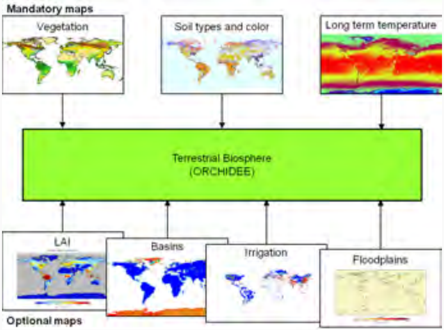
Different models that can be run at global scale ...



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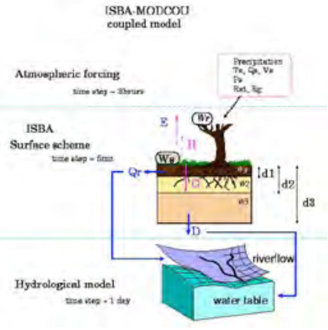

ISBA MODCOU

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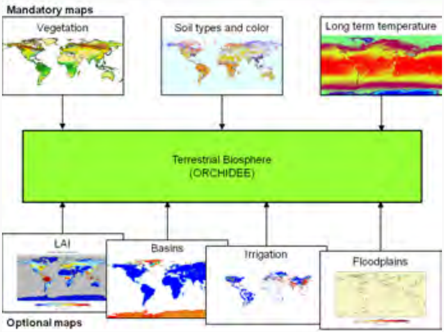

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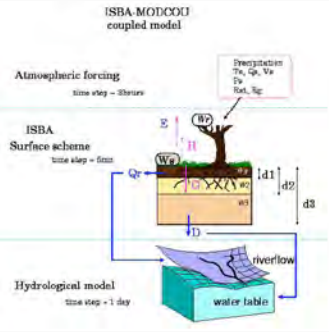

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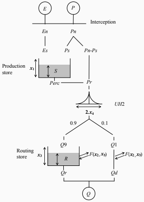
... which need to be calibrated from physical description

Introduction

GRSD : A GR semi-distributed model. Applied at a country scale.



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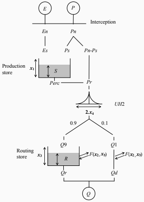

A conceptual model with different issues

- designed for operational perspective (eg. flood prediction)

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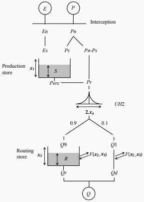

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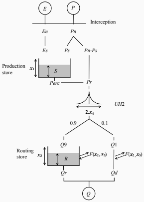

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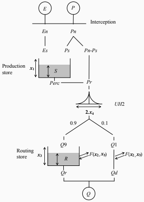


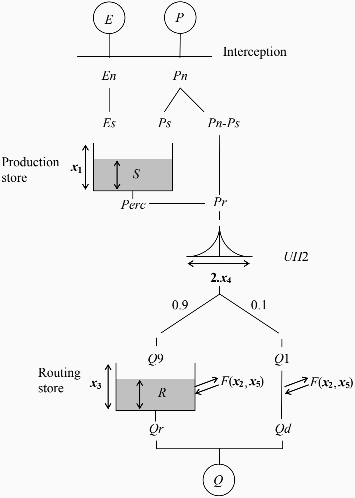
A conceptual model with different issues

- designed for operational perspective (eg. flood prediction)
- based on a lumped model with only 5 parameters
- calibrated only according to discharge time series ...

How to performed spatial calibration of such a model?
What about parameter's identifiability?

GRSD: a semi-distributed model

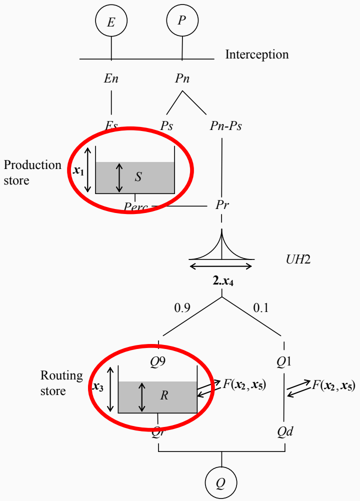
The GR5J model



A conceptual model with 5 parameters:

- 2 buckets
  (parameter X1 and X3)

The GR5J model



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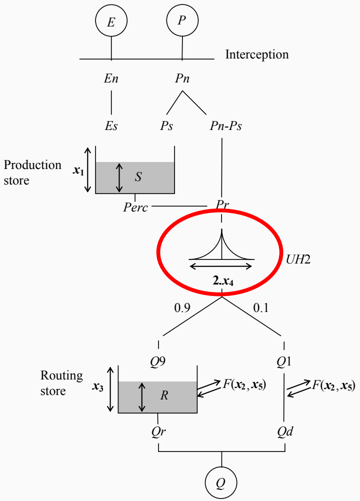

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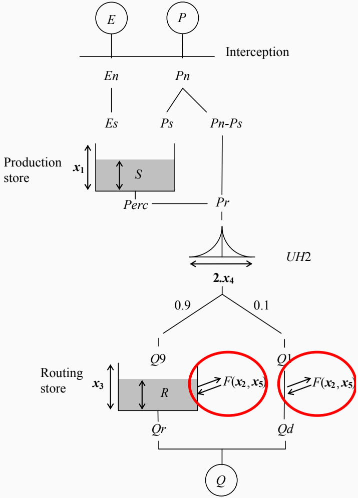

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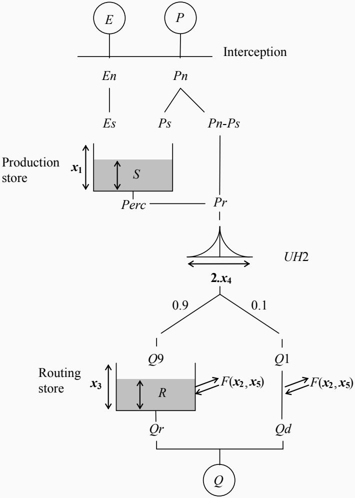

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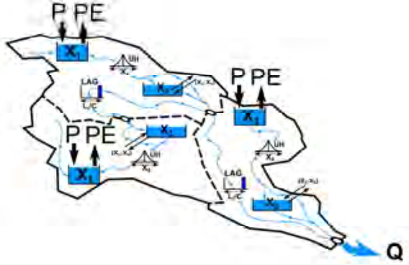
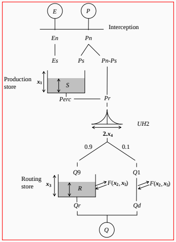
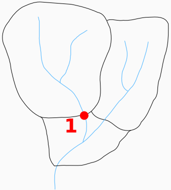


(Lobligeois et al., 2014)

A sequential calibration

Upstream catchment 1

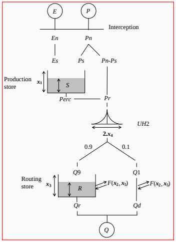




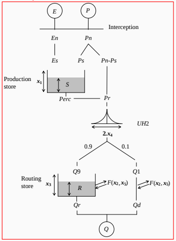
1. Upstream catchments are calibrated first

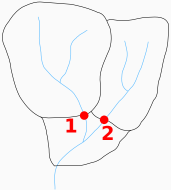
A sequential calibration

Upstream catchment 1



Upstream catchment 2





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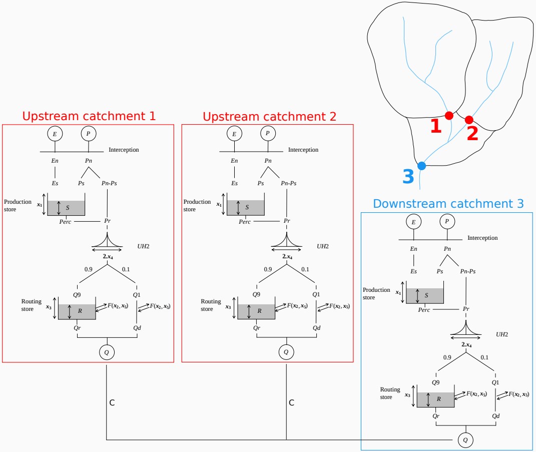
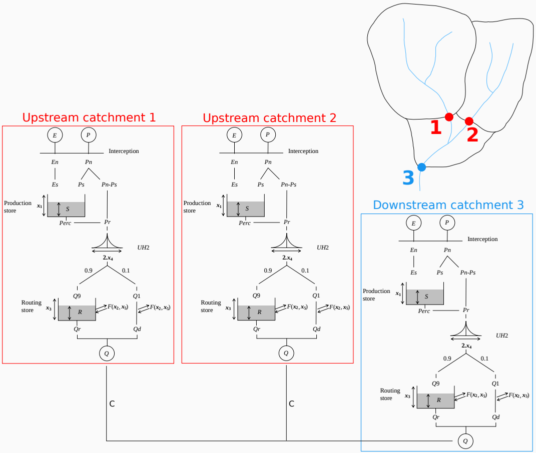


1. Upstream catchments are calibrated first
2. Simulated outflow is routed to downstream station (parameter C)

A sequential calibration



1. Upstream catchments are calibrated first
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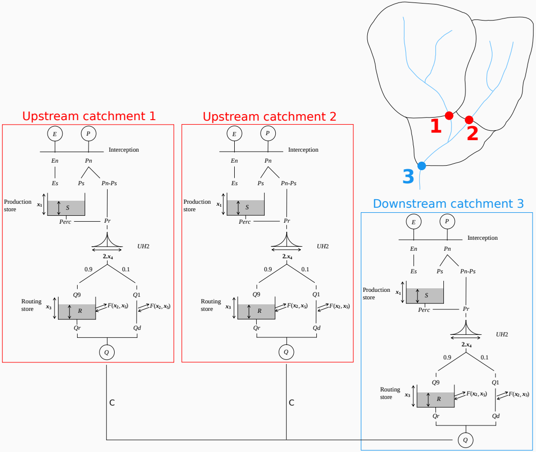


1. Upstream catchments are calibrated first
2. Simulated outflow is routed to downstream station (parameter C)
3. Contribution of downstream intermediary sub-catchment is calibrated
4. Repeat steps 1,2,3 to the last outlet

Our objective function

The Kling-Gupta Efficiency (KGE):

$$KGE(S,O) = 1 - \sqrt{(r-1)^2 + (\frac{\theta_s}{\theta_o} - 1)^2 + (\frac{\mu_s}{\mu_o} - 1)^2} \quad (1)$$

where O and S are the observed and simulated discharges

Parameter identifiability

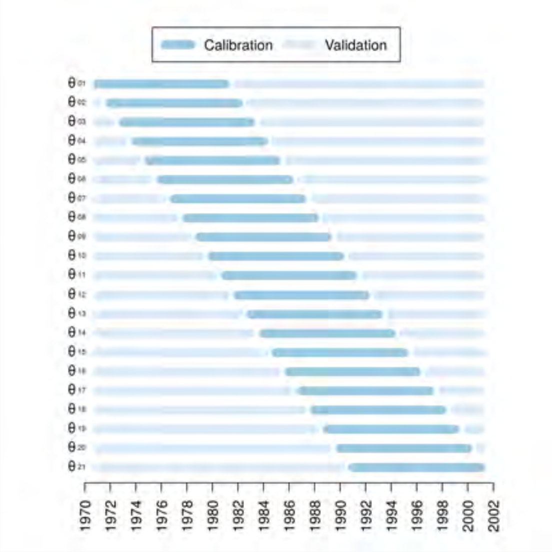
Rolling calibration period methodology

A benchmark for identifiability of parameters:

21 parameter sets θ_i^j can be identified for each catchment j

Rolling calibration period methodology

A benchmark for identifiability of parameters:



Temporal coefficient of variation

of parameter X between periods i within a catchment:

$$CV(X) = \frac{\sigma(X_i)}{\overline{X_i}}$$

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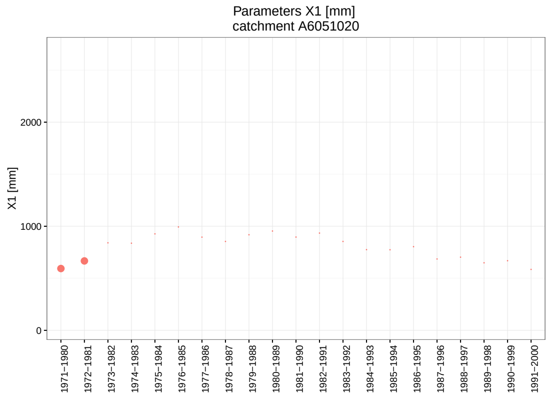

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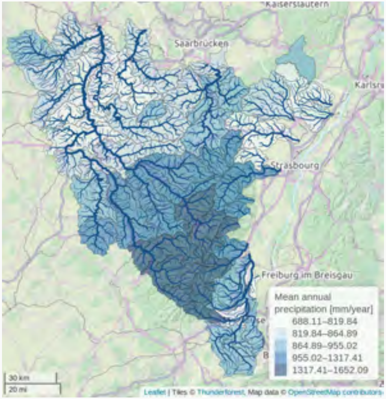
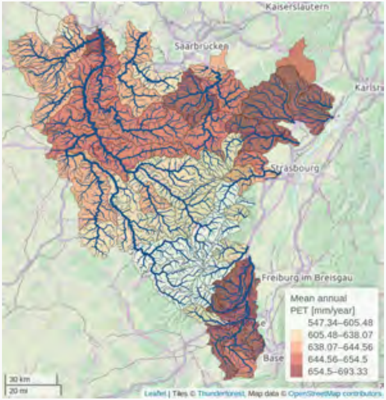
Moselle, Sarre and Rhine

Moselle, Sarre and Rhine

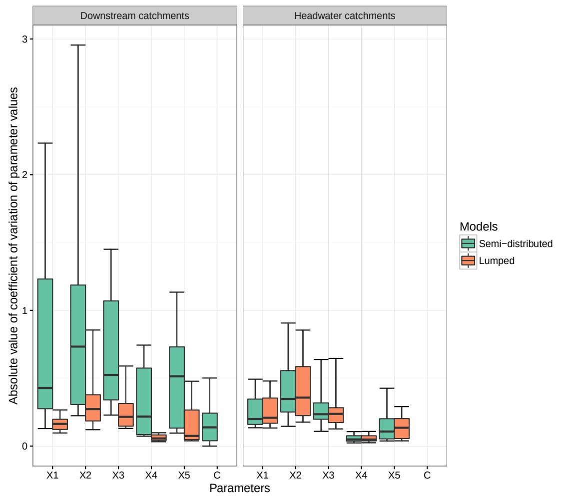
64 sub-catchments

Total area: 4340 km^2





Temporal variability



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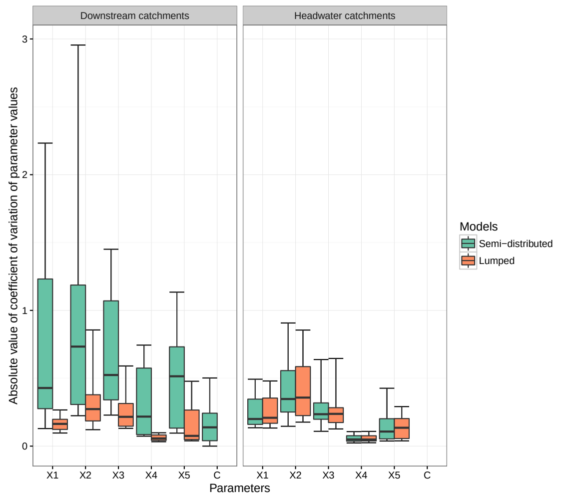

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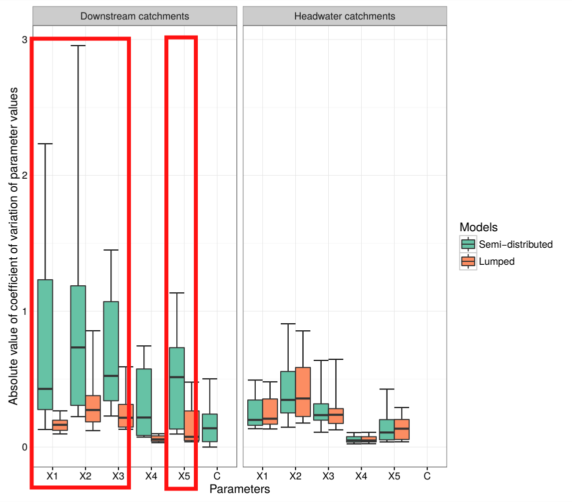
Greater variability with GRSD at downstream catchments

Temporal variability



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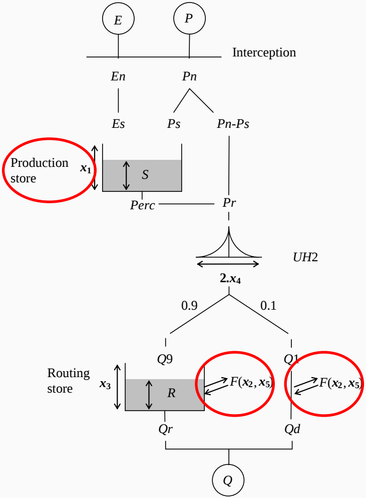
Issue related to parameters impacting water balance

Temporal variability



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Issue related to parameters impacting water balance

Temporal variability: What should we understand?

THE FACTS:

Identifiability Lumped > Semi-distributed

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Model's component Water balance

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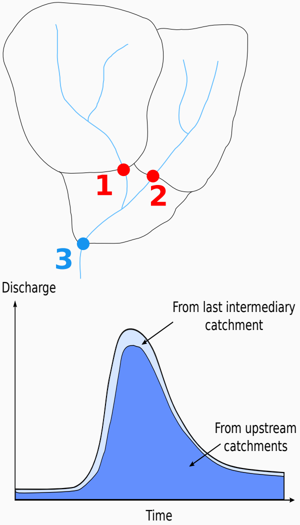
THE POSSIBLE REASONS:

Observation issue Sequential calibration
& discharge uncertainty?



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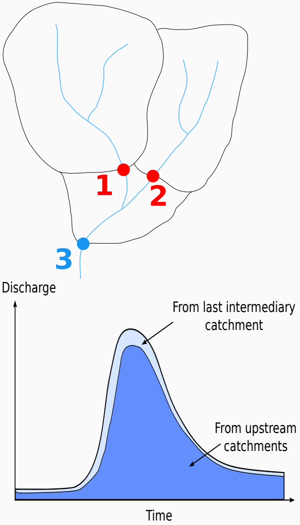

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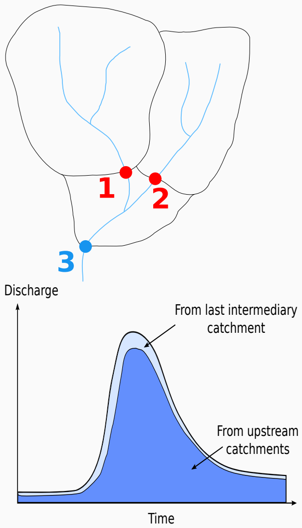
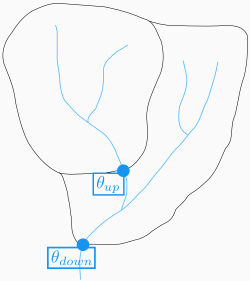
Model structure Sensitivity issue at downstream station?



A spring based calibration

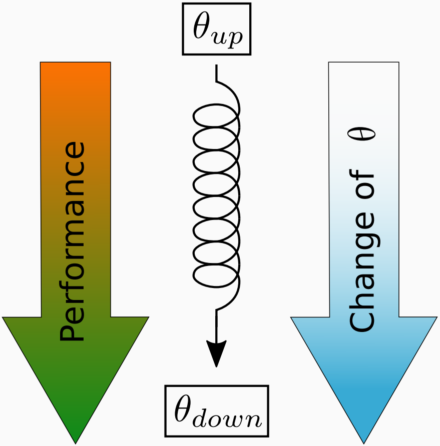
The concept idea



Does the performance really benefit from a large change of θ?

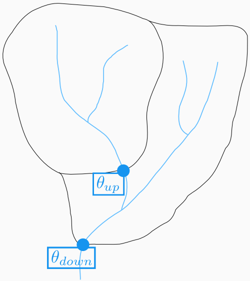
YES

Optimised parameter set of an upstream catchment



Parameter set of a downstream catchment under optimisation

The concept idea



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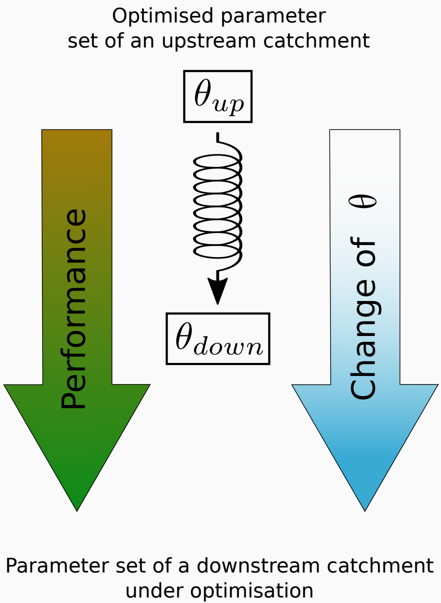

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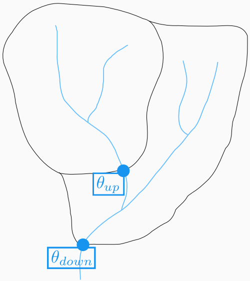
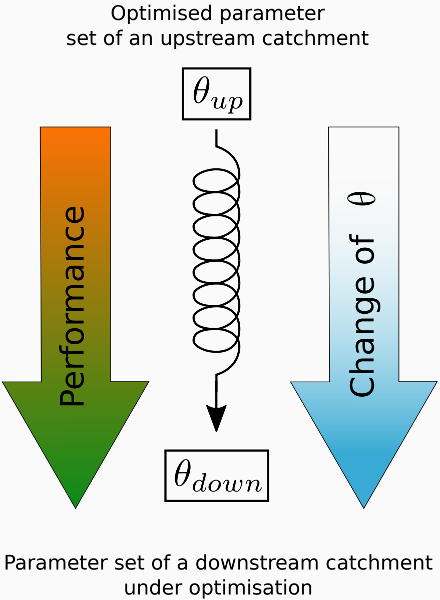


How much do we allow changes of θ?

LARGE



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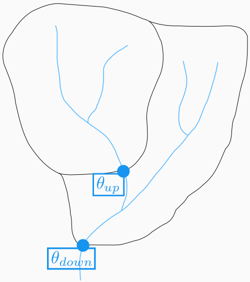

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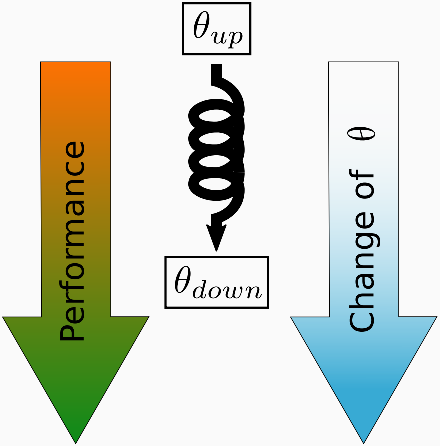
FEW

Optimised parameter set of an upstream catchment



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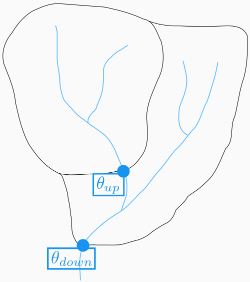

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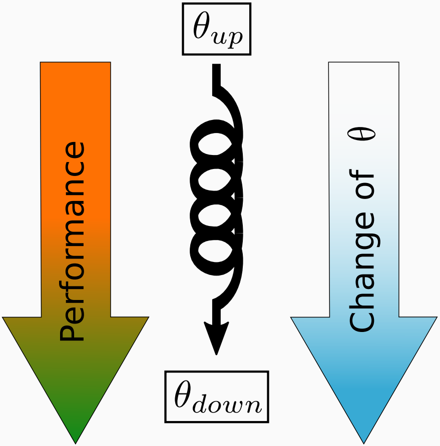

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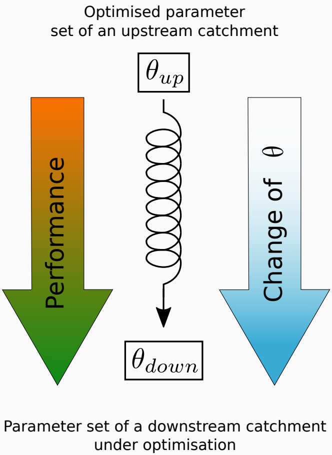
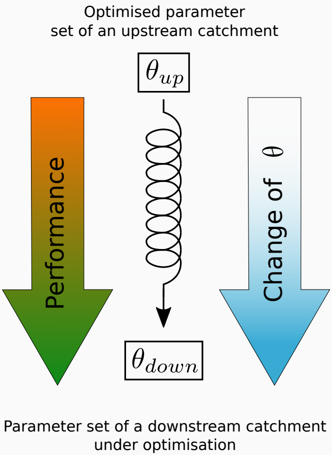


$$CRIT(\theta_{down}) = (1 - k) \cdot KGE(\theta_{down}) - k \cdot DIST(\theta_{up}, \theta_{down})$$

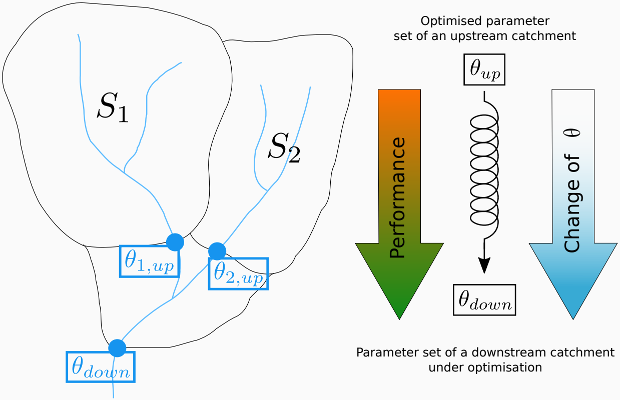
The concept idea



$$CRIT(\theta_{down}) = (1-k) \cdot KGE(\theta_{down}) - k \cdot \sqrt{\sum_{i=1}^{n} \left(\frac{\theta_{up}^{i} - \theta_{down}^{i}}{\theta_{up}^{i}} \right)^2}$$

The concept idea

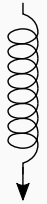
The case of more than one upstream catchment



$$CRIT(\theta_{down}) = (1 - k) \cdot KGE(\theta_{down}) - k \cdot \frac{\sum_{k=1}^{m} S_k \cdot DIST(\theta_{k,up}, \theta_{down})}{\sum_{k=1}^{m} S_k}$$

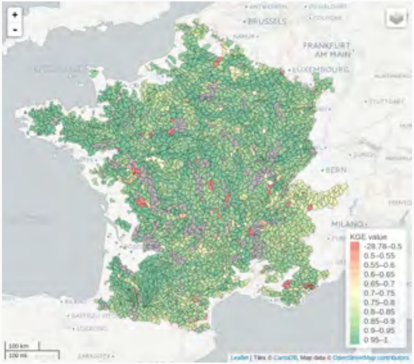
Map of performances

Results of Kling-Gupta Efficiency (KGE)

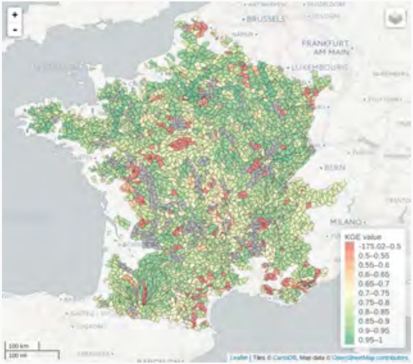


$k = 0\%$

Calibration



Validation



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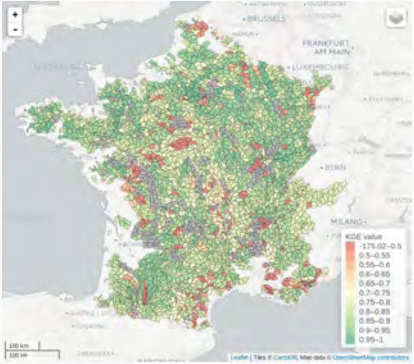
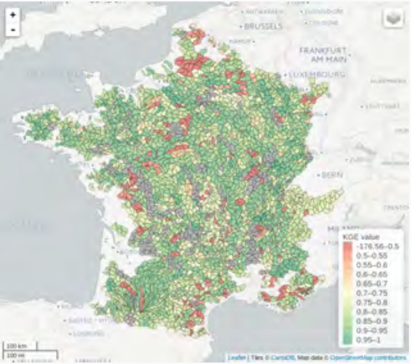
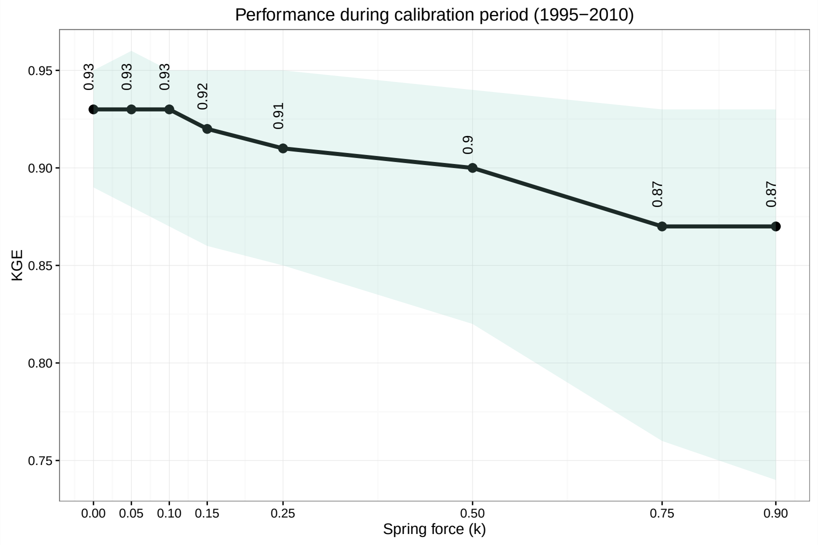


Validation

$k = 5\%$

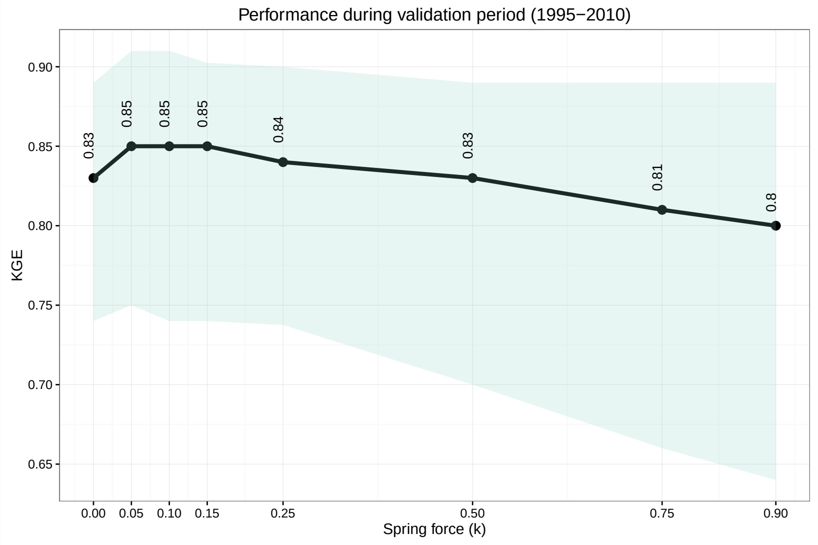


Goodness of fit vs spring force



Median values of performances (and quantile interval) for 923 downstream catchments

Goodness of fit vs spring force



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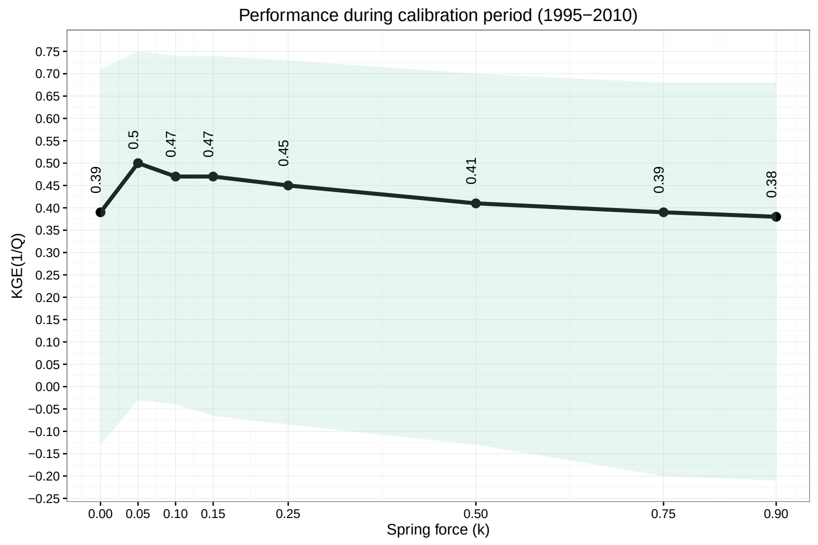

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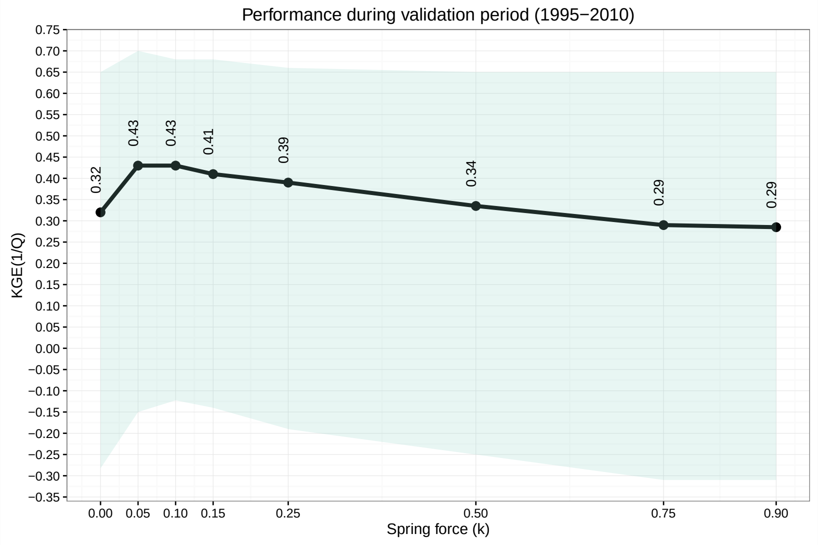

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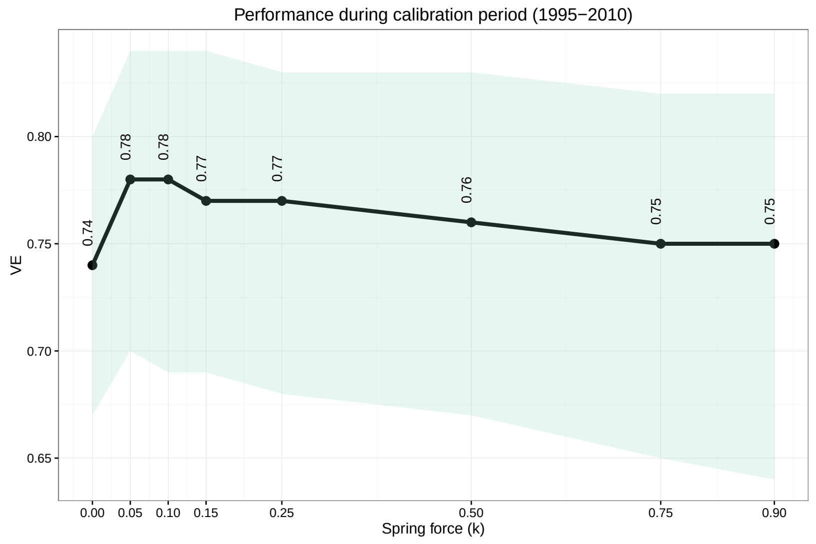
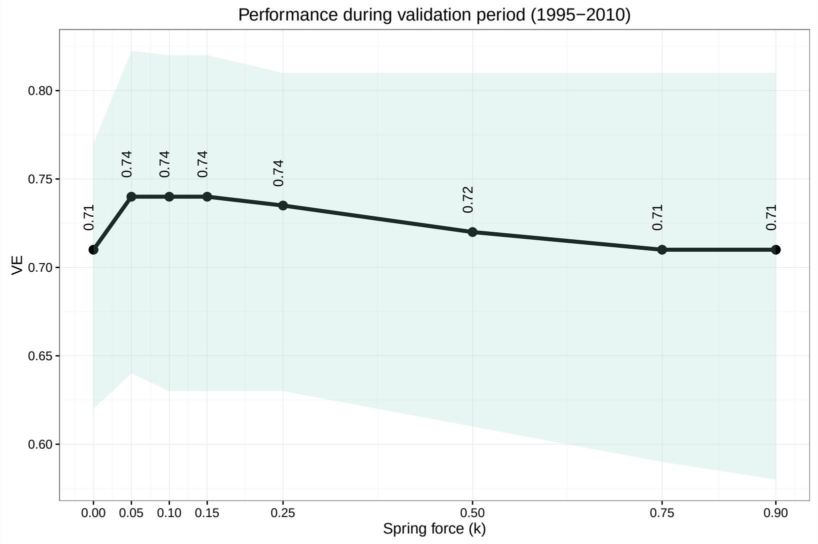


Median values of performances (and quantile interval)
for 923 downstream catchments

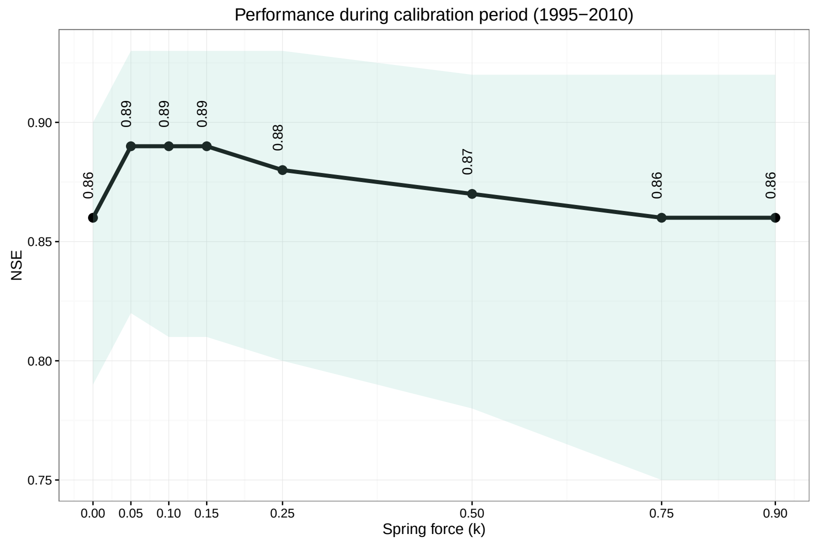
Goodness of fit vs spring force



Median values of performances (and quantile interval)

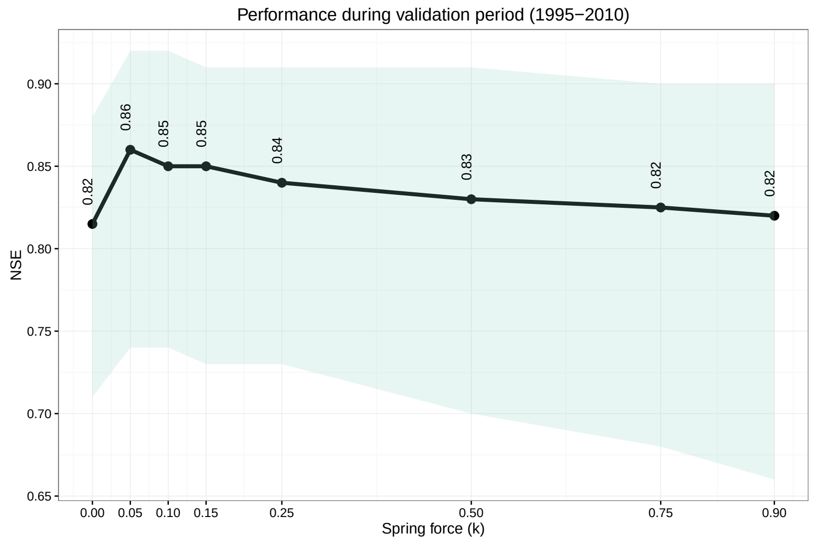
for 923 downstream catchments

Goodness of fit vs spring force



Median values of performances (and quantile interval)
for 923 downstream catchments

Goodness of fit vs spring force



Median values of performances (and quantile interval)
for 923 downstream catchments

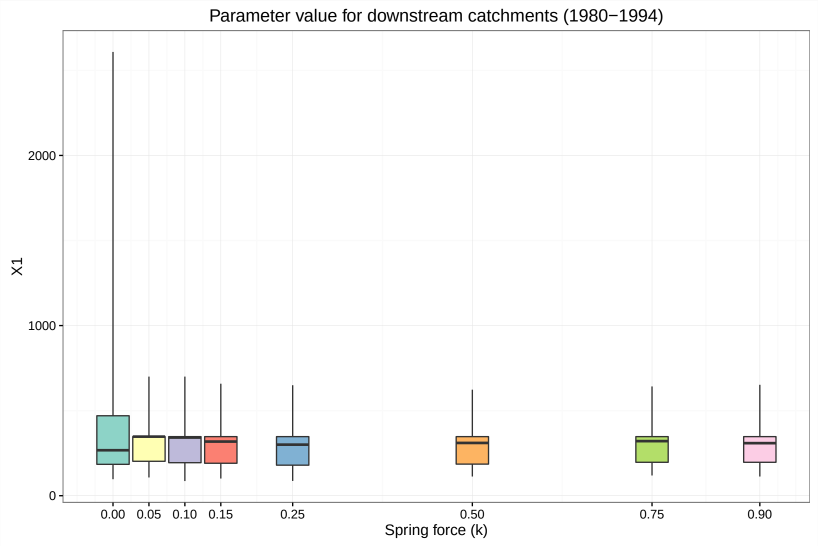
Spatial distribution of parameters

Spatial distribution of parameter X1

$k = 0\%$

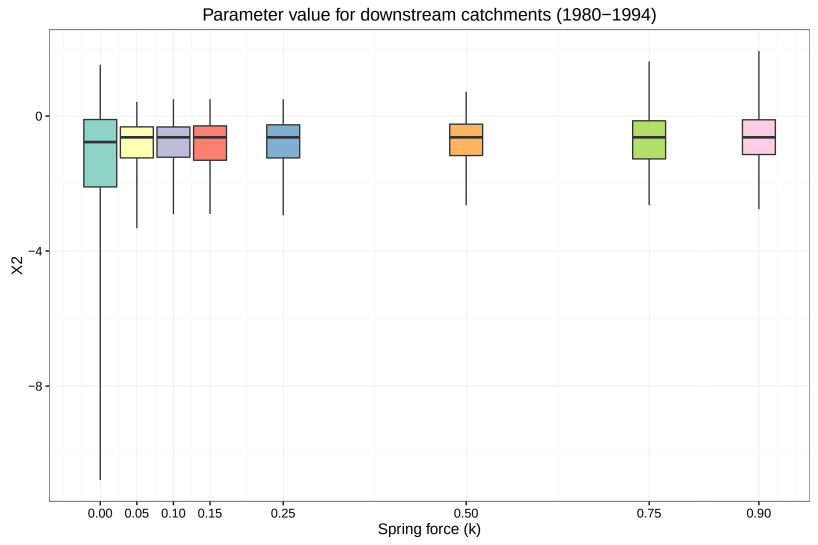
$k = 5\%$

Variability of parameter



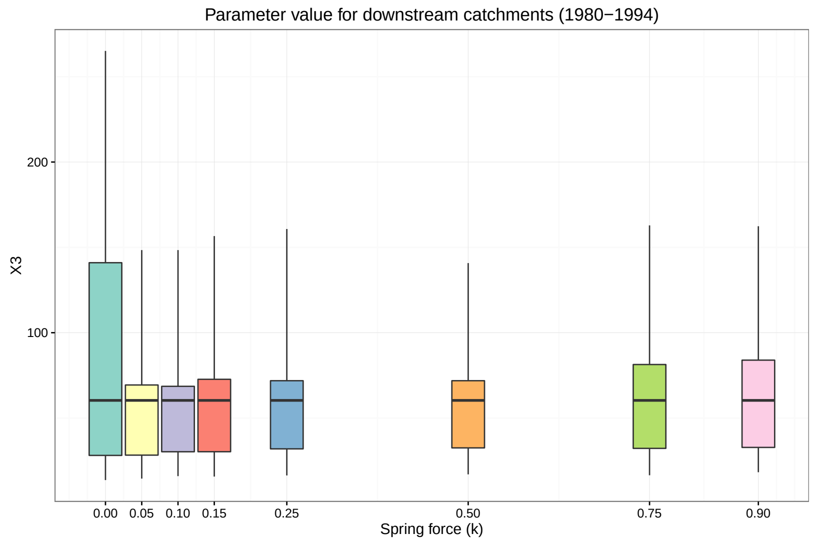
Parameter variability is reduced, even with k=5%

Variability of parameter



Parameter variability is reduced, even with k=5%

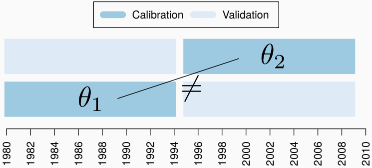
Variability of parameter

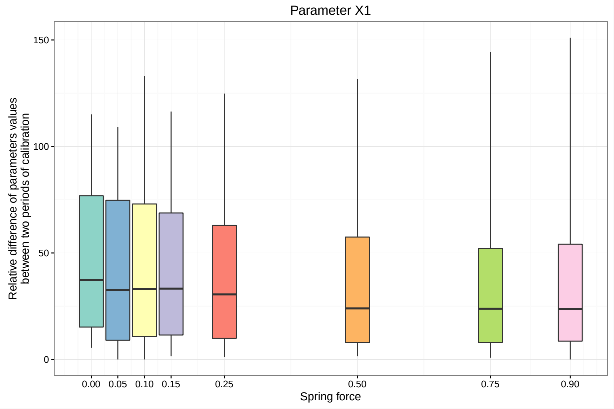


Parameter variability is reduced, even with k=5%

Identifiability of parameter

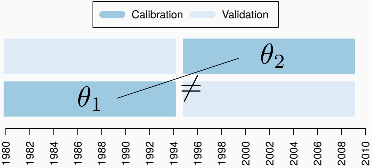
Difference of parameters between two periods

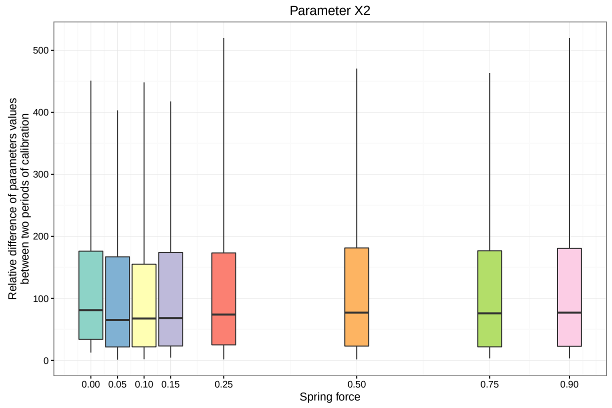




Identifiability of parameter

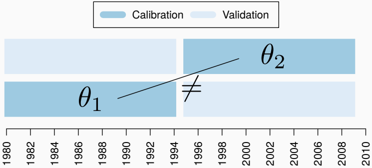
Difference of parameters between two periods

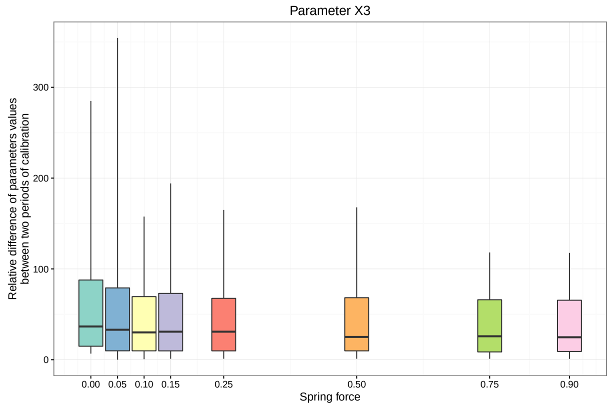




Identifiability of parameter

Difference of parameters between two periods





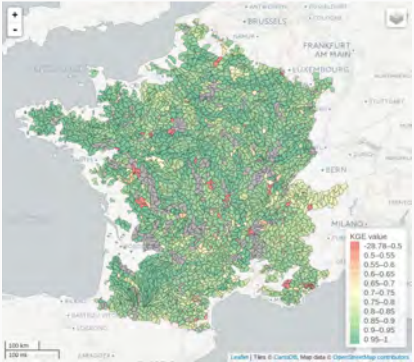
Conclusion

Conclusion

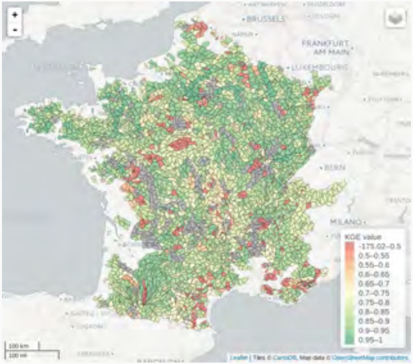
A new semi-distributed model able to run over France

based on GR5J lumped model

Calibration



Validation



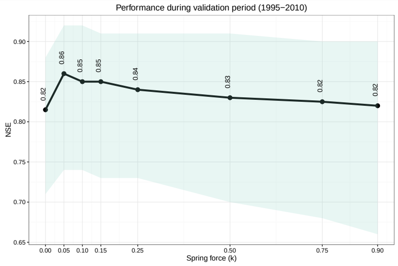
Further implementation:

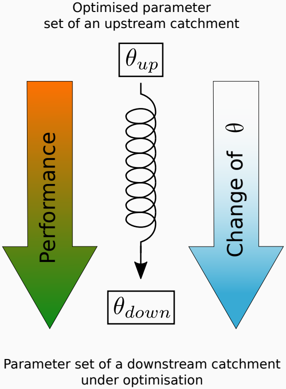
- Implementation of a dam reservoir inside the model (following Payan et al. 2008)

Conclusion

Key points of calibration strategy:

- Improve robustness of optimal parameter set

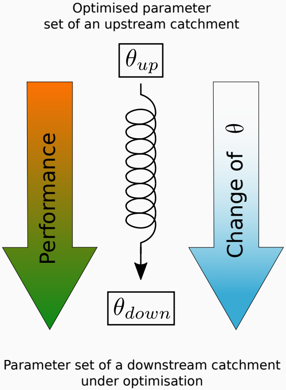


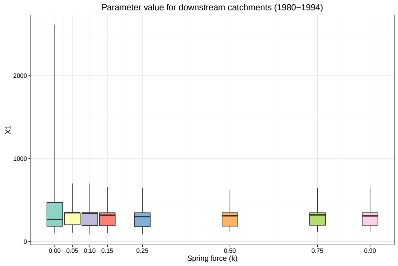


Conclusion

Key points of calibration strategy:

- Improve robustness of optimal parameter set
- Reduce numerical problem (sensitivity issue)

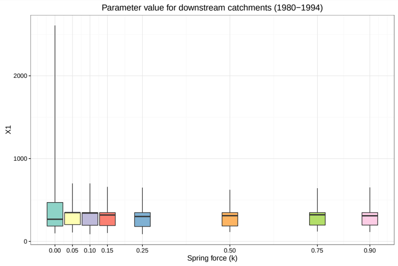


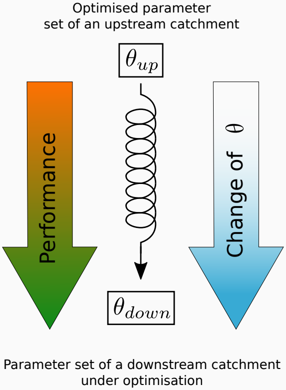


Conclusion

Key points of calibration strategy:

- Improve robustness of optimal parameter set
- Reduce numerical problem (sensitivity issue)
- Facilitate spatial consistency, so regionalisation

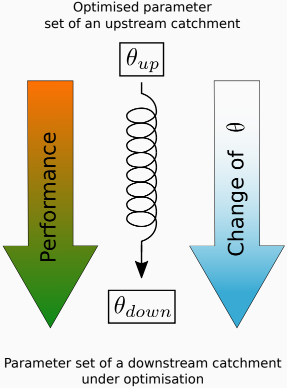




Conclusion

Perspectives of this calibration strategy:

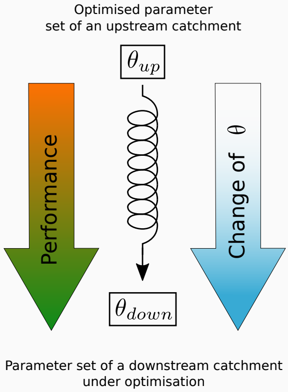
- Evaluation of θ_{up} (All θ_{up} are not efficient)



Conclusion

Perspectives of this calibration strategy:

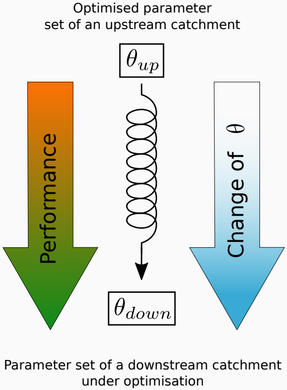
- Evaluation of θ_{up} (All θ_{up} are not efficient)
- Change θ_{up} by a regionalized θ_{reg}



Conclusion

Perspectives of this calibration strategy:

- Evaluation of θ_{up} (All θ_{up} are not efficient)
- Change θ_{up} by a regionalized θ_{reg}
- Spatial variation of k



A sequential calibration strategy for an operational semi-distributed river flow model

Implementation all over France

A. de Lavenne, G. Thirel, V. Andréassian, C. Perrin, M.-H. Ramos

28th Sept 2016

Irstea (HBAN), Antony, France